

9. PALEOCENE SHALLOW-WATER FACIES AT EMPEROR SEAMOUNTS: DSDP LEG 55, NORTHWEST PACIFIC

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INTRODUCTION

This paper briefly summarizes the results of our study of the Paleocene reef sediments recovered at the Emperor Seamounts. During Leg 55, the *Glomar Challenger* drilled at four sites in the Emperor chain: 430 (Ōjin Seamount), 431 (Yōmei Seamount), 432 (Nintoku Seamount), and 433 (Suiko Seamount) (see locations in Figure 1). The main objective of this cruise was to study the tectonic history of the Pacific Oceanic plate relative to the fixed hot spot, presently situated beneath the Hawaiian Islands (Wilson, 1963; Morgan, 1972). Of principal interest in this study was whether the Emperor Seamounts, representing a linear chain of volcanoes, were once built as volcanic islands over the hot spot in the south, and whether the volcanoes were evolved to an atoll stage, bearing reef facies, before their northward and vertical motions (see Greene et al., 1978).

At three sites — 430 (Ōjin), 432 (Nintoku), and 433 (Suiko) — reef sediments overlie basaltic basement. In this paper, we discuss two sites (430 and 433) only; Site 432 (Nintoku) is treated elsewhere (Butt, this volume). Because of the strongly endemic character of the recovered reef biota at both sites, we cannot go into the

species details satisfactorily; nevertheless, we do document the following shallow-water microfossils: foraminifers, ostracodes, bryozoans, calcareous algae, and spirorbids. Although we found rare coral debris in the reef calcarenites, we classify the facies “bryozoan-algal” reef (Schlanger and Konishi, 1975). Our study also illuminates some biostratigraphic aspects of the reef sediment. Comparing the planktonic foraminiferal zones at Suiko in the north and Ōjin in the south, we recognize a northward increase in age within the Emperor chain. In addition, we also review the important ecological and climatic aspects of the ancient reef environment at the seamounts. On the basis of keeled planktonic foraminifers, spirorbids, and larger foraminifers (see Butt, this volume), we argue that a warm tropical watermass surrounded the Emperors as atolls during the Paleocene. It is pertinent to mention here, however, that the drilling at Ōjin and Suiko seamounts in the Emperor chain recovered, for the first time, Paleocene lagoonal facies in submerged atolls.

This report deals with 22 samples and 3 thin sections from Hole 430A, 66 samples and 7 thin sections from Hole 433A, 13 samples and 6 thin sections from Hole 433B, and 7 samples and 5 thin sections from Hole 433C. Relative abundance of the microfossils is shown in Table 1.

FAUNA AND FLORA

Pelagic Foraminifers

Pelagic foraminifers are rather rare. Their tests are often dwarflike and poorly preserved. It was therefore not possible to determine the species of most globigerinids, but some guide forms could be recognized among the globorotaliids.

The pelagic foraminifers of Holes 433A and 433B belong to the genera *Globigerina* and *Globorotalia* (subgenera *Globorotalia*, *Acarinina*, and *Morozovella*) (Plate 6, Figures 1, 5-9). There is a predominance of the group of *Globorotalia* (*Morozovella*) *angulata* (White)-*G. (Morozovella) conicotruncata* (Subbotina). Among others, *G. (Morozovella) angulata abundocamerata* Bolli is recognizable. *Globorotalia* cf. *pusilla pusilla* Bolli and *Globorotalia* cf. *imitata* Subbotina also occur.

In the samples from Hole 430A, *Globigerina nana* Khalilov (see Serova, 1970, pl. 31, fig. 1, 2) and *G. triangularis* White occur next to some globorotaliids. The following species of the genus *Globorotalia* could be

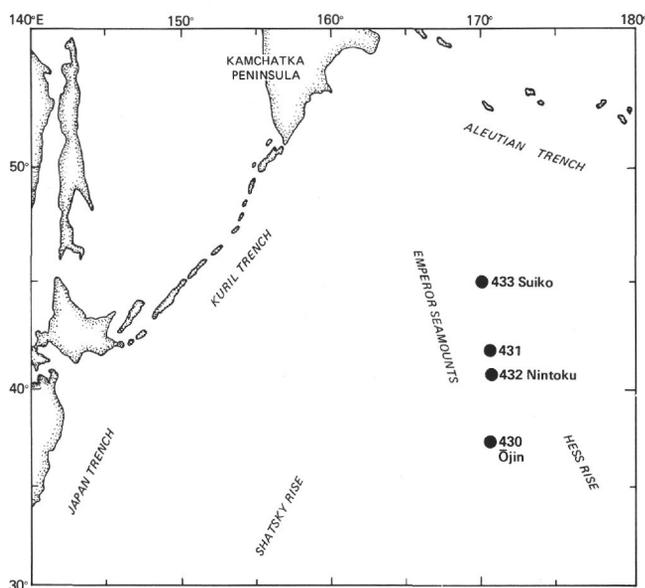


Figure 1. Locations of Leg 55 sites.

TABLE 1
Relative Abundances of the Paleocene Reef Fossils at Sites 430 and 433

433 A- 10-6	433 A- 14-1	433 B- 1-1	430 A- 2-1	430 A- 4-1	Section Faunal Components
					<i>Arenoturrspirillina</i>
					<i>Mitroidea</i>
					<i>Darbyella</i>
					<i>Marginulina</i>
					<i>Siphogenerinoides</i>
					<i>Discorbis</i>
					<i>Anomalinoidea A</i>
					<i>Anomalinoidea B</i>
					<i>Cibicides</i>
					<i>Spirorbidae</i>
					<i>Bryozoa</i>

identified: *G. pusilla laevigata* Bolli, *G. elongata* Glaessner, *G. (Morozovella) aequa* Cushman and Renz s. l., *G. (Morozovella) velascoensis* (Cushman) (pl. 6, fig. 2-4), and *G. (Morozovella) cf. marginodentata* (Subbotina). The subgenus *Acarinina* and the genus *Chiloguembelina* are also represented.

Benthic Foraminifers

Benthic foraminifers occur in varying quantities. The tests are often of dwarf size. They are usually poorly preserved; in many cases the tests are covered by fine powderlike calcite crystals. The faunas of Holes 433A through 433C differ in composition from those of Hole 430A (Table 1).

The benthic foraminifers of Holes 433A through 433C belong mainly to the genera *Arenoturrspirillina*, *Darbyella*, *Marginulina*, *Siphogenerinoides* and *Anomalinoidea*. In addition, normally represented only by a few or single specimens, the following genera are present: *Marssonella*, *Dentalina*, *Nodosaria*, *Lingulina*, *Fronicularia*, *Lagena*, *Globulina*, *Guttulina*, *Sigmomorphina*, *Bolivina*, *Stilostomella*, *Fissurina*, *Spirillina*, *Discorbis*, *Neoconorbina*, *Eponides*, *Alabama*, and *Karrerria*.

The comments following pertain to this fauna (Plate 4, Figure 2).

Arenoturrspirillina

(Plate 4, Figure 2; Plate 5, Figures 1, 2a, 2b)

A similar form from the Paleocene of New Zealand has been described by Webb (1974, p. 834, pl. 1, fig. 10, 11) as *A. micra* Subbotina. Our tests, however, are much larger than this species, found primarily in the upper Eocene of the Soviet Union. There are also affinities with *A. concavata* Samuel and Salaj, originally described according to its occurrence in the upper Eocene of the Carpathians (1962, p. 315, pl. 9, fig. 2a-2c). This genus seems to occur also in the Paleocene of Tunisia (Aubert and Berggren, 1976, p. 407, pl. 1, fig. 2a, 2b).

Darbyella

(Plate 4, Figure 2; Plate 5, Figures 3, 4)

The tests are slightly asymmetrical; the last whorl is somewhat trochospiral. The aperture is a clearly marked slit at the upper end of the septal area. Only in rare cases is the periphery somewhat angular. *Darbyella karatsuensis* Asano and Murata, from the uppermost Oligocene of Japan (fide *Catalogue of Foraminifera*, Ellis and Messina, 1940), may be a descendant of our species.

Marginulina

(Plate 4, Figure 2; Plate 5, Figure 6)

The present species corresponds very well to the tests of *M. jarvisi* Cushman figured by Hofker (1978, pl. 3, fig. 19) from the occurrences in the Paleocene of the Shatsky Rise in the northwest Pacific. This species has been originally described from its occurrence in the Lizard Springs Formation of Trinidad, B.W.I.

Siphogenerinoides

(Plate 5, Figures 9, 10)

Tests of this genus are common in the finer fraction. They can be identified with "*Siphogenerina*" *eleganta* Plummer (1926, p. 126, pl. 8, fig. 1a-1c) from the Midway Formation of Texas. Aubert and Berggren (1976, p. 421, pl. 5, fig. 3a-3c) found this slender species in the Paleocene of Tunisia; they determined it as *Siphogenerinoides*. Perhaps this determination should be revised in favor of the genus *Orthokarstenia* (see Loeblich and Tappan, 1964, p. C 567).

Anomalinoidea sp. A

(Plate 5, Figures 7, 8)

In some respects this species resembles *Anomalinoidea umbonifer* (Schwager) in the sense of Aubert and Berggren (1976, p. 430, pl. 9, fig. 4a-4c). As described by LeRoy (1953, p. 19, pl. 7, fig. 15-17), this Egyptian species however is very small, whereas our specimens are rather large. The last chambers are always strongly inflated.

Anomalinoidea sp. B

(Plate 4, Figure 2; Plate 5, Figures 11-14)

This is the most common species in our material. At first glance, it seems to belong to the group *Cibicides praecursorius* (Schwager), a species from the Paleocene of Egypt (see McGowran, 1965, p. 53, pl. 4, fig. 6; fig. 8). The periphery, however, is more rounded. The tests from Holes 433A through 433C are highly variable; forms transitional to *Anomalinoidea sp. A* sometimes occur. There are also certain similarities to the genus *Boldia*.

Presumably, the above-mentioned benthic foraminifers need much more study. In our material, several new species are probably hidden.

The benthic foraminifers of Hole 430A are represented mainly by the genera *Quinqueloculina* (Plate 1, Figures 2, 4), *Discorbis*, and *Cibicides*. A species of the

genus *Discorbis* can be compared to *D. perovalis* (Terquem), described by Ferrer (1975, p. 804, pl. 2, fig. 1-3) from an occurrence in the lowermost Eocene of Kōkō Seamount, northwest Pacific. The tests of the genus *Cibicides* are predominantly dwarf-sized; in some samples they are abundant. Less frequent are the genera *Bolivina*, *Angulogerina*, and *Stilostomella*.

Corals

Coral remains are very rare. A solitary coral occurs in Hole 433C (Plate 2, Figure 4). A few skeletal remains in other thin sections are hydrozoans (e.g., *Millepora*).

Vermes

Tubes of serpulids occur not infrequently in Leg 55 material (Plate 3, Figure 7). They are often grown together with red algae (Plate 1, Figure 1). The genera *Josephella* and *Neomicrorbis* were identified.

In Holes 433A through 433C, spirorbids form an essential part of the fauna (Plate 4, Figure 1). Mr. A. Lommerzheim (Mülheim/Ruhr) was kind enough to look at our material. He stated that it is very difficult to determine tubes of spirorbids without knowledge of the apertural area and the opercula. These features are usually missing in our specimens, but Mr. Lommerzheim was able to give the following preliminary list of 11 species:

- Bipygmaeus* cf. *pygmaeus* (Hagenow)
- "*Spirorbis*" (aff. *Spirorbis-Circeis*) sp., type A
- "*Spirorbis*" (aff. *Spirorbis-Circeis*) sp., type B
- "*Spirorbis*" (aff. *Protolaeospira-Eulaeospira*) sp.
- "*Spirorbis*" (aff. *Metalaespira*) sp., aff. *expansa* (Nielsen)
- "*Spirorbis*" (aff. *Janua*) sp., aff. *sulcata* (Nielsen)
- "*Spirorbis*" (aff. *Janua*) sp., aff. *heliciformis* (Eichwald) *corrugatus* (Nielsen)
- "*Spirorbis*" (aff. *Janua*) sp., type A
- "*Spirorbis*" (aff. *Janua*) sp., type B
- "*Spirorbis*" (aff. *Amplaria*) sp.
- "*Spirorbis*" (aff. *Pileolaria*) sp.

Spirorbids are rather scarce in Hole 430A. They occur only in the lower part of the section (Plate 3, Figure 4; Table 1).

Bryozoans

Well-preserved bryozoans are abundant in nearly all samples from Holes 433A through 433C. They can be divided into Cyclostomata and Cheilostomata. Branchy forms are by far the most abundant (Plate 1, Figure 5; Plate 2, Figures 2, 6; Plate 3, Figure 5; Plate 4, Figure 1). Some bryozoans are attached to the thalli of red algae. Among the numerous genera, the following could be recognized: *Petalopora*, "*Smittipora*," *Idmidronea*, *Reteporidaea*, *Mecynoecia* (Plate 6, Figures 11-15), and *Lichenopora* (Plate 4, Figure 1).

In Hole 430A bryozoans are not frequent; their state of preservation is rather bad, and their occurrence is restricted mainly to the lower sections of that hole (Table 1).

Brachiopods

Small brachiopods occur occasionally in several samples from Holes 433A through 433C. They seem to belong to the superfamily Thecideacea, and are closely related to the genus *Lacazella* (Plate 6, Figure 10).

Mollusks

Recrystallized debris of small lamellibranchiats and gastropods also forms part of the detrital limestones (Plate 1, Figure 6; Plate 3, Figures 5, 6). Predominantly slender gastropods with a high spire occur in Hole 430A.

Ostracodes

The ostracode record for Hole 433A is characterized by repeated occurrences of nearly constant ostracode assemblages in the uniform rock sequence of more than 110 meters thickness (ranging from 52.5 m to 163.5 m below sea floor). This statement is based upon inspection of 56 samples containing rather well preserved ostracodes. The fauna can be characterized as a community of bairdiids (four species) predominating by more than 50 per cent in each of the ostracode samples. The rest is divided up among five (to six?) different species of trachyleberidids, especially one of them which occurs rather frequently (Plate 7). Ubiquitous species in marine sediments, such as those belonging to the genera *Cytherella* and *Cytherelloidea*, are very rare, constituting less than 1 per cent of the fauna. There is no indication of an occurrence of cytherurine, loxoconchine, or any other cytherid ostracodes.

The neighboring Hole 433B yielded the same ostracode assemblage — a bairdiid/trachyleberidid association — as Hole 433A. The third hole, 433C, yielded but a single bairdiid fragment.

The ostracode report for Hole 430A differs remarkably from that for Holes 433A through 433C. Ostracodes do not occur repeatedly as almost constant assemblages of species, but in a varying mixture of rare single specimens. Core 1 contains a single tiny (juvenile) bairdiid carapace in the uppermost sample. Eight samples of Core 2 each contain single representatives of several ostracode taxa attributed to various genera such as *Cytherella*, *Cytherelloidea*, *Krithe*, *Paracypris*, small specimens (juvenile?) of the genus *Bairdia*, different representatives of Cytherurinae, species of *Occultocythereis*?, and a species probably identical to the faintly reticulated trachyleberidids figured by Oertli (in Ferrer, 1975, pl. 8-bottom).

Echinoderms

Most skeletal remains, such as plates and spines, belong to the echinoids (Plate 1, Figure 6). Ossicles of asteroids and holothuroids may also be present.

Crustaceans

In many samples from Holes 433A through 433C, tips of the fingers of thalassinoid shrimps occur (determination by Dr. R. Förster, Munich).

Fish

Teeth and bony elements of fishes occur in some samples.

Algae

In the sediments of Holes 433A through 433C, members of the genus *Lithothamnium* are the most important rock-builders. In some cases the algal balls are still preserved (Plate 1, Figures 1, 5); they can be called rhodoliths. The thalli are usually broken; their detritus is more or less rounded (e.g., Plate 1, Figures 3, 6; dark in the picture). A striking genus is *Archaeolithothamnium* with its marked tetraspores (Plate 2, Figure 5). Our species resembles *A. nummuliticum* (Gümbel), in the sense of Johnson (1963, pl. 25, fig. 2), from the Eocene of Japan. Both *Lithothamnium* and *Archaeolithothamnium* represent the subfamily Melobesioideae of the family Corallinaceae. They belong to the Rhodophycophyta or Red Algae (Johnson and Kaska, 1965).

The genus *Ethelia* (= *Pseudolithothamnium auctorum*) is a representative of the family Squamariaceae. *E. alba* (Pfender) occurs rather frequently (Plate 3, Figure 2).

From the stratigraphic point of view, *Elianella elegans* Pfender and Basse is the key fossil belonging to the family Solenoporaceae (Plate 2, Figures 1, 3; Plate 3, Figure 3). It has been originally described by the above-mentioned authors with reference to the Paleocene of Madagascar, and has proved to occur also in the Paleocene of the Northern Alps (Hagn and Ott, 1975).

The presence of green algae (*Halimeda*) is not yet certain. Perhaps Figure 1 on Plate 3 shows a tangential section through the pores in the outer wall. In thin sections of samples from Holes 433A through 433C, such remains are very rare.

In contrast to Holes 433A through 433C, there is a change in the algal flora in Hole 430A. The principal genera are *Lithoporella* vel *Melobesia* and *Jania*. *Jania* belongs to the subfamily Corallinoideae of the family Corallinaceae. All these genera have a more platy appearance (Plate 1, Figures 2, 4; Plate 3, Figures 4, 6). In addition, *Ethelia alba* is frequent. Another interesting genus is *Acicularia* (Plate 1, Figure 2), a member of the dasycladacean green algae (see Samuel, Borza, and Köhler, 1972, pp. 123–127). This fossil is also very similar to *Terquemella globularis* Elliott from the Paleocene or lower Eocene of Cuba (Beckmann and Beckmann, 1966, pl. 12, fig. 176–179).

BIOSTRATIGRAPHY

Judging from the pelagic foraminifers, the samples from Holes 433A and 433B must be middle Paleocene. This conclusion can be refined: the occurrence of *Globorotalia (Morozovella) conicotruncata* (Subbotina), *G. (M.) angulata abundocamerata* Bolli, and *G. cf. pusilla pusilla* Bolli indicates the upper part of the *G. pusilla pusilla* Zone. Since the fauna of Hole 433C very closely corresponds to faunas of the two other holes, we can assume that the sequences of Holes 433A through 433C

belong to the *Globorotalia pusilla pusilla* Zone (Bolli, 1957, p. 64, fig. 11) or to the *Globorotalia conicotruncata* Subzone (Krasheninnikov, 1971, p. 1059, table 1).

Siphogenerinoides eleganta (Plummer) is furthermore a guide fossil for the older Paleocene (Hofker, 1965, p. 40). *Elianella elegans* Pfender and Basse is also restricted to the Paleocene. The bryozoans have not yet been studied in detail. The same is true of the spirorbids, but Mr. Lommerzheim informs us that most of the species still show affinities with forms from the Upper Cretaceous and the Danian (lowermost Paleocene).

Since very little is known of circum-Pacific lower Paleogene ostracodes, their biochronological evidence for an age determination is not conclusive. Still, a very useful aid is offered by a similar ostracode fauna (from the southeastern slope of Kōkō Seamount, Site 308 of Leg 32) reported by Oertli (Appendix A in Ferrer, 1975, pl. 7 and 8). The similarity is suggested by the occurrence of bairdiids (op. cit., pl. 7, two different species at top left and top middle) and roughly reticulated trachyleberidids (op. cit., pl. 7 at bottom right and pl. 8 at center). Since the Kōkō Seamount ostracodes are classified as being lower Eocene, we may expect a close relationship to the older Suiko Seamount ostracodes rather than to the upper Eocene ostracodes from Tonga (Hazel and Holden, 1971).

The pelagic community of Hole 430A indicates a somewhat lesser age than that of the material from Holes 433A through 433C. The association of *Globigerina nana* Khalilov, *Globorotalia pusilla laevigata* Bolli, *G. elongata* Glaessner, *G. (Morozovella) aequa* Cushman and Renz, and *G. (M.) velascoensis* (Cushman) indicates the lower upper Paleocene, i.e., the *Globorotalia pseudomenardii* Subzone (Bolli, 1957, p. 64, fig. 11; Serova, 1967, p. 25; Krasheninnikov, 1971, p. 1059, table 1).

It is obvious that the difference in the ages at Holes 430A through 433C is not very large; it amounts only to one foraminiferal subzone. In this connection, the ostracodes in Samples 2, CC and 3, CC, as well as in three more samples from Core 430A-4 (ranging from 57.0 to 66.0 m below sea floor), are the same as those in Holes 433A and 433B.

PALEOECOLOGY

Nearly all faunal and floral elements of Holes 433A through 433C, as well as those of Hole 430A, indicate a shallow-water facies. The relatively sparse and mostly dwarflike pelagic foraminifers do not contradict this conclusion, because atolls usually have passages which allow for a connection with the open ocean (Wiens, 1962, pp. 225, 247).

The foraminiferal fauna of Holes 433A through 433C cannot be compared to "normal" Paleocene associations as described from occurrences all over the world. Only a few known species, e.g., *Siphogenerinoides eleganta* (Plummer) and *Marginulina jarvisi* Cushman, are present in samples from these holes. Presumably the other species are new and indicate an endemic character of the fauna. Further, the lagoonal faunas

from Holes 433A through 433C are composed of only a few genera. Really we have here a highly restricted biotope (*Extrembiotop*).

The faunas from Holes 433A through 433C are characterized by smooth, not sculptured, tests. In addition to the agglutinated genus *Arenoturrspirillina*, we find mainly lagenids, polymorphinids, and simple rotaliid forms. Members of the Buliminacea are extremely rare, with one exception (*Siphogenerinoides*). Miliolids and rotaliids (those with a knob on the umbilical side) are missing. We found no broken or worn tests. Therefore, we can assume that the energy level of the water was not very high.

The spirorbids are typical for shallow and euhaline water. Most of them occur from littoral depths to about 50 meters. The present tubes have been attached to plants, especially seaweed; their base is plane to concave. This indicates a rich flora on the bottom of the lagoon. The biotope of the spirorbids must be the photic zone.

The abundance of bryozoans indicates favorable living conditions. The finely sculptured zoecias usually are not damaged. Some stems are coated by thin calcareous laminae of algal origin. This leads to the conclusion that the bryozoans lived in the phytal zone in relatively calm water.

In contrast, the composition of the ostracode assemblages suggests a high-energy environment in the shallow-water realms of the lagoon. The carapaces are thick-walled and well ornamented in part. This indicates that the water was not deeper than 10 meters.

The thalassinoid shrimps occur mainly at a depth between 5 and 30 meters; their maximum depth does not exceed 50 meters.

The algal detritus has been transported from algal meadows destroyed by wave action. It formed the substratum for the benthic organisms which settled on the bottom of the lagoon.

To summarize, then, the sediments cored in Holes 433A through 433C were apparently deposited in depths between 5 and 30 meters. The energy level was changeable between moderate and high. The repeated occurrence of homogeneous assemblages of foraminifers, worms, bryozoans, and ostracodes indicates a constant ecological habitat throughout a relatively long time. We infer that the Suiko Seamount had a steady development; the rapid subsidence resulted in a remarkable thickness of more than 110 meters.

As indicated in the foregoing, the faunas from Hole 430A are very different from those of Holes 433A through 433C (cf. Table 1). The slightly different ages cannot explain this; one must look to ecological factors. Cushman, Todd and Post (1954) wrote, of the lagoons of the Marshall Islands, "The reasons for these variations are also obscure but probably bottom conditions have a very important part in determining what foraminiferal species are to be found. Many factors other than depth affect these faunas, which are not entirely life associations."

The lowermost deposits of Hole 430A are typical shallow-water sediments, as indicated by the miliolids

and specimens of *Discorbis*. In the higher parts, gypsum crystals and extremely dwarf-sized *Cibicides* specimens suggest a hypersaline medium. This is not surprising, because many recent atolls are known to have saline lagoons (Wiens, 1962). The Ōjin Seamount, therefore, differs in its development from Suiko Seamount.

Finally, a few remarks on paleoclimatology. Schlang-er and Konishi (1975) discriminated between a "coral-algal" and "bryozoan-algal" facies. The former is situated nearer the equator; the latter characterizes the higher latitudes. The sediments cored by the *Glomar Challenger* in the Ōjin and Suiko Seamounts are poor in corals but extremely rich in red algae and bryozoans. From this we can conclude that these seamounts were situated in the region of the "bryozoan-algal" facies, i.e., in more northern regions, during the Paleocene. This facies resembles very strongly the *Lithothamnium*-bryozoan limestones of the foreland of the Bavarian Alps (upper Eocene) which fringed the Tethyan Sea in the north. It cannot be assumed, however, that cold water conditions prevailed, because of the spirorbids, which have a broad base for attachment; in cold water this base is markedly narrower. In addition, the globorotaliids show fine pustulations on the periphery and on the sutures — also characteristic for warm water.

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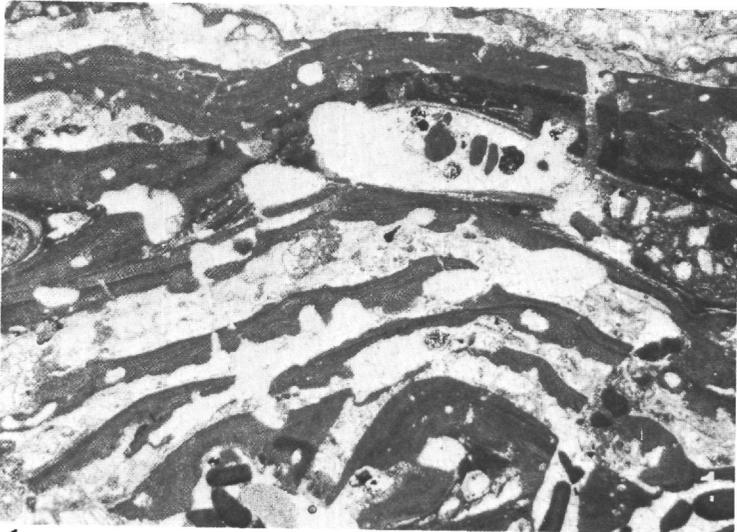
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PLATE 1

- Figure 1 *Lithothamnium* grown together with serpulids. Thin section. 433C-1-1, 15-19 cm ($\times 17$).
- Figure 2 *Acicularia* sp. (above), *Quinqueloculina* sp. (below). Thin section. 430A-4-1, 5-7 cm ($\times 42$).
- Figure 3 Pyroclastic component (above), detrital limestone (below). Debris of *Lithothamnium* (dark) and of *Ethelia* (bright). Thin section. 433B-4-1, 32-36 cm ($\times 33$).
- Figure 4 *Quinqueloculina* sp., platy debris of Corallinaceae, pyroclastic components. Thin section. 430A-4-1, 5-7 cm ($\times 42$).
- Figure 5 Bryozoan limestone with sparitic matrix. Thin section. 433C-1-1, 4-7 cm ($\times 33$).
- Figure 6 Spine of echinoid, shell remains of gastropod, rounded debris of red algae. Thin section. 433C-1-1, 20-25 cm ($\times 19$).

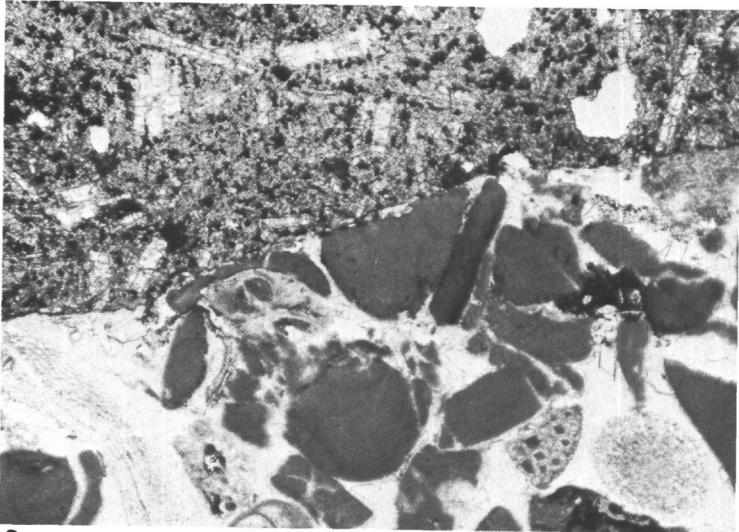
PLATE 1



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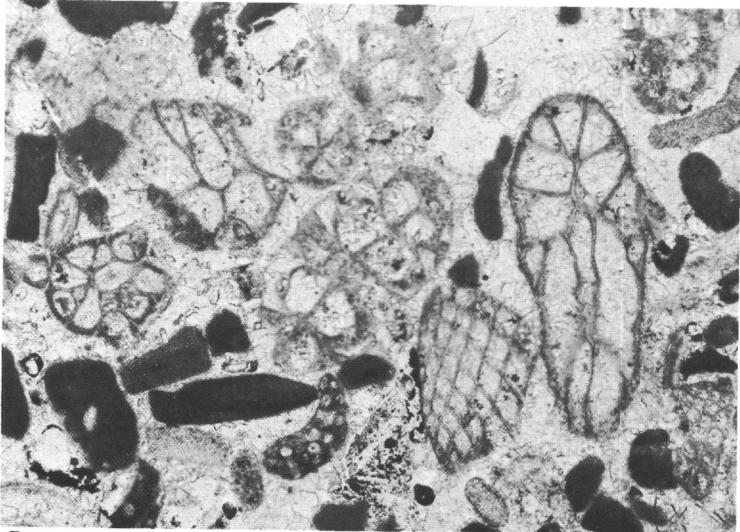
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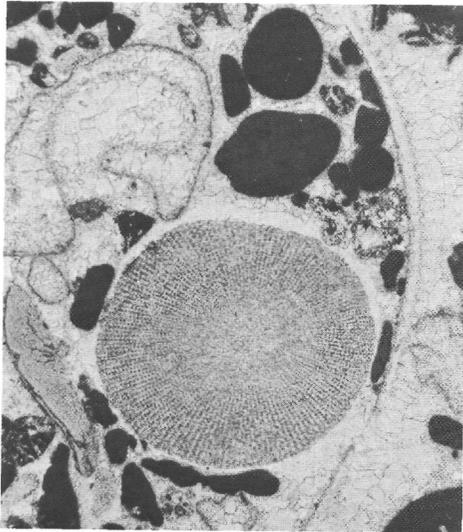
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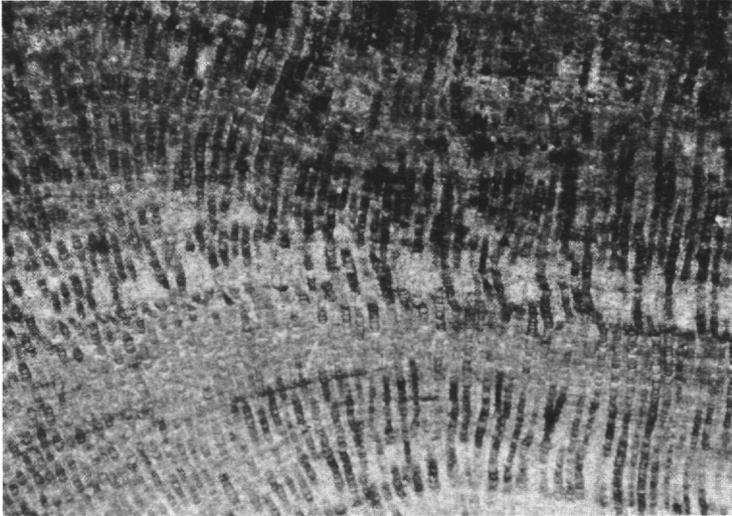


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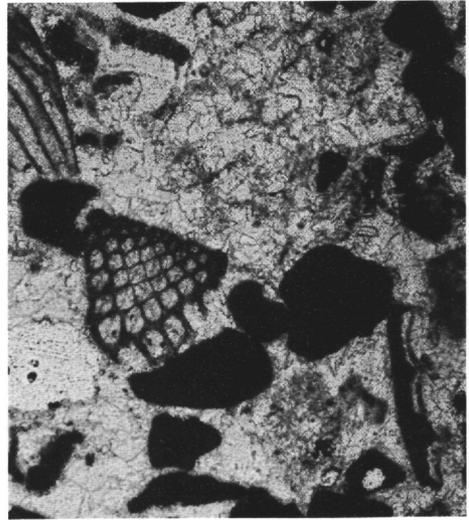
PLATE 2

- Figure 1 *Elianella elegans* Pfender and Basse. Thin section. 433C-1-1, 20-25 cm ($\times 42$).
- Figure 2 Bryozoan-*Lithothamnium* limestone. Thin section. 433C-1-1, 15-19 cm ($\times 33$).
- Figure 3 *Elianella elegans* Pfender and Basse. Thin section. 433C-1-1, 20-25 cm ($\times 42$).
- Figure 4. Solitary coral. Thin section. 433C-1-1, 4-7 cm ($\times 17$).
- Figure 5 *Archaeolithothamnium* sp. Thin section. 433C-1-1, 20-25 cm ($\times 42$).
- Figure 6 Bryozoan stem. Thin section. 433A-18,CC, 0-3 cm ($\times 33$).

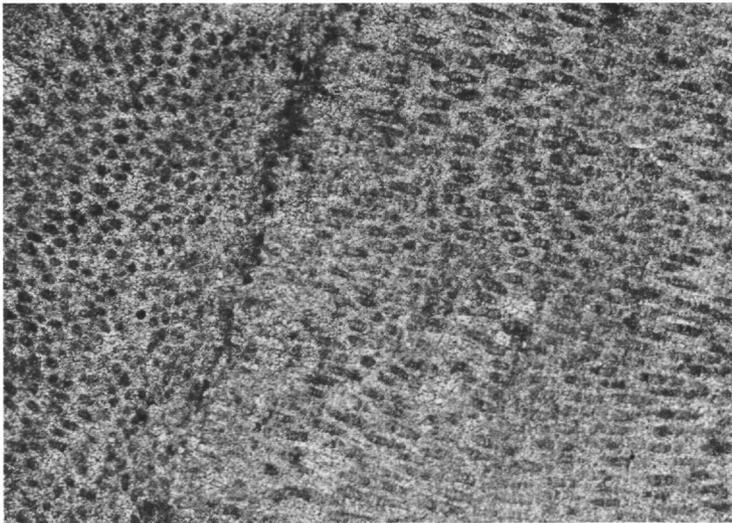
PLATE 2



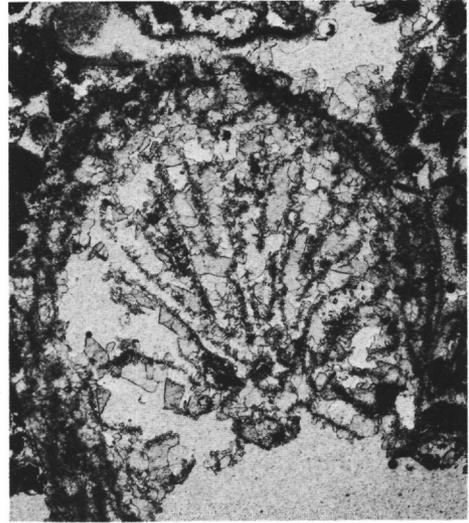
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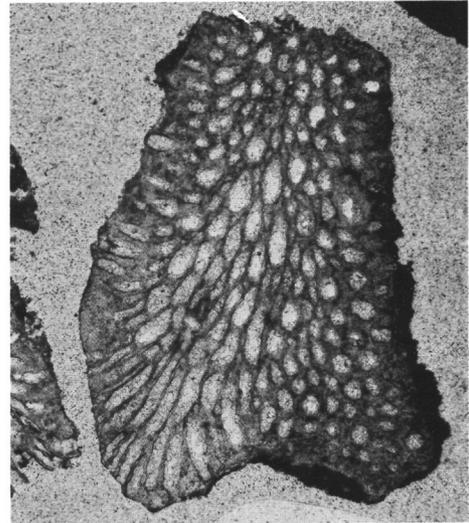
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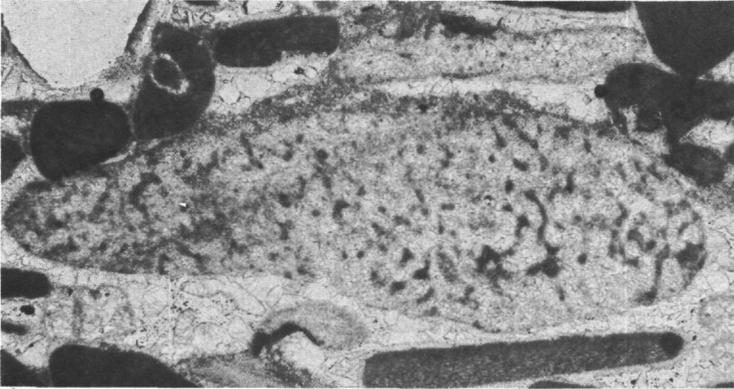


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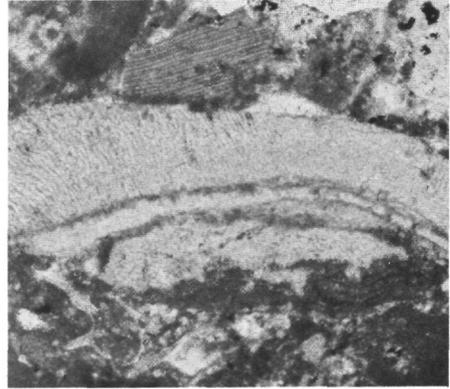
PLATE 3

- Figure 1 *Halimeda?* Tangential section. Thin section. 433B-4-1, 28-32 cm ($\times 33$).
- Figure 2 *Ethelia alba* (Pfender). Thin section. 433A-19, CC ($\times 43$).
- Figure 3 *Elianella elegans* Pfender and Basse. Thin section. 433B-4-1, 28-32 cm ($\times 33$).
- Figure 4 *Spirorbis* sp. Thin section. 430A-4-1, 5-7 cm ($\times 42$).
- Figure 5 Detrital limestone with bryozoan skeleton, *Lithothamnium*, and other debris. Thin section. 433C-1-1, 20-25 cm ($\times 19$).
- Figure 6 Small gastropod. Thin section. 430A-4-1, 5-7 cm ($\times 42$).
- Figure 7 Tube of serpulid. Thin section. 433C-1-1, 4-7 cm ($\times 33$).
- Figure 8 *Anomalinooides* sp. Thin section. 433B-4-1, 32-36 cm ($\times 43$).

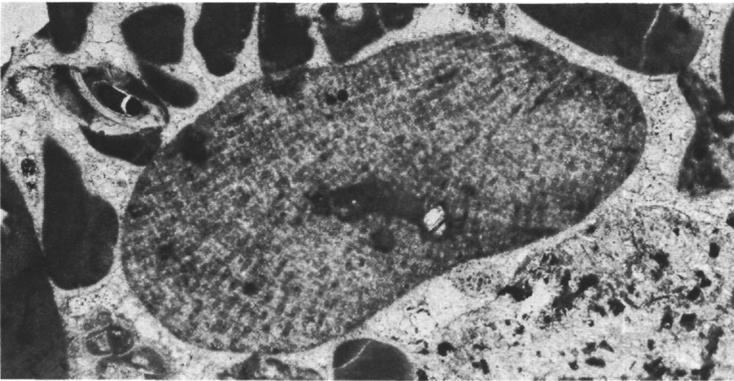
PLATE 3



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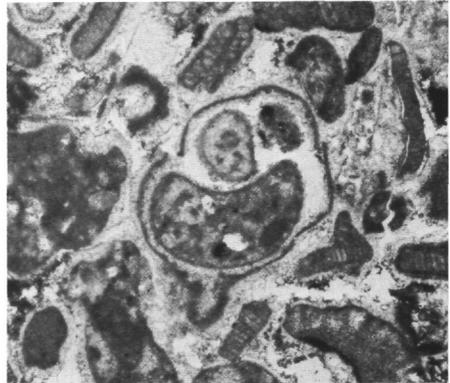
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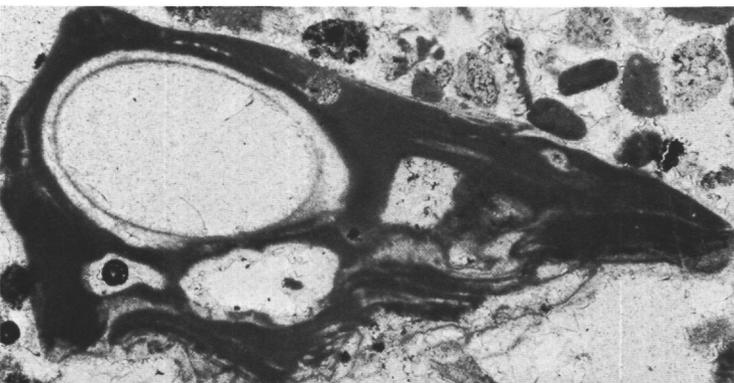
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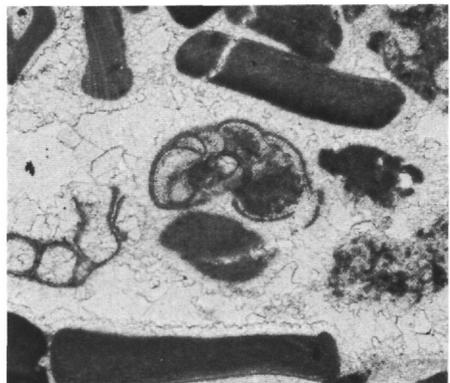
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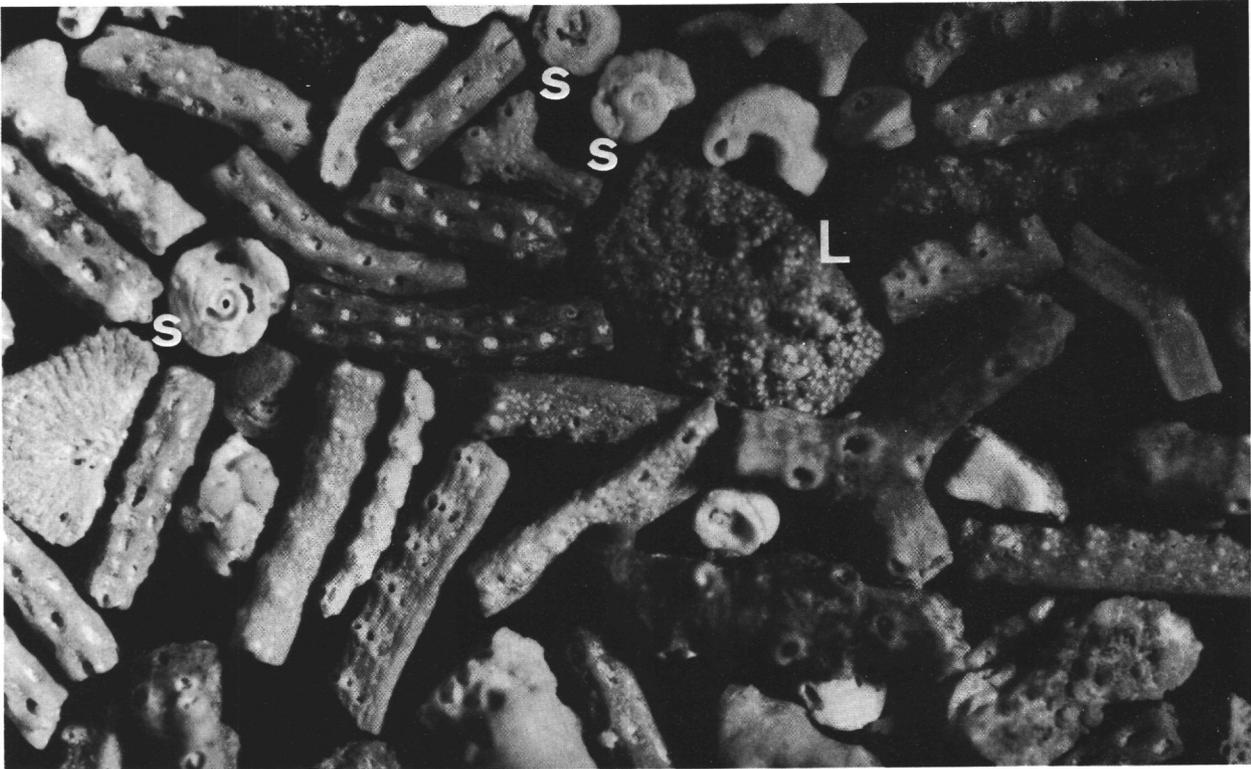


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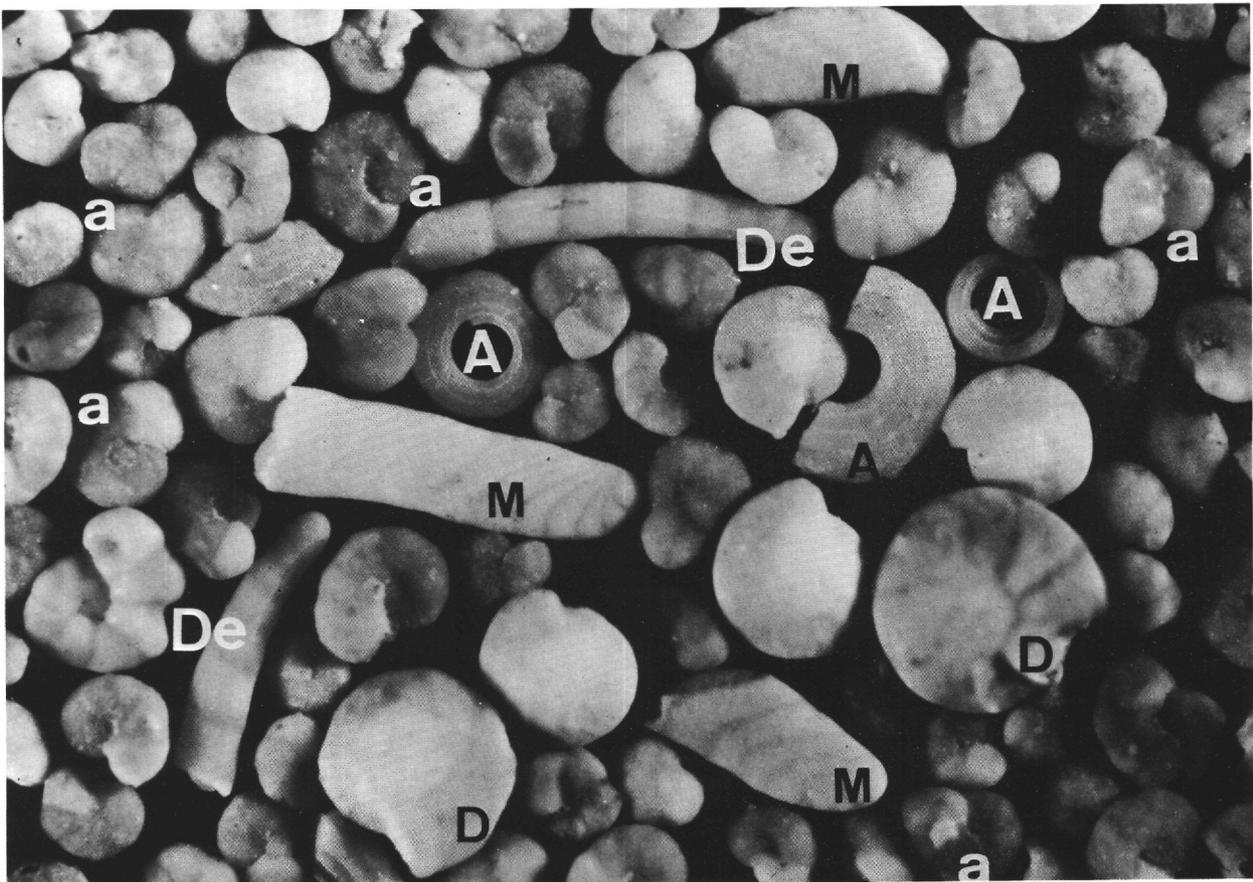
PLATE 4

- Figure 1 Bryozoan-*Spirorbis* assemblage. 433B-1-4, 67-70 cm ($\times 17$).
S = *Spirorbis*, L = *Lichenopora*.
- Figure 2 Foraminiferal assemblage. 433B-1-1, 39-41 cm ($\times 30$).
A = *Arenoturrspirillina*, D = *Darbyella*, De = *Dentalina*, M = *Marginulina*, a = *Anomalinoides* sp. B.

PLATE 4



1



2

PLATE 5

- Figure 1 *Arenoturrspirillina* sp. 433A-14-1, 54–56 cm ($\times 30$).
- Figure 2a, b *Arenoturrspirillina* sp. Dto.
- Figures 3, 4 *Darbyella* sp. 433A-12-2, 49–51 cm ($\times 30$).
- Figure 5 *Nodosaria* sp. 433A-12-2, 117–120 cm ($\times 30$) (may be a contamination from the Neogene).
- Figure 6 *Marginulina jarvisi* Cushman. 433A-14-1, 54–56 cm ($\times 30$).
- Figure 7 *Anomalinoides* sp. A, dorsal side. 433A-7-5, 140–142 cm ($\times 60$).
- Figure 8 *Anomalinoides* sp. A, dorsal side. 433A-14-1, 75–77 cm ($\times 60$).
- Figure 9 *Siphogenerinoides eleganta* (Plummer). 433A-7-6, 30–32 cm ($\times 75$).
- Figure 10 *Siphogenerinoides eleganta* (Plummer). 433A-14-1, 54–56 cm ($\times 75$).
- Figures 11–13 *Anomalinoides* sp. B., spiral side, peripheral view, umbilical side. 433B-3-1, 6–8 cm ($\times 60$).
- Figure 14 *Anomalinoides* sp. B, umbilical side. 433A-8-4, 30–32 cm ($\times 60$).

PLATE 5

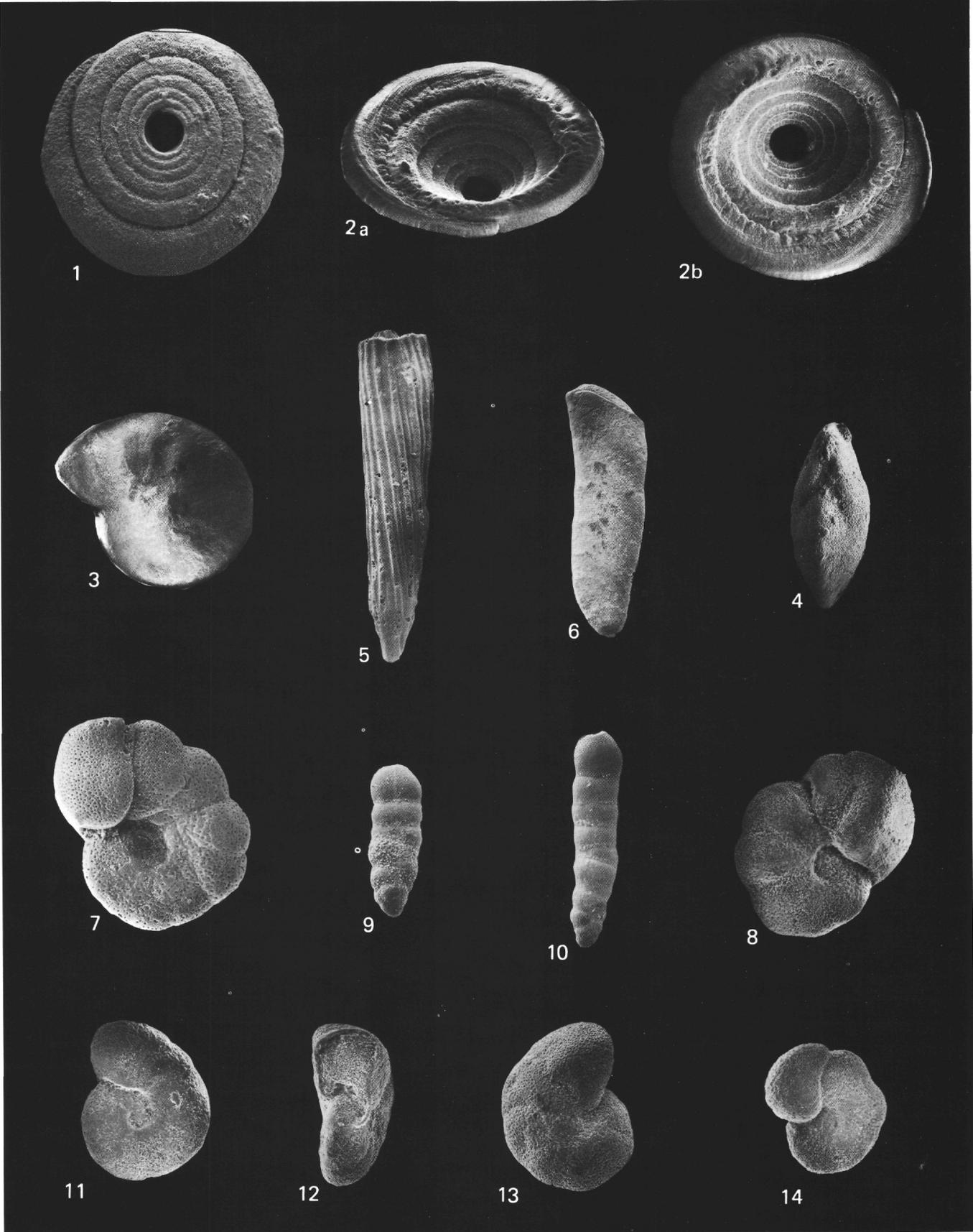


PLATE 6

- Figure 1 *Globigerina* cf. *triangularis* White, dorsal side. 433A-10-6, 77-79 cm ($\times 75$).
- Figure 2 *Globorotalia* (*Morozovella*) *velascoensis* (Cushman), umbilical side. 430A-2-1, 121-125 cm ($\times 75$).
- Figure 3 *Globorotalia* (*Morozovella*) *aequa* Cushman and Renz, dorsal side. 430A-3-1, CC ($\times 75$).
- Figure 4 *Globorotalia* (*Morozovella*) *aequa* Cushman and Renz, umbilical side. 430A-3-1, CC ($\times 75$).
- Figures 5, 6 *Globorotalia* (*Morozovella*) cf. *conicotruncata* (Subbotina), spiral and umbilical side. 433A-10-6, 128-131 cm ($\times 75$).
- Figure 7 *Globorotalia* (*Morozovella*) cf. *conicotruncata* (Subbotina), peripheral view. 433A-10-6, 77-79 cm ($\times 75$).
- Figure 8 *Acarinina* sp., umbilical side. 433A-10-4, 59-61 cm ($\times 75$).
- Figure 9 *Globorotalia* cf. *imitata* Subbotina. 433A-10-6, 128-131 cm ($\times 75$).
- Figure 10 Small brachiopod. 433A-16-1, 79-81 cm ($\times 30$).
- Figure 11 *Petalopora* sp. 433C-3-2, 88-91 cm ($\times 15$).
- Figure 12 "*Smittipora*" sp. 433C-3-3, 30-33 cm ($\times 15$).
- Figure 13 *Idmidronea* sp. 433C-10, CC ($\times 15$).
- Figure 14 *Reteporidaea* sp. 433C-3-3, 30-33 cm ($\times 15$).
- Figure 15 *Mecynoecia* sp. 433C-3-1, 106-109 cm ($\times 15$).

PLATE 6

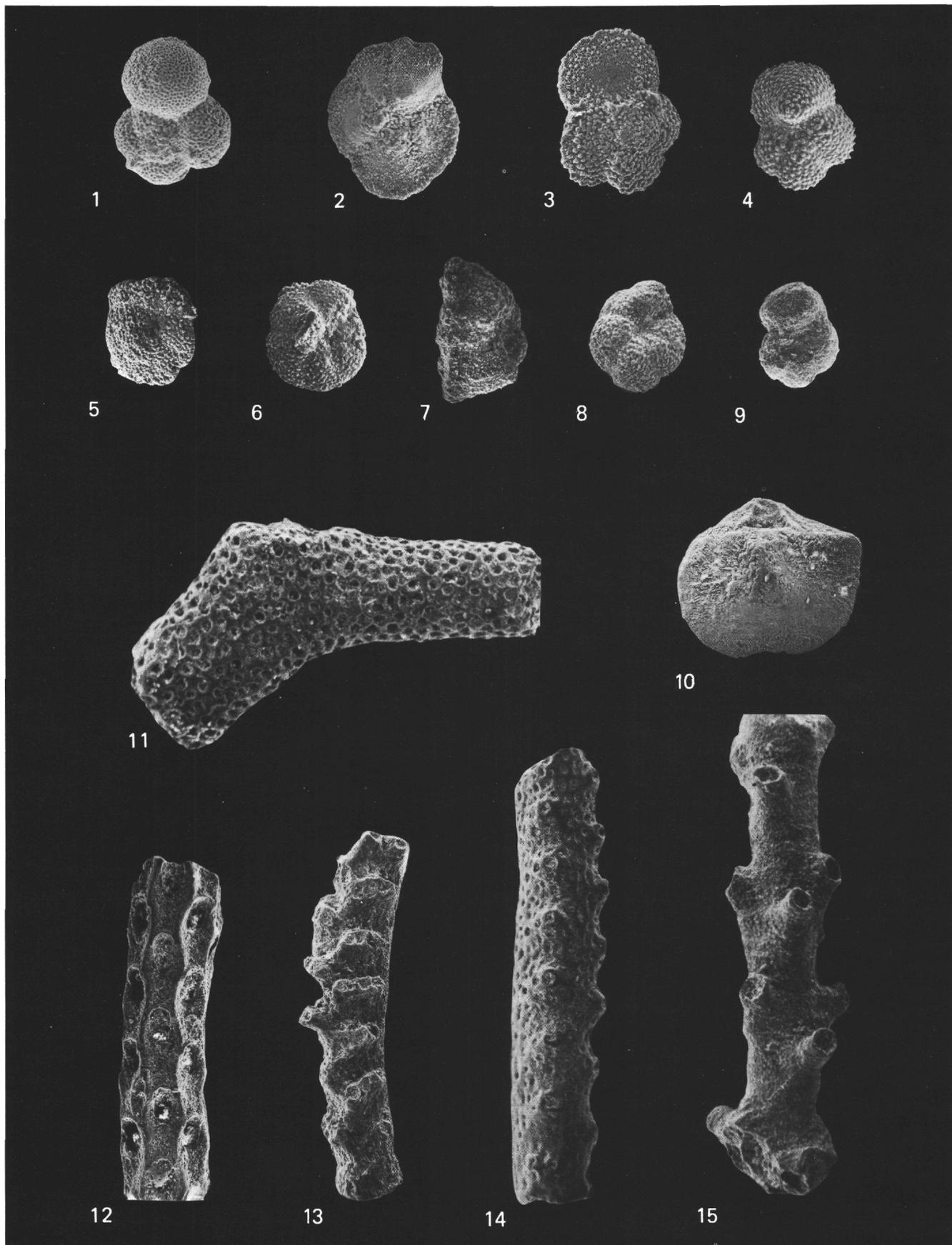


PLATE 7

Ostracodes from Suiko Seamount, Site 433

Magnification: all approximately $\times 100$

LV = left valve, C = carapace;

numbers in brackets = lengths of specimens (mm)

The figured specimens were selected for their good preservation from various cores and sections of Holes 433A and 433B. They are representative of the whole trachyleberidid ostracode fauna, which occurs repeatedly within most of the cored intervals (for further reference see text). Though they are named under open nomenclature for the present, the grouping of species can be supported by common features in outline and surface ornament. Internal characteristics of the carapace, such as muscle scars, hinge, and marginal pore canals, are still awaiting more intensive study.

- Figures 1-3 Suiko species H (protruding mid-dorsal rib).
1. LV (0.60). Sample 433B-1-5, 145-147 cm.
2. C (0.60). Sample 433B-3-1, 6-8 cm.
3. C (0.60). Sample 433B-3-1, 6-8 cm.
- Figures 4-6 Suiko species O (peripheral ribs surrounding smooth median part).
4. C (0.68). Sample 433A-14-1, 54-56 cm.
5. C (0.70). Sample 433A-14-1, 54-56 cm.
6. C (0.69). Sample 433A-10-3, 102-104 cm.
- Figures 7, 8 Suiko species B (reticulate pattern subdivided by dense polymeshed network).
7. C (0.62). Sample 433B-1-7, 10-13 cm.
8. C (0.63). Sample 433A-10-5, 20-22 cm.
- Figures 9, 10 Suiko species K (compressed coffer form).
9. C (0.75). Sample 433A-16-1, 33-36 cm.
10. C (0.73). Sample 433A-16-1, 79-81 cm.
- Figures 11, 12 Suiko species W (corrugate surface ornament).
11. C (0.84). Sample 433B-3-1, 6-8 cm.
12. C (0.76). Sample 433B-3-1, 6-8 cm.

PLATE 7

