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29. A MODEL FOR THE DEVELOPMENT OF RHODOLITHS ON PLATFORMS INFLUENCED BY STORMS: MIDDLE MIOCENE CARBONATES OF THE MARION PLATEAU (NORTHEASTERN AUSTRALIA)[1]

José M. Martín,[2] Juan C. Braga,[2] Kenji Konishi,[3] and Christopher J. Pigram[4]

ABSTRACT

Middle Miocene carbonates of the Marion Plateau consist of dolomitized bioclastic floatstones and rudstones with rhodoliths (up to 6 cm in size) as the most prominent component. These rhodoliths are embedded in a bioclastic matrix with *Halimeda*, echinoids, bivalves, gastropods, bryozoans, small coralline fragments, benthic (and planktonic) foraminifers, and rare dasyclads. Corals (not abundant) occur only as fragments and may serve as nuclei for some of the rhodoliths.

Two main types of rhodoliths are evident. The commonest type is formed by *Lithothamnion* and *Sporolithon*, together with minor *Hydrolithon*, *Mesophyllum*, *Spongites*, and *Lithoporella*. The other type is made up mainly of *Mesophyllum*. Laminar growths are always predominant inside the rhodoliths. Both the growth types and the algal associations are characteristic of rhodoliths that formed at depths of some tens of meters and below the normal wavebase. Similar coralline associations presently occur in the Indo-Pacific area at depths between 30 and 80 m. Clearly, these depths are below the normal wavebase, but within the reach of storms.

Encrusting foraminifers, serpulid worm tubes, bryozoans, and vermetids are sometimes important elements within these rhodoliths and occur either as more-or-less discrete layers interbedded with the coralline growths or in their nuclei. Bioclastic sediment is also incorporated within the rhodoliths. Some of the rhodoliths now appear partially broken and, presumably, were reworked in the environment of deposition. Others exhibit several phases of growth and reworking. Some of them have also been bored. The context in which these rhodoliths developed was that of a neritic, open-platform environment. They were reworked and partially broken and abraded during storms and then grew once more during the intervening calm periods. The internal structure of the rhodoliths is complex in detail, with successive coralline laminae encrusting more-or-less eroded former growths, and in turn being partially destroyed during the next storm event.

INTRODUCTION

Coralline algae are important paleoenvironmental indicators. Their associations and growth forms, in combination with the petrologic and sedimentological data, can be used to determine the environment of deposition and the genesis of the sediments in which they occur. Examples of such studies can be found in Adey (1979), Bosence (1983; in press), Braga and Martín (1988), and Aguirre et al. (in press), among others.

Coralline algae are important elements in the middle Miocene carbonates drilled at Site 816 of Leg 133 in the Marion Plateau area (Fig. 1). They are the most conspicuous components in lithologic Unit II (93-164 mbsf), described as dolomitized, rhodolith-bearing, bioclastic floatstone and rudstone, and Unit III (163.7-250 mbsf), consisting of dolomitized coralline algal and coral framestone with rhodoliths. Unit II was first considered to have been deposited in a shallow (< 5 m), lagoonal area, while Unit III was presumed to have formed in a very shallow (< 2 m?), reef-flat zone (Shipboard Scientific Party, 1991; Site 816) (Fig. 2).

Here, we present a detailed study of the rhodoliths of both units, with an indication of the types of algae, algal associations, and growth forms. Our analysis shows that both units are identical in regard to both bioclasts and texture. Our study also shows that the rhodoliths were formed in an open-platform environment and that the former attribution to shallow lagoon/reef-flat areas is incorrect. This interpretation has important geological implications with respect to the Miocene evolution of the northern margin of the Marion Plateau. Site 816 was positioned to determine, among other things, the facies association of a prominent mound near the northern edge of the plateau. This mound had been interpreted as a reefal complex by Feary et al. (1990). The results of this study of the rocks and the rhodoliths suggest that the morphology of the upper surface of the early-to-middle Miocene platform at this location results solely to erosion and that the mound is not a reefal complex. Finally, a model of rhodolith formation in open-platform environments affected by sporadic storms also is presented.

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[2] Departamento de Estratigrafía y Paleontología e Instituto Andaluz de Geología Mediterránea, Facultad de Ciencias, Universidad de Granada, Campus de Fuentenueva s.n. 18002, Granada, Spain.
[3] Department of Earth Sciences, Kanazawa University, Kanazawa City 920, Ishikawa, Japan.
[4] Australian Geological Survey Organisation (formerly Bureau of Mineral Resources), Australia, P.O. Box 378, Canberra, ACT 2601, Australia.

METHODS

Twenty-seven thin sections of samples containing rhodoliths from Units II and III (Site 816) were selected and studied, and the carbonate facies and coralline algae (types, growth forms, and associations) determined. Eleven polished slabs also were prepared and studied with the help of a lens.

RHODOLITH CHARACTERISTICS

All the samples studied are bioclastic floatstones and rudstones that contain abundant, spheroidal to discoidal rhodoliths up to 6 cm in diameter. The sediment enclosing the rhodoliths incorporates loose coralline-algal growths (branching and laminar), as well as benthic (and some planktonic) foraminifers, bryozoans, echinoids, bivalves, gastropods, *Halimeda*, corals (sometimes as nuclei in the rhodoliths), and rare dasyclads. All these bioclasts tend to be fragmented (Pl. 1, Fig. 1).

Two main types of rhodoliths are evident (Pl. 1, Fig. 2). One is dominated by *Lithothamnion* (Pl. 1, Figs. 3–6) and *Sporolithon* (Pl. 2, Figs. 1 and 2), together with minor *Hydrolithon* (Pl. 2, Fig. 3), *Mesophyllum* (Pl. 2, Fig. 4), *Spongites*, and, rarely, *Lithoporella*. Squa-

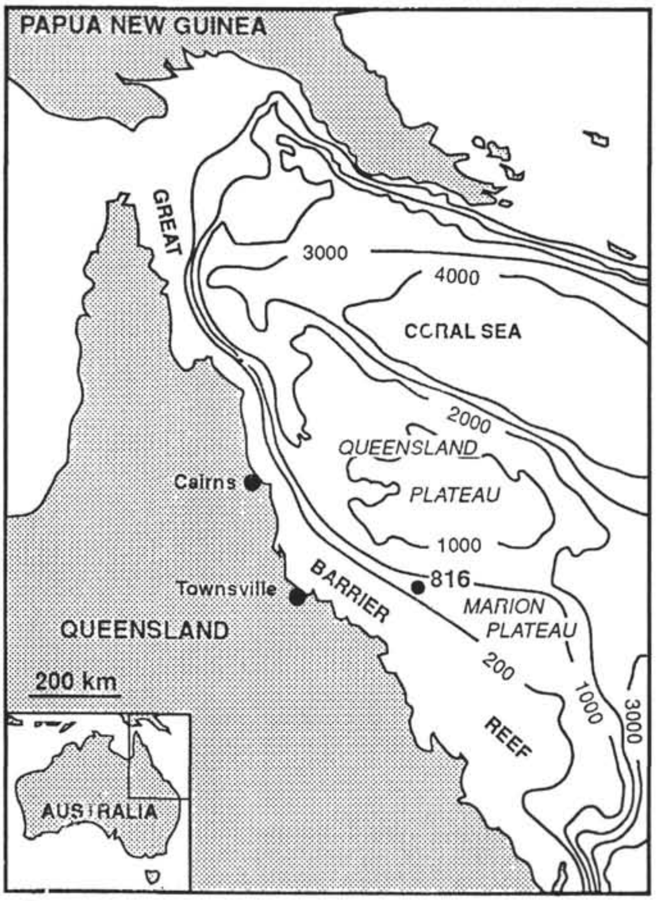

Figure 1. Geographical location of Site 816 at the northern margin of the Marion Plateau. Bathymetry in meters.

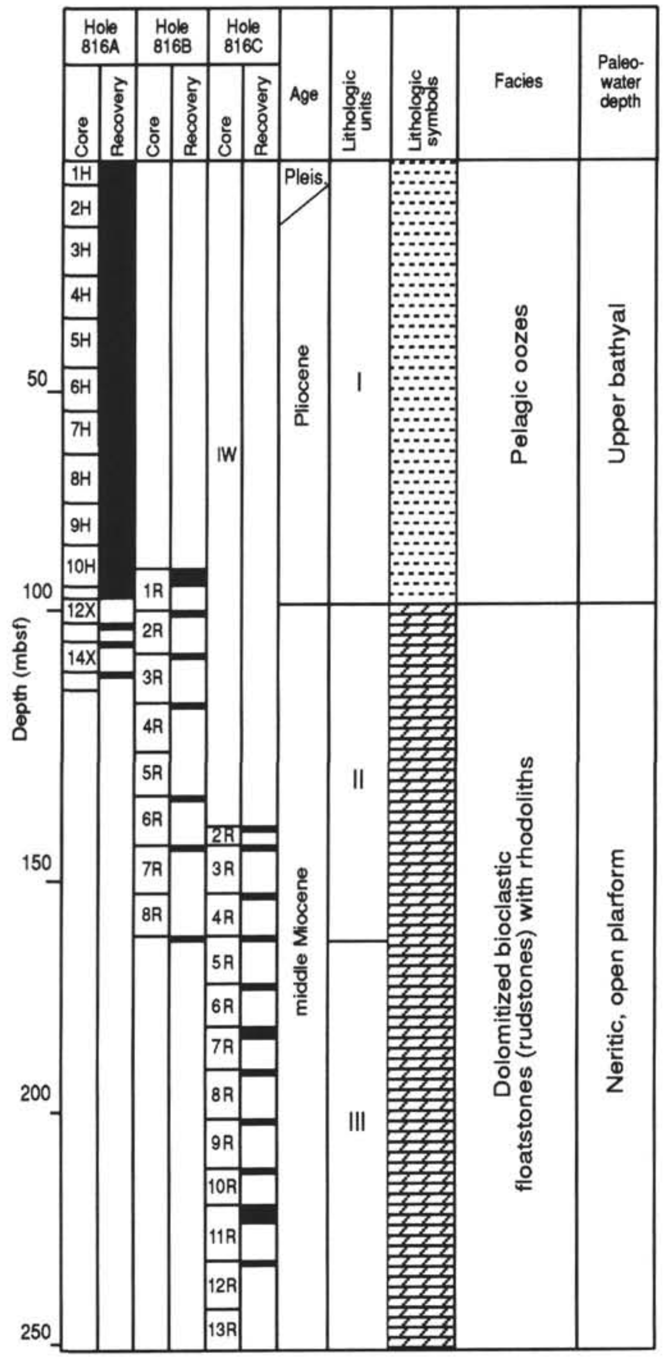

Figure 2. Site 816, lithostratigraphic section (modified from fig. 6, Shipboard Scientific Party, 1991, "Site 816" chapter). The facies of the rhodolith-bearing units (II and III) are much the same.

mariaceae (red algae), serpulids, bryozoans (Pl. 1, Fig. 5), vermetids (Pl. 1, Fig. 6), and encrusting foraminifers can all be found intergrowing with corallines inside these rhodoliths. Bioclasts (mainly coral and mollusk fragments) serve as nuclei for these rhodoliths. The other type consists almost exclusively of *Mesophyllum* crusts.

A few different nodules (foralgaliths in the sense of Prager and Ginsburg, 1989) are made up of encrusting foraminifers (*Ladoronia vermicularis* Hanazawa, 1957, det. G.C.H. Chaproniere, this volume) and some crusts of corallines, mainly *Lithothamnion*.

Delicate, laminar coralline crusts (usually less than 0.5 mm thick) are dominant inside the rhodoliths (Pl. 1, Fig. 3, and Pl. 2, Fig. 4). Small protuberances (2–3 mm high and 2–3 mm in diameter) stick out from the laminar thalli in places.

Several growth phases can normally be distinguished inside the rhodoliths, separated by intraerosional surfaces that cut across former sets of laminae (Pl. 1, Fig. 4). Bioclastic sediment is sometimes incorporated between laminae. This sediment also occurs as intraclasts, which may occasionally act as nuclei for some rhodoliths. Some of the rhodoliths have also been bored.

GENETIC MODEL

The algal associations in the rhodoliths and loose coralline fragments in the middle Miocene sediments of the Marion Plateau are dominated by members of the subfamily Melobesioideae (91% of the coralline thalli present in the studied samples). The rest of these corallines belong to the subfamily Mastophoroideae, whereas no lithophylloids were recorded. Such a composition of coralline floras is characteristic of environments below the normal wavebase in subtropical and tropical areas (Bosence, in press), according to the available data from both Holocene and Miocene examples of coralline distribution (Buchbinder, 1977; Adey, 1979; Braga and Martín, 1988; Martín and Braga, 1989; Bosence, in press).

Lithothamnion dominates the coralline associations at the generic level (65% of thalli in the samples), followed by *Mesophyllum* (15%), *Sporolithon* (10.5%), and *Hydrolithon* (8%). These generic proportions are most similar to those found by Adey (1979) in present-day coralline associations at a water depth of approximately 70 m in the

Hawaiian Islands; *Lithothamnion* and *Mesophyllum* dominate the coralline floras from 30 to 80 m on the shelves of the Indo-Pacific region (Adey, 1979).

Delicate, laminar crusts and branches predominate in "deep-water" rhodoliths (i.e., Braga and Martín, 1988) and are especially characteristic of open-shelf environments (Bosence, in press).

Encrusting-foraminifer/coralline nodules having similar components to the ones at Site 816 have been recorded on Florida's outer shelf in 35- to 65-m-deep, quiet-water environments (Prager and Ginsburg, 1989).

Evidence from both the coralline associations and rhodolith morphology points, therefore, to an open-platform setting for the rhodolith growth. Paleobathymetry can be estimated as being some tens of meters, presumably 30 to 80 m.

Two well-differentiated phases can be seen in the development of these rhodoliths: a low-energy one, with active growth, and a high-energy one, during which they were reworked and partially destroyed. The alternation of these two phases brought about recolonization by corallines and subsequent erosional episodes. As a result of all this, the final internal structure of the rhodoliths is very complex (Fig. 3).

This succession of calm episodes, with active growth, and high-energy episodes, with partial destruction of the rhodoliths, might easily have happened in an open-platform environment influenced by sporadic storms. Rhodolith growth took place during calm periods, and they were reworked and partially eroded when storms occurred. The possibility of some bioerosion also playing a role in the development of some of these intraerosional surfaces cannot be discarded. The range of paleowater depths that are indicated by the assemblages (30–80 m) are well below the normal wavebase, but within the reach of storms. This situation would favor the development of delicate, laminar (and branching) growths in fair weather and their reworking and partial destruction during storms. Taking into account the average rhodolith size (3–5 cm), the present-day rates of rhodolith growth (1–2 cm/100 yr [Bosellini and Ginsburg, 1971]) for shallow-water rhodoliths (a figure that must be reduced for deep-water ones), and the number of intraerosional surfaces (3–5) inside the rhodoliths, we can estimate periods of some tens of years between the storms.

Skeletal components within the sediment (*Halimeda*, mollusks, foraminifers) also were probably reworked and fragmented during the storm events and mixed up sporadically with elements such as corals, coming from shallower areas. Intraclasts also formed in places where the sediment was partly lithified. Presumably, micrite was winnowed, although it filtered in later during the next calm period. All this resulted in the formation of the poorly to highly washed, bioclastic sediments accompanying the rhodoliths. No evidence can be seen of shallower rhodoliths reworked into this area.

CONCLUSIONS

Middle Miocene rhodoliths from the Marion Plateau formed in an open-platform environment subjected to the influence of sporadic storms. Inside the rhodoliths, delicate, laminar coralline growths are the predominant constituents and occur together with serpulids, bryozoans, vermetids, and encrusting foraminifers. The algal association comprises the following genera: *Lithothamnion*, *Mesophyllum*, *Sporolithon*, *Hydrolithon*, *Spongites*, and rare *Lithoporella*. Active growth took place in the calm periods between storms, while rhodolith reworking and partial erosion occurred during the latter. The repeated development of low- and high-energy events resulted in the formation of rhodoliths having a complex internal structure, in which successive sets of laminae have been separated and cut across by internal erosional surfaces.

The two middle Miocene lithologic units of the Marion Plateau (see Shipboard Scientific Party, 1991; "Site 816" chapter) appear to be exactly the same as far as lithology and rhodoliths (their most characteristic and conspicuous elements) are concerned, and their attribution to shallow-lagoon/reef-flat environments is incorrect. The morphology of the surface on top of the early to middle Miocene platform is the result of erosion and was not conditioned by any reef structure.

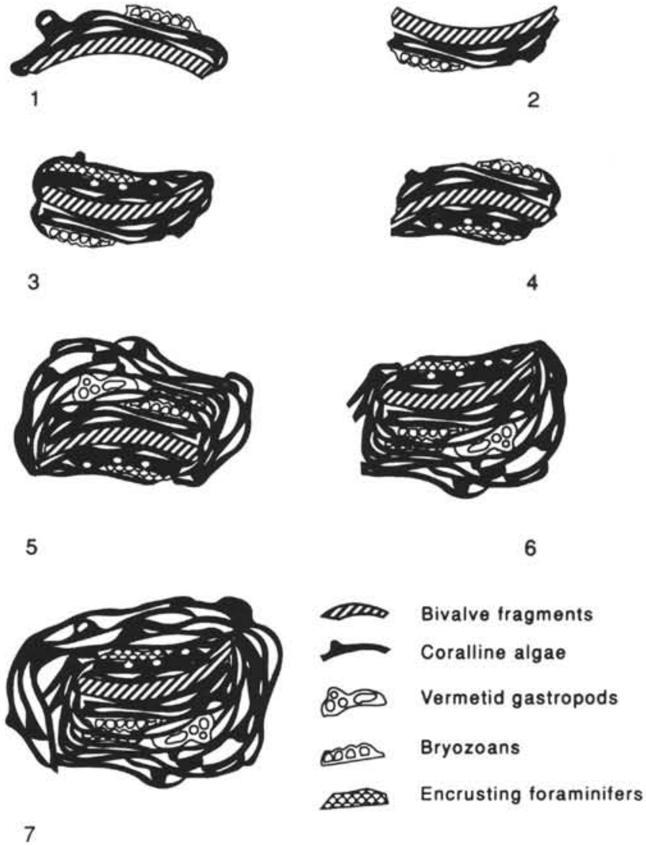

Figure 3. Model of rhodolith development. Illustrations 1, 3, 5, and 7 are different stages of growth, whereas 2, 4, and 6 are erosional events. Active growth of the corallines and associated encrusting biota (bryozoans, vermetids, and foraminifers) took place in a quiet-water, open-platform environment, in the calm periods between storms. During the latter, they were overturned and partly eroded. Corallines developed mainly as thin laminae and small protuberances. The nucleus of the rhodolith, in this case, is a bivalve fragment.

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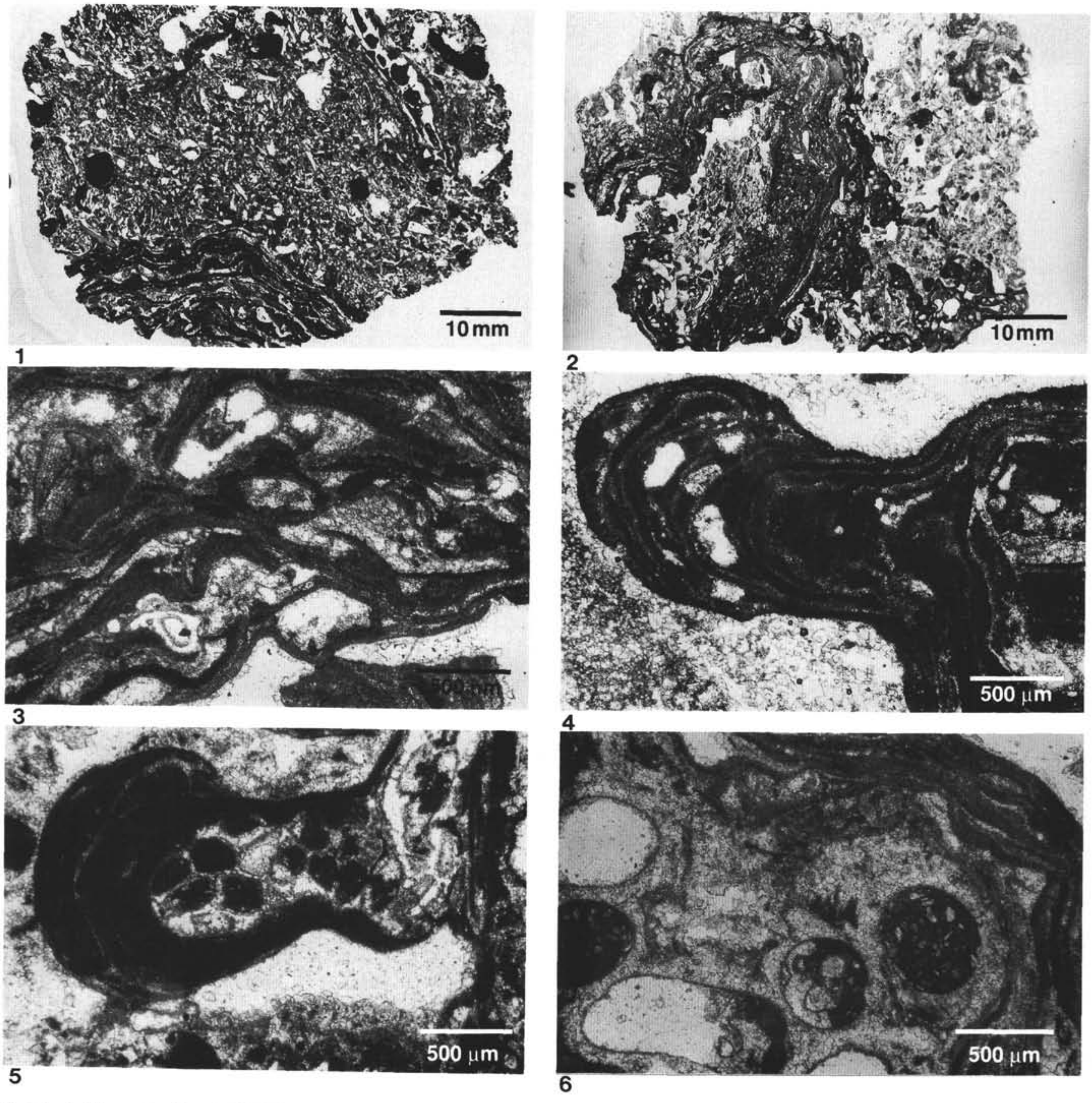

Plate 1. **1.** Thin section (Sample 133-816C-6R-1, 70–73 cm) of a rhodolith in a highly washed, bioclastic matrix with fragments of benthic foraminifers, bryozoans, *Halimeda*, gastropods, corals, echinoids, and loose corallines (scale bar = 10 mm). **2.** Thin section (Sample 133-816C-5R-1, 14–19 cm) showing the two types of rhodoliths: the complex one, composed in this case of *Lithothamnion*, *Sporolithon*, *Hydrolithon*, and *Mesophyllum* (to the left of the picture), and the simple one consisting mainly of *Mesophyllum* (bottom right) (scale bar = 10 mm). **3.** Close-up of laminar *Lithothamnion* growths in the complex rhodolith of the previous picture (Sample 133-816C-5R-1, 14–19 cm; scale bar = 500 µm). **4.** A small protuberance of *Lithothamnion* covering eroded *Hydrolithon* laminar growths of a previous stage (Sample 133-816C-13R-1, 17–22 cm; scale bar = 500 µm). **5.** *Lithothamnion* encrusting a bryozoan (Sample 133-816C-6R-1, 88–90 cm; scale bar = 500 µm). **6.** Laminar *Lithothamnion* on vermetids (Sample 133-816C-5R-1, 14–19 cm; scale bar = 500 µm).

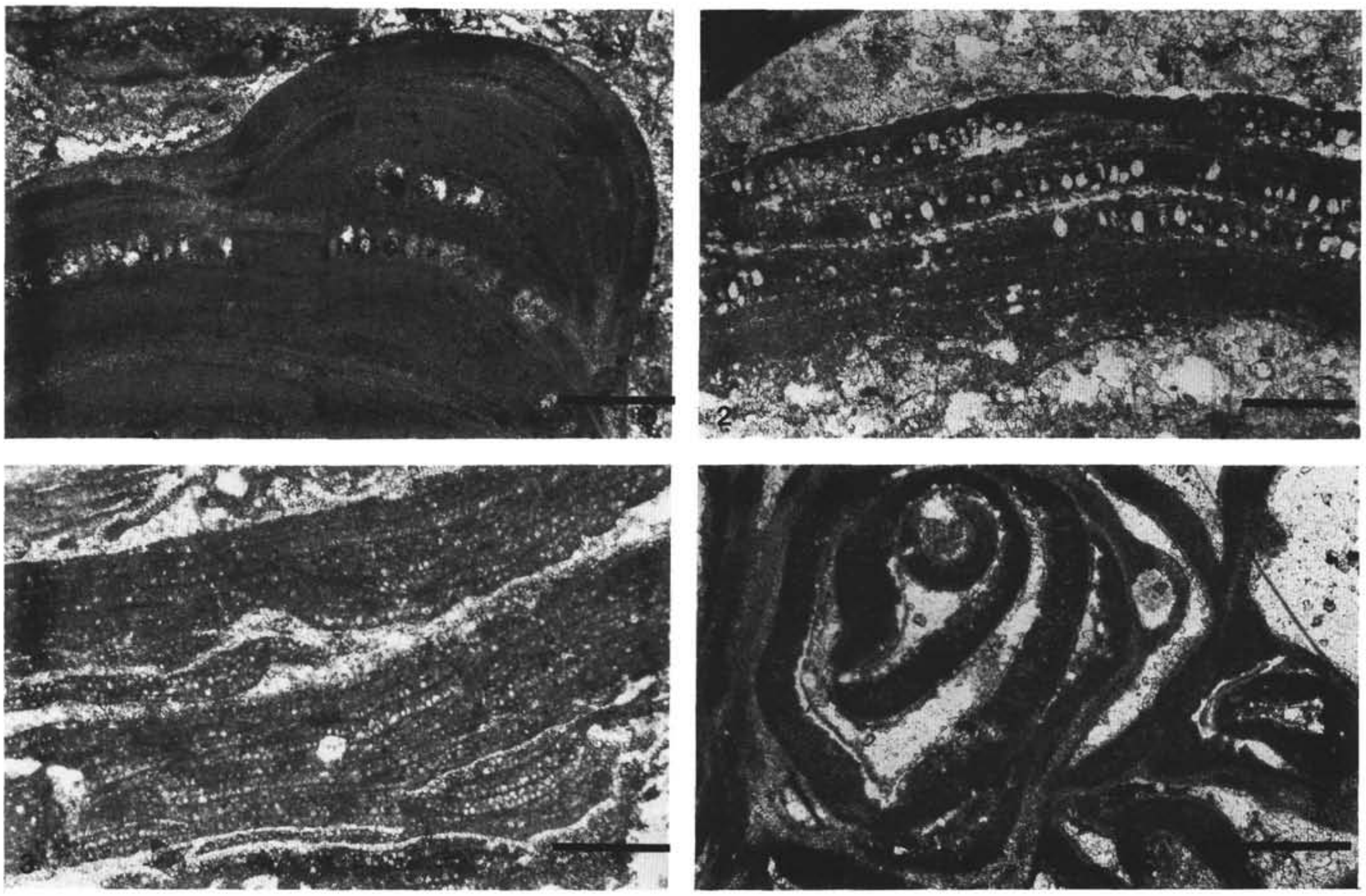

Plate 2. Thin-section photomicrographs of different coralline algae inside rhodoliths. **1** and **2.** *Sporolithon* (Sample 133-816B-8R-1, 118–120 cm; scale bars = 500 μm). **3.** *Hydrolithon* (Sample 133-816C-11R-3, 76–80 cm; scale bar = 500 μm). **4.** *Mesophyllum* (Sample 133-816C-5R-1, 14–19 cm; scale bar = 500 μm).