

## 5. EOCENE TO PLIOCENE CORALLINE ALGAE IN THE QUEENSLAND PLATEAU (NORTHEASTERN AUSTRALIA)<sup>1</sup>

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### ABSTRACT

Sediments containing coralline algae in the Queensland Plateau range from the middle Eocene to the early Pleistocene in age.

In the middle Eocene sediments, the corallines occur as highly fragmented and eroded particles in temperate, platform carbonates (grainstones and rudstones) with abundant bryozoans, benthic foraminifers, and bivalves. They occasionally interbed with thin intervals of tropical to subtropical sediments that contain abundant *Halimeda*, coral debris, and coralline fragments, mainly of *Lithoporella* and *Mesophyllum*. In the upper Oligocene sediments, similar temperate carbonates, in which small, scarce, unidentifiable coralline fragments can be seen, also occur.

The lower Miocene platform carbonates consist of grainstones and packstones having a tropical assemblage with corals and *Halimeda*, together with a shallow-water coralline association of geniculate (*Jania*, *Corallina*, *Amphiroa*) and encrusting forms (*Lithoporella* and *Spongites*). Allochthonous fragments of geniculate and encrusting corallines (*Mesophyllum* and *Lithothamnion*) of early Miocene age occur in clasts in bioclastic floatstones (debris-flow deposits) of middle Miocene age. The algal composition points to an outer-shelf origin for these clasts.

The middle Miocene carbonate sediments that contain corallines are also tropical and consist of bioclastic packstones to wackestones, with *Halimeda*, and corals. Coralline-algal debris is predominantly composed of loose, abraded, branching thalli of *Sporolithon* and *Lithothamnion*, and small rhodoliths (up to 2 cm). The nuclei of most of the rhodoliths consist of a small branch fragment. They are encrusted by laminar growths of *Lithothamnion*, *Mesophyllum*, *Hydrolithon*, and *Sporolithon*. Some fragments of the rare coralline genus *Aethesolithon* also have been found. The depositional environment is that of a low-energy, neritic, open platform, as can be deduced from the predominance of delicate branching growths, the smaller size of the rhodoliths, the abundance of fine-grained sediments, and the scarceness of reworking.

Lower Pliocene corallines occur as redeposited elements in debris flows. They appear mainly as very thin laminae in foragaliths that are intimately associated with encrusting foraminifers. The most common alga is *Lithoporella*.

The present-day, shallow-water, reefal coralline associations dominated by members of the subfamily Mastophoroideae were not detected in any of the sediments drilled in the Queensland Plateau.

### INTRODUCTION

Coralline algae were common components of the shelf carbonates deposited in the Queensland Plateau area during the Tertiary period. Samples containing corallines can be found in all the sites drilled in the Queensland Plateau. These sites are located in two different areas (Fig. 1): at the western margins of the plateau adjacent to the Queensland Trough (Sites 823, 824 and 811/825), and at the southern margins adjacent to the Townsville Trough (Sites 812, 813, 814, and 817). Coralline algae are found in the western part in lower Pliocene (Site 824), lower Miocene (Sites 823 and 824), upper Oligocene (Site 824), and middle Eocene (Site 825) samples. All the corallines found in the southern part (Sites 812, 813, 814, and 817) belong to the middle Miocene. The degree of recovery and preservation changes from site to site; however, the coralline record is generally good enough to allow a detailed study of the algae. Coralline algae can be used as paleobathymetric as well as paleoclimatic indicators, although further studies on their distribution in fossil and modern environments are needed to specifically determine their paleoenvironmental significance. The available data show changes in coralline algal associations and coralline morphology in response to changes in water depth and turbulence, as well as the presence of distinct coralline floras in the different climatic belts (see Adey and McIntyre, 1973; and Bosence, in press, for a summary). In this report, these data have been used together with other sedimentological and paleontological evidence to

interpret the paleoenvironments of the Tertiary sediments containing red algae drilled from the Queensland Plateau.

### METHODS

Sixty-nine thin sections of samples from all the sites located in the Queensland Plateau were studied, and the carbonate petrography and coralline algae (types, growth forms, and associations) determined. Samples were taken whenever corallines appeared in the cores (Figs. 2 and 3). A detailed list of the samples for each specific time interval and site is given below.

### THE CORALLINE FACIES: TEMPORAL DISTRIBUTION AND CHARACTERISTICS

#### Middle Eocene

All the samples containing corallines from the middle Eocene belong to Site 825, lithologic Unit VI (Samples 133-825B-6R-1, 27–29 cm, and 54–56 cm; 133-825B-7R-1, 32–33 cm, and 68–71 cm; and 133-825B-8R-1, 0–12 cm, and 19–21 cm), the precise age of which recently has been determined by Betzler and Chaproniere (this volume). These are grainstones and rudstones (sometimes floatstones) having abundant fragments of bryozoans, benthic foraminifers, coralline algae, intraclasts, gastropods, echinoids, and bivalves. Coralline algal remains in general are poorly preserved and unidentifiable. Some samples (such as 133-825B-6R-1, 54–56 cm, and 133-825B-7R-1, 32–33 cm) exhibit frequent coral and *Halimeda* fragments. Poorly preserved remains of *Lithoporella* have been identified in these samples. Fragments of *Mesophyllum*, *Spongites*, *Lithothamnion*, *Jania*, and *Corallina* also can be recognized (Pl. 1, Fig. 1).

<sup>1</sup> McKenzie, J.A., Davies, P.J., Palmer-Julson, A., 1993. *Proc. ODP, Sci. Results*, 133: College Station, TX (Ocean Drilling Program).

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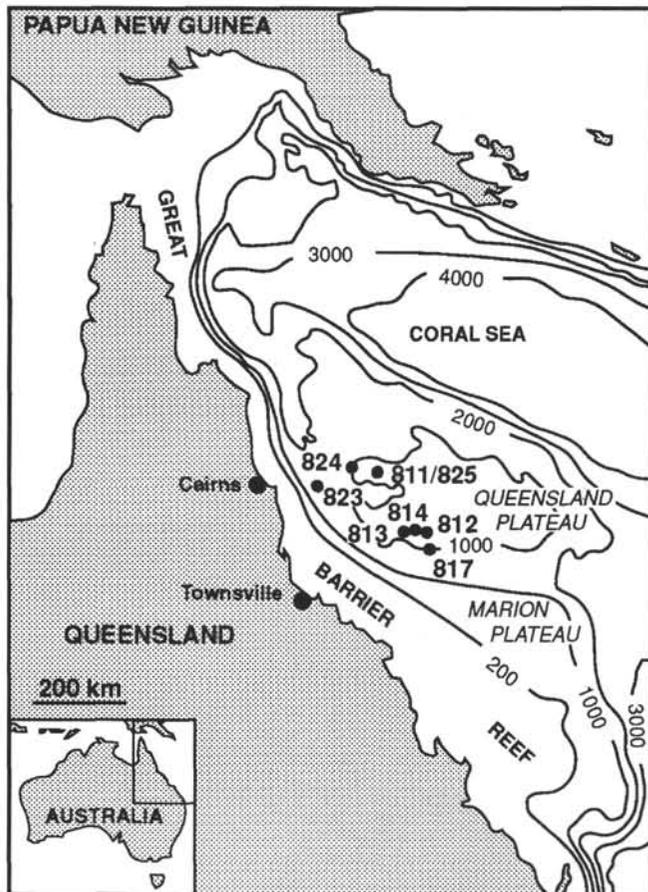


Figure 1. Geographical location of Sites 812, 813, 814, and 817 and Sites 823, 824, and 811/825 at the southern and western margins of the Queensland Plateau, respectively.

### Late Oligocene

The two samples studied containing corallines from the late Oligocene belong to Unit VI of Site 824 (Samples 133-824A-36X-CC, 20–22 cm, and 31–34 cm). These are foraminiferal/bryozoan packstones/grainstones (rudstones) having echinoids, gastropods, intraclasts and corallines, with the latter being scarce, highly fragmented, and completely unidentifiable.

### Early Miocene

Lower Miocene sediments containing corallines can be found in lithologic Subunit VB, Site 824, initially considered to be of middle to late Miocene age (Shipboard Scientific Party, 1991h, Site 824), but later dated as early Miocene by Betzler and Chaproniere (this volume). The corallines also occur as redeposited debris within middle Miocene sediments (again see datings by Betzler and Chaproniere, this volume) in Unit VII, Site 823. The samples studied are from Site 824: 133-824A-29X-CC, 0–18 cm; 133-824A-30X-CC, 0–17 cm; and 133-824C-8R-1, 45–50 cm, 61–63 cm, and 91–96 cm; and Site 823: 133-823C-13R-2, 122–125 cm, and 133-823C-13R-4, 31–36 cm.

Lower Miocene platform carbonates from Site 824 consist of packstones/grainstones/rudstones having fragments of coralline algae, benthic foraminifers (sometimes abundant), and rare planktonic foraminifers, gastropods, bivalves, echinoids, corals (some of them encrusted by corallines and foraminifers), *Halimeda*, and a few detrital grains. Among the corallines, *Lithoporella* is dominant (Pl. 1, Fig. 2).

Redeposited early Miocene corallines are found in shallow-water, platform-derived pebbles and clasts in debris flows (bioclastic floatstones) of middle Miocene age, together with fragments of *Halimeda*, foraminifers, bryozoans, bivalves, echinoids, and corals (Shipboard Scientific Party, 1991g, Site 823). The coralline association is here composed of *Mesophyllum*, *Lithothamnion*, and geniculate corallines (*Jania* and *Corallina*) (Pl. 1, Fig. 3).

### Middle Miocene

The middle Miocene samples containing corallines were found at Sites 812, 813, 814, and 817, all of which are located in the southern part of the Queensland Plateau. At the first three sites, these corallines are autochthonous, but at Site 817 they appear to be redeposited clasts and pebbles in debris flows.

At Site 812, all of the samples belong to lithologic Unit III, in which three subunits, considered to be of lagoonal and/or back-reef origin, were differentiated (Shipboard Scientific Party, 1991c, Site 812). Most of the samples come from Subunit IIIA. These include 133-812A-18X-1, 7–8 cm, and 32–33 cm; 133-812A-18X-CC, 8–9 cm; 133-812A-19X-1, 11–12 cm; 133-812A-20X-1, 29–31 cm, and 93–95 cm; 133-812A-22X-1, 19–20 cm, and 44–45 cm; 133-812B-3R-1, 15–16 cm, 113–114 cm, and 140–142 cm; 133-812B-3R-2, 2–3 cm, and 20–21 cm; 133-812B-4R-1, 24–25 cm, and 51–52 cm; 133-812B-5R-1, 71–72 cm, and 105–106 cm; 133-812B-6R-1, 6–7 cm, 82–83 cm, and 107–108 cm; 133-812B-7R-1, 25–26 cm, 105–106 cm, 118–119 cm, and 127–128 cm; 133-812B-8R-1, 2–3 cm, 28–29 cm, and 32–33 cm; and 133-812B-9R-1, 24–25 cm, and 137–138 cm. From Subunit IIIB, the samples are 133-812B-10R-1, 24–25 cm, and 33–34 cm; 133-812B-11R-1, 1–2 cm, and 133-812B-12R-1, 2–3 cm; from Subunit IIIC, 133-812B-18R-1, 5–7 cm, and 18–23 cm.

The coralline samples studied from Site 813 belong to Unit V, considered to be shallow neritic (Shipboard Scientific Party, 1991d, Site 813). These samples are 133-813A-25CC, at 2–3 cm and 21–22 cm. Coralline samples at Site 814 are from the top of Unit IV, interpreted as a middle ramp or slope (Shipboard Scientific Party, 1991e, Site 814). These are 133-814A-17X-1, 20–21 cm, and 20–25 cm; and 133-814A-18X-1, 1–2 cm. At Site 817, in the Townsville Trough, the samples studied belong to Subunit IIIB, deposited in a base-of-slope debris apron (Shipboard Scientific Party, 1991f, Site 817). The samples are 133-817D-23R-1, 27–30 cm, and 32–33 cm; 133-817D-25R-1, 42–46 cm; and 133-817D-33R-1, 68–71 cm.

The carbonate sediments containing corallines at Site 812 consist of dolomitized wackestones, packstones, and floatstones with benthic (and some planktonic) foraminifers, echinoids, dasyclad algae, bivalves, gastropods, *Halimeda*, bryozoans, and coral fragments, the latter sometimes encrusted by thin coralline laminae. Some samples from Subunit IIIC are rich in benthic foraminifers. Corallines occur as loose and abraded fragments of branching thalli and as small (less than 2 cm), spheroidal-to-ellipsoidal rhodoliths. Most branching growths belong to *Sporolithon* (Pl. 1, Fig. 4) and/or *Lithothamnion*. The internal structure of the rhodoliths is simple, with their nuclei being a branch fragment (normally *Sporolithon*), or occasionally a coral fragment covered by thin laminae of *Lithothamnion* (Pl. 1, Fig. 5) and *Mesophyllum*, sometimes accompanied by *Hydrolithon*. Encrusting foraminifers may be intergrown with coralline crusts within the rhodoliths, which also have been bored locally and exhibit small internal erosional surfaces. Fragments of *Jania* and *Corallina* are dispersed in the micritic matrix.

Loose fragments of *Aethesolithon* Johnson, bored by sponges, appear in some samples (Pl. 2, Figs. 1 and 2). *Aethesolithon* was determined and has only been described by Johnson (1961, 1964) from the Miocene of Guam. Although it has a distinctive vegetative anatomy (with large cell fusions in the inner parts of the thallus), the status and affinities of this genus need revision. Some samples from the Queensland Plateau show uniporate conceptacles that closely resemble those of the genus *Hydrolithon*.

TOWNSVILLE TROUGH TRANSECT

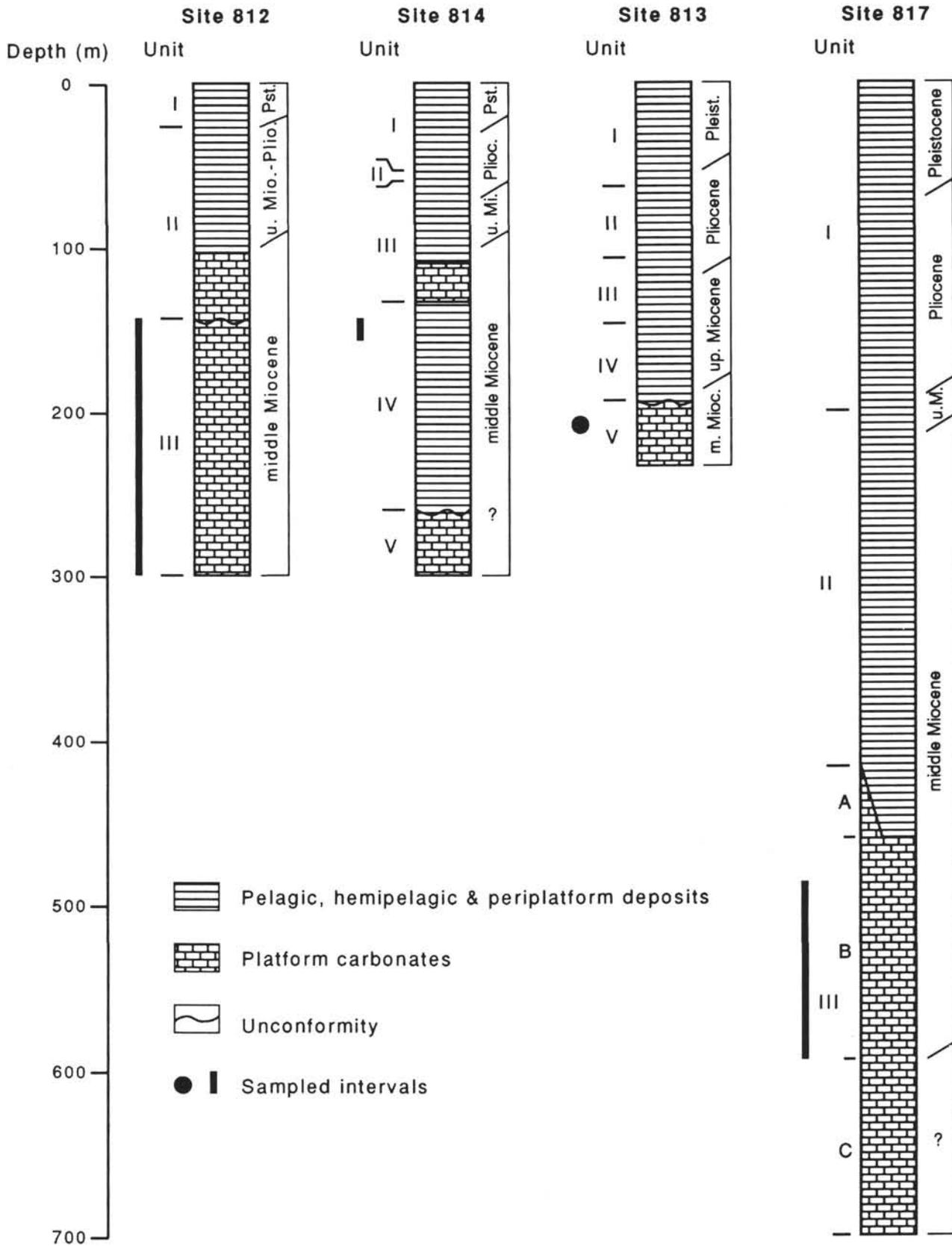


Figure 2. Townsville Trough transect. Simplified stratigraphic sections of Sites 812, 813, 814, and 817 (modified from Shipboard Scientific Party, 1991a, Fig. 2) with indications of units and positions of the coralline samples.

QUEENSLAND TROUGH TRANSECT

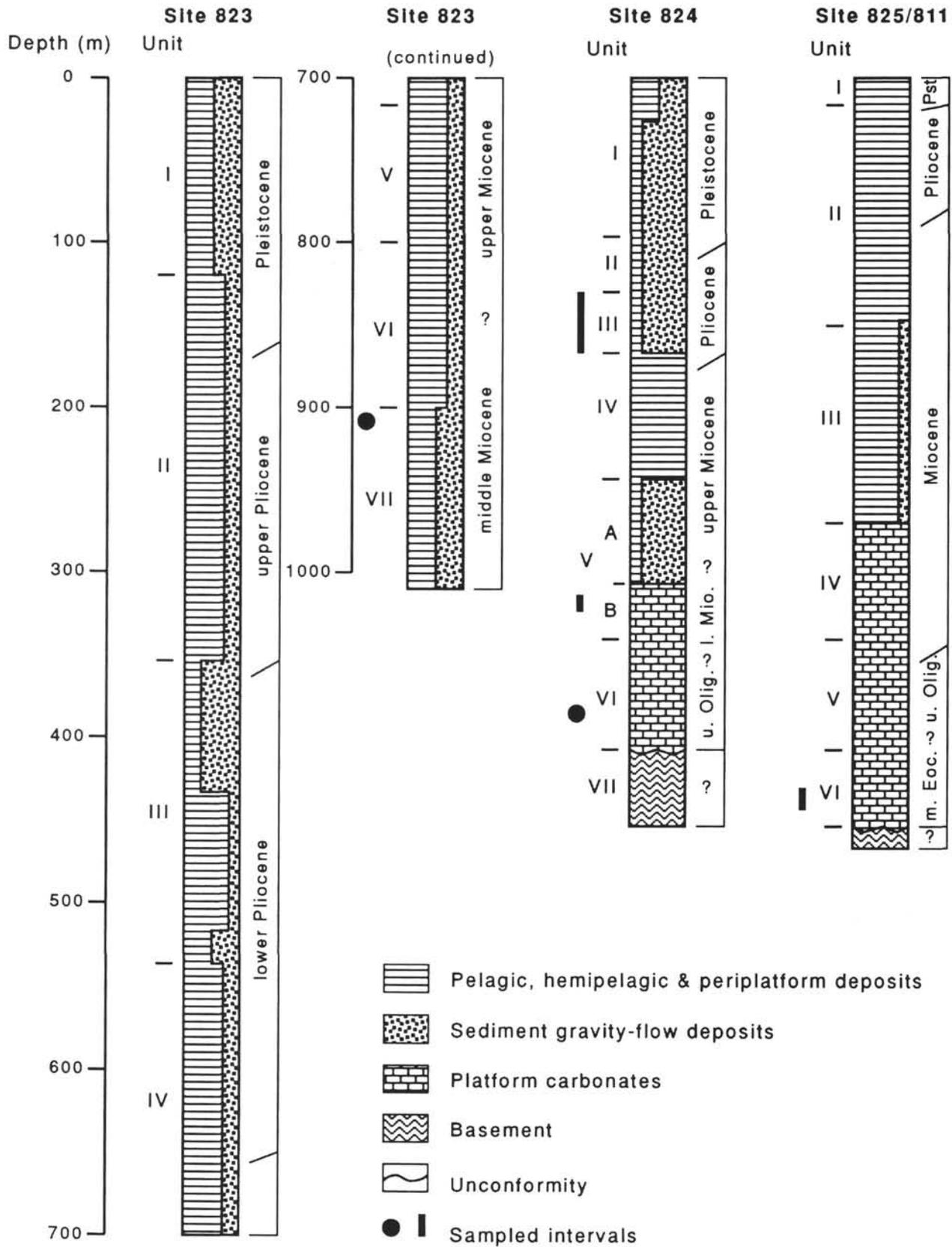


Figure 3. Queensland Trough transect. Simplified stratigraphic sections of Sites 823, 824, and 825 (modified from Shipboard Scientific Party, 1991a, Fig. 3) with indications of units and positions of the coralline samples.

The three subunits of Site 812 (Shipboard Scientific Party, 1991c, Site 812) show the same coralline association. Much the same can be said of the facies.

Distal-slope, fine-grained carbonates with corallines occur at Sites 814 and 813. These are wackestones having highly fragmented benthic (and rare planktonic) foraminifers, echinoids, and bivalves. The corallines are poorly preserved and are presumed to be the same genera as those appearing at Site 812. Grain size progressively diminishes downslope westward from Site 812 to 814 and 813.

Undolomitized or partially dolomitized bioclastic floatstones (debris flows) having abundant benthic and planktonic foraminifers, echinoids, bryozoans, gastropods, corals, *Halimeda*, intraclasts, and corallines occur as platform-derived sediments that have been redeposited in a deeper-water setting at Site 817 in the Townsville Trough. Rhodoliths similar to those of the Marion Plateau (see Martín et al., this volume) of *Mesophyllum* (Pl. 1, Fig. 6) and *Lithothamnion* are found together with branching fragments of *Sporolithon*, *Lithothamnion*, and laminar crusts of *Mesophyllum* and *Lithoporella* that are identical to those appearing at Site 812 in the Queensland Plateau.

### Early Pliocene

All of the lower Pliocene carbonates containing corallines are from Unit III, Site 824, and contain redeposited clasts of bioclastic rudstones and packstones that have been interpreted as debris-flow deposits (Shipboard Scientific Party, 1991h, Site 824). The samples studied are 133-824A-10H-1, 75–77 cm, 84–88 cm, 88–90 cm, 113–116 cm, 132–138 cm, and 140–143 cm; 133-824A-10H-CC, 2–5 cm, and 5–9 cm; 133-824A-11X-CC, 2–5 cm; and 133-824A-14H-1, 48–50 cm.

Fragments of echinoids, benthic and planktonic foraminifers, bivalves, corals, bryozoans, and *Halimeda* can be found in the clasts, together with the corallines. These latter are mainly present in the form of thin laminar growths between thick layers of encrusting foraminifers inside foragaliths (Pl. 2, Fig. 3). The term "foragalith" was first introduced by Prager and Ginsburg (1989) to describe nodules consisting of encrusting foraminifer and coralline growths intimately associated. *Lithoporella* is dominant (Pl. 2, Fig. 4). *Lithothamnion* and *Mesophyllum* also are found as minor components.

### CORALLINE PALEOENVIRONMENTS

In the middle Eocene, corallines appear in typical temperate carbonates that were deposited on an inner-neritic shelf (Shipboard Scientific Party, 1991b, Site 811/825). However, because of the poor degree of preservation, coralline algae cannot be identified. In the intercalated intervals of tropical/subtropical carbonates with *Halimeda* and corals, *Lithoporella* is the commonest red alga. This genus is also characteristic of tropical/subtropical environments (Lemoine, 1976). The upper Oligocene corallines, highly fragmented and completely unidentifiable, are related again to inner-neritic, foraminifer/bryozoan, temperate-platform carbonates (Shipboard Scientific Party, 1991h, Site 824).

The lower Miocene platform carbonates, with abundant coral and *Halimeda* fragments, have an unquestionable tropical character. At Site 824, some coralline debris (the mastophoroids *Spongites* and *Neogoniolithon*?) may suggest a shallow-water origin for these carbonates, but these algae now occur as reworked and fragmented particles, possibly incorporated into sand bars. The foraminifer assemblages point to a similar environment (Betzler and Chaproniere, this volume). The redeposited lower Miocene coralline assemblage of Site 813, composed of *Mesophyllum*, *Lithothamnion*, and geniculate corallines (*Jania* and *Corallina*) (Pl. 1, Fig. 3), seems to come from a deeper setting (outer shelf) than that at Site 824 (see below).

The middle Miocene algal associations drilled at Site 812 are completely dominated (more than 80% of coralline thalli) by members of the subfamily Melobesioideae (nongeniculate coralline algae). This is characteristic of deep-water shelf environments in low-lati-

tude areas in both fossil and recent examples (Bosence, in press). Although precise proportions of the different genera cannot be established due to the high number of unidentifiable fragments, these associations (composed mainly of *Lithothamnion*, *Mesophyllum*, and *Sporolithon*) are similar to those described by Adey (1979) in outer-platform settings at depths between 30 and 80 m in the present-day Pacific Ocean (Hawaiian Islands). The attribution of these facies to lagoonal or back-reef environments (Shipboard Scientific Party, 1991c, Site 812) may be incorrect.

These algal associations from the middle Miocene of the Queensland Plateau also are similar to those drilled in the middle Miocene of the Marion Plateau (see Martín et al., this volume), although some small differences do exist between the two areas. In the Marion Plateau, rhodoliths of up to 6 cm in size are dominant and exhibit several phases of growth and reworking (Martín et al., this volume). The sediments are normally washed, bioclastic calcarenites. In the Queensland Plateau, delicate, branching, and thin laminar growths embedded in a micrite-rich facies dominate. Marion Plateau rhodoliths are considered to have been formed in an outer-platform area that was influenced by sporadic storms (Martín et al., this volume). The Queensland corallines are thought to have grown in a comparable setting, although it was probably either less energetic (without significant storms) or slightly deeper.

At Site 817, the existence of redeposited rhodoliths, similar to those of the middle Miocene of the Marion Plateau, and transported branching coralline fragments, identical to those appearing in the middle Miocene of the Queensland Plateau, may suggest the existence of two sources for the sediments that arrived at the Townsville Trough during the middle Miocene.

In the lower Pliocene, coralline algae occur inside foragaliths (in redeposited clasts) closely associated to encrusting foraminifers. Modern analogs of these foragaliths with a similar algal composition have been recorded on the outer shelf of Florida, in a 35-to-65-m-deep, quiet-water environment (Prager and Ginsburg, 1989). It is thus interpreted that the source area of these redeposited clasts was the outer shelf.

The modern, shallow-water coralline association in the Pacific reefs, dominated by mastophoroids, has not been detected in any of the sediments drilled in the Queensland Plateau. Species formerly included in *Porolithon* Foslie, *Goniolithon* Foslie, or *Paraporolithon* Johnson are characteristic of the algal ridges and other shallow-water environments in Neogene (Johnson, 1961) and in present-day (Foslie, 1907; Setchell, 1928; Littler and Doty, 1975) Pacific reefs. The absence of these corallines and of other components of shallow-water coralline associations, such as members of the subfamily Lithophylloidea (Littler and Doty, 1975; Adey, 1979), supports the hypothesis of a relatively deep-water origin for most of the recorded corallines in Neogene sediments of the Queensland Plateau.

### CONCLUSIONS

At all sites drilled in the Queensland Plateau during Leg 133, coralline algae were found throughout the Tertiary, albeit with an incomplete record.

In the temperate platform carbonates of the Eocene-Oligocene, coralline remains, unfortunately, are poorly preserved and cannot be identified, except in the case of some brief, tropical, coral-rich episodes in the middle Eocene, which contain fragments of *Lithoporella*, *Mesophyllum*, and *Spongites*.

Fragments of *Spongites* and *Lithoporella*, together with abundant geniculate corallines (*Jania*, *Corallina*, *Amphiroa*), can be found incorporated in sand bars in lower Miocene sediments. They represent an original shallow-water association. In redeposited sediments of the same age, an outer-shelf assemblage of *Mesophyllum* and *Lithothamnion* appears together with the geniculate corallines.

In the middle Miocene sequence, the algal associations consist of *Lithothamnion*, *Sporolithon*, *Mesophyllum*, *Hydrolithon*, and

*Aethesolithon*. The predominant growth forms are branching and thinly laminar in loose fragments and small rhodoliths. All this, together with the abundance of micrite, points to a low-energy, outer-shelf environment.

In the early Pliocene section, foragaliths of *Lithoporella* and encrusting foraminifers (which formed in an outer-shelf setting and were later redeposited in deeper areas) are the only elements found.

The present-day, shallow-water reef association in the Pacific Ocean, dominated by mastophoroids (i.e., species formerly included in *Porolithon* Foslie), has not been detected in any of the sediments drilled in the Queensland Plateau.

### ACKNOWLEDGMENTS

We thank the crew and scientific party of Leg 133 for their logistic and scientific support, and ODP for samples. JMM is grateful to the Spanish Consortium for the Ocean Drilling Program, which supported his participation during this cruise. We would like to thank B. Buchbinder, as well as an anonymous referee, for the critical reading and suggestions to improve the paper.

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\* Abbreviations for names of organizations and publications in ODP reference lists follow the style given in *Chemical Abstracts Service Source Index* (published by American Chemical Society).

Date of initial receipt: 11 March 1992

Date of acceptance: 10 December 1992

Ms 133SR-243

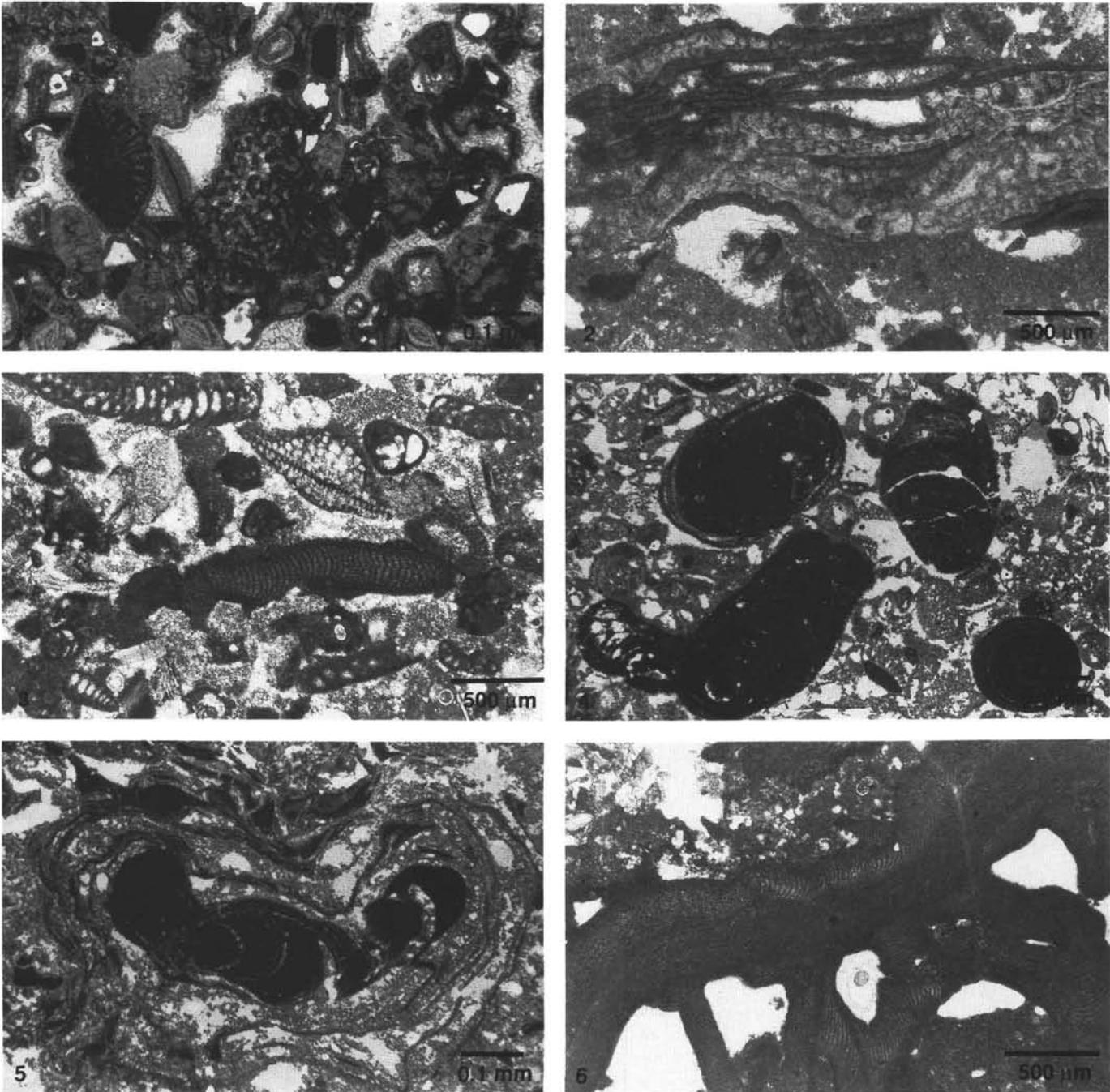


Plate 1. **1.** Photomicrograph of a bioclastic floatstone from the middle Eocene with benthic foraminifers, corals (*Porites*), and coralline remains. Sample 133-825B-7R-1, 32–33 cm. (Scale bar = 1 mm). **2.** Photomicrograph of a sample (133-824A-30X-CC, 0–17 cm) from the lower Miocene showing interlaminated *Lithoporella* growing on foraminifers. (Scale bar = 500  $\mu$ m). **3.** Middle Miocene bioclastic floatstone with redeposited lower Miocene bioclasts (mainly corallines and benthic forams) and intraclasts. A fragment of the geniculate alga *Jania* stands out clearly in the center. Sample 133-823C-13R-2, 122–125 cm. (Scale bar = 500  $\mu$ m). **4.** Branching growths of *Sporolithon* in a packstone of middle Miocene age. Sample 133-812B-7R-1, 25–26 cm. (Scale bar = 1 mm). **5.** A small rhodolith having a nucleus of branching *Sporolithon* encrusted by laminar *Lithothamnion* and foraminifers. Sample 133-812A-18X-1, 7–8 cm. (Scale bar = 1 mm). **6.** A fragment of a lower Miocene rhodolith consisting mainly of *Mesophyllum* in redeposited middle Miocene sediments. Sample 133-817D-23R-1, 27–30 cm. (Scale bar = 500  $\mu$ m).

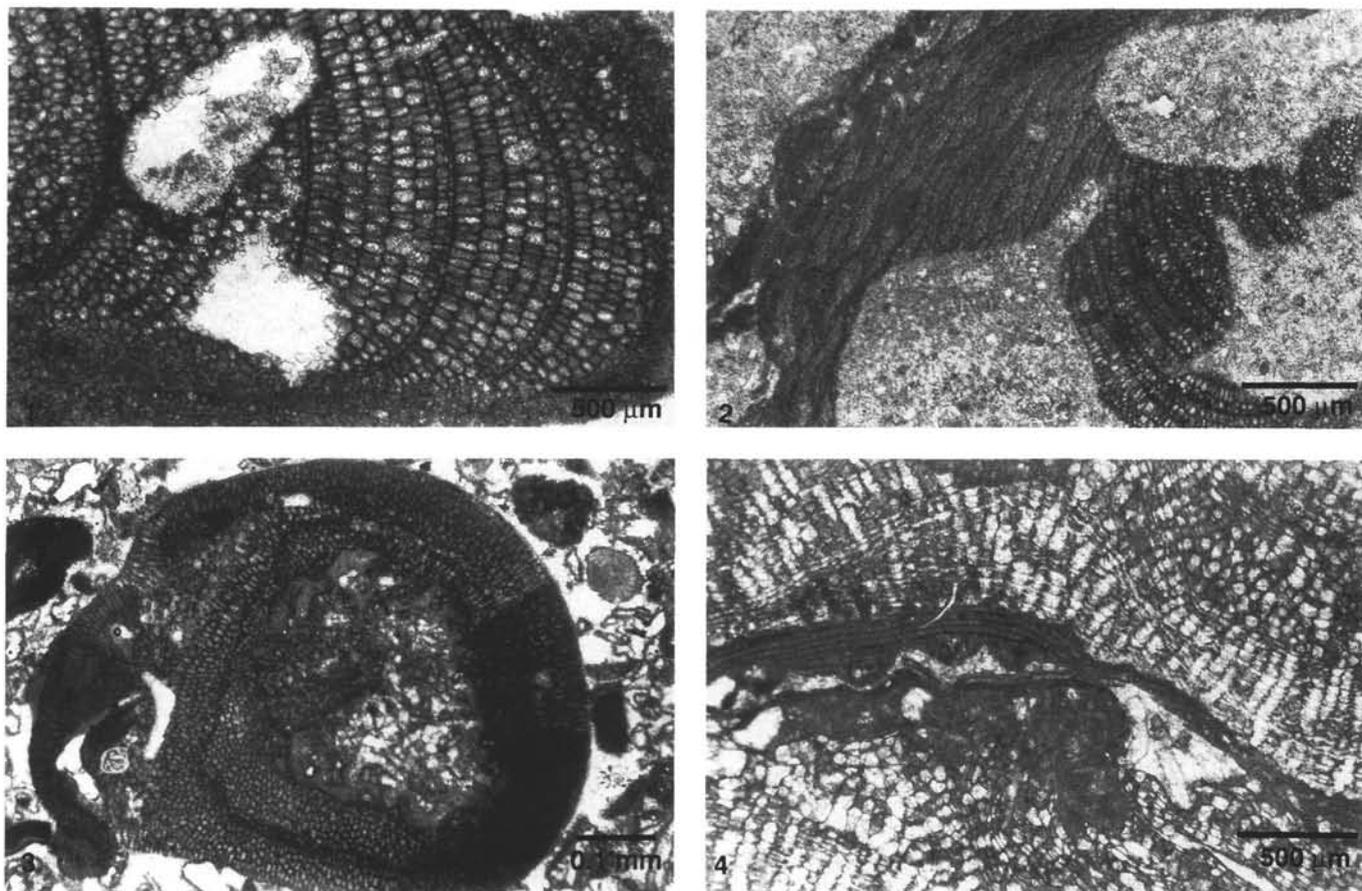


Plate 2. 1–2. *Aethesolithon thalli* bored by sponges. Middle Miocene. Samples 133-812B-10R-1, 24–25 cm, and 133-812B-7R-1, 127–128 cm. (Scale bars = 500 μm). 3. A foralgalith in a lower Pliocene rudstone. Sample 133-824A-10H-1, 84–88 cm. (Scale bar = 1 mm). 4. A close-up of a lower Pliocene foralgalith showing thin laminae of *Lithoporella* between thick layers of encrusting foraminifers. Sample 133-824A-10H-1, 75–77 cm. (Scale bar = 500 μm).