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Transect RIB-02A[1]

Expedition 325 Scientists[2]

Chapter contents

Introduction

During Integrated Ocean Drilling Program (IODP) Expedition 325, cores were recovered from four holes (two sites) at Ribbon Reef 3, comprising transect RIB-02A (Holes M0049A–M0051A) (Fig. **F1**), with an average transect recovery of 17.38% of the drilled length. Water depths ranged from 78.13 to 97.63 m (lowest astronomical tide) and were taken from tidally corrected EM300 multibeam bathymetry data. Existing data sets were evaluated prior to arrival at each site, and drilling targets and their respective coordinates were chosen from within the agreed area approved by the IODP Environmental Protection and Safety Panel.

Hole M0049A

Operations

Transit to transect RIB-02A

Following regular assessment of weather conditions at all three geographical drilling locations, the *Greatship Maya* departed Townsville Anchorage (Australia) and began the transit to Ribbon Reef 3 at 2040 h on 19 March 2010, arriving at 1930 h on 20 March. At 2030 h, the *Greatship Maya* began dynamic positioning (DP) trials ~0.3 nmi seaward from transect RIB-02A, Site 4. These trials continued into 21 March because of problems with the bow thrusters. At 1530 h on 21 March, new DP software was installed, and testing continued until 1645 h, when the *Greatship Maya* began to move onto station at Site 4.

Site 4, Hole M0049A

At 1900 h on 21 March 2010, the *Greatship Maya* arrived on station, and the seabed transponder was deployed (Table **T1**). The anchor was also made ready for fast deployment as per the Environmental Management Plan for the Ribbon Reef sites. Running of American Petroleum Institute (API) pipe commenced at 1950 h. Between 2225 and 2240 h, a downpipe camera survey of the seabed was conducted prior to tagging the seabed at 2300 h.

The first core arrived on deck at 2330 h. However, after two extended nose corer runs (3.5 meters below seafloor [mbsf]), a problem with the water swivel/flush pipe at 0040 h on 22 March necessitated tripping the API pipe to ~7 m above the seabed. The

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[2]**Expedition 325 Scientists' addresses.**

vessel remained on DP and on station during the repairs.

Sedimentology and biological assemblages

Hole M0049A is divided into two lithostratigraphic units.

Unit 1: Section 325-M0049A-1X-1: modern coralgal boundstone

The uppermost Unit 1, consisting only of Section 325-M0049A-1X-1, is composed of coralgal boundstone fragments in a lime sand that is rich in *Halimeda* and contains mollusks and worm tubes (Fig. F2). Most boundstone fragments consist of thin coralline algal framework (Fig. F3). Brown-stained boundstone fragments and recently living coralline algal fragments at several levels are probably derived from the modern seafloor and indicate mixing of recent and older material within the section. Gravelly fine-grained sand from interval 325-M0049A-1X-1, 6–11 cm, contains generally well preserved specimens of *Cycloclypeus, Amphistegina,* and *Planostegina*.

The only corals in Unit 1 are a few pieces of Agariciidae, probably foliaceous *Leptoseris*.

Unit 2: Sections 325-M0049A-2X-1 through 2X-CC: unconsolidated sediment

The lowermost Unit 2, spanning Sections 325-M0049A-2X-1 through 2X-CC), consists of fragments that appear to have come from the overlying boundstone, corals, mollusks, and *Halimeda* (of Unit 1) as a result of disturbance during drilling. There are no larger foraminifera in the gravelly coarse sands from interval 325-M0049A-2X-CC, 7–12 cm.

Most coral fragments are too small for identification, but they include *Porites, Montipora,* and Agariciidae.

Physical properties

Hole M0049A was cored to a total depth of 3.50 m drilling depth below seafloor (DSF-A), of which 0.77 m was successfully recovered (22.0% recovery). Physical property data for this hole are summarized in Table T2.

Density and porosity

In Hole M0049A, bulk density varies from 1.37 to 2.24 g/cm^3 (Fig. F4). Owing to the very shallow hole and limited core recovery, only the first core was logged on the multisensor core logger, and it is therefore difficult to comment on downhole trends. Two discrete samples were measured with the pentapycnometer. The porosity of these discrete samples is 38% and 39%, with bulk densities of 1.99 and 2.17 g/cm^3 and grain densities of 2.78 and 2.85 g/cm^3, respectively (Fig. F5).

P-wave velocity

Whole-core *P*-wave measurements taken offshore on the first core range from 1505 to 1852 m/s (Fig. F4). Values at the lower end of this range are likely a product of diminished core quality and should therefore be treated with caution (see "Physical properties" in the "Methods" chapter). Discrete measurements were not taken on any material from this hole.

Magnetic susceptibility

Recovered core from Hole M0049A exhibits a small range of magnetic susceptibility values, from 1.28×10^{-5} to 3.26×10^{-5} SI (Fig. F4). On the one core measured, no evidence for any downcore trends in terms of magnetic susceptibility exists.

Electrical resistivity

As with the other multisensor core logger measurements, data for electrical resistivity from Hole M0049A material are only available for one core. Electrical resistivity for this core ranges from 0.86 to 1.35 Ωm (Fig. F4), with no evidence of a downcore trend.

Digital line-scans and color reflectance

All cores from Hole M0049A were digitally scanned, and, where appropriate, cores were measured for color reflectance. Color reflectance varies between 52.87% and 63.00% L* (Fig. F6). Owing to core quality, Section 325-M0049A-1X-1 (coralgal boundstone) was the only section measured with the color reflectance sensor. The other core from this hole is not appropriate for this measurement because it is composed of lime granules. Dispersion found in the reflectance and color measurements is small, and they are grouped in relation to the variation in color for the same unit.

Paleomagnetism

Measurements of low-field and mass-specific magnetic susceptibility (χ) were performed on samples taken from the working half of the recovered core (Fig. F7). The record shows two positive susceptibility samples located at 0.37 and 2.18 mbsf with susceptibility values of 0.81×10^{-8} and 2.58×10^{-8} m^3/kg, indicating the presence of paramagnetic and/or ferromagnetic minerals.

Hole M0049B

Operations

Site 4, Hole M0049B

Coring recommenced at Site 4, Hole M0049B, at 0400 h on 22 March 2010 and continued for 13 runs (extended nose corer Runs 1–3; standard rotary corer Runs 4–13) until the hole was terminated at 15.6 mbsf at 1520 h with an average recovery of 17.9% (Table T1). The API pipe was tripped to just above the seabed, and a downpipe camera survey was conducted between 1550 and 1610 h.

Sedimentology and biological assemblages

Hole M0049B is divided into two lithostratigraphic units.

Unit 1: Sections 325-M0049B-1X-1 to 10R-1, 11 cm: coralgal-microbialite boundstone

The uppermost Unit 1, spanning Sections 325-M0049B-1X-1 to 10R-1, 11 cm, consists of different sized fragments of slightly bioeroded coralgal-microbialite boundstone. The proportions of corals, coralline algae, and microbialites in the boundstone vary. The boundstone forming the uppermost part of Unit 2 includes a framework of thin foliose coralline algae overgrowing a large bryozoan fragment (Fig. F8). Microbialite crusts are more abundant in the interval formed by Sections 325-M0049B-5R-1 through 6R-CC. They are brown and poorly laminated (Fig. F9) or structureless. Internal bioclastic sediments are lime sand with *Halimeda* and mollusk fragments. Geopetal fabrics are common in small cavities in Section 325-M0049B-9R-CC (Fig. F10). Small stalactitic and stalagmitic columns also occur in some coral cavities (Fig. F11). There are no larger foraminifera in intervals 325-M0049B-4R-CC, 4–9 cm, and 8R-CC, 10–15 cm.

The coral assemblage is diverse. Larger corals are increasingly abundant toward the base of the unit and are dominated by massive *Porites* (Fig. F12), submassive to massive *Astreopora*(?) and Faviidae, robustly branching *Lobophyllia* or *Euphyllia,* and encrusting (and/or platy) *Montipora*(?). Associated corals are branching *Acropora* and *Seriatopora,* submassive *Porites* and/or *Montipora,* Faviidae, Agariciidae, and Mussidae(?). Fragments include *Acropora, Pachyseris, Leptoseris, Porites, Montipora,* and unidentifiable Agariciidae, Faviidae, and Mussidae(?).

Unit 2: Sections 325-M0049B-10R-1, 11 cm, through 12R-1: coralgal boundstone with complex microbialite

The lowermost Unit 2, spanning Sections 325-M0049B-10R-1, 11 cm, through Section 12R-1, consists of slightly bioeroded coralgal-microbialite boundstone in which the proportion of microbialite in relation to coral and coralline algae is high throughout the unit. The microbialite has finger- to dome-like shapes and is brown with distinct laminations (stromatolitic). Microbialite crusts appear to be interlayered in several places with different types of internal sediment varying from *Halimeda* rudstone to floatstone to laminated grainstones. Major components of the internal sediment include fragments of *Tubipora musica,* bryozoans, and mollusks. Cavities are partially filled with geopetal fabrics and "microstalactitic" microbialite (?) cement (Fig. F13). The surface of the cement lining some cavities is stained red.

The main corals are submassive to massive *Porites*(?) or *Montipora*(?), which are often difficult to distinguish when embedded in microbialite. Smaller corals and fragments include *Tubipora musica, Seriatopora, Acropora,* and *Millepora*(?).

Physical properties

Hole M0049B had a penetration depth of 15.60 m DSF-A, of which 2.79 m of core was successfully recovered (17.88% recovery). Table T2 summarizes the petrophysical properties of this core.

Density and porosity

Multisensor core logger bulk density varies from 1.06 to 2.46 g/cm^3 in cores from Hole M0049B (Fig. F14). Owing to core recovery and the fact that the recovered cores are generally short, there is not a continuous record of bulk density downhole. Hole lithologies are dominated by lime pebbles of coralgal-microbialite boundstones. Nine discrete samples from Hole M0049B were measured for moisture and density (Fig. F15). Porosity fluctuates between 17% and 35% between 0 and 13.36 m core depth below seafloor (CSF-A). The minimum value (17%) corresponds to two core plugs taken at 14 and 14.16 m CSF-A. In the entire hole, bulk density varies between 2.17 and 2.48 g/cm^3. Grain density varies across the samples from 2.75 to 2.79 g/cm^3 (Fig. F15).

P-wave velocity

P-wave velocity measurements taken on whole cores offshore yielded no data because of core quality issues (Fig. **F14**). Two 20 mm core plugs were taken from boundstone lithologies. Velocities measured on these samples were 4560 and 4993 m/s (mean resaturated values) (Fig. **F16**), which are appropriate values for well-lithified, porous formations such as these microbialites. The two available data points on the bulk density/*P*-wave velocity cross-plot indicate that velocity decreases with increasing density (Fig. **F16**).

Magnetic susceptibility

Magnetic susceptibility values from core recovered in Hole M0049B range from -0.64×10^{-5} to 4.29×10^{-5} SI (Fig. **F14**). Recovery is such that it is impossible to comment on downhole trends or interesting intervals.

Electrical resistivity

Electrical resistivity measured on whole cores is highly variable and ranges from 6.17 to 78.34 Ωm (Fig. **F14**). Owing to recovery and the fact the cores are generally short and either rubbly or biscuited, resistivity data are greatly compromised. This is evidenced in the erratic nature of the multisensor core logger data summary plots (Fig. **F14**).

Digital line-scans and color reflectance

Cores from Hole M0049B were digitally scanned, and, where appropriate, cores were measured for color reflectance. Color reflectance varies from 48.34% to 82.98% L* (Fig. **F17**). In the uppermost few centimeters of the hole, a coralgal boundstone is present. Color reflectance measurements for this interval range from 60% to 70% for L* (Fig. **F17**) and are variable in terms of all the color reflectance indexes. Values of a* and b* are positive for all depths, indicating a predominance of red and yellow color. Measurements taken from 2 to 4 m CSF-A and from 5 m CSF-A to the base of the hole show a dispersion of ~20% for all sections measured because of the presence of lime pebbles and cobbles. Between 3.7 and 4 m CSF-A, the presence of a massive coral creates an increase in reflectance to 80% with less dispersion in the measurements than in other parts of the borehole. No general trend is observed in this hole.

Paleomagnetism

Measurements of low-field and mass-specific magnetic susceptibility (χ) were performed on samples taken from the working half of the recovered core (Fig. **F18**). Positive susceptibility samples range from 0.09×10^{-8} to 4.15×10^{-8} m^3/kg and have an arithmetic mean of 1.90×10^{-8} m^3/kg, indicating the presence of paramagnetic and/or ferromagnetic minerals. In addition, there are four negative (diamagnetic) susceptibility measurements for samples located at 2.22, 13.57, 15.13, and 15.41 mbsf with values of -0.37×10^{-8}, -0.06×10^{-8}, -0.12×10^{-8}, and -1.50×10^{-8} m^3/kg.

Chronology

Two calibrated radiocarbon ages (4 calibrated years before present [cal y BP; years before 1950 AD], Core 325-M0049B-2X; 12 cal y BP, Core 4R) (Fig. **F19**) and one U-Th age (16 cal y BP, Core 9R) (see Table **T10** in the "Methods" chapter) are consistent with their stratigraphic positions. The U-Th age is only slightly affected by corrections for initial ^{230}Th (the seawater correction makes the age 0.6 k.y. younger). This hole recovered material from the early to middle deglaciation, and the Holocene.

Hole M0050A

Operations

Site 4, Hole M0050A

The downpipe camera was retained inside the API pipe while the vessel moved 4 m under dynamic positioning to Site 4, Hole M0050A. A precoring seabed survey was completed by 1650 h on 22 March 2010, and the first run (extended nose corer) was started (Table **T1**). Standard rotary corer coring (Core 2R downhole) continued until 2120 h, when the hole was terminated at 10.5 mbsf after encountering a change in lithology interpreted to be the older Pleistocene deposits, with an average recovery of 17.8%. The API pipe was tripped to just above the seabed, and a downpipe camera survey was conducted between 2200 and 2220 h. Between 2220 and 2245 h, the API pipe was tripped until there was ~60 m hanging beneath the drill floor. The seabed transponder was then recovered, and at 2305 h the vessel began moving under dynamic positioning 78 m closer to the modern reef to Site 3.

Sedimentology and biological assemblages

Hole M0050A is divided into two lithostratigraphic units.

Unit 1: Sections 325-M0050A-1X-1 through 1X-CC: coralgal boundstone and sand

The uppermost Unit 1, spanning Sections 325-M0050A-1X-1 through 1X-CC, consists of coralgal boundstone fragments mixed with lime sand containing fragments of *Halimeda,* mollusks, benthic foraminifera, and coralline algae. These sediments are locally consolidated to form packstone/rudstone. The boundstone is mainly composed of an open framework of thin foliose coralline algae (algal bindstone). Most boundstone fragments have brownish staining. The presence of recently living coralline algae at several levels in Section 325-M0050A-1X-1 indicates mixing of recent and older sediments in the core. Medium to coarse sand from interval 325-M0050A-1X-1, 4–9 cm, includes many well-preserved specimens of *Cycloclypeus, Amphistegina,* and *Operculina*.

The only corals in Unit 1 are rare fragments of *Porites,* Acroporidae, Faviidae, and Agariciidae.

Unit 2: Sections 325-M0050A-2R-1 through 6R-1: coralgal-microbialite boundstone

The lowermost Unit 2, spanning Sections 325-M0050A-2R-1 through 6R-1, consists of fragments of slightly bioeroded coralgal-microbialite boundstone. Coralline algae occur as thick crusts on top of corals or form open frameworks of thin foliose plants. A branching coralline algae occurs at the base of Section 325-M0042A-3R-1 (Fig. **F20**). Thick microbialite crusts are brown and poorly to clearly laminated (stromatolitic) and contain trapped bioclasts. The surfaces of a few corals have reddish stains. Well-preserved specimens of *Amphistegina* are common in medium to coarse sands from interval 325-M0050A-2R-1, 15–20 cm.

The main corals are small pieces of Acroporidae, Agariciidae (including *Leptoseris*), *Porites, Montipora*(?), and *Goniopora*(?). Occasional coral fragments include Agariciidae (*Leptoseris*(?)) and *Porites*.

Physical properties

A total of 1.87 m of core was recovered from Hole M0050A, which was drilled to 10.50 m DSF-A (17.81% recovery). Physical property data are summarized in Table **T2.**

Density and porosity

In Hole M0050A, whole-core multisensor core logger (MSCL) measurements range from 1.72 to 2.43 g/cm^3 (Fig. **F21**). Core quality may have compromised data quality. Unfortunately, there were no discrete samples taken for moisture and density measurements.

P-wave velocity

P-wave velocity MSCL measurement of Hole M0050A cores yielded very few data points (because of core quality issues), which range from 1507.04 to 1845.36 m/s (Fig. **F21**). As with other *P*-wave data sets in this transect, values at the lower end of the range (close to 1500 m/s) should be treated with caution. Similar to the density and porosity measurements, no samples were available for discrete analysis with the *P*-wave logger. The lack of data in this hole makes it impossible to comment on downhole trends.

Magnetic susceptibility

In Hole M0050A, magnetic susceptibility increases overall with increasing depth (Fig. **F21**). Values obtained by measurement offshore on the MSCL range from 2.07×10^{-5} to 31.60×10^{-5} SI.

Electrical resistivity

Whole-core noncontact resistivity measurements on Hole M0050A cores range from 0.63 to 1.50 Ωm (Fig. **F21**). Despite the small data set available for this hole, electrical resistivity clearly increases with depth.

Digital line-scans and color reflectance

All cores from Hole M0050A were digitally scanned, and, where appropriate, measured for color reflectance. Color reflectance varies between 45.08% and 74.93% for L* (Fig. **F22**). Variations in color reflectance parameters show high dispersion in the uppermost meter of the hole. This can be attributed to heterogeneity in the lithology at this depth, comprising lime pebbles, coralgal boundstones, and coral fragments, with the dispersion in the color reflectance values indicating the presence of fragments of different material. Lithologies from 2 to 7 m CSF-A are composed of a heterogeneous mix of lime pebbles of coralgal-microbialite boundstones. The variation in lithology creates a more dispersed pattern in the color reflectance data. Measurements taken from 6.5 to 6.7 m CSF-A are grouped in a similar way, with an average value of 60% for reflectance. This average value indicates that, despite the presence of both lime pebbles and microbialite, the color is more homogeneous in this section than in previous ones. The presence of coralgal boundstones makes the measurements taken between 8 and 9.61 m CSF-A more consistent, with reflectance values varying from 65% to 68%.

Paleomagnetism

Measurements of low-field and mass-specific magnetic susceptibility (χ) were performed on samples taken from the working half of the recovered core (Fig. **F23**). The record shows positive susceptibilities throughout the entire length of the core, with susceptibility values ranging from 0.60×10^{-8} to $11.79 \times$

10^{-8} m^3/kg, with an arithmetic mean of 3.97 × 10^{-8} m^3/kg. In addition, a prominent peak at 2.73 mbsf has a value of 11.79 × 10^{-8} m^3/kg. These positive susceptibility values indicate the presence of paramagnetic and/or ferromagnetic minerals.

Chronology

This hole has one calibrated radiocarbon age of 11 cal y BP from Core 325-M0050A-2R (Fig. F24). There are only four cores beneath this 11 cal y BP section, indicating that this hole probably only contains material from the last deglaciation.

Hole M0051A

Operations

Site 3, Hole M0051A

The seabed transponder was deployed at 2315 h on 22 March 2010 with the *Greatship Maya* coming onto station at Site 3 (Hole M0051A) at 2320 h. API pipe started being run at 2330 h. A downpipe camera survey was conducted between 2255 and 0030 h (23 March). The first standard rotary corer core was on deck at 0105 h (Table T1). However, the second core could not be recovered because of a hydraulic failure of the elevator and mud valve at 0230 h, effectively terminating the hole at 2.5 mbsf. At 0800 h, having recovered the seabed transponder, the vessel was moved into deeper water for safety while repairs on the hydraulics continued. However, by 0900 h, the decision was taken to trip the API pipe using manual elevators. The core barrel was recovered from the bottom-hole assembly once in the slips, between 1315 and 1345 h, but minimal core remained.

Another prerequisite of the Environmental Management Plan was for a Great Barrier Reef Marine Park Authority Environmental Site Supervisor (ESS) to be onboard while Sites 1 and 2 at Ribbon Reef 3 were drilled. At 1300 h on 23 March, the ESS came alongside in the Reef Charters vessel *Hurricane*. However, after numerous attempts at a boat-to-boat transfer, it was decided that the sea swell and winds were too high to enable any safe transfer. The ESS and *Hurricane* returned to Cooktown, Australia, at 1400 h, and the *Greatship Maya* began waiting on weather, as conditions prohibited starting a new hole. At 1530 h, following operational discussions regarding the limited drilling options at the Ribbon Reef sites with no ESS available, the seabed transponder was recovered and the drill floor and moonpool secured for transit. The *Greatship Maya* came off dynamic positioning at 1645 h and departed for Noggin Pass.

Sedimentology and biological assemblages

Hole M0051A contains a single lithostratigraphic unit.

Unit 1: Sections 325-M0051A-1R-1 through 2R-CC: coralgal boundstone

The single Unit 1, spanning Sections 325-M0051A-1R-1 and 2R-CC, consists of coralgal boundstone fragments with algal nodules (rhodoliths) (Fig. F25). Thick lumpy crusts of coralline algae make up the nodules and cover coral skeletons, intergrowing with encrusting foraminifera (*Homotrema*). All components are slightly bioeroded, and a brownish stain covers surfaces of the coralline algal crusts. No samples were examined for larger foraminifera in this hole.

The only corals are one altered piece of *Pocillopora*(?) and a few unidentifiable fragments.

Physical properties

Hole M0051A was cored to a total depth of 2.50 m DSF-A, of which 0.15 m was successfully recovered (6.0% recovery). Because of the very small amount of core recovered, no physical property measurements were taken from Hole M0051A material with the exception of one color reflectance measurement, which was 58.03% L* (Table T1).

Paleomagnetism

Measurements of low-field and mass-specific magnetic susceptibility (χ) were performed on one sample taken from the working half of the recovered core. The sample recorded a positive susceptibility of 0.34 × 10^{-8} m^3/kg at a depth of 0.04 mbsf. This positive susceptibility value indicates the presence of paramagnetic and/or ferromagnetic minerals.

Chronology

This hole has one calibrated radiocarbon age of 10 cal y BP from Core 325-M0051A-2R (Fig. F26). There are no cores beneath this 10 cal y BP section, indicating that this hole only contains material from the last deglaciation.

Transect RIB-02A summary

Sedimentology and biological assemblages

Only a rough summary of the lithostratigraphic distribution pattern can be proposed for transect RIB-02 because of poor recovery in the four holes (M0049A, M0049B, M0050A, and M0051A) (Fig. F27). A limited lithological succession is proposed for three holes (M0049A, M0049B, and M0050A) in which drilling penetrated below the modern and subrecent seafloor. In Hole M0050A, recovered material probably represents subrecent seafloor sediment mixed with fossil material. The following lithological succession is proposed.

At the top of two of the three holes (M0049A and M0050A), the uppermost sediment consists of brown-stained fragments of coralgal boundstone in lime sand that is rich in *Halimeda*. The fragments appear to include both lithified and unconsolidated modern or subrecent seafloor sediment. In Holes M0049B and M0050A, coralgal-microbialite boundstones occur below the modern sediment. The recovered unit varies from 8 to 16 m thick. No underlying lithologic information was obtained.

Table T3 documents all the larger foraminifera described in this transect in association with hole, run, and depth (below seafloor).

Physical properties

Recovery at transect RIB-02A sites was partial with an average recovery of ~16%. However, recovery at Holes M0049A and M0049B reached ~20%. Cores were partially saturated and often disturbed, fractured, or contaminated, which affects the quality of physical property data collected. Borehole depths for this transect are as follows:

- Hole M0049A = 97.63 mbsl, 3.50 m DSF-A.
- Hole M0049B = 97.63 mbsl, 15.6 m DSF-A.
- Hole M0050A = 97.63 mbsl, 10.5 m DSF-A.
- Hole M0051A = 79.63 mbsl, 2.50 m DSF-A

Plugs and samples taken for discrete *P*-wave and moisture and density measurements were obtained from both consolidated and unconsolidated material.

Density and porosity

Bulk density was measured at transect RIB-02A using the gamma ray attenuation sensor on the multisensor core logger (MSCL). Gamma ray attenuation provides an estimate of bulk density (also referred to as gamma density) from whole cores. Discrete moisture and density measurements are also taken with a pentapycnometer on plugs and/or rock fragments. This provides grain density, bulk density (in the case of plug samples), and porosity data. One observes a classic linear relationship between the porosity (ϕ) and bulk density ($\rho = \rho_s[1 - \phi] + \rho_w\phi$) of discrete samples measured for all boreholes at transect RIB-02A (Fig. F28). Average grain density (ρ_s) is 2.78 g/cm^3. Grain density varies between 2.75 and 2.79 g/cm^3 and may correspond to a value between the grain density of calcite (2.71 g/cm^3) and aragonite (2.93 g/cm^3). Porosity values for both measured boreholes in this transect can be viewed in Figure F29. Porosity ranges from 17% to 45%; however, the majority of porosity measurements acquired hover around 30%.

P-wave velocity

Only two core plugs were collected from this transect, and both were from Hole M0049B. Whole-core MSCL data (over ~6.5 cm) ranges from 1504.7 to 1845.36 m/s. Values at the lower end of this range (1500 m/s) should be treated with a degree of caution because the proximity of the values to the velocity of seawater suggests that core quality issues (including inundation by drilling fluid) may have compromised the data validity. As expected, because of where discrete samples are taken from cores (biased toward well-consolidated, good-quality samples that should yield good data), much lower *P*-wave velocity values have been recorded by the MSCL for coralgal and coralgal-microbialite units compared to discrete measurements on core plugs.

Magnetic susceptibility

Magnetic susceptibility data are very difficult to interpret for this transect owing to low core recovery in all holes. Very few values were obtained on whole cores, but data range from -0.63×10^{-5} SI (Hole M0049B) to high values of 31.6×10^{-5} SI (Hole M0050A). The most data were collected for Hole M0049B; however, no obvious trends are visible in the data.

Electrical resistivity

Over the entire transect resistivity is highly variable, with the lowest value (0.63 Ωm) measured in Hole M0050A and the highest value (78.34 Ωm) recorded in Hole M0049B. Because of the relatively poor core quality and undersaturated cores, very little confidence can be placed in these data.

Color reflectance

In transect RIB-02A, recovery for Hole M0051A was very low (<10 cm), and only one value of color reflectance spectrophotometry was taken. Holes M0049A, M0049B, and M0050A were located at the same water depth and are therefore comparable. Discrete measurements of reflectance values for all the boreholes in this transect are represented in Figure F30. No particular trends were observed in these three boreholes, but reflectance values were consistent in all cores where units were recovered from similar depths downhole.

Paleomagnetism

Four holes at two sites were drilled in transect RIB-02A, with recovered materials mainly composed of corals and calcareous sediments. The recovered materials show mainly positive values of low-field and mass-normalized magnetic susceptibility. The arithmetic mean values of the sites indicate the presence of paramagnetic and/or ferromagnetic materials.

Most of the peaks in magnetic susceptibility occur at specific depth intervals of 2–3, ~5, 17–20, and 27–30 mbsf, associated with variations in lithology. The features at 17–20 and 27–30 mbsf are related to the occurrence of sandy layers or other terrigenous material.

Magnetic susceptibility for these sites is stronger than at the southern sites on transects HYD-01C, HYD-02A, and NOG-01B, possibly because the Ribbon Reef transect is located much closer to land and thus to a source of magnetic materials. Further studies of ferromagnetic material will facilitate detection and definition of important features of the magnetic record and geomagnetic behavior. Further rock magnetic studies on these layers may provide information on the nature and processes that have contributed to the presence of these features. Environmental magnetic studies may reinforce the climatic origin of these layers and provide information on the amount, composition, and grain size of the magnetic component retained. The magnetic susceptibility record will allow alternative hypotheses to be investigated other than a simple concentration of magnetic minerals due to proximity to the eroded continent.

Geochemistry

Only two interstitial water samples (one aliquot each from Holes M0049A and M0050A) were collected from transect RIB-02A. Samples were analyzed for cations and anions (Table T4). All measurement parameters including alkalinity, pH, and concentrations of ammonium, cations, and anions were within the normal ranges for marine sediments. Because of the scarcity of interstitial water samples in this transect, interpretations relating to vertical variations could not be made.

Chronology

A short hole (M0051A at Site 3) (Fig. F27) drilled into an 80 m feature at 78 m water depth (lowest astronomical tide [LAT]) returned an age of 10 cal y BP (Core 325-M0051A-2R), indicating that this hole recovered material from the middle of the deglaciation. Three more holes (M0049A, M0049B, and M0050A; Site 4) were drilled at 97 m water depth (LAT) in transect RIB-02A. These holes were drilled into a 100 m feature, and the youngest age recovered was 4 cal y BP (Core 325-M0049B-2R), suggesting some accumulation of Holocene material. Other ages from these holes range from 16 to 11 cal y BP (Cores 325-M0050A-2R, 325-M0049B-4R, and 9R), indicating material was accumulating during the last deglaciation at this site.

References

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Reimer, P.J., Baillie, M.G.L., Bard, E., Bayliss, A., Beck, J.W., Blackwell, P.G., Bronk, R.C., Buck, C.E., Burr, G.S., Edwards, R.L., Friedrich, M., Grootes, P.M., Guilderson, T.P., Hajdas, I., Heaton, T.J., Hogg, A.G., Hughen, K.A., Kaiser, K.F., Kromer, B., McCormac, F.G., Manning, S.W., Reimer, R.W., Richards, D.A., Southon, J.R., Talamo, S., Turney, C.S.M., van der Plicht, J., and Weyhenmeyer, C.E., 2009. Intcal09 and Marine09 radiocarbon age calibration curves, 0–50,000 years cal BP. *Radiocarbon,* 51(4):1111–1150. http://digitalcommons.arizona.edu/restrictedobjectviewer?o=http://radiocarbon.library.arizona.edu/Volume51/Number4/49691745-6a68-4e2c-a26f-08f0a16c1a53

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MS 325-105

Figure F1. Contour plot showing transect RIB-02A (Ribbon Reef 3), Expedition 325. Sites 1–4 and Holes M0049A–M0051A are indicated. See Figure F2 in the "Expedition 325 summary" chapter for general location. EPSP = Environmental Protection and Safety Panel, GBRMPA = Great Barrier Reef Marine Park Authority.

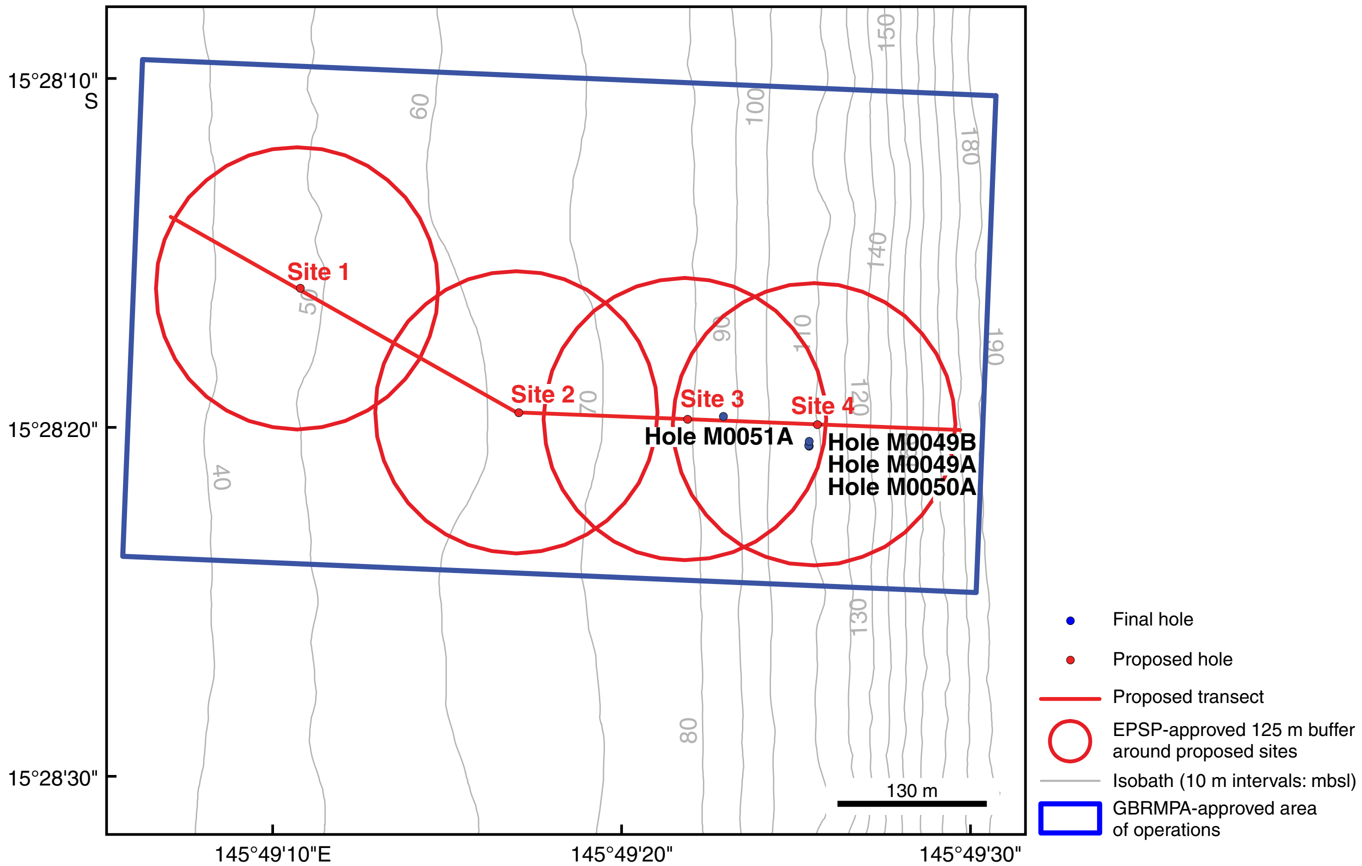


Figure F2. High-resolution line scan image of rudstone to lime pebbles in sand rich in *Halimeda* segments and mollusk shells (interval 325-M0049A-1R-1, 18–25 cm). Coralline algae are also present.

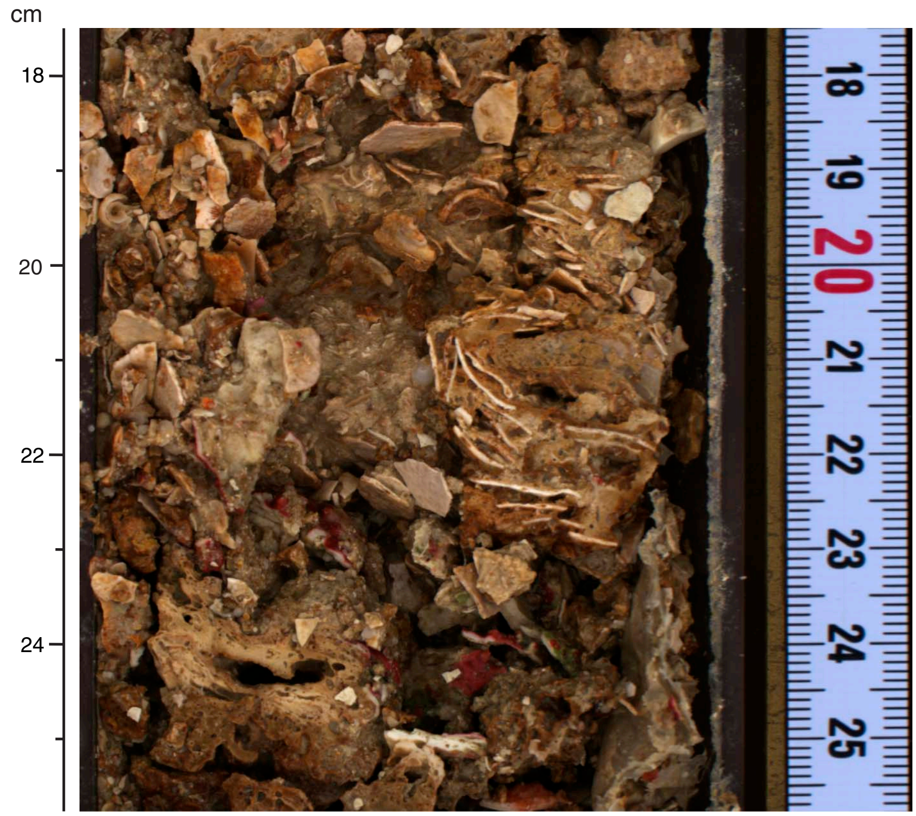


Figure F3. High-resolution line scan image of a coralgal boundstone with foliose coralline algae in sand rich in *Halimeda* and mollusk shell fragments (interval 325-M0049A-1R-1, 8–18 cm).

Figure F4. Summary diagram showing data collected on whole cores using the MSCL, Hole M0049A.

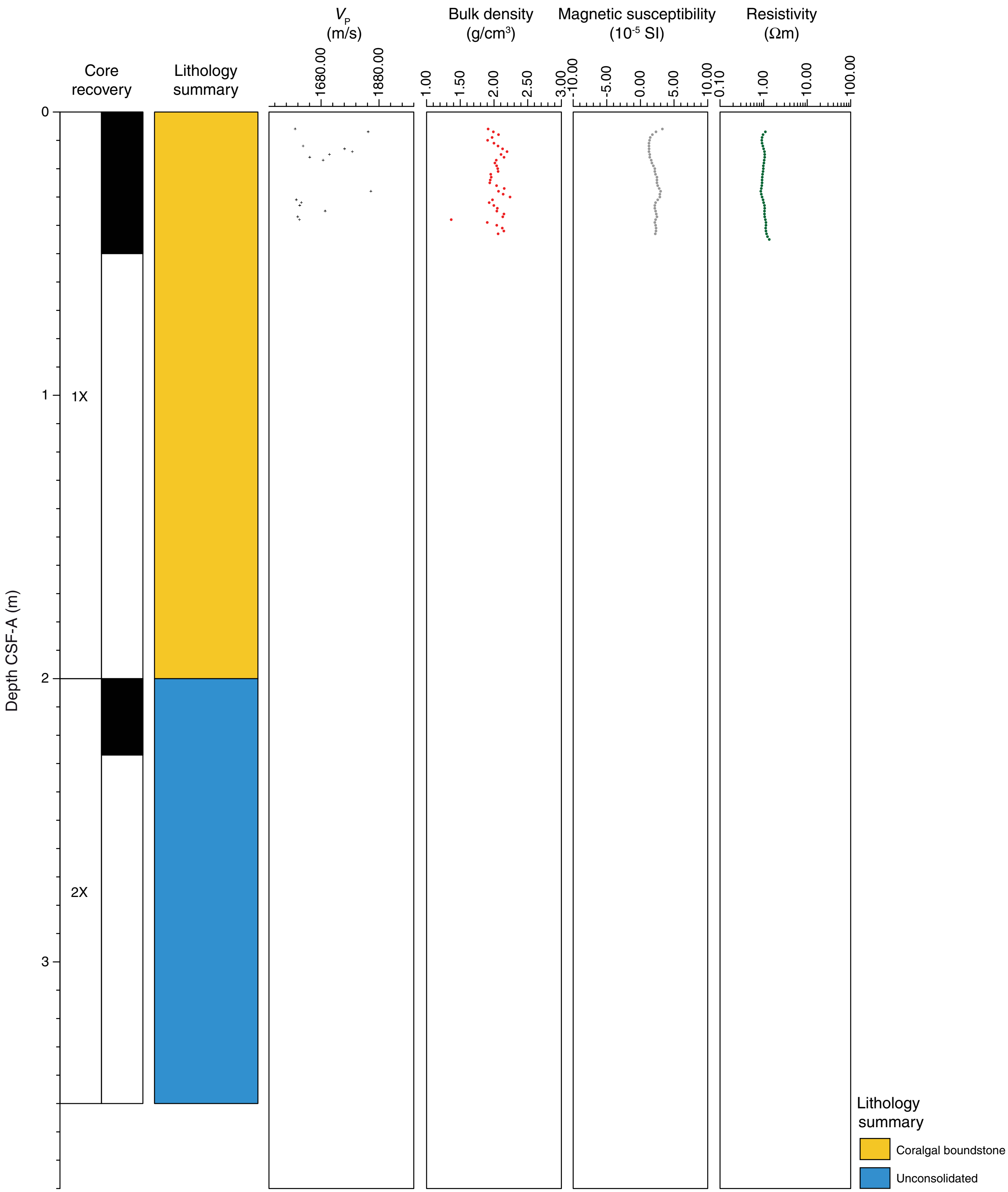


Figure F5. Plots of petrophysical measurements obtained from discrete samples with a pycnometer, Hole M0049A. Bulk density measured on whole cores with the MSCL is shown in red on the bulk density plot.

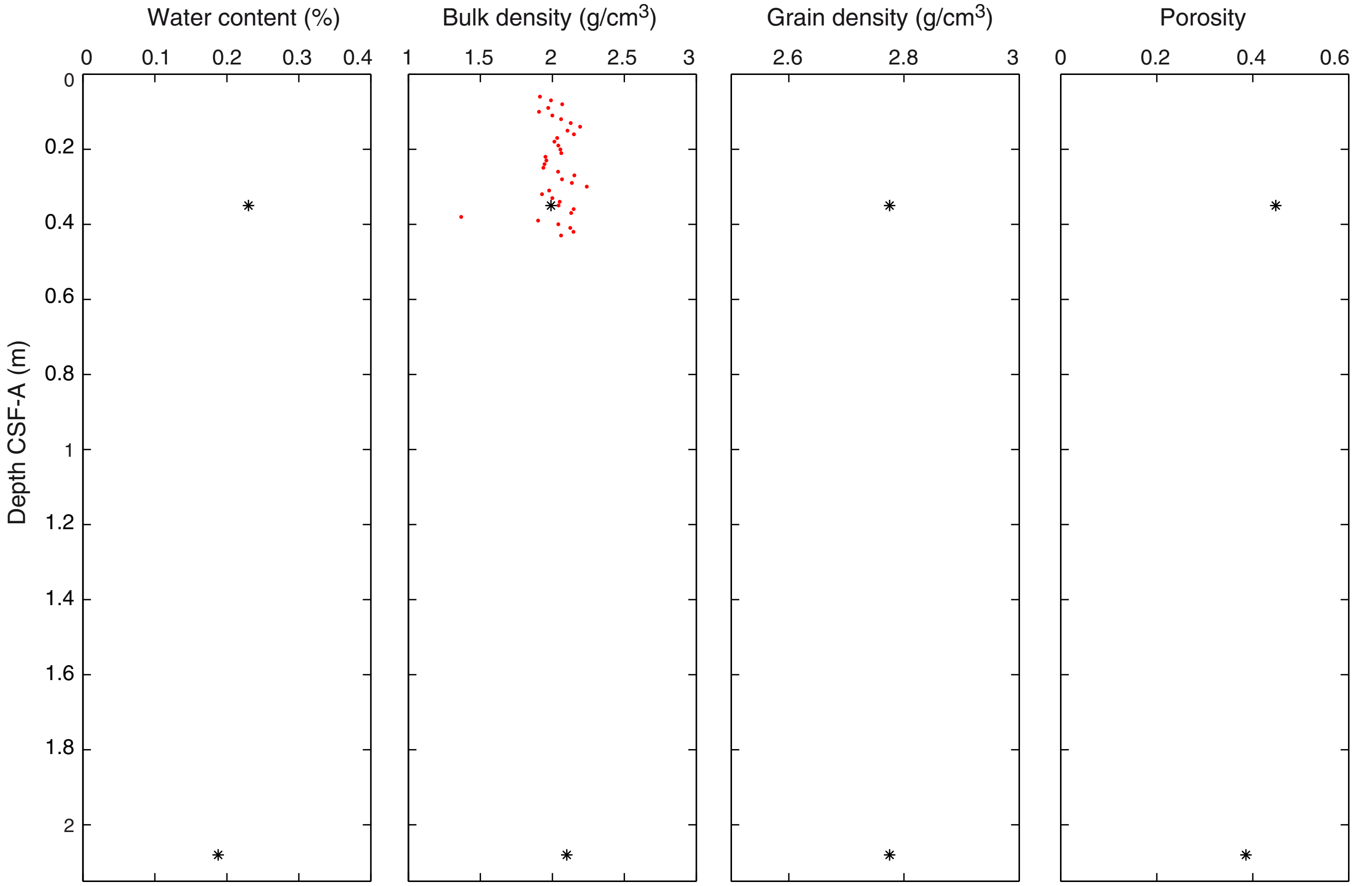


Figure F6. Values of reflectance (L*), green to red (a*), and blue to yellow (b*) indexes, along with ratio a*/b* for Hole M0049A.

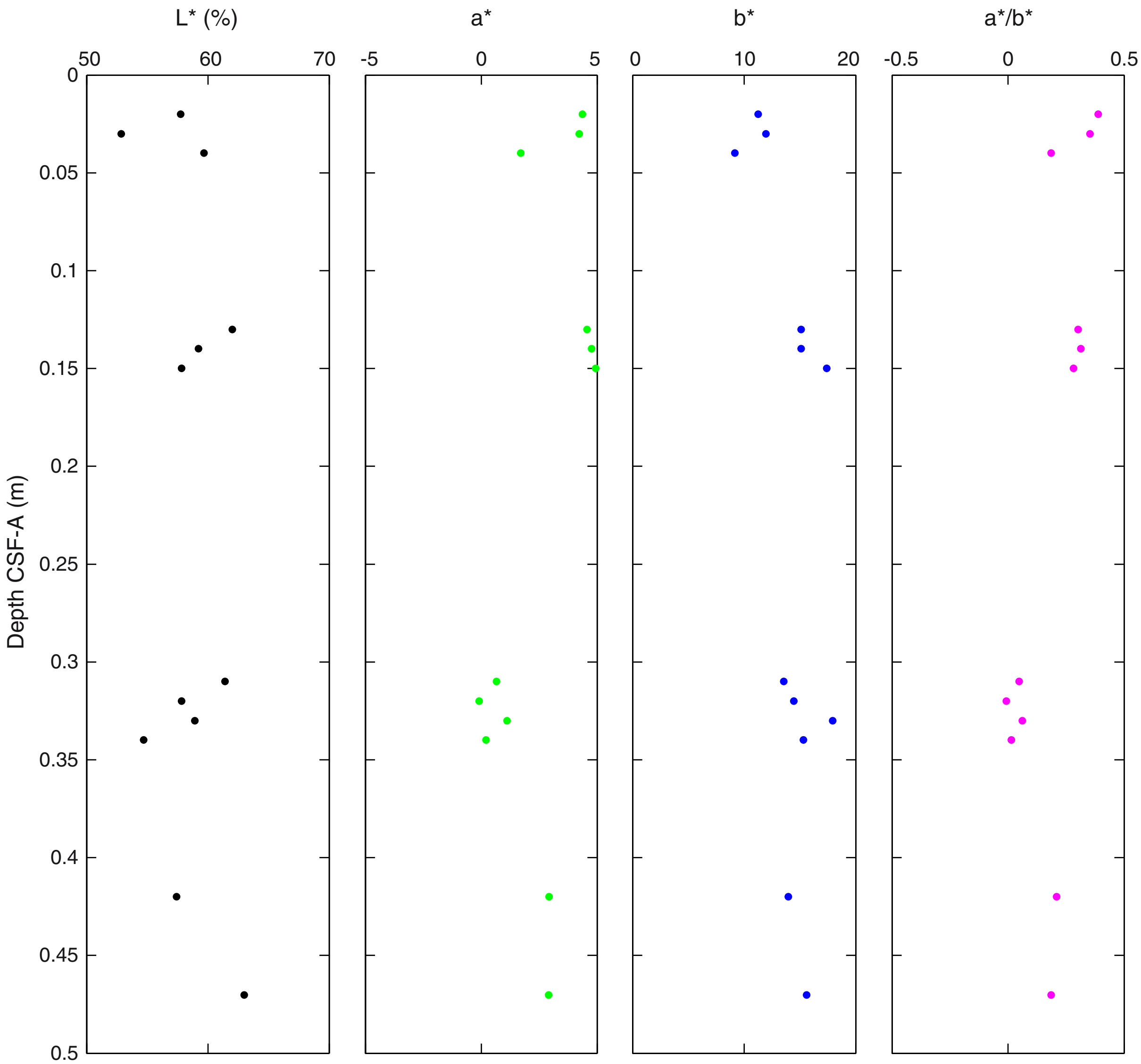


Figure F7. Magnetic susceptibility record for Hole M0049A. Water depth = 97.63 m (LAT).

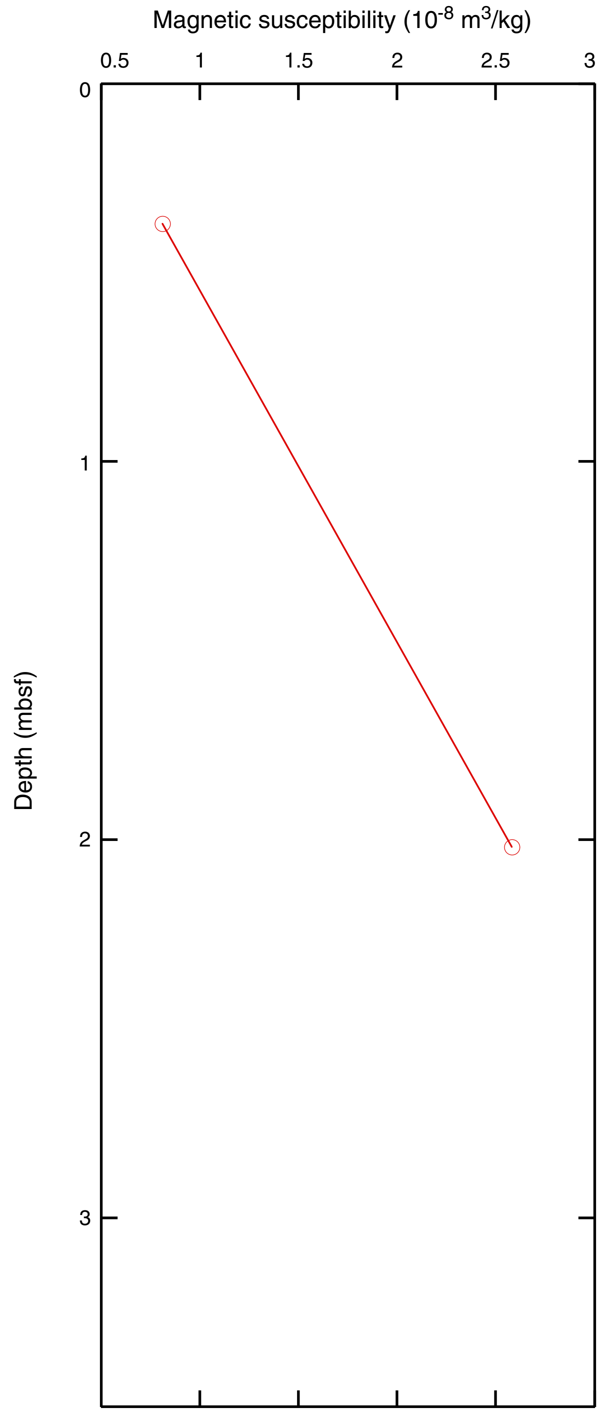


Figure F8. High-resolution line scan image of coral with mixed bryozoans encrusted by thin coralline algae. *Halimeda* floatstone is at the top of the image (interval 325-M0049B-1X-1, 1–9 cm).

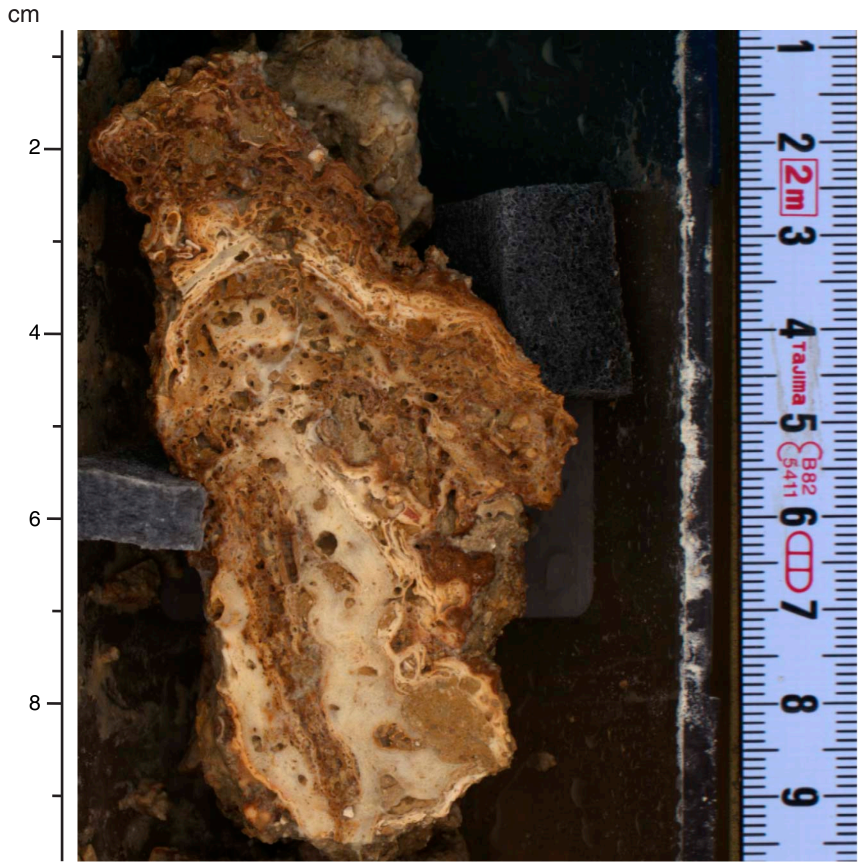


Figure F9. High-resolution line scan image of coralline algae encrusted by poorly laminated microbialites (interval 325-M0049B-5R-1, 10–15 cm).

Figure F10. High-resolution line scan image of a massive *Porites*(?) colony with geopetal infilling of a cavity (interval 325-M0049B-9R-2, 0–6 cm).

Figure F11. High-resolution line scan image of a cavity in a massive *Porites* colony with small stalagmitic and stalagtitic columns (interval 325-M0049B-9R-CC, 0–6 cm).

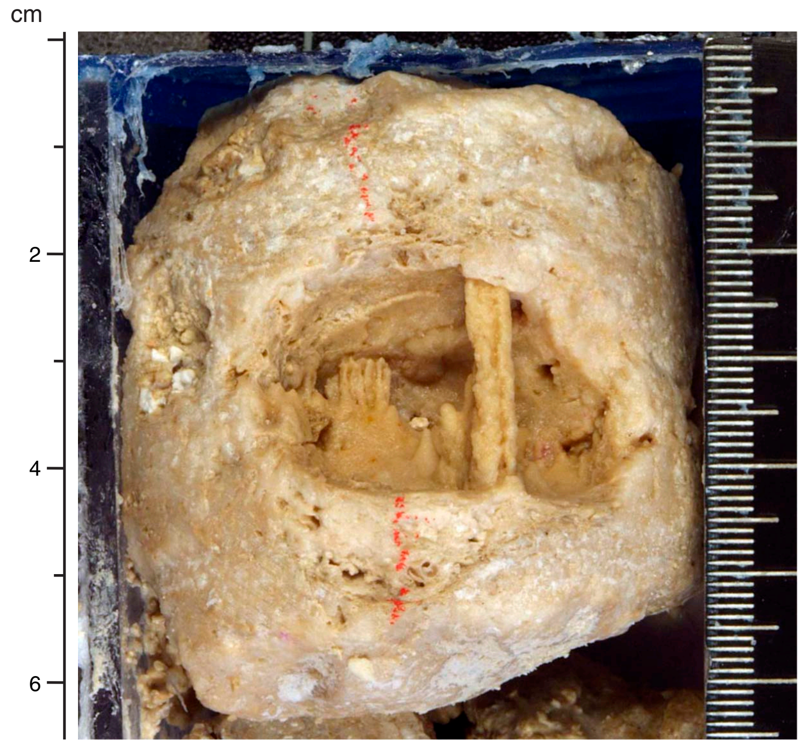


Figure F12. High-resolution line scan image of a massive *Porites* colony (interval 325-M0049B-4R-1, 3–7 cm).

Figure F13. High-resolution line scan image of a fragment of coralgal-microbialite boundstone with internal sediment rich in *Halimeda,* and covered by laminated microbialites (interval 325-M0049B-10R-1, 31–38 cm). Cavities partially filled with geopetal fabrics and "microstalactitic" cement. A massive *Porites* and calcareous sponge are also present.

Figure F14. Summary diagram showing data collected on whole cores using the MSCL, Hole M0049B.

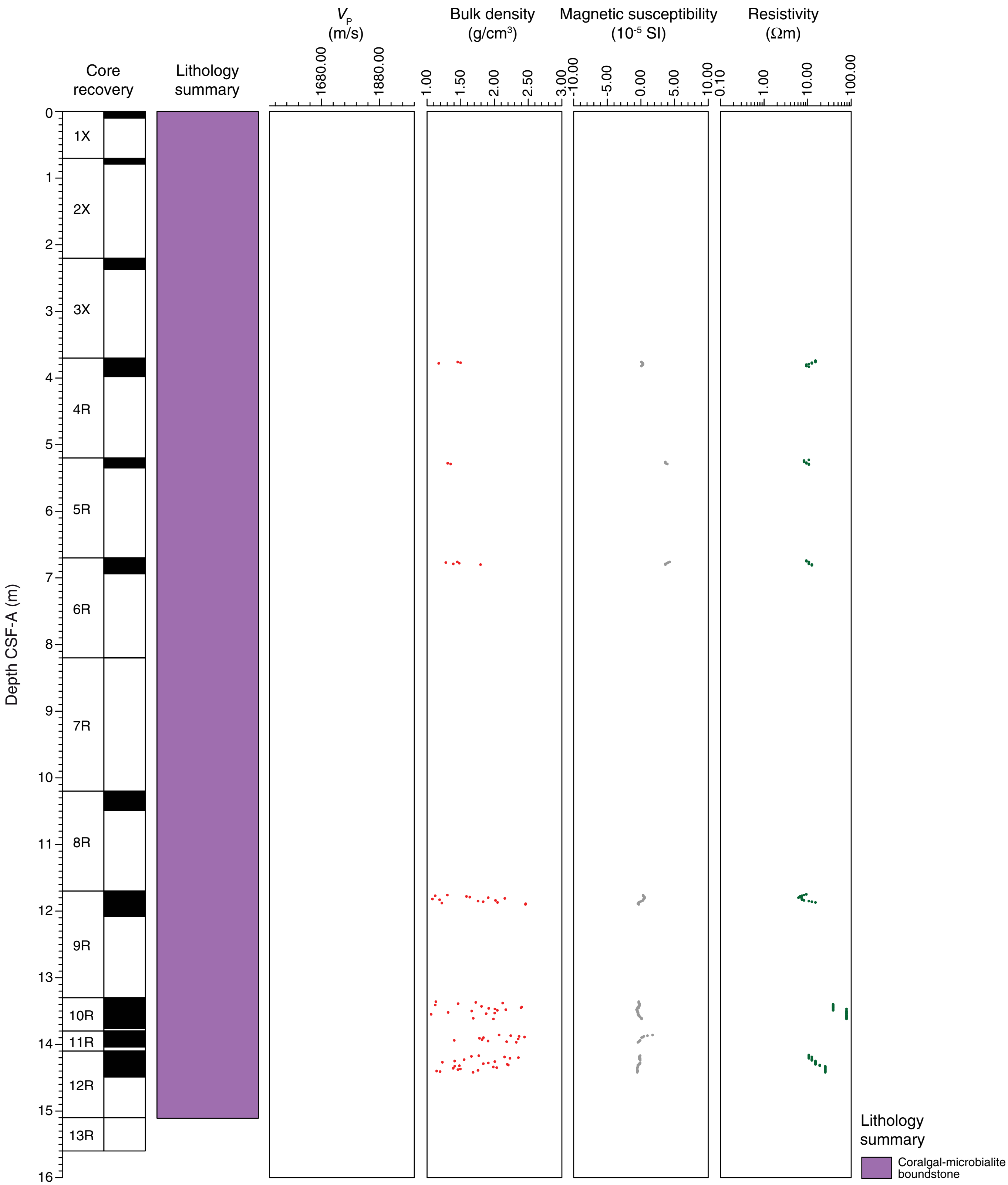


Figure F15. Plots of petrophysical measurements obtained from discrete samples with a pycnometer, Hole M0049B. Bulk density measured on whole cores with the MSCL is shown in red on the bulk density plot.

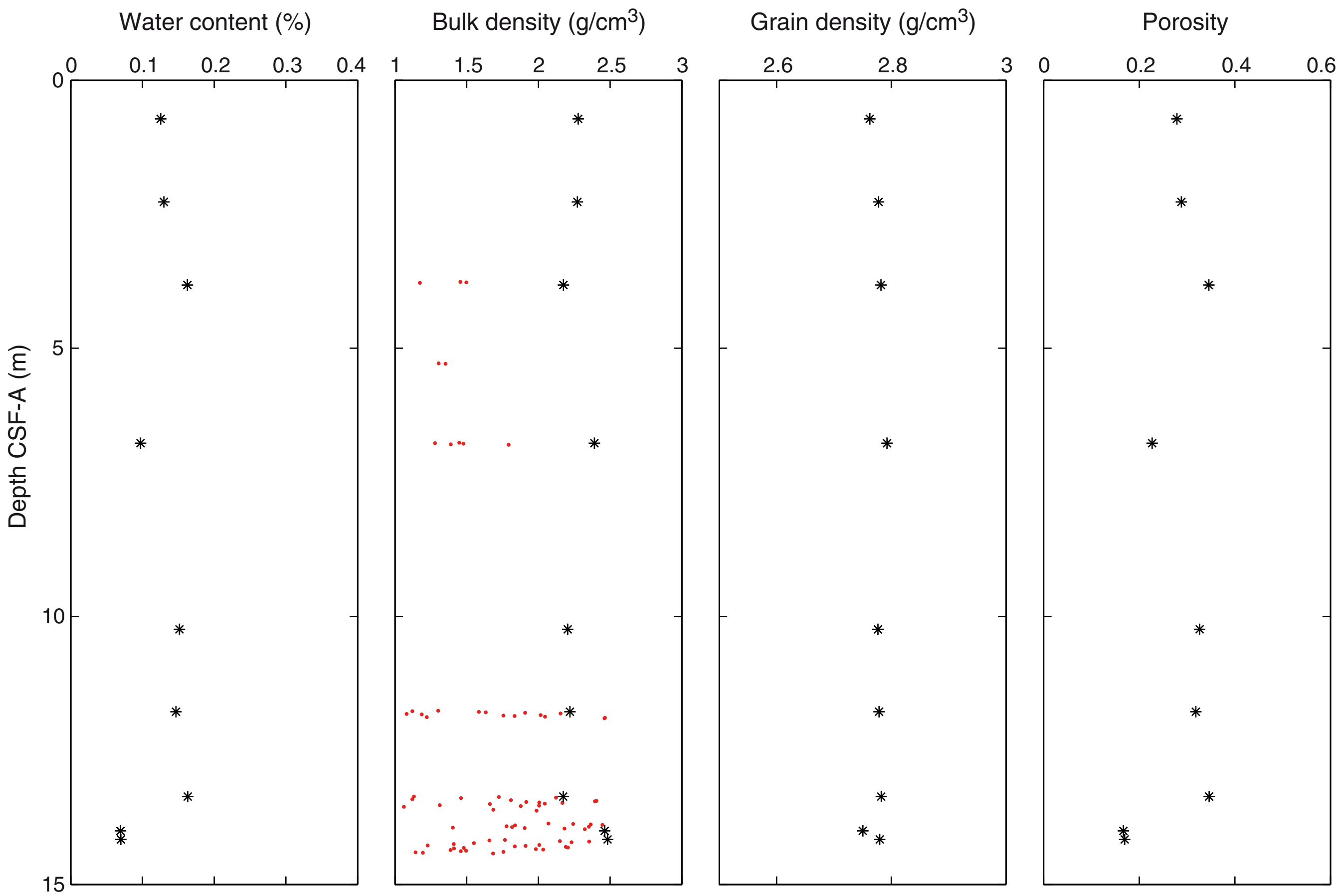
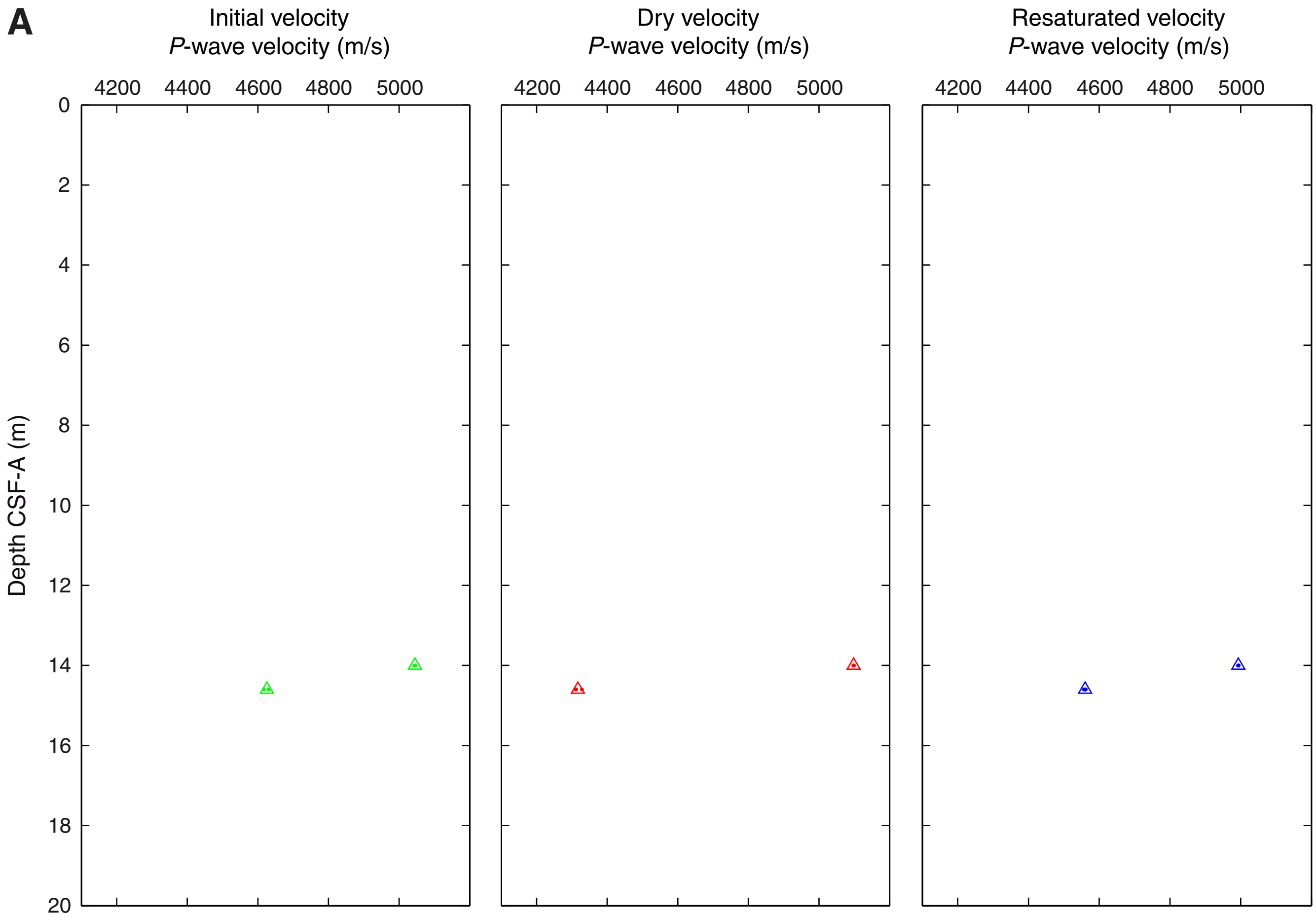


Figure F16. *P*-wave velocity data, Hole M0049B. **A.** Plot of initial, dry, and resaturated *P*-wave velocity measurements on discrete samples vs. depth. Three measurements were taken at each depth and are denoted by a dot. Average values are plotted as an open triangle. **B.** Plot showing discrete *P*-wave velocity vs. discrete bulk density.



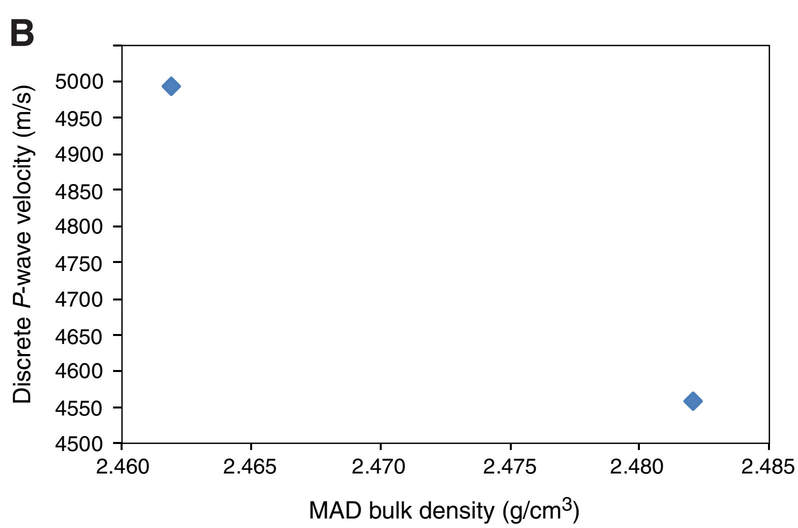


Figure F17. Values of reflectance (L*), green to red (a*), and blue to yellow (b*) indexes, along with ratio a*/b* for Hole M0049B.

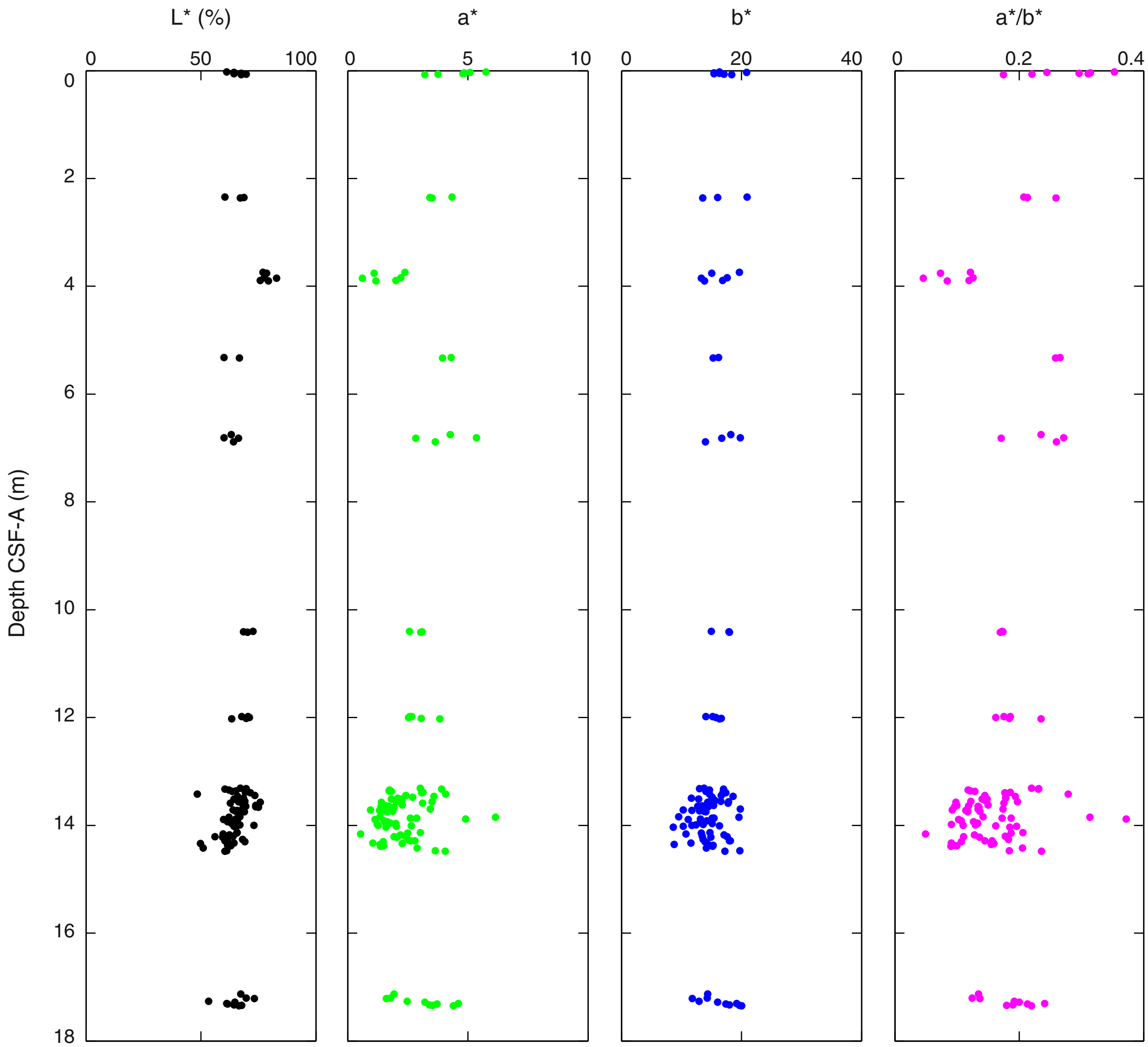


Figure F18. Magnetic susceptibility record for Hole M0049B. Water depth = 97.63 m (LAT).

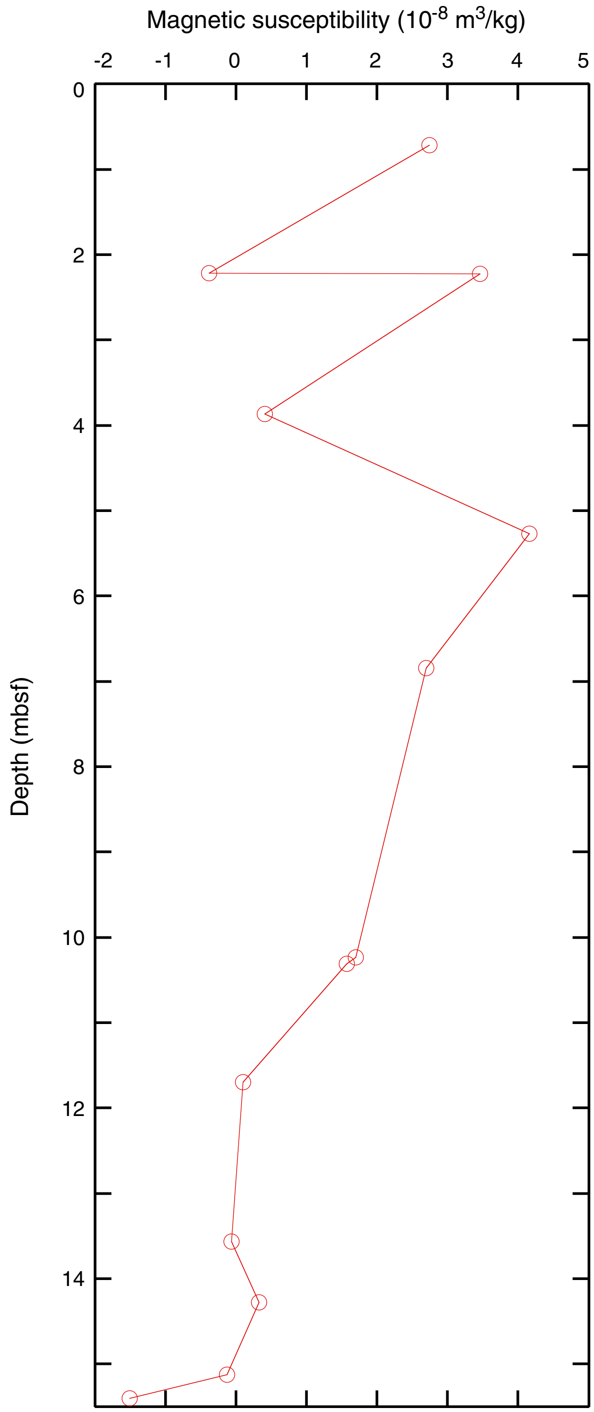


Figure F19. Preliminary chronology for Hole M0049B. Radiocarbon data are presented as graphs with the uncalibrated radiocarbon age and uncertainty shown as the red normal distribution on the ordinate axis and the probability distribution of the calibrated age shown in gray on the abscissa. The marine09 calibration curve is shown in blue. Horizontal bars indicate portions of the age distribution that are significant at the 95.4% confidence interval and the mean age (white circle ±1 standard deviation) used for the purposes of the preliminary dating. All ages are presented as thousands of calendar years BP (1950 AD). See Table T10 in the "Methods" chapter. (See Bronk Ramsey [2009], as well as Bronk Ramsey [2010] at c14.arch.ox.ac.uk/oxcal.html.)

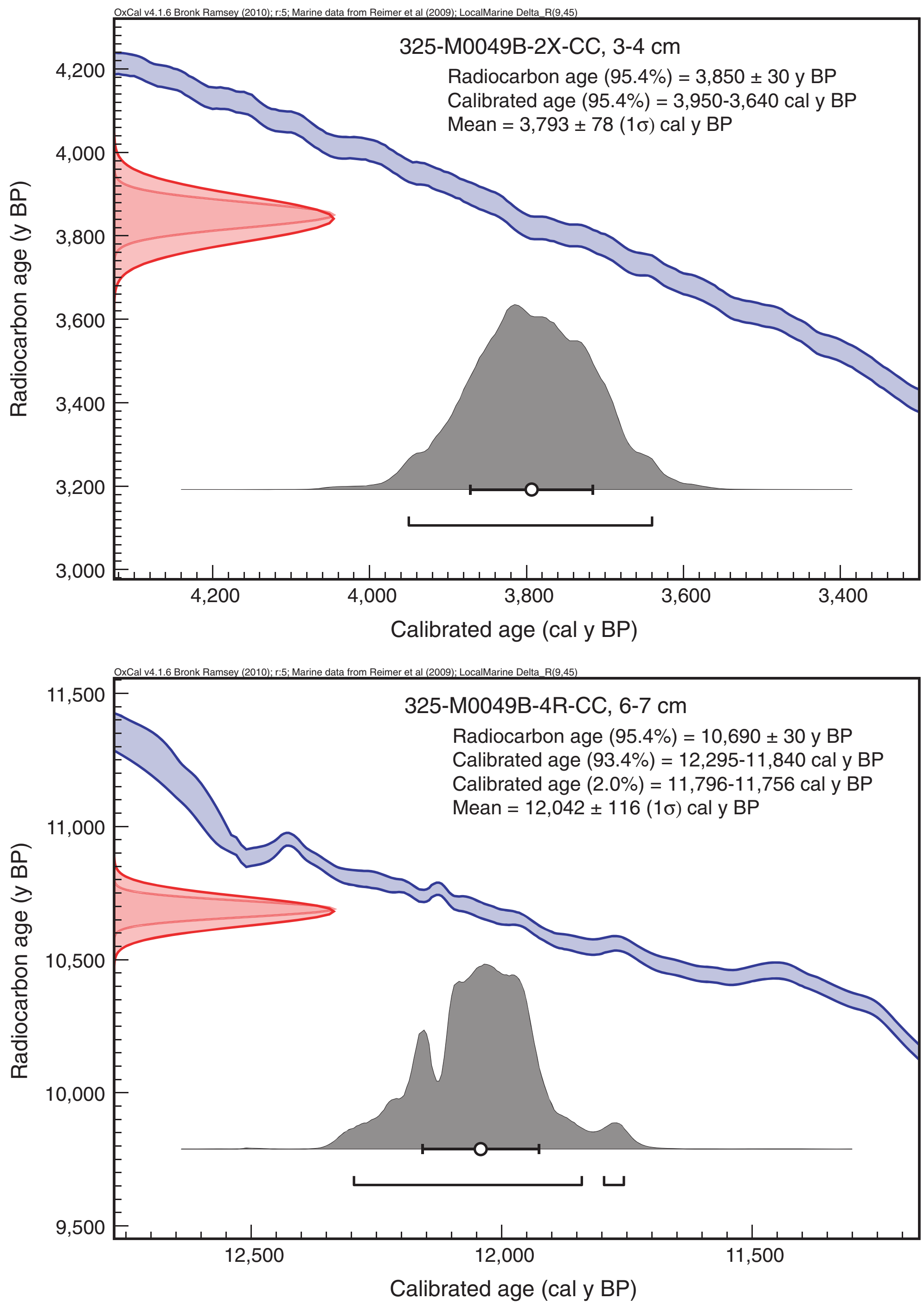


Figure F20. High-resolution line scan image of branching coralline algae and bryozoans (interval 325-M0050A-3R-1, 10–14 cm).

Figure F21. Summary diagram showing data collected on whole cores using the MSCL, Hole M0050A.

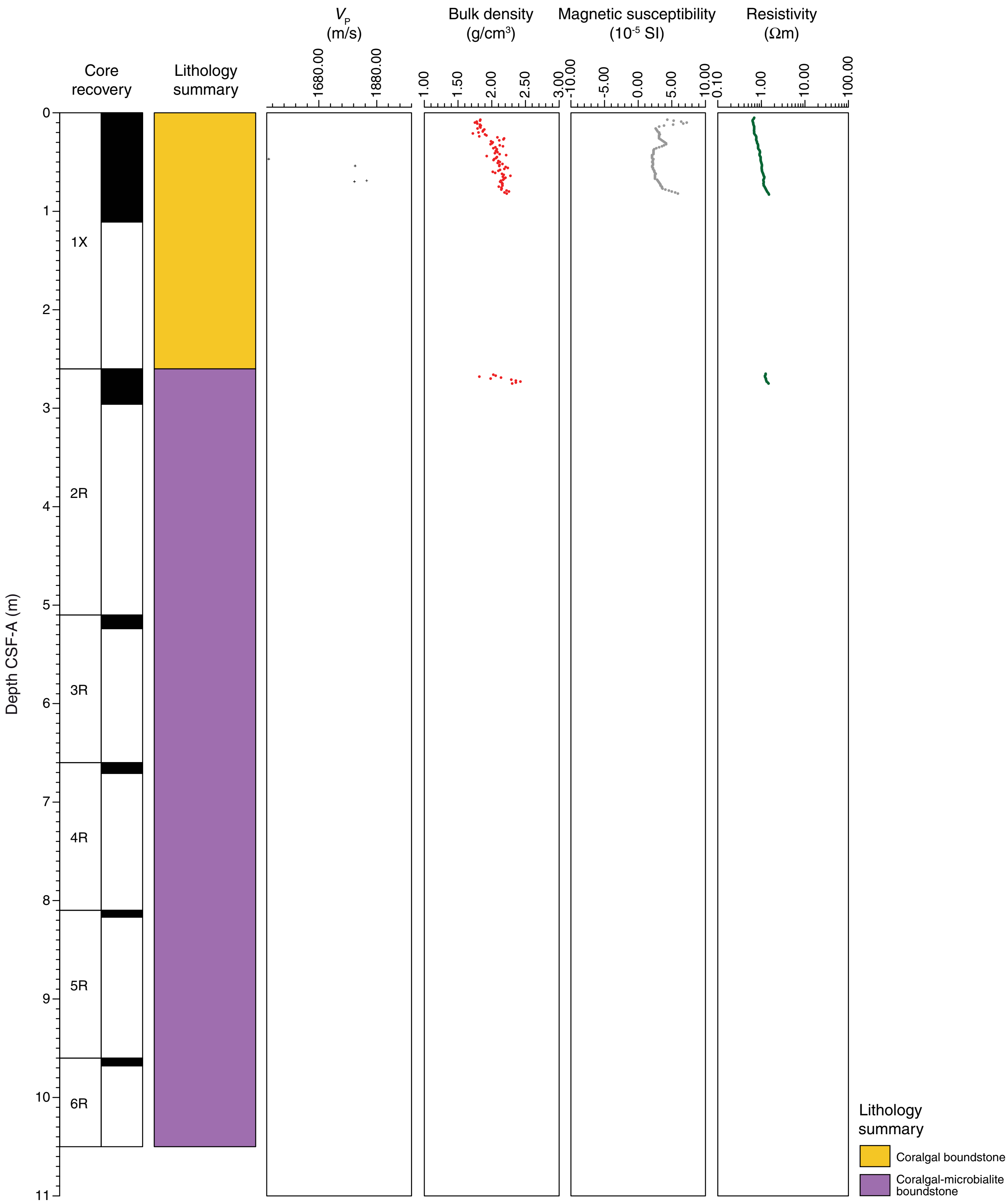


Figure F22. Values of reflectance (L*), green to red (a*), and blue to yellow (b*) indexes, along with ratio a*/b* for Hole M0050A.

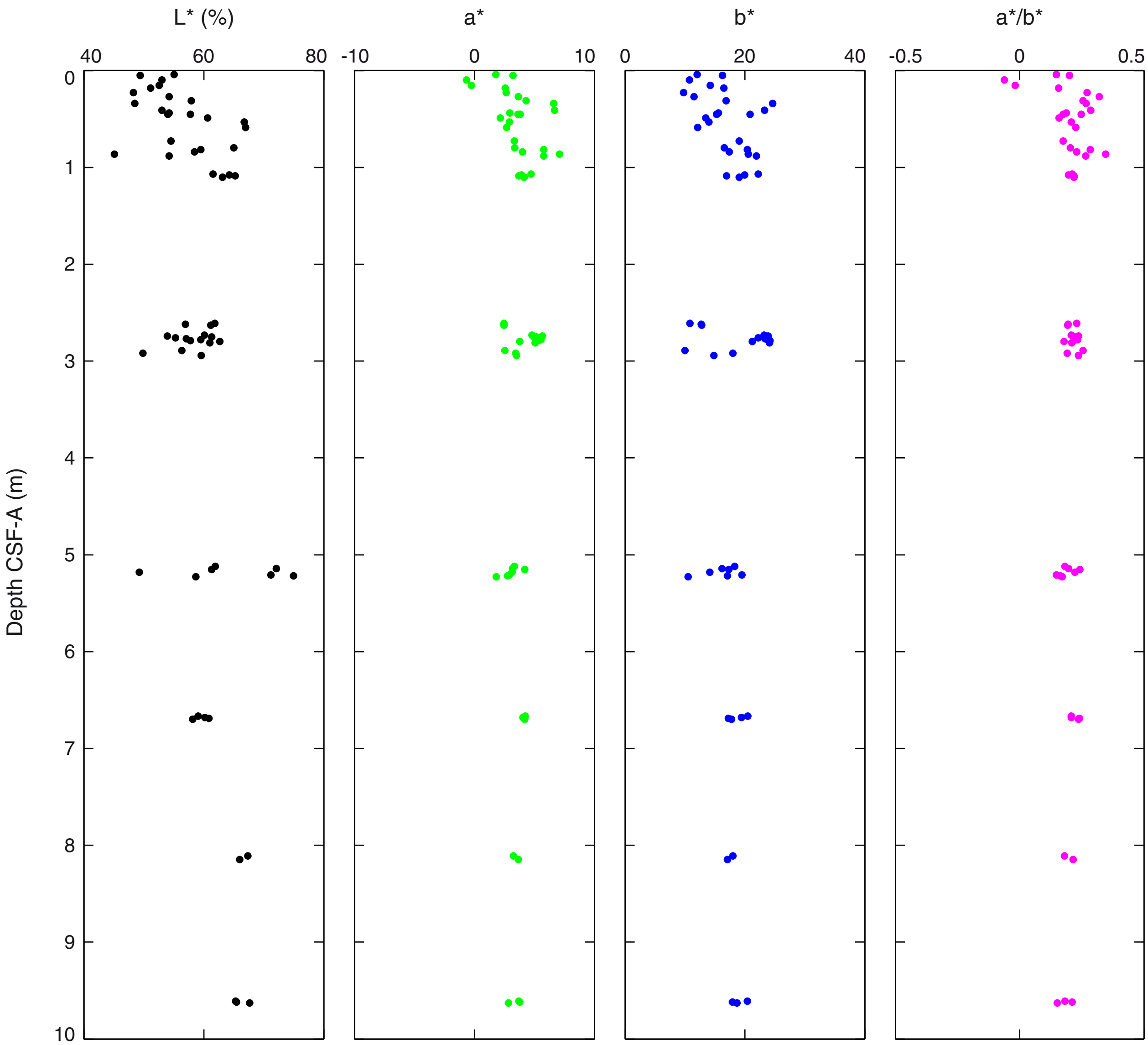


Figure F23. Magnetic susceptibility record for Hole M0050A. Water depth = 97.63 m (LAT).

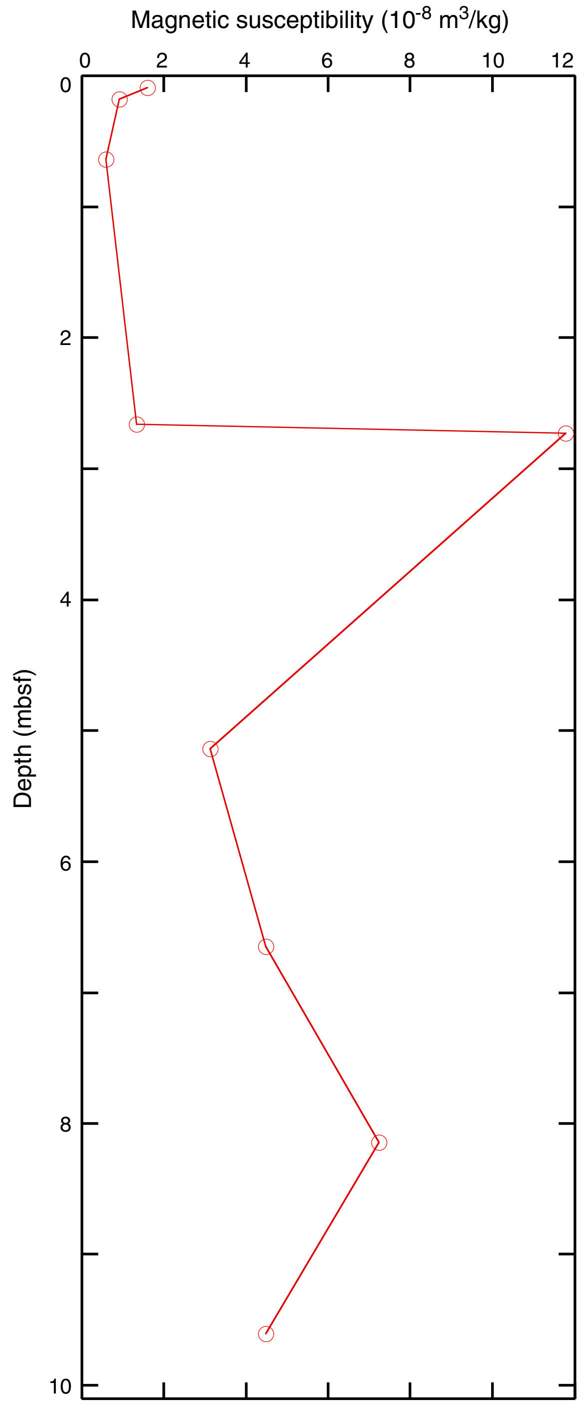


Figure F24. Preliminary chronology for Hole M0050A. Radiocarbon data are presented as graphs with the uncalibrated radiocarbon age and uncertainty shown as the red normal distribution on the ordinate axis and the probability distribution of the calibrated age shown in gray on the abscissa. The marine09 calibration curve is shown in blue. Horizontal bars indicate portions of the age distribution that are significant at the 95.4% confidence interval and the mean age (white circle ±1 standard deviation) used for the purposes of the preliminary dating. All ages are presented as thousands of calendar years BP (1950 AD). See Table T10 in the "Methods" chapter. (See Bronk Ramsey [2009], as well as Bronk Ramsey [2010] at c14.arch.ox.ac.uk/oxcal.html.)

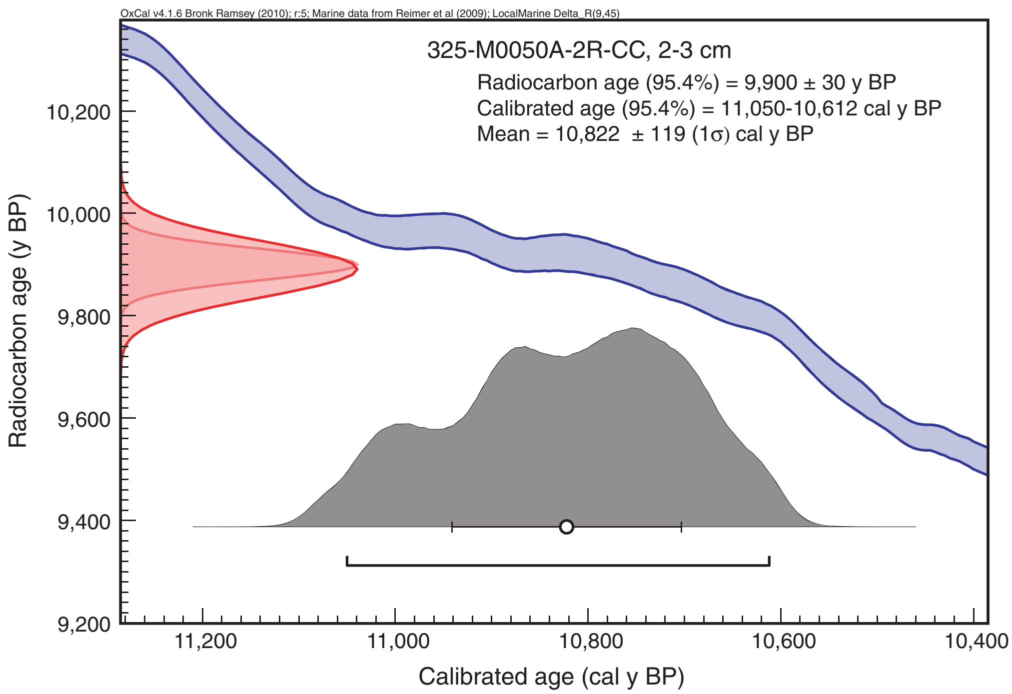


Figure F25. High-resolution line scan image of rhodoliths enclosing encrusting bryozoans (interval 325-M0051A-1R-1, 0–10 cm).

Figure F26. Preliminary chronology for Hole M0051A. Radiocarbon data are presented as graphs with the uncalibrated radiocarbon age and uncertainty shown as the red normal distribution on the ordinate axis and the probability distribution of the calibrated age shown in gray on the abscissa. The marine09 calibration curve is shown in blue. Horizontal bars indicate portions of the age distribution that are significant at the 95.4% confidence interval and the mean age (white circle ±1 standard deviation) used for the purposes of the preliminary dating. All ages are presented as thousands of calendar years BP (1950 AD). See Table **T10** in the "Methods" chapter. (See Bronk Ramsey [2009], as well as Bronk Ramsey [2010] at **c14.arch.ox.ac.uk/oxcal.html.**)

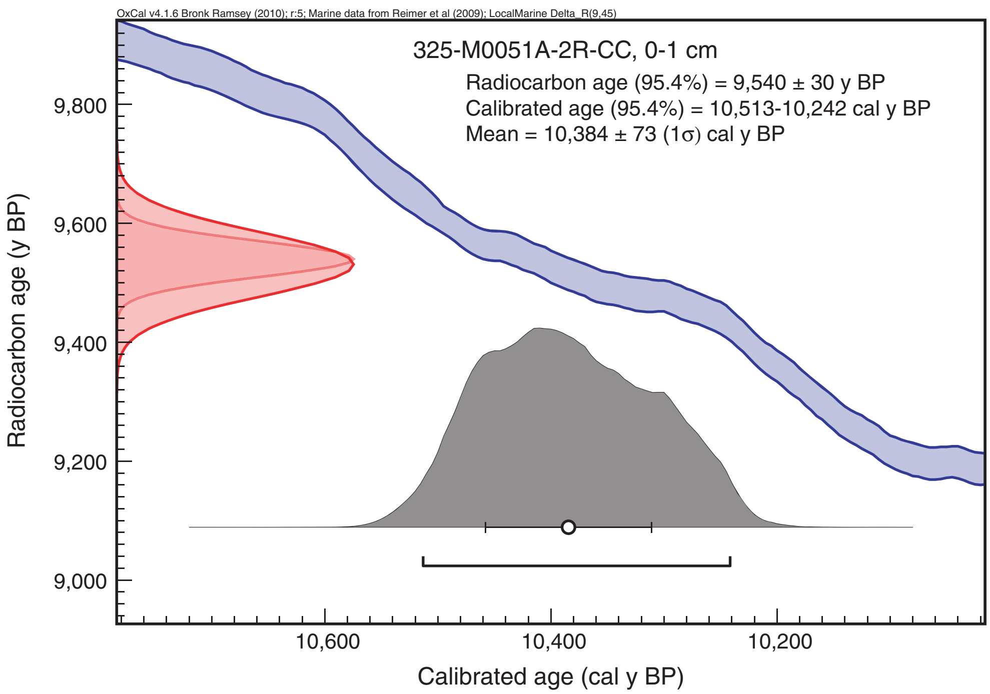


Figure F27. Transect RIB_02A summary showing recovery, main lithological units, and their interpretation for holes drilled offshore of the Ribbon 5 reefs. Holes are plotted against present-day sea level (LAT taken from corrected EM300 multibeam bathymetry). Distances between holes are indicated on the diagram, but are not drawn to horizontal scale.

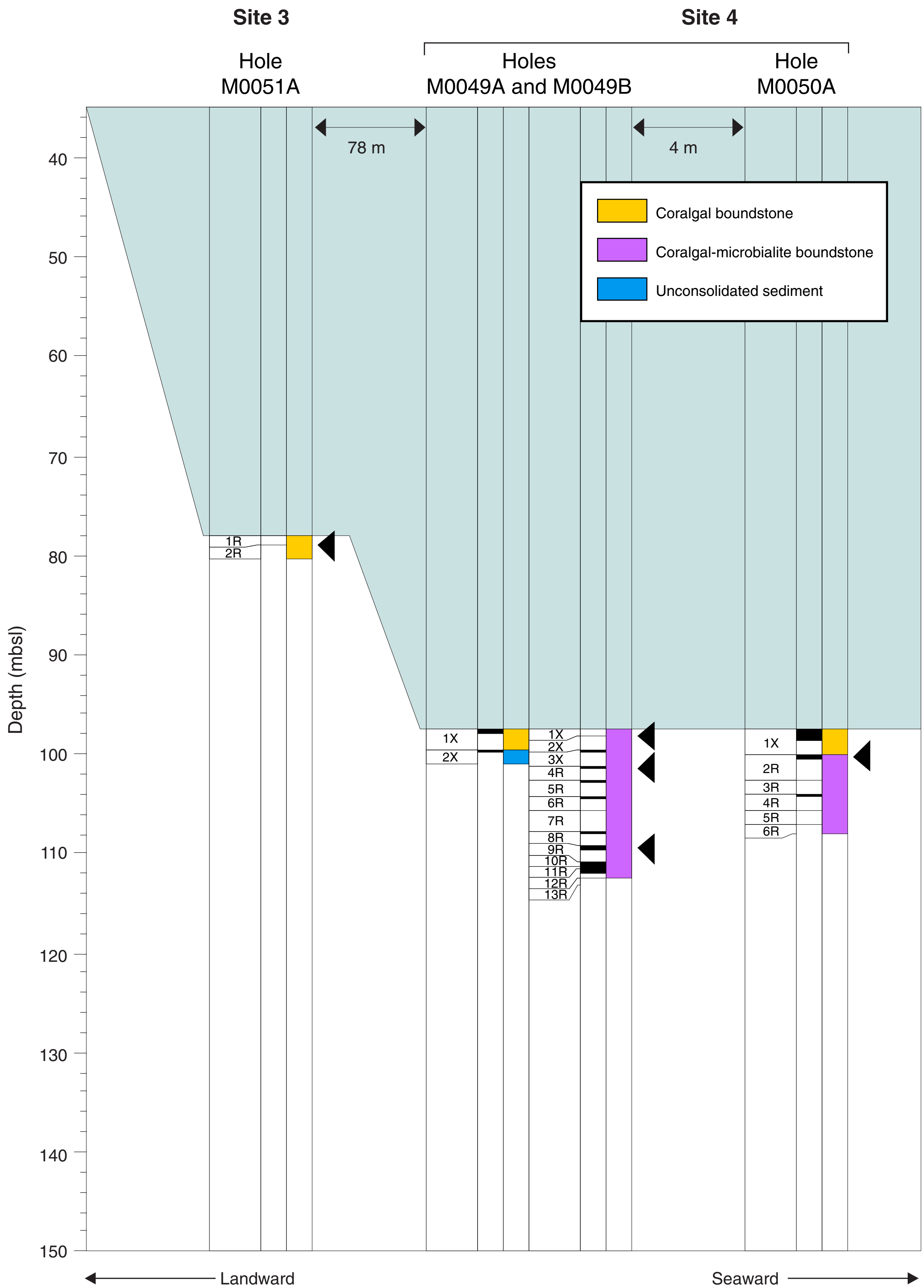


Figure F28. Cross-plot showing porosity vs. bulk density measured in discrete samples from transect RIB-02A.

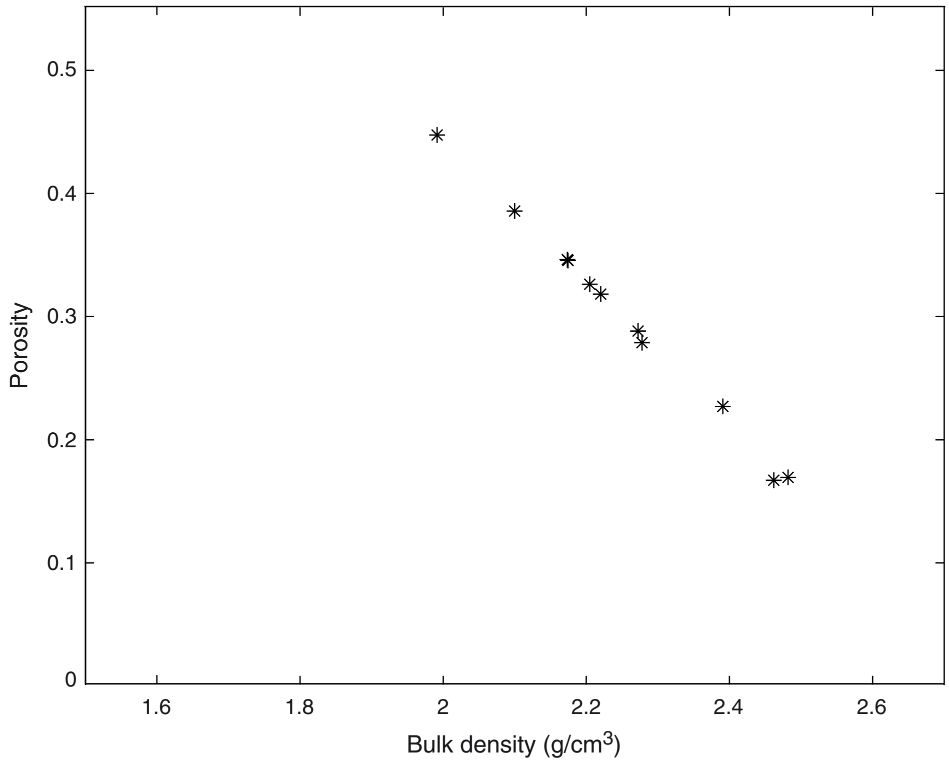


Figure F29. Porosity of discrete samples for all holes measured in transect RIB-02A from shallow water to deep water (left to right).

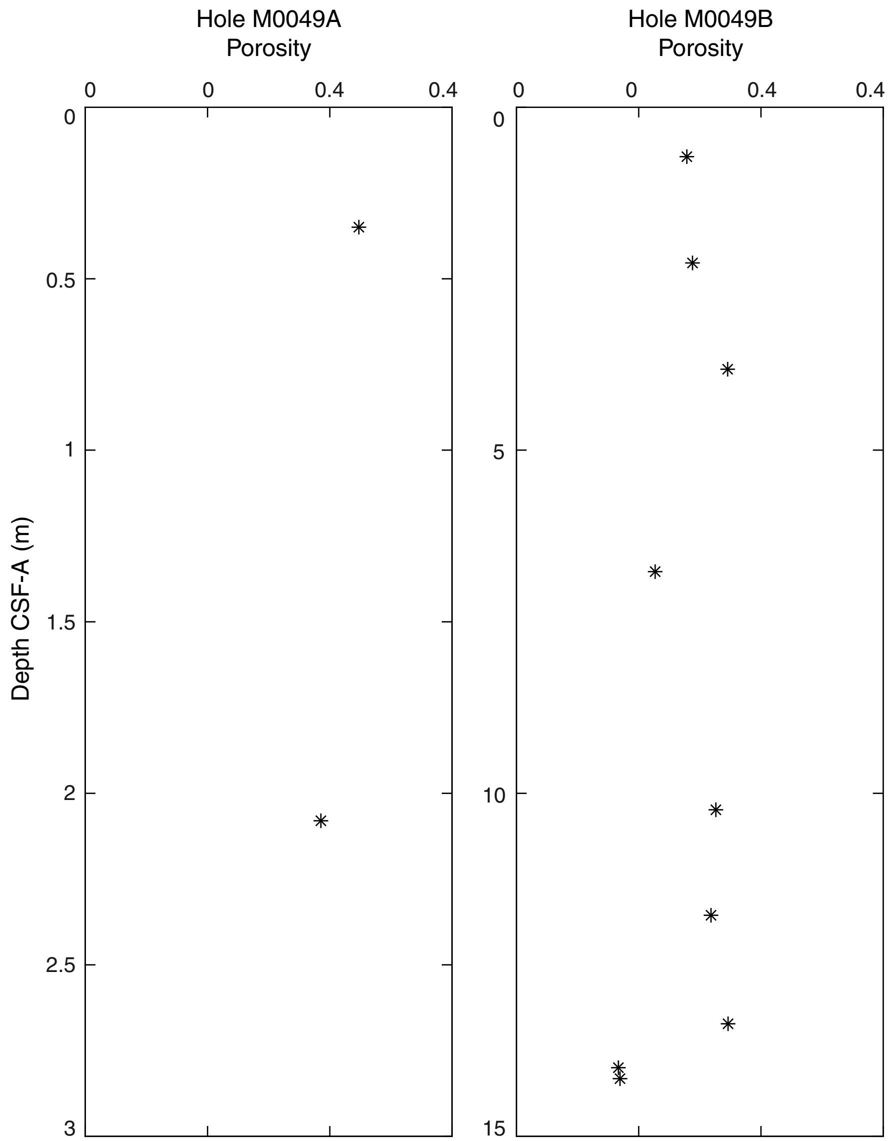


Figure F30. Color reflectance (L*) for all transect RIB-02A holes from shallow water to deep water (left to right).

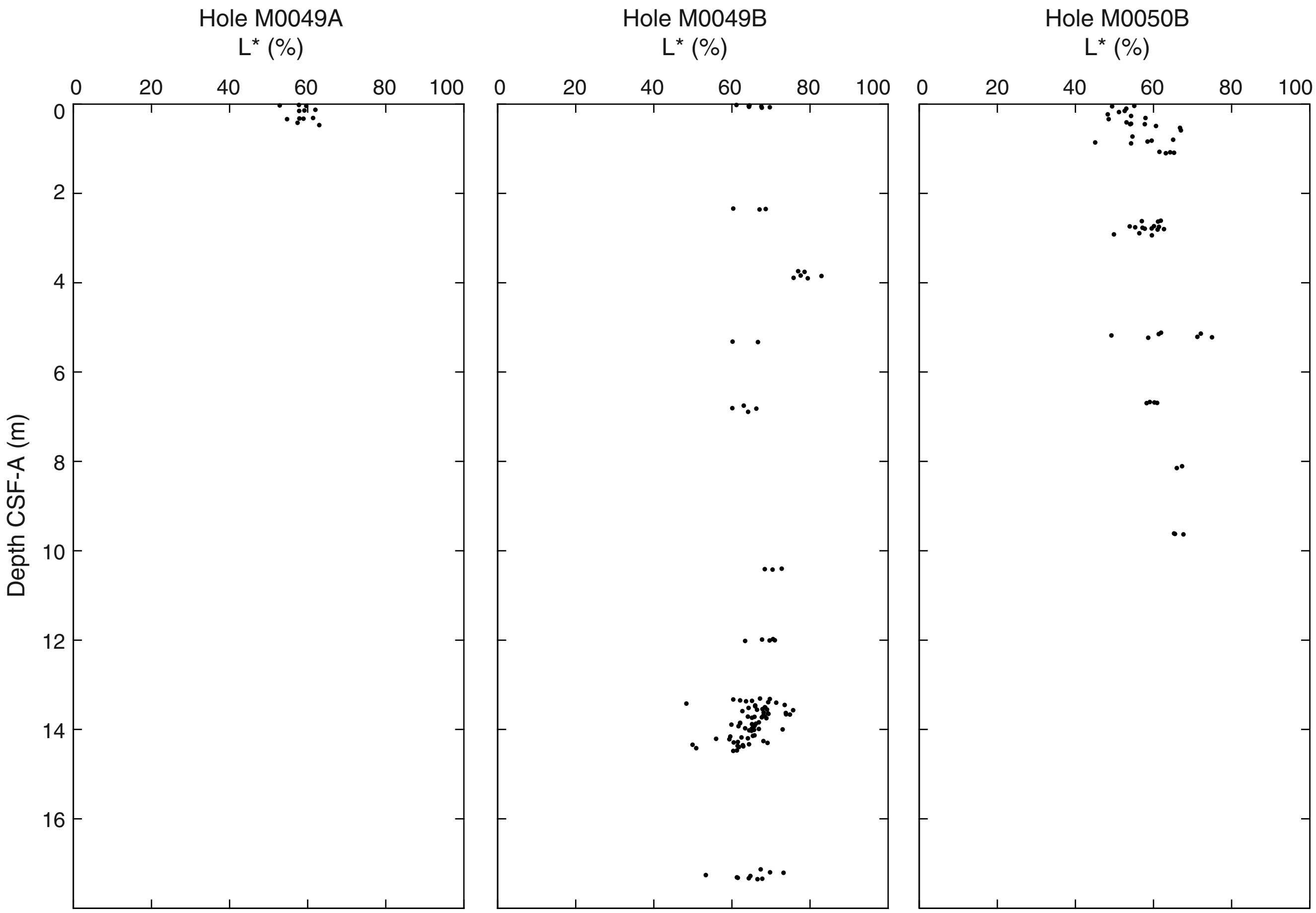


Table T1. Coring summary, transect RIB-02A. (See table note.)

Core	Date (2010)	Time (UTC)	Depth (mbsf) Top	Depth (mbsf) Bottom	Length (m) Cored	Length (m) Recovered	Recovery (%)	Comments
325-M0049A-								
1X	21 Mar	2330	0	2	2	0.5	25.00	Fluorescent microspheres.
2X	22 Mar	0025	2	3.5	1.5	0.27	18.00	Borehole stopped because of excessive leak at flush pipe/water swivel.
325-M0049B-								
1X	22 Mar	0420	0	0.7	0.7	0.1	14.29	Fluorescent microspheres.
2X	22 Mar	0500	0.7	2.2	1.5	0.09	6.00	
3X	22 Mar	0535	2.2	3.7	1.5	0.17	11.33	
4R	22 Mar	0615	3.7	5.2	1.5	0.28	18.67	
5R	22 Mar	0650	5.2	6.7	1.5	0.15	10.00	
6R	22 Mar	0730	6.7	8.2	1.5	0.24	16.00	
7R	22 Mar	0800	8.2	10.2	2	0	0.00	
8R	22 Mar	0840	10.2	11.7	1.5	0.29	19.33	
9R	22 Mar	0935	11.7	13.3	1.6	0.38	23.75	
10R	22 Mar	1050	13.3	13.8	0.5	0.46	92.00	Significant vibration through drill string limits RPM.
11R	22 Mar	1150	13.8	14.1	0.3	0.24	80.00	
12R	22 Mar	1350	14.1	15.1	1	0.39	39.00	
13R	22 Mar	1520	15.1	15.6	0.5	0	0.00	Core slipped on retrieval.
325-M0050A-								
1X	22 Mar	1720	0	2.6	2.6	1.11	42.69	
2R	22 Mar	1820	2.6	5.1	2.5	0.36	14.40	
3R	22 Mar	1855	5.1	6.6	1.5	0.14	9.33	
4R	22 Mar	1930	6.6	8.1	1.5	0.11	7.33	Drive tube top thread gave out—replaced tube and added new bit.
5R	22 Mar	2020	8.1	9.6	1.5	0.07	4.67	
6R	22 Mar	2120	9.6	10.5	0.9	0.08	8.89	
325-M0051A-								
1R	23 Mar	0105	0	1	1	0.1	10.00	
2R	23 Mar	1400	1	2.5	1.5	0.05	3.33	ALN barrel stuck in BHA because of broken latch lug. Bit crushed. API drill sting tripped to recover barrel.

Note: UTC = Universal Time Coordinated, RPM = revolutions per minute, ALN = alien corer (standard rotary corer), BHA = bottom-hole assembly, API = American Petroleum Institute.

Table T2. Physical properties summary, transect RIB-02A. (See table notes.)

Hole	Value	*P*-wave MSCL (m/s)	*P*-wave saturated discrete samples (m/s)	Magnetic susceptibility MSCL ($\times 10^{-5}$ SI)	Electrical resistivity MSCL (Ωm)	Bulk density MSCL (g/cm^3)	Bulk density discrete samples (g/cm^3)	Porosity (%)	Grain density (g/cm^3)	L* (D65)	a* (D65)	b* (D65)	a*/b*
325-													
M0049A	Min	—	1505	1.28	0.86	1.37	1.99	38	2.78	52.87	–0.1	9.18	–0.01
	Max	—	1852	3.26	1.35	2.24	2.17	39	2.85	63	4.94	17.95	0.39
	Mean ± SD	—	1669 ± 99	2.14 ± 0.53	1.02 ± 0.10	2.03 ± 0.14	2.13 ± 0.05	38.5 ± 0.5	2.81 ± 0.05	58.56 ± 2.88	2.69 ± 1.90	14.24 ± 2.49	0.20 ± 0.14
M0049B	Min	4560	—	–0.64	6.17	1.06	2.17	17	2.75	48.34	0.53	8.6	0.05
	Max	4993	—	4.29	78.34	2.46	2.48	35	2.79	82.98	6.14	20.93	0.37
	Mean ± SD	4777 ± 306	—	0.27 ± 1.26	24.94 ± 23.36	1.75 ± 0.40	2.30 ± 0.12	27 ± 7	2.78 ± 0.01	66.07 ± 5.65	2.64 ± 1.18	15.21 ± 2.59	0.17 ± 0.06
M0050A	Min	—	1507	2.07	0.63	1.72	—	—	—	45.08	–0.67	9.76	–0.06
	Max	—	1845	31.60	1.50	2.43	—	—	—	74.93	7.11	24.68	0.35
	Mean ± SD	—	1740 ± 157	5.62 ± 6.97	0.98 ± 0.24	2.07 ± 0.15	—	—	—	55.04 ± 6.28	3.73 ± 1.46	17.71 ± 4.15	0.21 ± 0.06
M0051A	Min	—	—	—	—	—	—	—	—	58.03	1.87	14.36	0.13
	Max	—	—	—	—	—	—	—	—	58.03	1.87	14.36	0.13
	Mean ± SD	—	—	—	—	—	—	—	—	—	—	—	—

Notes: MSCL = multisensor core logger. SD = standard deviation. — = no measurement taken.

Table T3. Larger foraminifera observed in cores from transect RIB-02A. (**See table note.**)

Hole, core, section, interval (cm)	Abundance	Preservation	*Alveolinella*	*Amphistegina*	*Baculogypsina*	*Calcarina*	*Cycloclypeus*	Elphidiidae	*Gypsina*	*Heterostegina*	*Homotrema*	*Lenticulina*	*Marginopora*	Miliolida	*Operculina*	*Planorbulinella*	*Planostegina*	Rotallida	Soritinae	*Sphaerogypsina*	Textulariida
325-																					
M0049A-1X-1, 6–11	C	Good		X			X										X				
M0049A-2X-CC, 7–12	Ab																				
M0049B-4R-CC, 4–9	Ab																				
M0049B-8R-CC, 10–15	Ab																				
M0050A-1X-1, 4–9	C	Good		X			X								X						
M0050A-2R-1, 15–20	C	Good		X																	

Note: Abundance: C = common, Ab = absent.

Table T4. Geochemical data relating to interstitial water collected from transect RIB-02A.

Hole, core, section, interval (cm)	Depth (mbsf)	Sample ID	pH	Alk (mM)	NH_4 (µM)	Ca (mM)	Si (µM)	Sr (µM)	Mg (mM)	B (µM)	K (mM)	S (mM)	Na (mM)	Ba (nM)	Li (µM)	Al (µM)	As (nM)
325-																	
M0049A-1R-1, 35	0.35	S39	7.76	2.85	22	10.5	47.9	87.1	53.0	433	10.29	28.8	457	1933	25.9	42.5	603
M0050A-1R-1, 45	0.45	S40	7.70	3.83	23	10.8	29.5	90.1	52.4	432	10.00	28.1	463	90	23.8	42.9	224

Hole, core, section, interval (cm)	Depth (mbsf)	Sample ID	Be (nM)	Cd (nM)	Co (nM)	Cr (nM)	Cu (nM)	Fe (µM)	Mn (µM)	Mo (nM)	Ni (nM)	P (µM)	Pb (nM)	Ti (nM)	V (nM)	Zn (µM)
325-																
M0049A-1R-1, 35	0.35	S39	153	0	0	1	0	0.93	1.00	0	224	19.27	0	0	122	35.06
M0050A-1R-1, 45	0.45	S40	191	0	101	3	0	1.09	2.56	0	0	4.57	10	0	312	3.67

Hole, core, section, interval (cm)	Depth (mbsf)	Sample ID	Zr (nM)	Cl (mM)	Br (µM)	SO_4 (mM)
325-						
M0049A-1R-1, 35	0.35	S39	315	554	895	29.2
M0050A-1R-1, 45	0.45	S40	734	559	897	29.5