Integrated Ocean Drilling Program
Expedition 325 Scientific Prospectus

Great Barrier Reef environmental changes

The last deglacial sea level rise in the South Pacific: offshore drilling northeast Australia 2009

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Abstract

The history of sea level and sea-surface temperature variation associated with the last deglaciation is of prime interest to understanding the dynamics of large ice sheets and their effects on Earth's isostasy. So far, the only sea level record that encompasses the whole deglaciation is based on offshore drilling of Barbados coral reefs. The Barbados coral reefs overlie an active subduction zone, implying that the apparent sea level record may be biased by tectonic movements. Furthermore, Barbados is located in a region close to the former ice sheets, implying that the sea level record might have been affected by hydro-isostatic mechanisms.

Integrated Ocean Drilling Program (IODP) Proposal 519 was designed to establish the course and effects of the last deglaciation in reef settings that developed in tectonically inactive areas located far away from glaciated regions. Two complementing expeditions were envisaged, one offshore Tahiti (French Polynesia) and the other on the Great Barrier Reef (offshore northeast Australia). The first of these, IODP Expedition 310 (Tahiti Sea Level), was successfully completed in 2005 and 2006 and recovered a near-complete record of sea level change during the last deglaciation.

IODP Expedition 325 proposes to core at several offshore sites along transects on the Great Barrier Reef using a dynamically positioned drilling vessel. The first objective will be to reconstruct the deglaciation curve for the period 20,000 to 10,000 calendar years before present (cal. y BP) in order to establish the minimum sea level during the Last Glacial Maximum and to assess the validity, timing, and amplitude of meltwater pulses (so-called 19 ka MWP, MWP-1A, and MWP-1B events; ca. 19,000, 13,800, and 11,300 cal. y BP), which are thought to have disturbed the general thermohaline oceanic circulation and, hence, global climate. Secondly, we aim to establish the sea-surface temperature variation accompanying the transgression at each transect. These data will allow us to examine the impact of sea level changes on reef growth, geometry, and biological makeup, especially during reef drowning events, and will help improve the modeling of reef development. The third major objective will be to identify and establish patterns of short-term paleoclimatic changes that are thought to have punctuated the transitional period between present-day climatic conditions following the Last Glacial Maximum. It is proposed to quantify the variations of sea-surface temperatures based on high-resolution isotopic and trace element analyses on massive coral colonies. When possible, we will try to identify specific climatic phenomena such as El Nino-Southern Oscillation in the time frame prior to 10,000 cal. y BP.

Introduction

The timing and course of the last deglaciation is considered an essential component for understanding the dynamics of large ice sheets (Lindstrom and MacAyeal, 1993) and their effects on Earth's isostasy (Lambeck, 1993; Peltier, 1994). Moreover, the disappearance of glacial ice sheets was responsible for dramatic changes in the freshwater fluxes to the oceans that disturbed the general thermohaline circulation and, hence, global climate (e.g., Stocker and Wright, 1991). Coral reefs are excellent sea level indicators, and their accurate dating by mass spectrometry is of prime importance for determining the timing of deglaciation events and, thus, for the understanding of the mechanisms driving the glacial–interglacial cycles. Furthermore, scleractinian coral colonies can monitor sea-surface temperatures (SSTs) as well as other oceanographic parameters (e.g., salinity and sediment run-off) and fossil corals can be used as recorders of past variations in these parameters.

Sea level changes as global climate indicator

Prior to Integrated Ocean Drilling Program (IODP) Expedition 310 (Tahiti Sea Level), only three deglaciation curves based on coral reef records had been accurately dated for times reaching the Pleistocene/Holocene boundary: in Barbados between 19,000 and 8,000 calendar years before present (cal. y BP) (Fairbanks, 1989; Bard et al., 1990a, 1990b), in New Guinea between 13,000 and 6,000 cal. y BP (Chappell and Polach, 1991; Edwards et al., 1993), and in Tahiti between 13,750 cal. y BP and 2,380 ^{14}C y BP (Bard et al., 1996) (Fig. **F1**). Until recently, the Barbados curve was the only one to encompass the whole deglaciation because it is based on offshore drilling. However, this site, like New Guinea, is located in an active subduction zone where tectonic movements can be large and discontinuous, so that the apparent sea level records may be biased by variations in the rates of tectonic uplift. Hence, there is a clear need to study past sea level changes in tectonically stable regions or in areas where vertical movements are slow and/or regular. The expeditions linked to IODP Proposal 519 (Tahiti Sea Level and Great Barrier Reef Environmental Changes [GBREC]) aim to provide new deglaciation curves from tectonically stable regions. Expedition 310 was successfully completed in 2005 and 2006 (Camoin, Iryu, McInroy, et al., 2007).

The Barbados record suggests that the last deglaciation was characterized by three brief periods of accelerated melting superimposed on a smooth and continuous rise of sea level with no reversals (Fig. **F1**). These so-called 19 ka MWP, MWP-1A, and MWP-1B events (ca. 19,000, 13,800, and 11,300 cal. y BP) are thought to correspond to massive inputs of continental ice (~50–40 mm/y, roughly equivalent to annual discharge rates of 16,000 km^3 for MWP-1A). The MWP-1A corresponds to a short and intense cooling between 14,100 and 13,900 cal. y BP in the Greenland records (Johnsen et al., 1992; Grootes et al., 1993) and therefore postdates the initiation of the Bölling-Alleröd warm period at ~14,900–14,700 cal. y BP (Broecker, 1992). The sea level jump evidenced in New Guinea at 11,000 cal. y BP (Edwards et al., 1993) is delayed by a few centuries when compared to that observed at Barbados. Two of these three meltwater pulses are thought to have induced reef-drowning events (Blanchon and Shaw, 1995). Two "give-up" reef levels have been reported at 90–100 and 55–65 m water depth on the Mayotte foreslopes (Comoro Islands) and have been related to the Bölling and the post–Younger Dryas meltwater pulses (Dullo et al., 1998); similar features are recorded in the southern Great Barrier Reef (GBR) (Troedson and Davies, 2001) and in the Caribbean (Macintyre et al., 1991; Grammer and Ginsburg, 1992). A third *Acropora* reef-drowning event at ca. 7,600 cal. y BP has been assumed by Blanchon and Shaw (1995).

However, there are still some doubts concerning the general pattern of sea level rise during the last deglaciation events, including the amplitude of the maximum lowstand during the Last Glacial Maximum (LGM) and the occurrence of increased glacial meltwater with resultant accelerated sea level rise (Broecker, 1990). Furthermore, saw-tooth sea level fluctuations between 19,000 and 15,280 cal. y BP (Locker et al., 1996; Yokoyama et al., 2000a, 2000b, 2001) and a sea level fall coeval with climatic changes around 11,000 cal. y BP are still controversial topics (Lambeck et al., 2003).

Worldwide sea level compilations indicate that local sea level histories varied considerably around the world in relation to both the postglacial redistribution of water masses and to a combination of local processes (Lambeck, 1993; Peltier, 1994; Lambeck et al., 2003), although significant deviations between model predictions and field data have been noted in several regions (Camoin et al., 1997). The post-LGM sea level changes at sites located far away from glaciated regions ("far field") provide basic information regarding the melting history of continental ice sheets and the rheological structure of the Earth. The effect of hydro-isostasy will depend on the size of the islands: at very small islands, the addition of meltwater will produce a small differential response between the island and the seafloor, whereas the meltwater load will produce significant differential vertical movement between larger islands or continental margins and the seafloor (Lambeck, 1993). There is, therefore, a need to establish the validity of such effects at two ideal sites located at a considerable distance from the major former ice sheets: on a small oceanic island and on a continental margin. In both cases, it is essential for the sites chosen that the tectonic signal is small or regular within the short time period proposed for investigation, so that rigorous tests of proposed northern and southern hemisphere deglaciation curves from Barbados and New Guinea can be made. Two such places are proposed: Tahiti (completed in 2005 and 2006) and the GBR. Expedition 325 will conduct investigations at GBR sites only.

Climatic and oceanographic changes during last deglaciation events

During latest Pleistocene and early Holocene times, climatic variability was primarily related to the effects of seasonality and solar radiation. The results of the Climate: Long range Investigation, Mapping, and Prediction (CLIMAP) Program suggested that the LGM tropical SSTs were similar to the modern ones. However, this interpretation is not consistent with snowline reconstructions and paleobotanic data (Rind and Peteet, 1985; Anderson and Web, 1994).

The available Sr/Ca and U/Ca data from coral reef areas report SSTs 5°C cooler than today during the LGM and 2°C cooler around 10,000–9,000 cal. y BP at Barbados (Guilderson et al., 1994), whereas studies in the west Pacific indicate that the full amplitude of the glacial-Holocene temperature change may have ranged between 3° and 6°C (McCulloch et al., 1996; Beck et al., 1997; Gagan et al., 1998) (Fig. **F1**). Troedson and Davies (2001) define SSTs immediately south of the GBR as 4.5°C cooler during the LGM and 1°C cooler at 10,000 cal. y B.P. This casts doubt upon the phase shift of 3000 y for climate changes between the two hemispheres that was assumed by Beck et al. (1997), in contrast to the apparent synchronism of the last deglaciation, inferred from various sources (i.e., coral records, ice cores, snowline reconstructions, vegetation records, and alkenone paleothermometry) (Bard et al., 1997).

Recent studies have documented Holocene climatic variations. 1°C warmer SSTs, monsoonal rainfall, and possibly weaker El Nino-Southern Oscillation (ENSO) around 5,800 y B.P. in Eastern Australia have been deduced from isotopic and Sr/Ca high-resolution measurements on corals from the central GBR (Gagan et al., 1998). An ENSO-like cyclic climatic variation with a return period of 3–5 y has been evidenced in a 4150 y old coral from the Seychelles, although the intensity of the annual decrease in SST caused by monsoonal cooling was lower than today (Zinke et al., 2005).

Additional information is required for a better knowledge of climatic conditions in tropical regions during the last deglaciation. In these areas, the most debated points are twofold: 1) the quantification of SSTs and the identification of related climatic variations during the last deglaciation events and 2) the timing of the relevant postglacial warming in the two hemispheres.

Scientific objectives

The objectives of IODP Proposal 519 and Expedition 325 are well aligned with the high-priority objectives of the theme "Environmental Change, Processes and Effects" from the IODP Long-Range Plan. A fundamental research initiative outlined for the IODP Long-Range Plan concerns the record and causes of rapid climate changes that are the basic objectives of our proposal for the late Pleistocene and the Holocene. Such records of natural climate change provide a framework for evaluating the possible effects of anthropogenic change on the environment.

The scientific objectives of Expedition 325 are

1. *To establish the course of postglacial sea level rise at the GBR (i.e., to define the exact shape of the deglaciation curve for the period 20,000 to 10,000 cal. y BP). The expected results are the following:*
   - To assess the validity, timing, and amplitude of MWP events (e.g., 19,000 cal. y BP event, MWP-1A, and MWP-1B);
   - To assess the maximum sea level drop during the LGM and establish the timing of its termination;
   - To prove or disprove saw-tooth pattern of sea level rise during the last deglaciation (Locker et al., 1996); and
   - To test predictions based on different ice and rheological models.

The reconstruction of sea level curves will rely on the absolute dating of in situ corals and other reef building biota provided by radiometric methods ($^{230}Th/^{234}U$ by thermal ionization mass spectrometry [TIMS]; ^{14}C by accelerator mass spectrometry [AMS]) and paleobathymetric information deduced from biological communities (corals, algae, benthic foraminifers, and molluscs) that live in a sufficiently narrow or specific depth range to be useful as absolute sea level indicators.

2. *To define SST variations for the region over the period 20,000 to 10,000 cal. y BP in order to get a better knowledge of*
   - The regional variation of SSTs in the southwest Pacific;

- The climatic variability and the identification of specific phenomena such as ENSO; and
- The global variation and relative timing of postglacial climate change in the Southern and Northern Hemispheres.

Methods include stable isotope ($\delta^{18}O$) and trace element (Sr/Ca ratios by TIMS) analyses on high-resolution (i.e., at the monthly scale) sampling of massive coral colonies. Coupled analyses of $\delta^{18}O$ and Sr/Ca on the same sample may yield estimates of both temperature and salinity (McCulloch et al., 1996). $\delta^{13}C$ measurements, systematically coupled with those of $\delta^{18}O$ in coral skeletons, will provide information on other parameters (e.g., solar variations or metabolism processes). Geochemical methods will be coupled with measurements and analyses of the band widths and micro-structural variations in the coral skeletons.

3. *To analyze the impact of sea level changes on reef growth and geometry, especially*
    - The impact of glacial meltwater phases (identification of reef drowning events);
    - The morphological and sedimentological evolution of the foreslopes (highstand versus lowstand processes);
    - The modeling of reef building; and
    - Environmental changes during reef development.

A numerical model simulating reef building will be used in order to study the effect of abrupt sea level rise events on reef geometry and to assess qualitatively the effect of sea level fluctuations on reef shape and composition as well as age–depth relationships.

The present proposal may provide the opportunity to better constrain the deglacial history (Peltier, 1994; Fleming et al., 1998; Okuno and Nakada, 1999) by documenting the LGM lowstand in well-studied cores in the far-field and by comparing the MWP-1A in the Pacific and the Atlantic. Furthermore, the study of very early deglacial coral material should allow the first Sr/Ca SSTs for the LGM in the Pacific, which could then supplement the Barbados sample data (Guilderson et al., 1994), the study of Papua New Guinea marine isotope Stage 6 corals (McCulloch et al., 1999) and the results of Expedition 310 (Camoin, Iryu, McInroy, et al., 2007).

Proposed drill sites

Site location

The GBR is the largest epicontinental reef system currently existing on this planet, extending 2000 km in a northwest–southeast direction along the northeast coast of Queensland (Davies et al., 1989) (Fig. F2). The origin of this morphologically and biologically important sedimentary system is poorly constrained; recently, an age of <500,000 y has been assigned to the initiation of the GBR system (International Consortium, 2001).

The northern, central, and southern GBR define ideal sites for the evaluation of sea level changes in the period 20,000 to 8,000 cal. y BP. The reefs on the shelf edge east of Cooktown form the semicontinuous outer barrier of the northern GBR. In this area, as well as in the far northern GBR, the reef is narrow with ribbon reefs on its eastern edge, extensive coastal fringing reefs, and patch reefs; in the south, it broadens with patch reefs separated by open water or narrow channels. In the outer shelf east-northeast of Townsville, modern reefs form a line of pinnacles in front of the main reef edge and lateral growth on the windward margin. South of 15°30′S, the reefs are generally ≥30 km offshore and reach 100 km at 22°30′S. Farther south the shelf widens considerably, reaching widths >200 km. East of Mackay the modern reefs form a complex, double series of flood-tide deltaic reefs (i.e., Pompey Complex) (Hopley, 2006). The coastal lagoon between the main body of the GBR and the mainland has a maximum depth of 145 m but rarely exceeds 60 m (Wolanski, 1982).

Previous scientific investigations on the Great Barrier Reef

Previous sedimentological and geophysical studies have identified a succession of subsea morphologic structures interpreted as drowned reefs at depths of 100, 90, 60–50, and 35–40 m (Carter and Johnson, 1986; Harris and Davies, 1989; Hopley, 2006; Beaman et al., 2007), especially in the four key areas:

1. Cooktown shelf and slope (Ribbon Reef);
2. Cairns shelf and slope (Grafton Passage, Flora Passage, and Noggin Pass);
3. Townsville shelf and slope (Bowl and Viper Reef); and
4. Mackay shelf and slope (Hydrographer's Passage).

A series of drowned linear reefs and lagoons occupy specific depths over at least a 30 km stretch on the outer continental shelf in the vicinity of Hydrographer's Passage in the southern GBR region (Fig. F2). Based on the RV *Southern Surveyor* cruise in September–October 2007 (Webster et al., 2008a, 2008b), the proponents have identified five primary drill sites from three of these key regions on the Cooktown, the Cairns, and the Mackay shelf edge (Fig. F2).

Studies on the GBR (McKenzie et al., 1993; Davies and Peerdeman, 1998) concentrating on the shelf edge southeast of Townsville and east of Cooktown have defined the morphologic shape of the outer reef–upper continental slope and the geological origin of the GBR itself. Based on high-resolution seismic profiles in the fore-reef section in front of the GBR, Feary et al. (in McKenzie et al., 1993) recognized three seismic megasequences (0–490, 490–555, and below 555 ms, respectively) that define a clearly aggradational upper sequence, a transitional middle sequence, and a progradational lower sequence. Ocean Drilling Program (ODP) drilling in 1991 (Leg 133) defined the origin of the GBR as very young (i.e., the GBR was initiated during marine isotope Stages 9–11) (McKenzie et al., 1993; Davies and Peerdeman, 1998).

A new phase of drilling in 1995 in Boulder Reef (15°23.944′S, 145°26.182′E) and Ribbon Reef 5 (15°22.40′S, 145°47.149′E) areas using a reef-mounted jack-up platform further enhanced this story, proving that the GBR is some 100 m thick, resting on a subreef subtropical red algal facies which in turn overlies a deepwater temperate grainstone facies (Davies and Peerdeman, 1998; International Consortium, 2001). Detailed stratigraphic and facies analysis of the 90 and 210 m long drill cores also shows the upper part of the platform to be composed of repeated cycles of transgressional coolwater coralline-dominated carbonates topped by shallow-water highstand coral reefs (Webster and Davies, 2003; Braga and Aguirre, 2004). The Holocene reef, however, does not show this couplet, as it is coral dominated from its inception at 8,000 cal. y BP. Strontium isotope and magnetostratigraphic data from the base of the Pleistocene coral reef sequence has confirmed that the origin of the GBR is very young, <500,000 y (International Consortium, 2001; Webster and Davies, 2003; Braithwaite et al., 2004).

Available site survey data at the Great Barrier Reef

The proposed drill sites on the GBR are distributed in three distinct regions (Fig. F2): offshore Cooktown (Ribbon Reef 5 and 3), offshore Cairns (Noggin Pass), and McKay shelf (Hydrographer's Passage).

From previous site survey data (described in detail in the June 2007 *Preliminary Report* to the Environmental Protection and Safety Panel (EPSP) and synthesized recently by Beaman et al., 2007), it was clear that a succession of barrier reefs occupy the outer shelf at water depths between 40 and 100 m with terrace features at ~80–110 m depth along much of the GBR. None of these structures has been adequately investigated, yet they have the potential to provide unique and critical information about the nature of sea level and climatic change offshore eastern Australia and important information about their role as habitats and substrates for present day biological communities. With the exception of the Ribbon Reef 5 region, only limited systematic high-resolution swath bathymetry mapping, imaging, or sampling has ever been attempted.

Recently, the proponents led a site survey cruise to gather the most comprehensive data set ever collected from the GBR shelf edge (Webster et al., 2008b). During the cruise on the *Southern Surveyor,* the remaining site survey information needed for IODP drilling operations in the GBR was acquired. Four study sites (Ribbon Reef, Noggin Pass, Viper Reef, and Hydrographer's Passage) were mapped along the Queensland margin where the approximate location of submerged reefs is known (Fig. **F2**). The data types acquired were

- EM300 swath bathymetry and backscatter;
- Subbottom sparker and Topas PS18 seismic reflection profiles;
- High-resolution underwater stereoscopic images and high-resolution multibeam bathymetry, acquired onboard a state-of-the-art Autonomous Underwater Vehicle (AUV);
- Continuous measurements establishing present day oceanographic conditions on the shelf edge, using the AUV's onboard Seabird Conductivity, Temperature, and Depth profiler (CTD); and
- Dredged rock samples from the tops of the shelf edge reefs, acquired using a standard rock dredge and a Smith-McIntyre sediment grab.

These data were used to define specific drill targets for IODP GBR drilling operations (see **"Coring strategy"** and **"Site summaries"** for proposed transect locations and available site survey information).

Summary of 2007 GBR site survey data for revised sites

Offshore Cooktown: Ribbon Reef 5 and 3 (RIB-01C and RIB-02A)

EM300 swath mapping of the Ribbon Reefs survey area covered 1609.87 km^2. The Ribbon Reef 5 area was also surveyed by Webster and colleagues in 2005 using a Reson 8101 (240 kHz) swath mapping system and Datasonics CAP-6600 Chirp 3.5 kHz subbottom profiler, and these data (Beaman et al., 2007) have previously been submitted to the IODP Site Survey Database (SSDB). Based on a detailed examination of all available site survey data (multibeam, backscatter, seismic profiles, AUV imagery, and bottom samples), we propose to drill two transects of holes across the most well developed fossil reef features, one off Ribbon Reef 5 (RIB-01C) and another off Ribbon Reef 3 (RIB-02A) (see Fig. **F2** for general location and Figs. **F3** and **F5** for detailed maps).

Site survey data seaward of modern Ribbon Reef 5 illustrate the succession of morphological features that define location RIB-01C (Figs. **F3, F4**):

1. A modern reef front talus zone, which extends from the base of the spurs and grooves at between 15 and 20 m to 47 m.
2. A gently sloping terrace ~150 m wide between 50 and 55 m that is also characterized by prominent subbottom reflectors.
3. A well-developed submerged reef observed at 50 m lying parallel to the shelf break. This defines the 50 m reef feature.
4. A gently sloping terrace ~140 m wide at a depth of 65 to 75 m.
5. The main shelf-break at 75 m, characterized by a subtle raised rim 1–2 m high that defines the 70 m reef feature.
6. The moderately sloping upper slope that descends from the main shelf-break at 75 m. Below 350 m the upper slope is deeply incised by well-developed canyons that extend down into the Queensland Trough in water depths >2 km.

Site survey data seaward of the modern Ribbon Reef 3 illustrate the succession of morphological features that define location RIB-02A (Figs. **F5, F6**):

1. A modern reef front talus zone, which extends to 44 m.
2. A well-developed reef detected on the shelf lying parallel to the shelf-break at 47 m that defines the 50 m reef feature.
3. A gently sloping terrace ~330 m wide in 55 to 80 m water depth, with prominent subbottom reflectors visible.

4. A submerged reef observed at 80 m that is characterized by a subtle raised rim 1–2 m high and defines the 70 m reef feature.
5. The main shelf-break at 105 m that is characterized by a 3–5 m raised rim that forms the 100 m reef feature. Below 500 m the upper slope is deeply incised by canyons that extend down into the Queensland Trough.

Offshore Cairns: Noggin Pass (NOG-01B)

EM300 swath mapping of the Noggin Pass survey area covered 1243.27 km^2. The available site survey data seaward of the modern Noggin Reef illustrate the succession of morphological features that define location NOG-01B (Figs. **F7, F8**):

1. A double fronted barrier reef 250 and 90 m wide and separated by a lagoon 80 m wide; the barrier reefs occur at a depth of 44 to 42 m.
2. A lagoon, up to 250 m wide, at a depth of 57 to 54 m with reef pinnacles some 50 m wide and rising to a depth of 56 m. The lagoon is characterized by prominent subbottom reflectors and is fronted by a discontinuous barrier, which tops at 55 m, that represents the 50 m reef feature.
3. A gently sloping terrace ~450 m wide in 60 to 80 m water depth. A break in slope at the edge of this terrace marks the 80 m reef feature.
4. A gently sloping terrace ~140 m wide in 91 to 99 m water depth. A distinct break in slope at the edge of this terrace marks the 100 m reef feature.
5. A narrow 50 m terrace at 108 m and the main shelf-break that forms the 110 m reef feature.
6. A gentle upper slope characterized by >100 m of fore-reef slope sediments. Below ~250 m water depth the upper slope is deeply incised by a well-developed canyon system that extends to 1400 m in the Queensland Trough.

Mackay shelf: Hydrographer's Passage (HYD-01C and HYD-02A)

EM300 swath mapping of the Hydrographer's Pass survey area covered 810.68 km^2. Based on a detailed examination of all available site survey data, we propose to drill two transects of holes across the most well developed fossil reef features, one in the northwest (HYD-01C) and the other in the southeast (HYD-02A) (see Fig. **F2** for general location and Figs. **F9** and **F11** for detailed maps).

Site survey data from the northwest of Hydrographer's Pass illustrate the succession of morphological features that define location HYD-01C (Figs. **F9, F10**):

1. A double fronted barrier reef 200 and 100 m wide and separated by a lagoon 2 km wide and up 70 m deep; the barrier reefs occur at a depth of 51 to 55 m. In some regions the lagoon is characterized by prominent subbottom reflectors, as well as 50 m wide patch reefs rising to 55 m.
2. A steep sloping 500 m wide terrace with a sharp break in slope marking the 80 m reef feature.
3. A complex 1 km wide lagoon and reef terrace system. The lagoon, at a depth of 85–87 m, is up to 600 m wide with numerous prominent subbottom reflectors. Seaward, the lagoon grades into a 400 m relatively flat terrace and a sharp break in slope that marks the 90 m reef feature.
4. A 700 m wide lagoon and reef pinnacle system. The lagoon is 300 m wide at a depth of 95 m and is characterized by prominent subbottom reflectors. The lagoon grades seaward into a dense system of patch reefs or pinnacles ~30–40 m across that range in depth between 95 and 97 m.
5. A major break in slope that defines the 100 m reef feature and has a series of smaller seaward pinnacles and terraces interpreted as reefs at depths of 110 and 120 m.
6. A gentle upper slope characterized by >160 m of fore-reef slope sediments.

Site survey data from the southeast of Hydrographer's Pass illustrate the succession of morphological features that define location HYD-02A (Figs. **F11, F12**):

1. A submerged reef shoal 600 m wide at 31 m with well-developed landward and seaward terraces at 40 m.
2. A double fronted barrier reef 250 and 150 m wide and separated by a lagoon 2.5 km wide and up to 55 m deep; the barrier reefs occur at a depth of 54 to 56 m. The lagoon is characterized by numerous prominent subbottom reflectors and partially buried patch reefs. The patch reefs become more dense seaward between 60 and 70 m.
3. A steep slope 400 m seaward of the 50 m reef is defined by a series of smaller pinnacles and terraces interpreted as distinct reefs at depths of 65, 70, and 80 m.
4. A complex 2.3 km wide lagoon along with a reef pinnacle and terrace system between 90 and 100 m. The lagoon is 2 km wide and up to 102 m deep with prominent subbottom reflectors that are only interrupted by significant breaks in slope that define the 90 and 100 m reef features.

5. The major break in slope, which occurs at 103 m and defines the 100 m reef feature, with a series of smaller pinnacles and terraces interpreted as reef features at a depth of 110 m.
6. A prominent 70 m wide reef terrace observed at 126–128 m. The feature is interpreted to be the LGM reef.
7. A gentle upper slope characterized by >160 m of fore-reef slope sediments.

Coring strategy

Barbados offshore drilling (Fairbanks, 1989) has demonstrated that the reef sequence corresponding to the last deglaciation developed on slopes and forms discontinuous successive terraces of various lateral extent and stratigraphic thickness. Therefore, to recover the whole post glacial reef sequence successive reef terraces that occur seaward of the living barrier reef must be drilled.

Our detailed analyses of the combined GBR site survey data sets have demonstrated the occurrence of successive reef features at various depths between 130 and 25 m which correspond to drilling targets. Thus, at each site, it is proposed to realize a transect of several offshore drill holes in order to recover the entire post glacial reef sequence (see below). Initial results obtained during Expedition 310 confirm that this drilling strategy is sound (Camoin, Iryu, McInroy, et al., 2007).

Totals for all sites are as follows:

Total sediment penetration = 1480 m,

Total substratum penetration = 360 m, and

Total penetration = 1840 m.

In this scenario, "sediment" refers to the reef structure and "substratum" the substrate on which the reefs are sitting (e.g., older reef, prereef sediments). Totals for individual sites are found in Tables **T1, T2, T3, T4,** and **T5.**

Operational strategy

Drilling platform

The water depths for the proposed drilling sites on the GBR range from ~30 to 200 m and so require the use of a mission specific platform (MSP) capable of working in shallow waters. The drilling platform, chosen by the contractor and inspected by the European Consortium for Ocean Research Drilling (ECORD) Science Operator (ESO), is the *Bluestone Topaz*, an International Maritime Organization (IMO) Class 1 dynamically positioned vessel.

The *Bluestone Topaz* is a geotechnical drilling vessel capable of working in water depths of up to 1800 m. The vessel is equipped with a large moonpool, a Bluestone TT150 derrick, and Foremost Hydraulic top drive.

The compact top drive onboard the *Bluestone Topaz* is a 150 ton Canadian-built system (Foremost Industries) that is both rugged and powerful. The Bluestone drilling department modified the design of this top drive system to make it ideal for geotechnical or scientific drilling, sampling, and coring activities. Key specifications of the top drive are as follows:

Maximum speed = 200 rpm,

Maximum torque = 32,000 ft lb,

Maximum hook load = 150 tons (300,000 lb), and

Maximum input power = 450 hp (335 kW).

The *Bluestone Topaz* will have sufficient capacity for food, water, and accommodation for 35 days of continuous operational capability. It is anticipated that there will be one port call for resupply and possible scientific personnel changes.

Coring methodology

General

For efficient drilling/coring it is essential to apply a steady weight onto the drill bit. Vessel heave can reduce or apply excessive weight to the drill bit. The drilling system onboard the *Bluestone Topaz* is versatile and heave compensated to allow for vessel movement. The drill string is suspended below the top drive and the drill string compensator. The fast line runs over a relative motion compensating heave (3.5 m stroke cylinders) and is connected to the draw works winch. The deadline similarly runs to the anchor point at the drill floor. Compensator loading is ~80 metric tons. Sea water will be used as drilling medium at all times to meet environmental requirements.

The components of the coring system are outlined below:

- Drill string. The drill string consists of 151 joints of drill pipes, 5 drill collars, 2 bottom-hole assemblies (BHAs), and a selection of drill bits. This will make up ~1400 m in total length, thus providing sufficient backup for most operations. The drill pipes are America Petroleum Institute (API) 5½ inch with 5½ inch full hole (FH) tool joints with 4 inch bore inner diameter (ID). The length of each joint is 31 ft. Additional drill pipes, if required, can be placed at the stern of the main deck.
- Bottom-hole assemblies:
  - API core barrel. Bluestone has recently collaborated with QD Tech Inc. to produce a versatile BHA for the API drill string that enables sampling, in situ testing, and rock coring to be conducted without having to trip the drill string. Impregnated and stag bits are currently available onboard. Wireline coring can be effected through this BHA.
  - Mining-type core barrel. An HQ-size (73 mm outer diameter [OD] and 66 mm ID) wireline core barrel deployed on a mining drill string which fits inside the API drill string. This BHA can also be deployed through the API system, using the API drill string as a conductor or casing.

Coring with API BHA

In normal circumstances, when borehole size and coring speed are less significant, coring of hard formations can be performed with the Bluestone BHA and API drill string as described above. Initially, a camera will be deployed through the API pipe to assess the sea bed and reef structures prior to drilling. The API pipe will then spud in, acting like a stinger and reducing the sea bed footprint, minimizing any potential impacts on the sea bed environment. An internal core barrel will run through the API string and collect standard size IODP cores in standard IODP plastic liners.

The wireline core barrel is deployed and retrieved with an overshot. Both the BHA bit and the core barrel bit will cut through the hard formation. Heave compensation is achieved automatically with the top drive system. The top drive onboard the *Bluestone Topaz* has excellent control on bit weight to ensure coring stability and quality.

Coring with HQ string

Because of the improved core recovery and time efficiency of using an HQ-size barrel, this method will be employed where core lithology and stability allow. To apply this method, the API drill string is first keyed in or locked into the hard formation. The API drill string is then hung from an elevator at the main deck. The top drive can then be detached from the API drill string, leaving the API string to act as casing. Subsequently, the top drive can commence the HQ string run inside the API drill string. If and where it is allowed, a seabed frame with line tensioner can be deployed to ensure stability of the API drill string. This set up can normally be applied at shallow water depths, probably <70 m.

Coring with HQ string and bumper sub

Alternatively, the method above can be improved with the introduction of a bumper sub in the API drill string make-up. This tool will help compensate heave on the API drill string by providing reliable telescopic movement. The location of the bumper sub has to be carefully planned, taking into account local tidal variation. Currently, a bumper sub with a 1.5 m stroke is available onboard the *Bluestone Topaz*. Other bumper subs may be considered nearer to the start of the expedition. It is anticipated that this set up will be most suitable for water depths >70 m.

Schematics of the drilling/coring system are presented in Figure **F13.** If required, the bumper sub can be locked (i.e., when placed at the top of the drill string).

Core run lengths

Typically with mining tools, the maximum core run to obtain optimum recovery is 3 m. Shorter core runs are made if the formation is blocking the bit or it is too friable to withstand a 3 m run. The excellent core recovery obtained during the IODP Tahiti land-based and offshore coring used this strategy and the same core diameter to be used during Expedition 325.

Seawater will be used for drilling in order to meet environmental requirements. Should the core liners start to tear or jam during drilling, a split metal liner will be used.

Core on deck

Once the drilling operation commences and cores begin to come on deck, the coring operations team will be responsible for delivering that core to the curation container for examination and curation. The operation will proceed using a changeover of inner core barrels to ensure continuity of the coring operation in as timely a fashion as possible. Deck operators will deploy an empty core barrel immediately after the full one has been retrieved and then address the core removal and readying of that core barrel for reuse. The cores will be collected in either plastic liners or metal “spoon” liners (before being transferred to plastic liners on the drill floor), with IODP curation procedures being followed.

Gas detection equipment will be carried as part of the total coring operation.

Downhole logging

In all expeditions the downhole logging program will be integrated with the scientific objectives to ensure maximum scientific output. This may include the use of specialist third party tools.

To facilitate downhole measurements and core petrophysics for MSPs, the European Petrophysics Consortium (EPC) has been developing protocols for use both offshore and as part of the Onshore Science Party (OSP).

Unlike the *Chikyu* and nonriser vessels where the pipe size will be constant and allow a standard set of logging tools to be deployed, MSPs have variable pipe sizes and drill in a variety of water depths, each of which provides constraints on the anatomy of logging operations. Pipe diameter is the controlling factor, and it is envisaged that a wide range of tools, from slim-line memory-mode to standard oilfield suites, may be utilized. Water depth is also an important constraint because some MSP expeditions will operate in very shallow territorial waters where the deployment of nuclear sources may be prohibited or be severely restricted.

Wireline logging

Coring arrangements allow wireline logging to be conducted with the following considerations:

- The OD of the wireline logging tool would have to be smaller than 80 mm to enable clear passage through the HQ string with the core barrel removed. This is required in case it is not possible to pull all of the HQ string, in which case logging can be run through the API bit, which allows a passage of 98 mm diameter.
- The wireline logging winch may have to be placed on the rooster box above the top drive where the rig is heave compensated. Free space may be limited on the rooster box, so a suitable winch size needs to be considered. Alternatively, rigging will have to be done via sheaves and pulleys to the deck.

Upon completion of a borehole, the HQ string will be pulled out and the power swivel reconnected to the API string. The wireline logging tool can run through the power swivel and API string.

This service will be contracted as part of the services for the expedition and will be managed by EPC. The logging equipment and team will be interfaced for a seamless operation, ready to undertake any requirements as the project progresses.

Camera and AUV images

The water depths involved in Expedition 325 range from 30 to 200 m. Of the 38 drill sites, 37 are deeper than 40 m, which corresponds to the limit where the abundance of the living cover (especially the coral cover) decreases sharply and becomes limited. Below this depth, coral coverage is patchy.

At each site, AUV data (if available) will be used to choose the initial site within the 125 m radius buffer zones. The final drill site location will be checked for coral/biota cover using a through-pipe video system. During the expedition, we will core on areas of bare rock or sand. Additionally, the same through-pipe video system will be utilized on completion of the borehole to take photographs to show the effects of coring in the immediate vicinity of the borehole. These before and after photographs will be stored with the drilling data. Experience using this video system during Expedition 310 has shown that it is highly effective at keeping drill sites away from living coral, with camera results revealing minimal or no observed after effects following coring.

Priorities and potential program of work

All aspects of the following work program are subject to change as our knowledge of hole conditions and the timing of operational activities improves.

The GBR transects will be attempted in the following order: HYD-01C (Hydrographer's Passage), HYD-02A (Hydrographer's Passage), NOG-01B (Noggin Pass), RIB-01C (Ribbon Reef 5), and finally RIB-02A (Ribbon Reef 3).

It is important to ensure that the drilling system is operating well, with good core recovery, and that the depth of the Pleistocene reef is established early for each transect. For this reason it is suggested that the sites at each transect are attempted as follows:

1. Target a lower priority site where the predicted target reef lies between 50 and 60 m depth (for example, Site 3 HYD-01C or Site 2 HYD-02A).
2. Progress to the highest priority sites that have the potential to best describe the critical meltwater pulse 1A and the LGM periods (the latter of which were not described during Expedition 310). These are anticipated to lie where the target reef is at 100–130 m depth (for example, Sites 7–9 and 11 HYD-01C and Sites 7–10 and 12 HYD-02A).
3. Progress back along each transect, working shoreward into increasingly shallower waters.
4. Finally, if the above goals have been reached, core a longer hole in both the shallower shelf, at 50–60 m water depth, and in the fore-reef slope sediments (for example, Site 10 HYD-01C and Site 11 HYD-02A).

It is recognized that this survey plan may incur additional time spent on each transect because of transit times between the shallower and deeper sites. This method of working may therefore be altered as our offshore operation evolves.

Open-hole logging will commence after coring, possibly in increments to reduce the risk of hole instability halting the logging runs. The exact pull-back increments will be established on-site once we have a better knowledge of the formations.

It is acknowledged that recording temperature measurements downhole is an IODP minimum measurement that cannot be omitted unless there is an operational reason for doing so. Drilling in Tahiti, and the proposed drilling strategy for the GBR, highlight a number of issues regarding this:

- The proposed hole penetration for 36 of the suggested 40 sites is only 40 meters below seafloor (mbsf). High and potentially laterally variable permeability within the coral structures may well cause a biased geothermal gradient to the seabed, indicating percolating seawater temperatures only.
- If the target depth lies within corals, penetration of the temperature instrument below the bottom of the drill bit may well be impossible without causing damage to the instrument.
- Attempting a temperature reading from the base of the casing while still inside the casing may only provide a biased temperature of the drilling fluids (in this case seawater) being supplied from the vessel.
- No temperature readings were undertaken during Expedition 310 for operational reasons.

It is therefore proposed that temperature measurements not be undertaken during Expedition 325.

Science operations

A Sampling and Measurements Plan for Expedition 325 (see the **"Appendix"**) was prepared to meet the scientific objectives of IODP Proposal 519 following the recommendations of the Science Advisory Structure (SAS).

Offshore science operations at the Great Barrier Reef

After due consideration, it has been decided that there will be no splitting of the cores at sea, as it will be more efficient to carry out most of the scientific analysis during the OSP at Bremen. Therefore, there would be only limited scientific analysis carried out onboard and only a limited number of scientists would be required to sail. It is currently planned that core will be cut (unless there is a continuous section of a massive coral colony) on board into 1.5 m lengths and curated (**www.marum.de/en/Offshore_core_curation_and_measurements.html**). The core catcher sample will be split and a visual description recorded. Samples for microbiology and geochemistry on pore water will be taken and suitably stored for analysis. Some ephemeral geochemical and microbiology measurements will be conducted offshore (see **"Inorganic geochemistry"** and **"Microbiology"** in the "Appendix"). All core will be run through the GEOTEK multisensor core logger (MSCL) offshore, which measures gamma density, *P*-wave velocity, electrical resistivity, and magnetic susceptibility. *P*-wave velocity measurements will only be attempted where cores are naturally saturated with water (possibly at the fore-reef slope). Refilling of nonsaturated core to enable *P*-wave velocity measurements will not take place because of the detrimental impact on fines and microbiology.

Staffing

Scientific staffing has been decided on the basis of task requirements and nominations from the ECORD Science Support Advisory Committee (ESSAC), the United States Science Advisory Committee (USSAC), the Japan Drilling Earth Science Consortium (JDESC), and the Ministry of Science and Technology (People's Republic of China) (MOST). ESO staffing is based on the need to carry out drilling and scientific operations efficiently and safely.

The following breakdown of ESO and science staffing includes 23 participants:

ESO:

- 1 Operations Superintendent
- 1 Staff Scientist
- 1 Trainee Staff Scientist
- 1 Petrophysics Staff Scientist
- 2 Curators
- 2 Drilling Coordinators
- 1 Database Manager
- 1 Electronics Engineer
- 1 ESO Petrophysicist
- 1 ESO Geochemist
- 2 Logging Contractors

Offshore science team:

- 2 Co-Chief Scientists
- 2 Carbonate Sedimentologists
- 2 Coral Specialists
- 1 Microbiologist
- 1 Geochemist (with microbiological experience)
- 1 Core Petrophysicist
- 1 GBR Marine Park Authority (GBRMPA) observer

Platform science activities

Science activities on the drillship are likely to be confined to those essential for early sampling and logging and for safety and curation (please see the **"Appendix"** for more details). Scientific activities will be (please also refer to the online tutorial at **www.marum.de/en/Offshore_core_curation_and_measurements.html**):

- Basic curation and labeling of core.
- Shoe sample (core catcher) for lithologic and macropaleontologic analysis, including taking a core catcher image.
- Core storage.

- All cores will be run on the MSCL (gamma density, *P*-wave velocity, electrical resistivity, and magnetic susceptibility; please see the **"Appendix"** for more detail). Pore water sampling for fluid chemistry/circulation studies.
- Microbiology samples will be collected and stored under appropriate conditions (both specific samples, if required by members of the Science Party, as well as routine IODP microbiology samples, if IODP Scientific Technology Panel [STP] Recommendation 0807-12, "Microbiology Routine Sampling for Frozen Preservation," is implemented by IODP Management International, Inc. [IODP-MI]).
- Associated data management of all activities (see below).

The coral reefs require rotary coring, and the hard rock cores will be collected in plastic liners or metal "spoon" liners (before being transferred to plastic liners on the drill floor). The cores will be split during the OSP in Bremen.

In order to carry out the science requirements on the drillship with a small crew, a staffing plan has been devised. The plan requires flexibility of approach from all participants, with priority to safety, core recovery, curation, and procedures for the measurement of ephemeral properties.

Report preparation will take place onboard as required by IODP-MI; the reports to be compiled include:

- Daily and weekly operations and science reports to IODP-MI, Science Party members, and relevant parties. Scientific reports are provided by the Co-Chief Scientists.
- Site summary reports to IODP-MI.
- Technical Operations Report (submission to IODP-MI due 60 days postcruise).
- Completion of the offshore sections of the Expedition Reports section of the *Proceedings* (primarily the "Methods" chapter).
- Operational Review Report (submission to IODP-MI due 2 months postcruise).
- Press releases in line with IODP-MI outreach policy.
- Information for posting on the ESO expedition website.

A detailed cruise report will be broken down into the following sections:

- Coring operations,
- Operations cost (which will be monitored daily),
- Preliminary scientific results, and
- Databasing.

Great Barrier Reef logging operations

Considering the anticipated shallow depth of many holes, short tool strings are highly recommended. Because of environmental concerns (shallow-water reef environment) the use of chemical sources is prohibited, thereby preventing the use of logging tools such as density and porosity that require these sources.

Five depth transects are planned, and the logging plan will be optimized through further discussions with the Co-Chief Scientists. It is envisaged that two holes per transect will be fully logged, with a reduced logging plan in some of the other holes (subject to hole conditions). The number of holes to be logged will remain flexible throughout the expedition.

Given the anticipated small diameter of the boreholes (HQ core bit OD is 96 mm), only slimline-type logging tools can be utilized. The following is a generic list of the logging measurements that were successfully acquired for Expedition 310 and are planned to be obtained for Expedition 325. These are minimum and additional tools, based on formation properties and not on operator-based trademark names:

- Optical images (for millimeter-scale geological description),
- Acoustic images (for centimeter-scale impedance and mesoscale porosity),
- Spectral gamma logging (for U, Th, K, and red algae),
- Acoustic velocity logging (for V_P and V_S at 10–20 kHz),
- Induction resistivity logging (for pore fluid salinity and porosity), and
- Hydrochemical borehole fluid logging (with p, T, pH, Eh, SP, and fluid electrical conductivity to identify fluid circulations).

Onshore science activities

The OSP normally takes place within 3–4 months of the end of offshore operations and will be held under the supervision of Dr. Ursula Röhl, the manager of the IODP Bremen Core Repository.

The following facilities will be available for the expedition scientists at the IODP Bremen Core Repository. (Please also refer to the online tutorial at **www.marum.de/en/Onshore_Science_Party_OSP.html** and see the **"Appendix"** for more detail).

- X-ray computed tomography (CT) scanning (Before the OSP; on special request and on selected core sections only),

- Core splitting,
- Core description,
- Core photography/imaging,
- Core sampling,
- Thin section and smear slide preparation,
- Micropaleontology,
- Inorganic geochemistry,
- X-ray diffraction analysis,
- Petrophysical measurements, and
- Color measurements.

Additional facilities can be made available through continuing close cooperation with additional laboratories at the Center for Marine Environmental Sciences (MARUM) and the Department of Geosciences at Bremen University, as well as the Max Planck Institute for Marine Microbiology (MPI), all of which are situated nearby on campus.

A staffing plan will be developed with the Co-Chief Scientists, the IODP Bremen Core Repository Manager, and the Staff Scientist prior to the OSP in order to ensure that all required analyses and subsampling, both for sample requests and IODP minimum measurements, can be carried out efficiently. The measurements plan will take into account IODP specifications for quality assurance/quality control (QA/QC) procedures, which are currently being developed.

Report preparation will take place during the OSP as required by IODP-MI; the reports to be compiled are:

- Twice weekly operations and science reports to IODP-MI and relevant parties. Scientific reports are produced by the Co-Chief Scientists.
- *Preliminary Report* (submission to IODP Publication Services 1 week after the OSP).
- Completion of the Expedition Reports portion of the *Proceedings* volume (submission to IODP Publication Services as soon as practically possible after the OSP).

Staffing

Scientific staffing has been decided on the basis of task requirements and nominations from ESSAC, USSAC, JDESC and MOST. ESO staffing is based on the need to carry out the scientific operations at the OSP efficiently.

The following breakdown of ESO and science staffing includes 39 participants and a laboratory team provided by the University of Bremen:

ESO:

- 1 Superintendent (Curation and Laboratory Manager)
- 1 Staff Scientist
- 1 Assistant Superintendent (Assistant Curation and Laboratory Manager)
- 1 Petrophysics Staff Scientist
- 1 ESO Petrophysicist
- 2 Curators
- 2 Database Operators
- 1 Trainee Staff Scientist
- 1 Yeoperson

Expedition Scientists:

- 2 Co-Chief Scientists (2 sailing)
- 5 Carbonate Sedimentologists (2 sailing)
- 2 Coral Specialists (1 sailing)
- 2 Microbiologist (1 sailing)
- 2 Core Petrophysicists (1 sailing)
- 1 Foraminifer Paleontologist
- 2 Coralline Algal Paleontologists (1 sailing)
- 10 Inorganic Geochemists (SST variation, paleoclimate, and dating) (1 sailing)
- 2 Paleomagnetists

Data management

A detailed specification and configuration of data management systems for Expedition 325 will be developed from the finalized science/operational data requirements and operational logistics.

The ExpeditionDIS will be configured to match the science/operational requirements of the expedition. The timing of transfer of metadata/data from the DIS to WDC-MARE/PANGAEA and the Lamont-Doherty Earth Observatory (LDEO) log database will depend on the data type and operational requirements (**www.marum.de/en/MSP_offshore_data_storage_and_computer_facilites.html**).

The outline plan is:

- A modified version of the IODP Drilling Information System (DIS)—the ExpeditionDIS—will be used to capture drilling and core-related data during the operation and postoperation "shore-party" phases.
- The ExpeditionDIS is a relational database and will be used to capture drilling, curation, and geoscience metadata and data during the offshore and onshore phases of the expedition.
- The ExpeditionDIS includes tools for data input, visualization, report generation, and data export.
- The database can be accessed directly by other interpretation or decision-making tools if required.
- A file server will be used for storage of data not captured in the database (for example, documents and image files), and the input/output of any data processing, interpretation, and visualization applications used during the expedition.
- The EPC will manage the capture of the downhole log, MSCL, and physical properties data. Logging metadata and MSCL data will be stored in the ExpeditionDIS. Downhole logging data will be stored separately by the EPC for processing and compositing.
- Between the end of the offshore phase and the start of the OSP, expedition scientists will have access to the data via a password-protected website.
- On completion of the OSP, expedition scientists will continue to have access to all data through a password-protected Web site throughout the moratorium period.
- During the moratorium period, all data will be transferred to World Data Center-Marine Environmental Sciences (WDC-MARE)/Publishing Network for Geoscientific and Environmental Data (PANGAEA) and the LDEO log database, the MSP long-term data repositories.
- The data management plan and the petrophysics plan (developed by the EPC) will be integrated.
- The longer term plan for data management will take into account IODP Information Services requirements once these are known.
- Cores will be transferred to the Kochi Core Center after the moratorium year.
- After the moratorium, all expedition data will be made accessible to the public.

Definition of Expedition Results data

Expedition Results data for Expedition 325 include:

- All data collected on the drilling vessel during the expedition (Table **T6**).
- All data derived from samples taken on the drilling vessel that are defined as minimum measurements by the STP.
- All data derived from preliminary shore-based analyses of core catcher samples.
- All data collected onshore during the OSP (Table **T6**).

Sample Allocation Committee and sample requests

The IODP Sample, Data, and Obligations policy is available on the IODP Web site (**www.iodp.org/program-policies/**) and will apply to Expedition 325. This documents the policy for distributing IODP samples and data and defines the obligations that sample and data recipients incur. A primary obligation is that all members of the scientific party must conduct expedition-related scientific research and publish their results by the determined deadline.

Scientists are required to submit their research plans using the Sample/Data Request online system available at **smcs.iodp.org** ~3 months prior to the expedition. Access to data and core samples for specific research purposes during the expedition and the subsequent 1 y moratorium must be approved by the Sample Allocation Committee (SAC). The moratorium for Expedition 325 will extend 12 months from the completion of the expedition, which in the case of MSP expeditions is defined as the end of the OSP.

All sample frequencies and sizes must be justified on a scientific basis and will depend on core recovery, the full spectrum of other requests, and the expedition objectives. Some redundancy of measurement may be unavoidable, but minimizing the duplication of measurements among the Scientific Party (which may include approved shore-based collaborators) will be a factor in evaluating sample requests.

Based on research requests (sample and data) submitted, the SAC will work with the Scientific Party to formulate a formal expedition-specific sampling and data-sharing plan for shipboard and onshore activities (both at OSP and at scientists' laboratories for individual postexpedition projects). This plan will be subject to modification depending upon the actual material/data recovered and collaborations that may evolve between scientists before and during the expedition. Modifications to the sampling plan (i.e., new plans, research objectives, new collaborations, etc.) during the expedition and postcruise moratorium require the approval of the SAC.

Sampling to acquire essential ephemeral data types, to describe and characterize the recovered section, and to achieve essential sample preservation will be conducted during the expedition. Although some sampling for individual scientist's postcruise research may be conducted during the offshore phase of the expedition, the majority of sampling will be deferred to the OSP. The SAC has agreed that the detailed review of sample requests will be deferred until after the offshore operations are completed, so that sample requests can be reviewed within the context of the known core recovery and lithology.

For Expedition 325, it is presumed that all drilled intervals will be unique, and therefore it is expected that all intervals will be designated as permanent archives. It should be stressed that the availability of archive halves for sampling depends on the presence of equivalent sedimentary sequences in adjacent holes that can be directly correlated and thereby identified as duplicate material. In the drilling of corals, similar to the situation in hard rock environments, the paucity of replicate material may severely limit the availability of nonpermanent archive-half material.

The Sample Allocation Committee (SAC) is composed of

Jody Webster: Co-Chief Scientist

Yusuke Yokoyama: Co-Chief Scientist

Ursula Röhl: ESO Curation Manager/IODP curator (or shipboard representative)

Carol Cotterill: ESO Staff Scientist

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Table T1. Location RIB-01C (Ribbon Reef 5).

Proposed site	Water depth (m)	Penetration (m)		Longitude	Latitude	Target
		Sediment	Substrate			
1	54.6	30	10	145°47.7649′E	15°22.6093′S	50 m terrace
2	46.5	30	10	145°47.7929′E	15°22.6519′S	50 m reef
3	70	30	10	145°47.8483′E	15°22.7075′S	70 m terrace
4	75	30	10	145°47.8744′E	15°22.7508′S	70 m reef
5	198.7	100	0	145°47.8825′E	15°22.8768′S	Fore-reef slope (upper slope)
Total penetration:		220	40			

Table T2. Location RIB-02A (Ribbon Reef 3).

Proposed site	Water depth (m)	Penetration (m)		Longitude	Latitude	Target
		Sediment	Substrate			
1	47.5	30	10	145°49.1785′E	15°28.267′S	50 m reef
2	61.6	30	10	145°49.2832′E	15°28.3262′S	70 m terrace
3	70.4	30	10	145°49.3637′E	15°28.3295′S	70 m reef
4	105.9	30	10	145°49.4254′E	15°28.332′S	100 m reef
Total penetration:		120	40			

Table T3. Location NOG-01B (Noggin Pass).

Proposed site	Water depth (m)	Penetration (m)		Longitude	Latitude	Target
		Sediment	Substrate			
1	44.6	30	10	146°33.7526′E	17°6.3461′S	40 m reef
2	43.3	30	10	146°33.8711′E	17°6.3104′S	40 m reef
3	54	30	10	146°34.0934′E	17°6.2346′S	50 m terrace
4	63.6	30	10	146°34.2739′E	17°6.1728′S	50 m reef
5	77.7	30	10	146°34.4216′E	17°6.1263′S	80 m reef
6	97.6	30	10	146°34.5746′E	17°6.0774′S	100 m reef
7	110.3	30	10	146°34.6249′E	17°6.0616′S	110 m reef
8	167.2	100	0	146°35.357′E	17°5.8356′S	Fore-reef slope
Total penetration:		310	70			

Table T4. Location HYD-01C (Hydrographer's Passage). (**See table note.**)

Proposed site	Water depth (m)	Penetration (m) Sediment	Substrate	Longitude	Latitude	Target
1	51.4	30	10	150°13.123′E	19°42.5293′S	50 m reef
2	54.1	30	10	150°13.5599′E	19°41.8799′S	50 m patch reef
3	57.3	30	10	150°13.8436′E	19°41.4936′S	50 m reef
4	76.8	30	10	150°13.9741′E	19°41.3116′S	80 m reef
5	85.3	30	10	150°14.2264′E	19°40.9583′S	85 m terrace
6	88.6	30	10	150°14.3622′E	19°40.759′S	90 m reef
7	96.1	30	10	150°14.5828′E	19°40.4512′S	100 m terrace
11*	104.2	30	10	150°14.658′E	19°40.345′S	100 m terrace
8	109	30	10	150°14.6942′E	19°40.2958′S	110 m reef
9	122.8	30	10	150°14.7346′E	19°40.2349′S	120 m terrace
10	145.1	100	0	150°15.1282′E	19°39.6829′S	Fore-reef slope
Total penetration:		400	100			

Note: * = extra hole added; pending approval by IODP.

Table T5. Location HYD-02A (Hydrographer's Passage). (See table note.)

Proposed site	Water depth (m)	Penetration (m)		Longitude	Latitude	Target
		Sediment	Substrate			
1	30.9	30	10	150°26.6047′E	19°51.06′S	40 m reef
2	51.3	30	10	150°26.8469′E	19°50.6955′S	50 m reef
3	69.7	30	10	150°27.5453′E	19°49.6643′S	60 m lagoon
4	53.7	30	10	150°27.8485′E	19°49.2161′S	60 m reef
5	62.9	30	10	150°27.9361′E	19°49.09′S	60 m reef
6	90.5	30	10	150°28.3187′E	19°48.5219′S	90 m terrace
7	94.5	30	10	150°28.6671′E	19°48.0469′S	100 m reef
12*	102.2	30	10	150°28.732′E	19°47.963′S	100 m reef
8	110.8	30	10	150°28.7996′E	19°47.8829′S	110 m reef
9	122.1	30	10	150°28.8521′E	19°47.8208′S	120 m reef
10	122.9	30	10	150°28.8848′E	19°47.7771′S	120 m reef
11	162.1	100	0	150°29.2987′E	19°47.1391′S	Fore-reef slope
Total penetration:		430	110			

Note: * = extra hole added; pending approval by IODP.

Table T6. Types of data collected offshore and onshore to be included in *Proceedings* volume. (**See table note.**)

Location of measurement	
Drilling vessel	Onshore Science Party, Bremen
Core catcher description (lithology, macropaleontology, core catcher photographs) MSCL (density, velocity, resistivity, magnetic susceptibility) Microbiology Physical properties Downhole logging Ephemeral inorganic geochemical analysis on interstitial water samples	Visual core description (including thin section and smear slide description) Core photographs Micropaleontology Inorganic geochemistry X-ray diffraction analysis Repeat whole core petrophysical measurements (as required) Thermal conductivity measurements Split core MSCL measurements Discrete sample index properties Color reflectance/digital line-scan image/X-ray CT scans (on request for selected intervals only)

Note: MSCL = multisensor core logger, CT = computed tomography.

Figure F1. A. Sea level history reconstructed for long drill cores from Tahiti (squares), Barbados (dots), and New Guinea (triangles) (from Bard et al., 1996). **B.** Reconstructed sea-surface temperatures for various time windows on corals from Vanuatu (Beck et al., 1997). y BP = years before present.

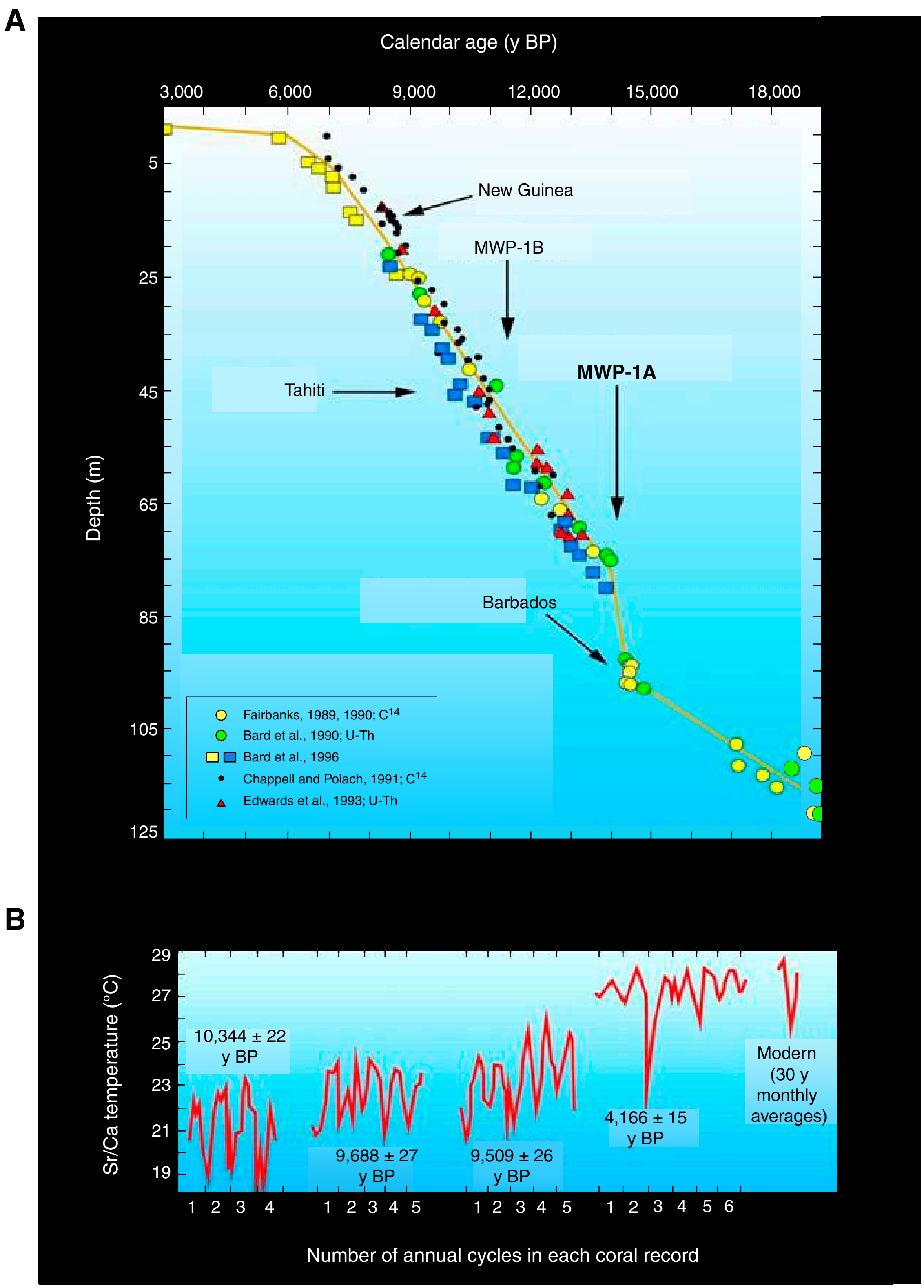


Figure F2. Regional map showing locations of the five proposed drill sites at the following regions: Ribbon Reef (RIB-01C and RIB-02A), Noggin Pass (NOG-01B) and Hydrographer's Passage (HYD-01C and HYD-2A).

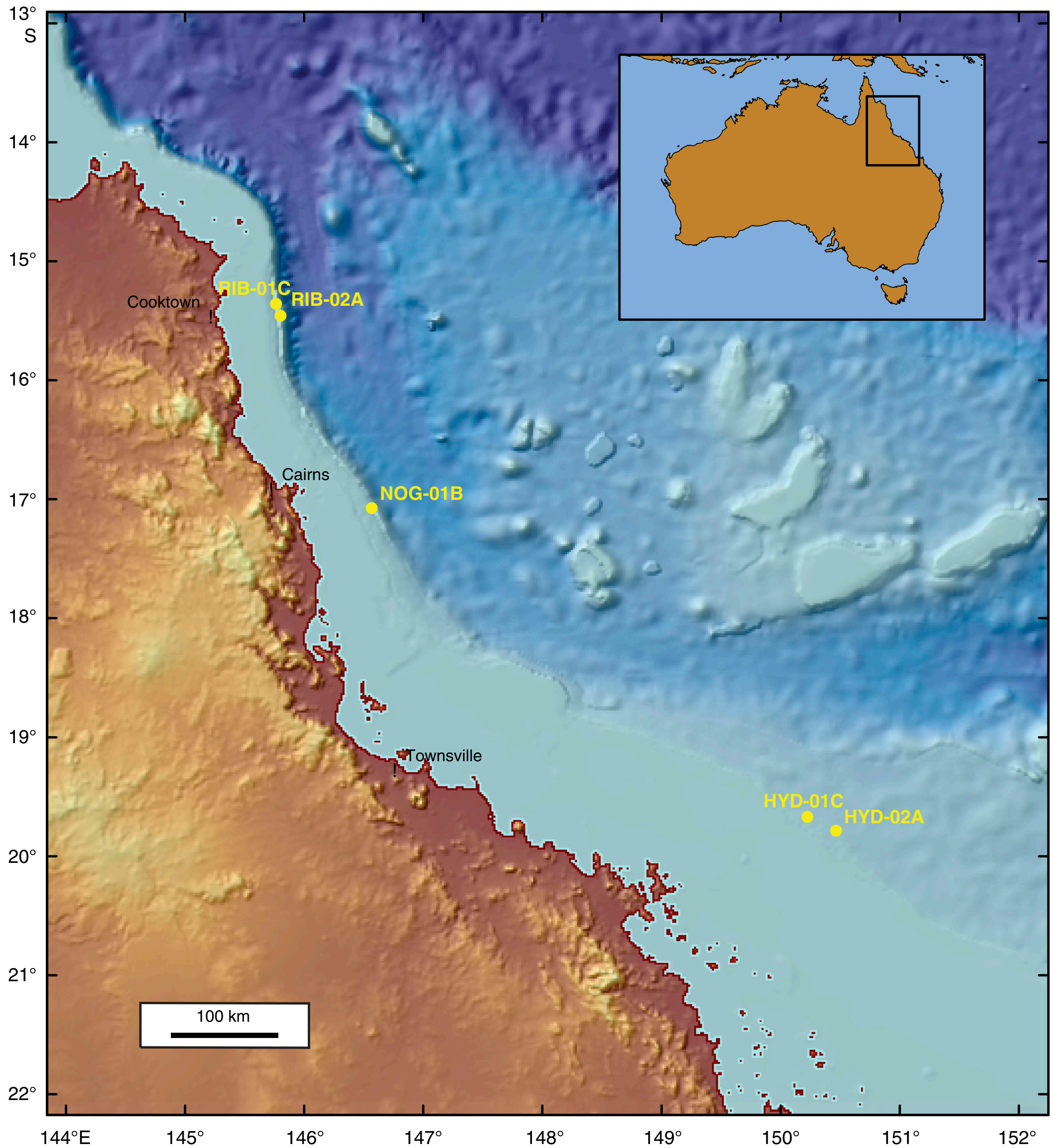


Figure F3. Contour plot around location RIB-01C (Ribbon Reef 5), proposed Sites 1–5. Contour interval = 10 m, contour values in meters. See Figure F2 for general location.

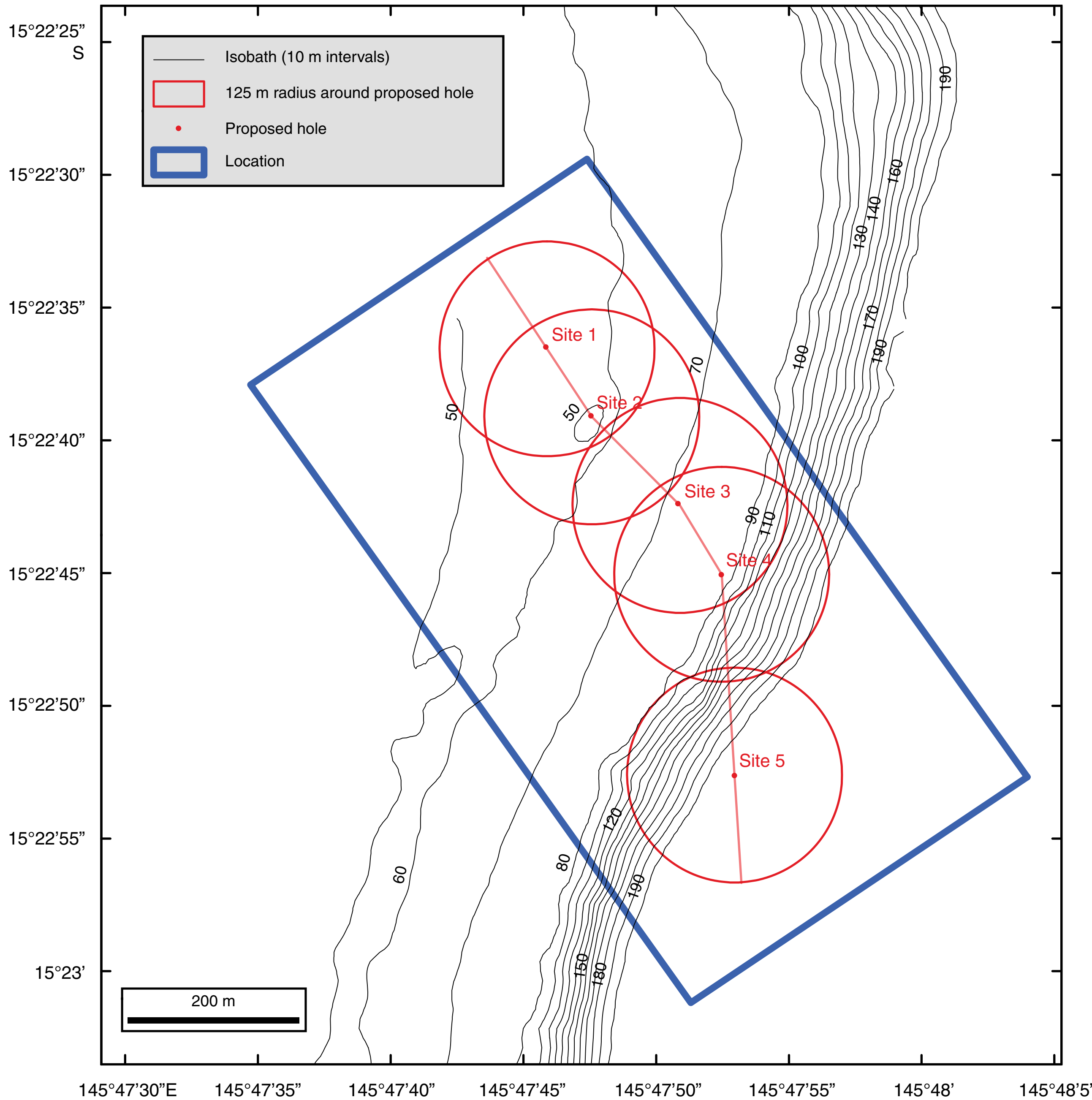


Figure F4. Topas PS18 seismic profile SEG_SS072007_009_001, showing location of proposed Sites 1–5 at location RIB-01C. Approximate location shown in Figure F3.

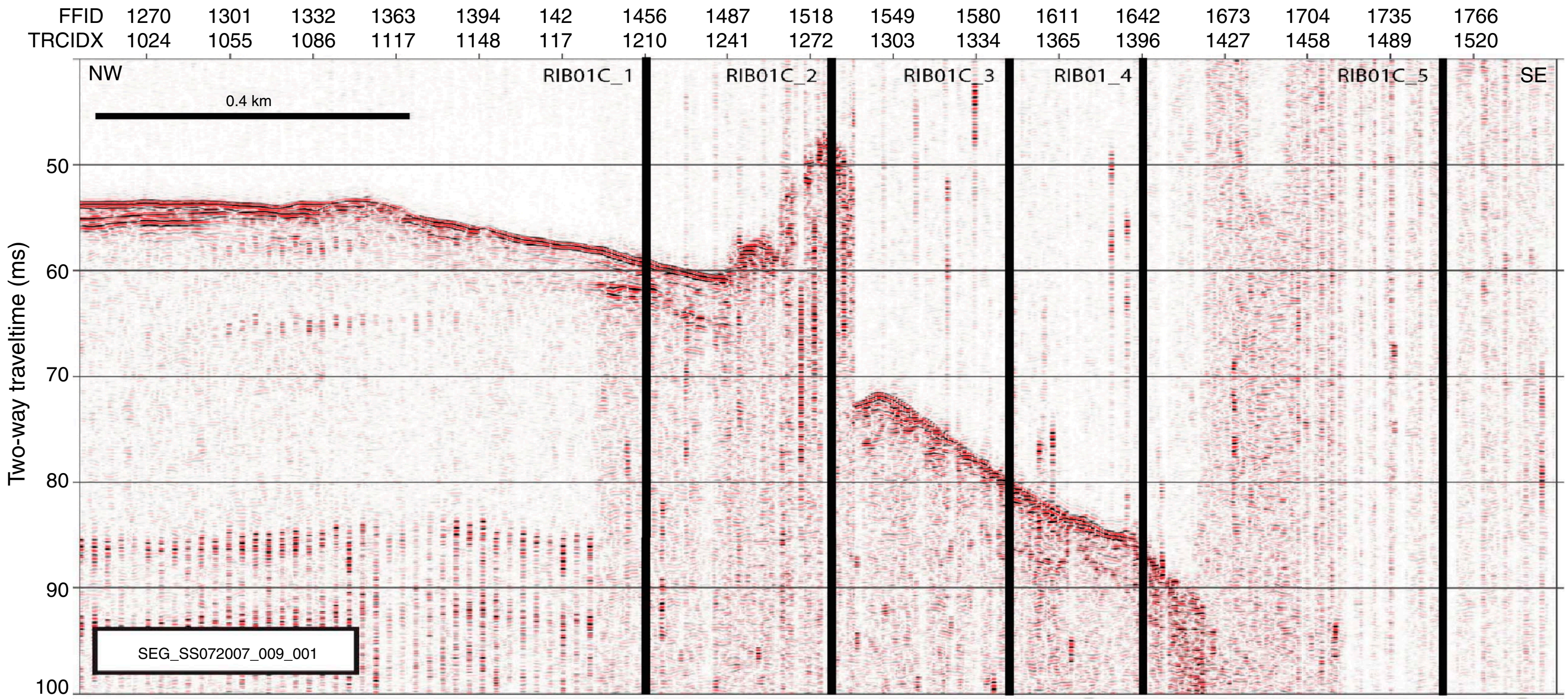


Figure F5. Contour plot around location RIB-02A (Ribbon Reef 3), proposed Sites 1–4. Contour interval = 10 m, contour values in meters. See Figure F2 for general location.

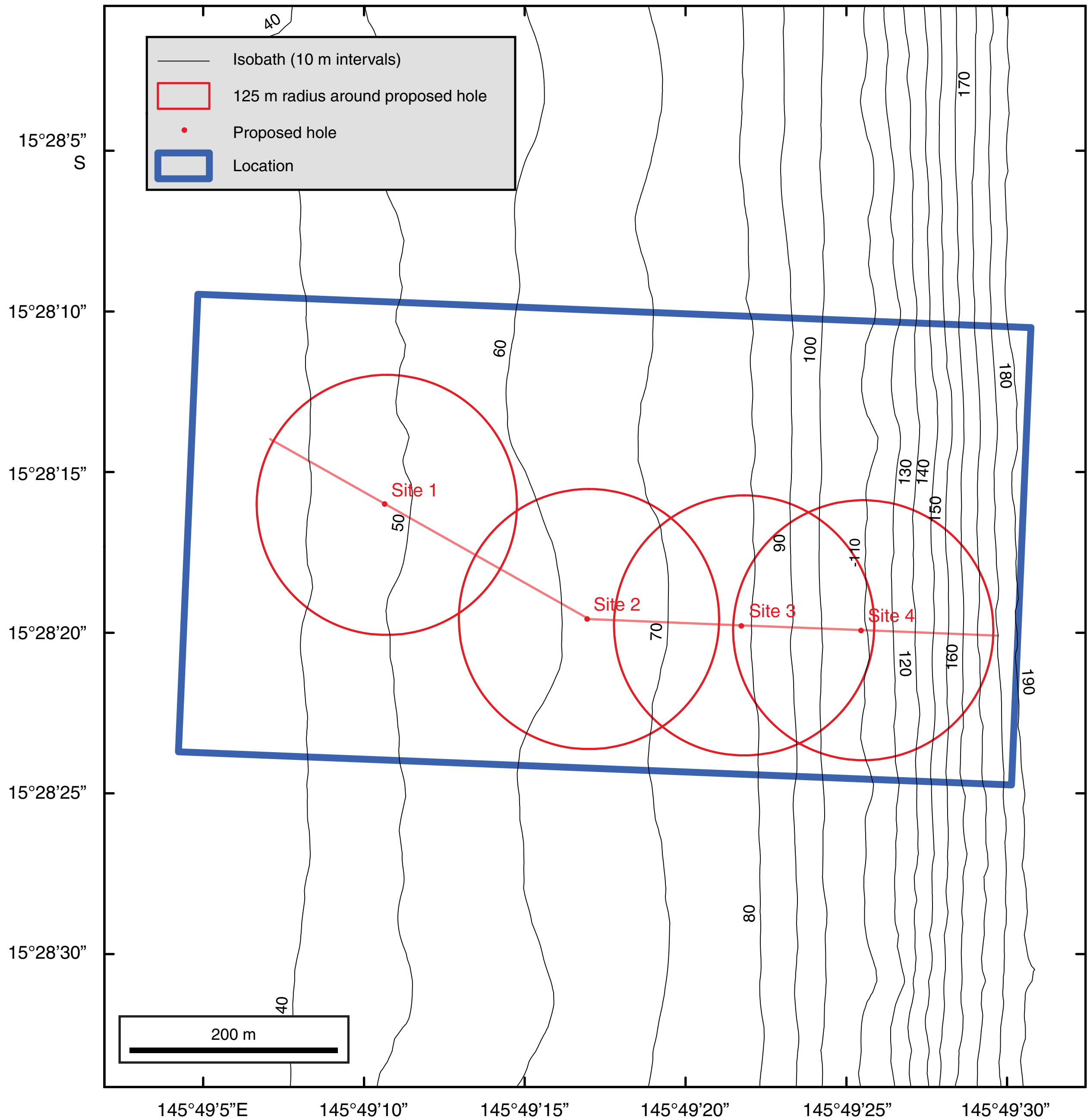


Figure F6. Topas PS18 seismic profile SEG_SS072007_006_003, showing location of proposed Sites 2–4 at location RIB-02A. Approximate location shown in Figure F5.

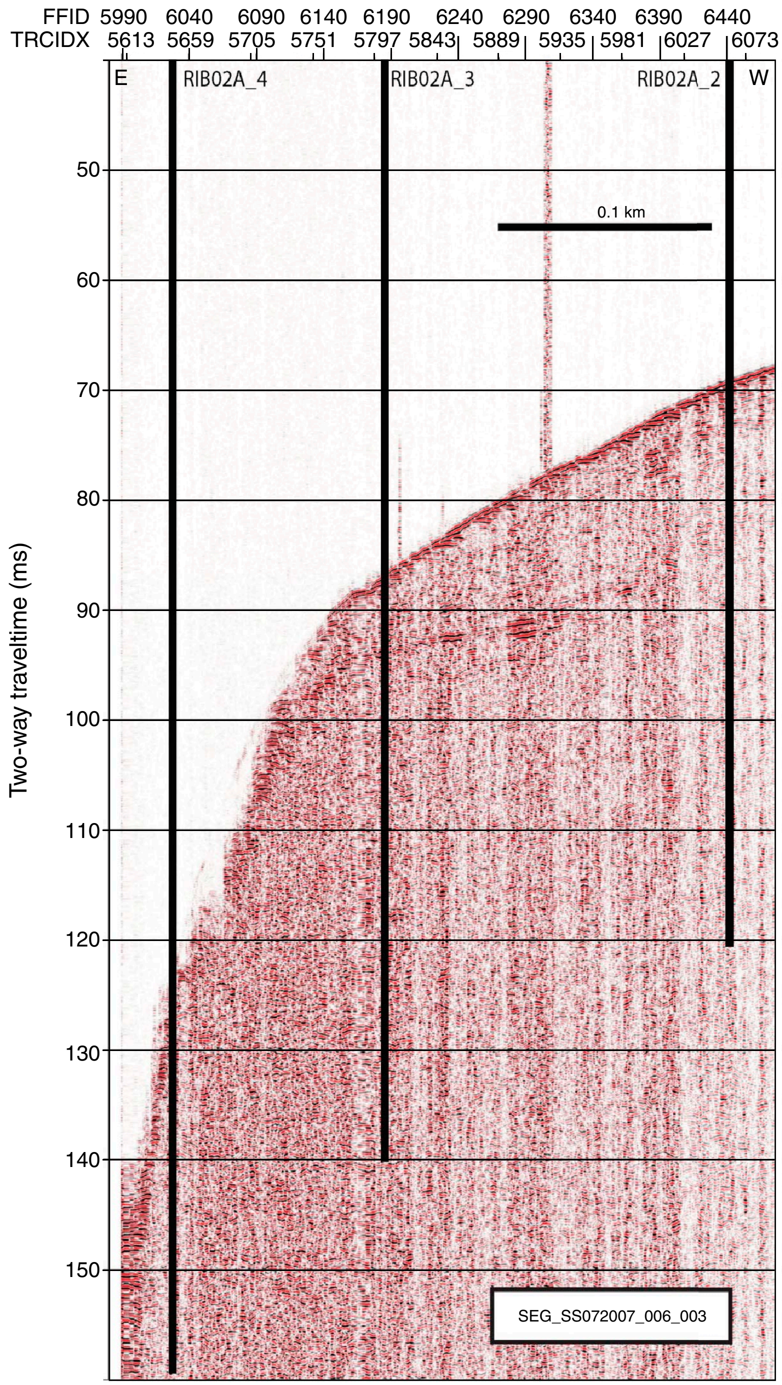


Figure F7. Contour plot around location NOG-01B (Noggin Pass), proposed Sites 1–8. Contour interval = 10 m, contour values in meters. See Figure F2 for general location.

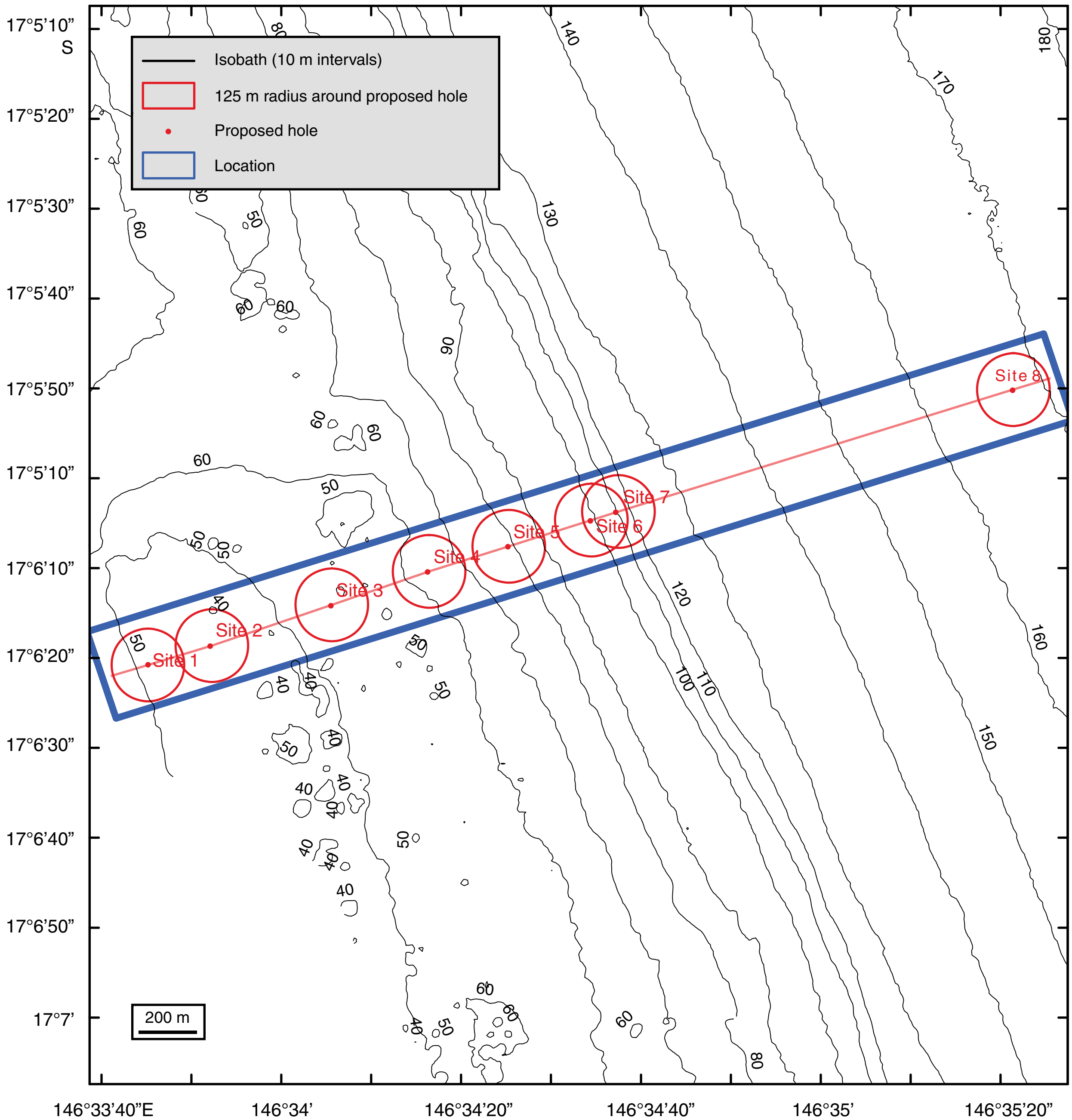


Figure F8. Topas PS18 seismic profile SEG_SS072007_012_012, showing location of proposed Sites 1–8 at location NOG-01B. Approximate location shown in Figure F7.

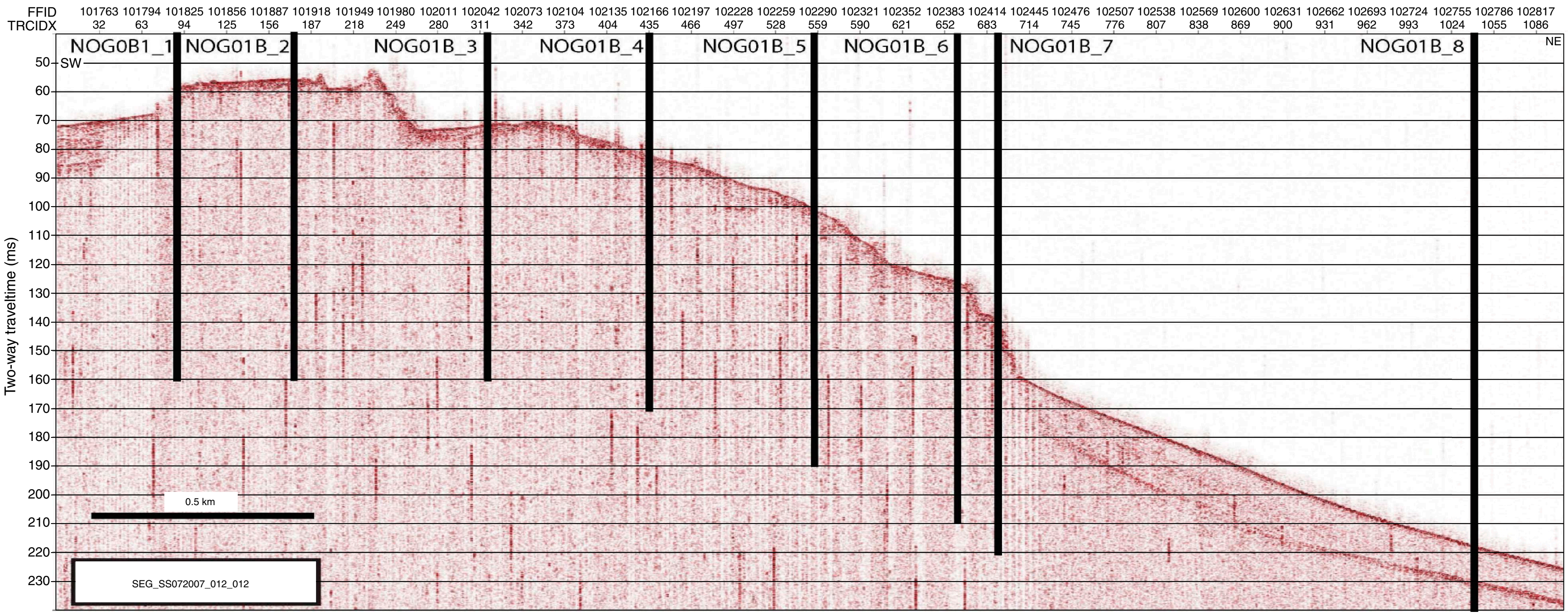


Figure F9. Contour plot around location HYD-01C (Hydrographer's Passage), proposed Sites 1–11. Contour interval = 10 m, contour values in meters. See Figure F2 for general location.

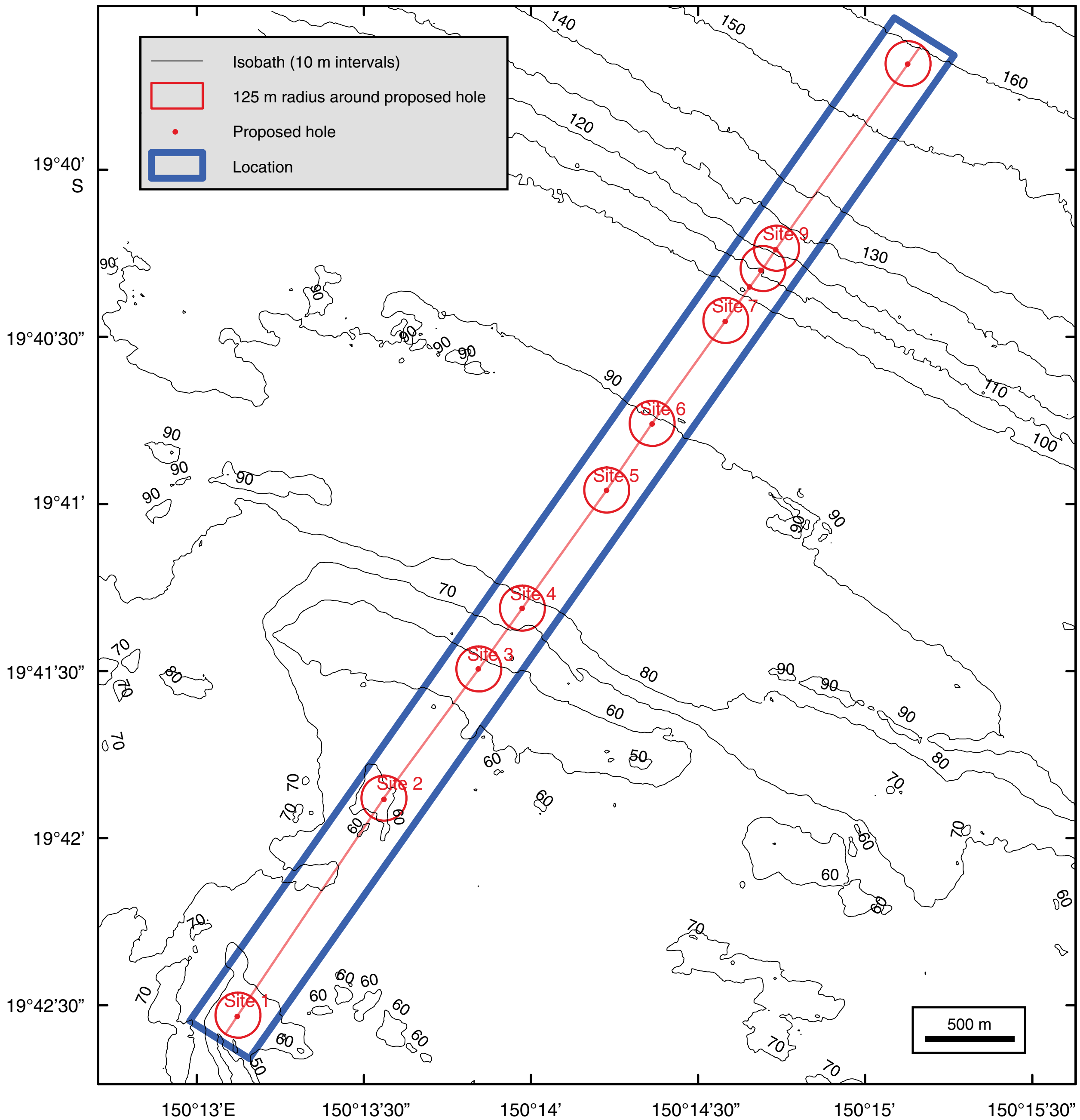


Figure F10. Topas PS18 seismic profile SEG_SS072007_026_006, showing location of proposed Sites 1–10 at location HYD-01C. Approximate location shown in Figure **F9.**

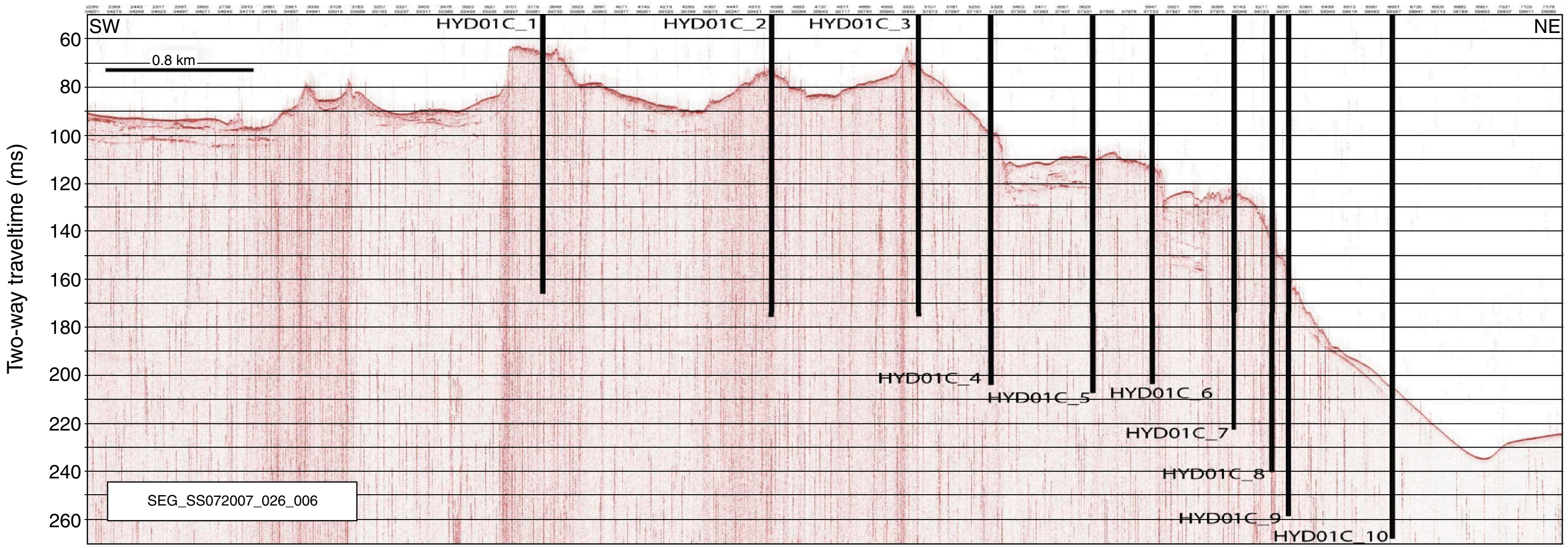


Figure F11. Contour plot around location HYD-02A (Hydrographer's Passage), proposed Sites 1–12. Contour interval 10 m, contour values in metres. See Figure F2 for general location.

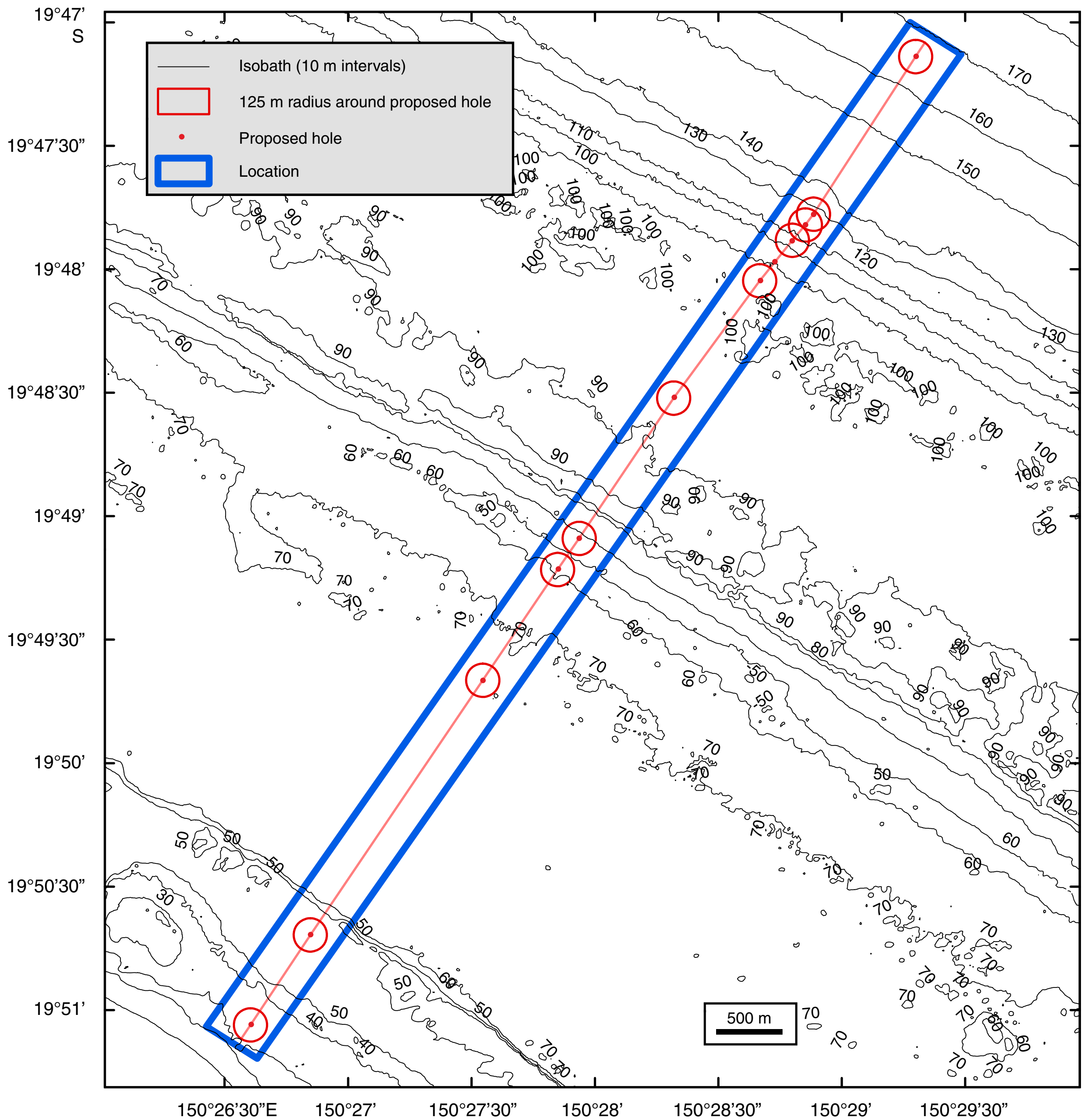


Figure F12. Topas PS18 seismic profile SEG_SS072007_024_030, showing location of proposed Sites 1–11 at location HYD-02A. Approximate location shown in Figure **F11.**

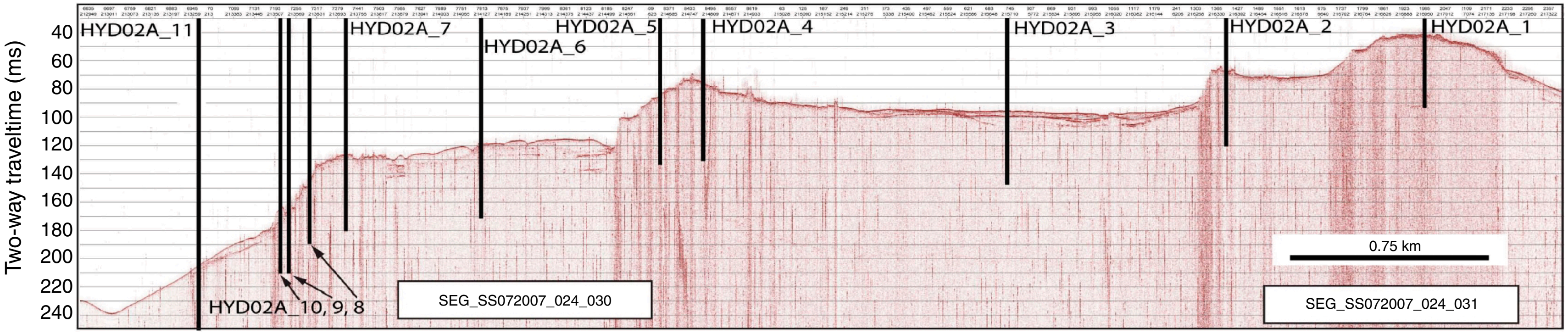
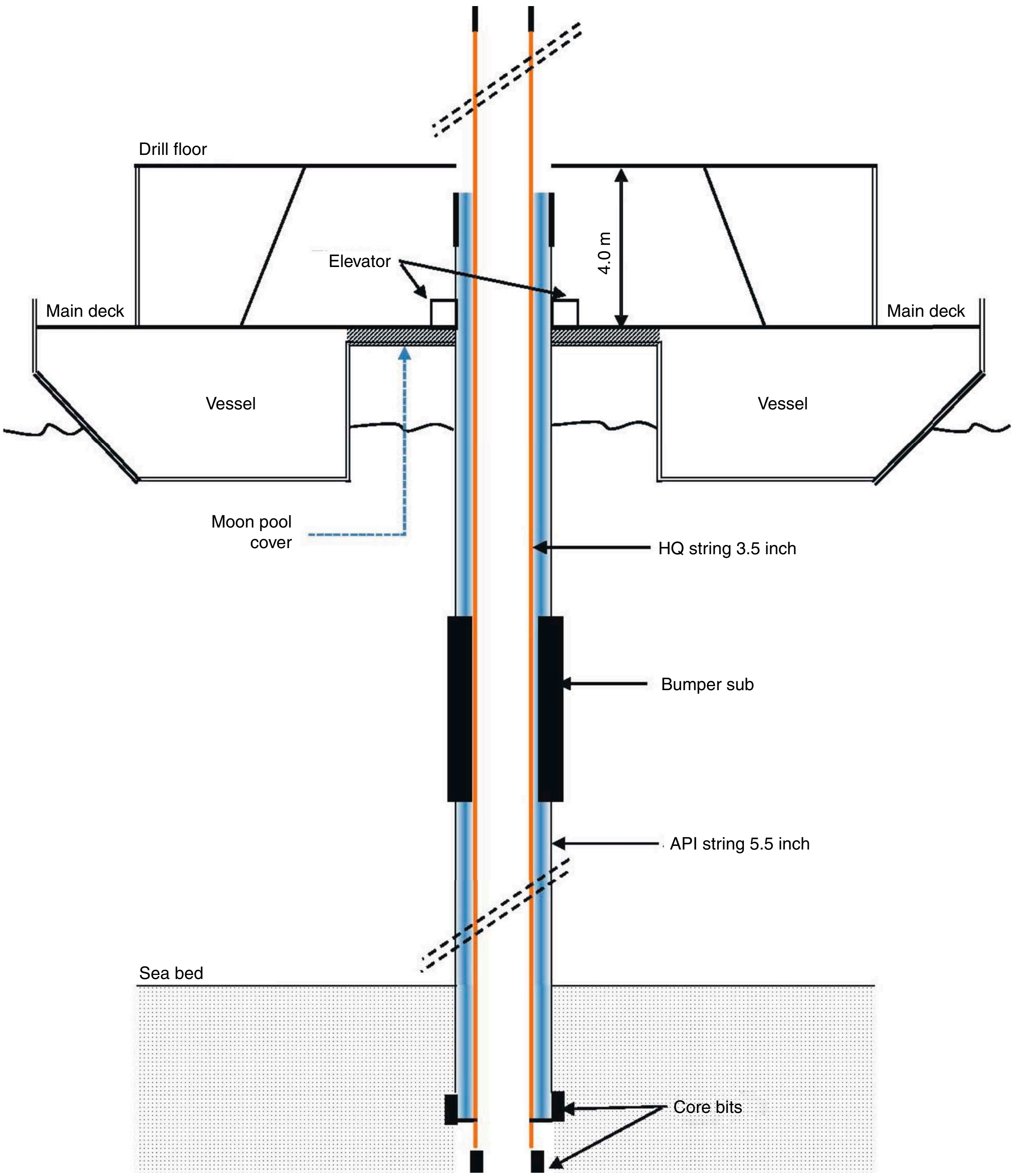


Figure F13. Diagram illustrating the drilling/coring system as used on the *Bluestone Topaz,* courtesy of Bluestone Offshore Pte. Ltd.



Site summaries

Sites at Location RIB-01C (Ribbon Reef 5)

Priority:	Primary
Position:	Site 1 = 145°47.7649′E, 15°22.6093′S Site 2 = 145°47.7929′E, 15°22.6519′S Site 3 = 145°47.8483′E, 15°22.7075′S Site 4 = 145°47.8744′E, 15°22.7508′S Site 5 = 145°47.8825′E, 15°22.8768′S
Water depth (m):	Site 1 = 54.6 Site 2 = 46.5 Site 3 = 70 Site 4 = 75 Site 5 = 198.7
Target drilling depth (mbsf):	Site 1 = 50 m terrace Site 2 = 50 m reef Site 3 = 70 m terrace Site 4 = 70 m reef Site 5 = fore-reef slope (upper slope)
Approved maximum penetration (mbsf):	260
Survey coverage:	Seismic: • High-resolution sparker seismic reflection data (collected September–October 2007, SS07 cruise). • Topas PS18 seismic reflection data (collected September–October 2007, SS07 cruise). • 3.5 kHz chirp data (collected December 2005, RV *James Kirby* cruise; see Beaman et al., 2007). Swath bathymetry/backscatter: • Reson 8110 swath bathymetry and backscatter, 5 m grid (collected December 2005, RV *James Kirby* cruise; see Beaman et al., 2007). • EM300 swath bathymetry and backscatter, 10 m grid (collected September–October 2007, SS07 cruise). Imagery: • Submersible (*Platypus*) and remotely operated vehicle [ROV] dive photographs available. • AUV stereographic imagery available from one dive during the SS07 cruise. Sampling: • 90 and 210 m long drill cores from Boulder Reef and Ribbon Reef 5 sites (International Consortium for Great Barrier Reef Drilling; Webster and Davies, 2003). • Sites 819–821 (Grafton Passage); Site 822 (offshore Cairns). • Three carbonate rocks sampled from the 50 m reef by deep divers in 2007; two rock dredges that recovered reef limestones during the SS07 cruise. Other: • Magnetics (Grafton Passage and offshore Cairns).

Objective (see text for details):	To establish course of postglacial sea level rise at the GBR (i.e., to define the exact shape of the deglaciation curve for the period 20,000 to 10,000 cal. y BP). To define short-term paleoclimatic changes, especially SST variations, for the region over the last 20,000 y. To analyze the impact of sea level changes on reef growth, geometry, and biological makeup.
Drilling, coring, and downhole measurement program:	Logging program: borehole diameter, spectral natural gamma ray, resistivity-induction, acoustic velocity, borehole optical and acoustic images, borehole hydrogeological properties.
Anticipated lithology:	Sediments: limestones and unconsolidated sands. Basement: limestones.

Site summaries (continued)

Sites at Location RIB-02A (Ribbon Reef 3)

Priority:	Primary
Position:	Site 1 = 145°49.1785′E, 15°28.267′S Site 2 = 145°49.2832′E, 15°28.3262′S Site 3 = 145°49.3637′E, 15°28.3295′S Site 4 = 145°49.4254′E, 15°28.332′S
Water depth (m):	Site 1 = 47.5 Site 2 = 61.6 Site 3 = 70.4 Site 4 = 105.9
Target drilling depth (mbsf):	Site 1 = 50 m reef Site 2 = 70 m terrace Site 3 = 70 m reef Site 4 = 100 m reef
Approved maximum penetration (mbsf):	160
Survey coverage:	Seismic: • High-resolution sparker seismic reflection data (collected September–October 2007, SS07 cruise). • Topas PS18 seismic reflection data (collected September–October 2007, SS07 cruise). Swath bathymetry/backscatter: • EM300 swath bathymetry and backscatter, 10 m grid (collected September–October 2007, SS07 cruise). Imagery: • None Sampling: • 90 and 210 m long drill cores from Boulder Reef and Ribbon Reef 5 sites (International Consortium for Great Barrier Reef Drilling; Webster and Davies, 2003). • Sites 819–821 (Grafton Passage); Site 822 (offshore Cairns). • Three carbonate rocks sampled from the 50 m reef by deep divers in 2007; two rock dredges that recovered reef limestones during the SS07 cruise. Other: • Magnetics (Grafton Passage and offshore Cairns).
Objective (see text for details):	To establish the course of postglacial sea level rise at the GBR (i.e., to define the exact shape of the deglaciation curve for the period 20,000 to 10,000 cal. y BP). To define short-term paleoclimatic changes, especially SST variations, for the region over the last 20,000 y. To analyze the impact of sea level changes on reef growth, geometry, and biological makeup.
Drilling, coring, and downhole measurement program:	Logging program: borehole diameter, spectral natural gamma ray, resistivity-induction, acoustic velocity, borehole optical and acoustic images, borehole hydrogeological properties.
Anticipated lithology:	Sediments: limestones and unconsolidated sands. Basement: limestones.

Site summaries (continued)

Sites at Location NOG-01B (Noggin Pass)

Priority:	Primary
Position:	Site 1 = 146°33.7526′E, 17°6.3461′S Site 2 = 146°33.8711′E, 17°6.3104′S Site 3 = 146°34.0934′E, 17°6.2346′S Site 4 = 146°34.2739′E, 17°6.1728′S Site 5 = 146°34.4216′E, 17°6.1263′S Site 6 = 146°34.5746′E, 17°6.0774′S Site 7 = 146°34.6249′E, 17°6.0616′S Site 8 = 146°35.357′E, 17°5.8356′S
Water depth (m):	Site 1 = 44.6 Site 2 = 43.3 Site 3 = 54 Site 4 = 63.6 Site 5 = 77.7 Site 6 = 97.6 Site 7 = 110.3 Site 8 = 167.2
Target drilling depth (mbsf):	Site 1 = 40 m reef Site 2 = 40 m reef Site 3 = 50 m terrace Site 4 = 50 m reef Site 5 = 80 m reef Site 6 = 100 m reef Site 7 = 110 m reef Site 8 = fore-reef slope
Approved maximum penetration (mbsf):	380
Survey coverage:	Seismic: • High-resolution sparker seismic reflection data (collected September–October 2007, SS07 cruise). • Topas PS18 seismic reflection data (collected September–October 2007, SS07 cruise). Swath bathymetry/backscatter: • EM300 swath bathymetry and backscatter, 10 m grid (collected September–October 2007, SS07 cruise). Imagery: • AUV stereographic imagery available from two dives during the SS07 cruise. Sampling: • Sites 819–821 (Grafton Passage); Site 822 (offshore Cairns). • Eleven rock dredges that recovered reef limestones during the SS07 cruise. Other: • Magnetics (Grafton Passage and offshore Cairns).

Objective (see text for details):	To establish the course of postglacial sea level rise at the GBR (i.e., to define the exact shape of the deglaciation curve for the period 20,000 to 10,000 cal. y BP). To define short-term paleoclimatic changes, especially SST variations, for the region over the last 20,000 y. To analyze the impact of sea level changes on reef growth, geometry, and biological makeup.
Drilling, coring, and downhole measurement program:	Logging program: borehole diameter, spectral natural gamma ray, resistivity-induction, acoustic velocity, borehole optical and acoustic images, borehole hydrogeological properties.
Anticipated lithology:	Sediments: limestones and unconsolidated sands. Basement: limestones.

Site summaries (continued)

Sites at Location HYD-01C (Hydrographer's Passage)

Priority:	Primary
Position:	Site 1 = 150°13.123′E, 19°42.5293′S Site 2 = 150°13.5599′E, 19°41.8799′S Site 3 = 150°13.8436′E, 19°41.4936′S Site 4 = 150°13.9741′E, 19°41.3116′S Site 5 = 150°14.2264′E, 19°40.9583′S Site 6 = 150°14.3622′E, 19°40.759′S Site 7 = 150°14.5828′E, 19°40.4512′S Site 11 = 150°14.658′E, 19°40.345′S (pending IODP approval) Site 8 = 150°14.6942′E, 19°40.2958′S Site 9 = 50°14.7346′E, 19°40.2349′S Site 10 = 150°15.1282′E, 19°39.6829′S
Water depth (m):	Site 1 = 51.4 Site 2 = 54.1 Site 3 = 57.3 Site 4 = 76.8 Site 5 = 85.3 Site 6 = 88.6 Site 7 = 96.1 Site 11 = 104.2 Site 8 = 109 Site 9 = 122.8 Site 10 = 145.1
Target drilling depth (mbsf):	Site 1 = 50 m reef Site 2 = 50 m patch reef Site 3 = 50 m reef Site 4 = 80 m reef Site 5 = 85 m terrace Site 6 = 90 m reef Site 7 = 100 m terrace Site 11 = 100 m terrace Site 8 = 110 m reef Site 9 = 120 m terrace Site 10 = fore-reef slope
Approved maximum penetration (mbsf):	500

Survey coverage:	Seismic: • High-resolution sparker seismic reflection data (collected September–October 2007, SS07 cruise). • Topas PS18 seismic reflection data (collected September–October 2007, SS07 cruise). Swath bathymetry/backscatter: • EM300 swath bathymetry and backscatter, 10 m grid (collected September–October 2007, SS07 cruise). Imagery: • AUV stereographic imagery available from two dives during the SS07 cruise. Sampling: • Two rock dredges that recovered reef limestones during the SS07 cruise. Other: • Magnetics (Grafton Passage and offshore Cairns).
Objective (see text for details):	To establish the course of postglacial sea level rise at the GBR (i.e., to define the exact shape of the deglaciation curve for the period 20,000 to 10,000 cal. y BP). To define-short term paleoclimatic changes, especially SST variations, for the region over the last 20,000 y. To analyze the impact of sea level changes on reef growth, geometry, and biological makeup.
Drilling, coring, and downhole measurement program:	Logging program: borehole diameter, spectral natural gamma ray, resistivity-induction, acoustic velocity, borehole optical and acoustic images, borehole hydrogeological properties.
Anticipated lithology:	Sediments: limestones and unconsolidated sands. Basement: limestones.

Site summaries (continued)

Sites at Location HYD-02A (Hydrographer's Passage)

Priority:	Primary
Position:	Site 1 = 150°26.6047′E, 19°51.06′S Site 2 = 150°26.8469′E, 19°50.6955′S Site 3 = 150°27.5453′E, 19°49.6643′S Site 4 = 150°27.8485′E, 19°49.2161′S Site 5 = 150°27.9361′E, 19°49.09′S Site 6 = 150°28.3187′E, 19°48.5219′S Site 7 = 150°28.6671′E, 19°48.0469′S Site 12 = 150°28.732′E, 19°47.963′S (pending IODP approval) Site 8 = 150°28.7996′E, 19°47.8829′S Site 9 = 150°28.8521′E, 19°47.8208′S Site 10 = 150°28.8848′, E19°47.7771′S Site 11 = 150°29.2987′, E19°47.1391′S
Water depth (m):	Site 1 = 30.9 Site 2 = 51.3 Site 3 = 69.7 Site 4 = 53.7 Site 5 = 62.9 Site 6 = 90.5 Site 7 = 94.5 Site 12 = 102.2 Site 8 = 110.8 Site 9 = 122.1 Site 10 = 122.9 Site 11 = 162.1
Target drilling depth (mbsf):	Site 1 = 40 m reef Site 2 = 50 m reef Site 3 = 60 m lagoon Site 4 = 60 m reef Site 5 = 60 m reef Site 6 = 90 m terrace Site 7 = 100 m reef Site 12 = 100 m reef Site 8 = 110 m reef Site 9 = 120 m reef Site 10 = 120 m reef Site 11 = fore-reef slope
Approved maximum penetration (mbsf):	540

Survey coverage:	Seismic: • High-resolution sparker seismic reflection data (collected September–October 2007, SS07 cruise). • Topas PS18 seismic reflection data (collected September–October 2007, SS07 cruise). Swath bathymetry/backscatter • EM300 swath bathymetry and backscatter, 10 m grid (collected September–October 2007, SS07 cruise). Imagery: • AUV stereographic imagery available from one dive during the SS07 cruise. Sampling: • Six rock dredges that recovered reef limestones during the SS07 cruise. Other: • Magnetics (Grafton Passage and offshore Cairns).
Objective (see text for details):	To establish the course of postglacial sea level rise at the GBR (i.e., to define the exact shape of the deglaciation curve for the period 20,000 to 10,000 cal. y BP). To define short-term paleoclimatic changes, especially SST variations, for the region over the last 20,000 y. To analyze the impact of sea level changes on reef growth, geometry, and biological makeup.
Drilling, coring, and downhole measurement program:	Logging program: borehole diameter, spectral natural gamma ray, resistivity-induction, acoustic velocity, borehole optical and acoustic images, borehole hydrogeological properties.
Anticipated lithology:	Sediments: limestones and unconsolidated sands. Basement: limestones.

Appendix

Great Barrier Reef Environmental Change ESO sampling and measurement plan

This plan was discussed and agreed on during various meetings and subsequent communications with the Co-Chief Scientists. Nevertheless, this plan is subject to amendment according to the scientific needs and interests of the Scientific Party or operational constraints. The most pressing operational constraint during the offshore period is likely to be space, with containers being located on both a mezzanine and deck level. In order to minimize core transit between containers and up/down stairs on the platform, the core flow scheme below has been devised.

Offshore sampling and analysis

Please see **www.marum.de/en/Offshore_core_curation_and_measurements.html** in addition to the text below.

Core curation

There will be a core curation laboratory container onboard the drilling vessel, supervised by the Chief Curator. A second Curator will cover the opposite shift. The Curators will have delegated responsibility in the absence of the ESO Curation Manager and IODP Curator Dr. Ursula Röhl. A sufficient number of core storage containers will be on the drilling vessel. There will be no splitting of the cores at sea, as it will be more efficient to carry out most of the scientific analysis during the OSP in Bremen.

As the cores will be collected in a plastic liner or a metal "spoon" liner (before being transferred to a plastic liner on the drill floor), the usual IODP curation procedures will be followed (please refer to **www.marum.de/en/Core_curation.html**). The core will be cut on board into 1.5 m lengths and curated. It has been noted that it is important to store corals in dry conditions to avoid growth of fungi and bacteria that can develop in coral skeletons, resulting in the strong possibility of alteration to the original geochemical signals.

Lithologic and macropaleontologic description

Core catcher samples will be collected, split, and labeled and the working half handed over for lithological and macropaleontological description. If no core catcher is collected, a sample from the lower end of the section will be taken for shipboard lithologic and macropaleontologic analysis. If the lower end of the core is a massive coral, no sample will be cut off the core.

Offshore core flow

For details of the offshore core flow, see Figure **AF1.**

Inorganic geochemistry

No major mud sequences are expected to be encountered at the proposed drill sites. Site survey cruises indicate that limestones and unconsolidated sands will be the dominant sediments expected. However, if suitable material is recovered, pore water sampling will be conducted for fluid chemistry/circulation studies. In this case, pore water should be extracted immediately from a core sample, and ephemeral properties such as salinity, alkalinity, and ammonia will be analyzed immediately (**www.marum.de/en/Interstitial_pore_waters_IW.html**).

Depending on the parameter, the interstitial water sample might be specially treated in order to conserve it for later analyses.

Microbiology

Sampling for microbiology studies will be undertaken if IODP implements STP Recommendation 0807-12, "Microbiology Routine Sampling for Frozen Preservation," or if specific samples are requested by microbiologist(s) from the Science Party.

If samples for microbiology are taken, they will be taken immediately in the field under the most sterile conditions possible. It will be important to know if microbes from the drilling fluids have entered the cavities during drilling. Ideally, fluorescent microspheres should be used during drilling, but they will not be used during Expedition 325 for environmental reasons. Results should be interpreted with care, as contamination may occur during drilling and any microbial material found may not be in situ. To limit the effects of contamination, samples will be washed with sterile seawater and only the attached microbes will be considered for further activity measurements (which includes typically >99% of the total biomass).

Depending on sample requests received and the implementation of microbiology during Expedition 325, potential studies may include

- Studying biofilms in the field using (4′,6-diamindino-2-phenylindole) DAPI staining, binocular microscopes, and fluorescence microscopes.

- Microbial abundance (counting). The microbial community can be chemically fixed and frozen at –80°C to be transported back to the laboratory, where microbial abundance (shipboard) and diversity (shore-based) can be studied microscopically using staining techniques.
- Scanning electron microscope (SEM) and energy dispersive analysis, X-ray (EDAX), studies of microbial-related carbonates (microbialites) can be made postcruise using the fixed samples.
- Growth studies. Appropriate growth media can be inoculated with selected core samples in the field. These can be returned to the laboratory, where the growth of microbes from samples can be studied postcruise. This living material can also be used for deoxyribonucleic acid (DNA) analysis.
- Activity measurements. Living cells can be sensitively detected using the adenosine triphosphate (ATP) test with a luminometer and the firefly-based enzyme assay. An alternative activity test is the measurement of microbial exo-enzymes by fluorometry.

Offshore petrophysics measurements

Core logging

Cores will be logged on the drilling vessel in a modified 20 ft container, housing a single MSCL track comprising one magnetic susceptibility loop, gamma density, *P*-wave velocity, and electrical resistivity sensors (**www.marum.de/en/Physical_Properties_3.html**). The single core-logger system will include a full spares kit.

All temperature-equilibrated core log data acquired at sea will provide QA/QC checks when compared to repeat measurements planned for Bremen.

Downhole logging

The following is a generic list of minimum and additional tools, based on formation properties discussed with proponents:

- Optical images (for millimeter-scale geological description),
- Acoustic images (for centimeter-scale impedance and mesoscale porosity),
- Spectral gamma logging (for U, Th, K, and red algae),
- Acoustic velocity logging (for V_P and V_S at 10–20 kHz),
- Induction resistivity logging (for pore fluid salinity and porosity),

- Hydrochemical borehole fluid logging (with p, T, pH, Eh, SP, and fluid electrical conductivity to identify fluid circulations), and
- Borehole diameter (for quality control and borehole corrections).

Onshore sampling and analysis

Onshore core flow

For details of the offshore core flow, see Figure **AF2.**

Location

After due consideration, it has been decided that there will be no splitting of the cores at sea. The OSP will be undertaken at the IODP Core Repository and laboratory at Bremen University in combination with access to the laboratories at MARUM and the Department of Geosciences.

Planned analysis and available facilities

The following facilities will be available for the expedition scientists at the Bremen IODP Core Repository (please also refer to the online tutorial at **www.marum.de/en/Onshore_Science_Party_OSP.html**). Note that it is not considered prudent to transport all these facilities onto a drilling vessel:

- Core splitting: An archive half will be set aside as per IODP policy.
- Core description: ESO will provide a system that is IODP standard. For data entry, ESO will employ an Offshore DIS system that is entirely compatible with others being used in IODP.
- Core photography: Core shots (table layout) will be taken on a routine basis, close-ups on request.
- Core sampling: A detailed sampling plan will be devised at the completion of the offshore phase and after the scientists have submitted their revised sample requests.
- Thin section and smear slide preparation: As requested—preparation, description, and interpretation.
- Micropaleontology, microscope laboratory: Includes hood for sample preparation if acids need to be applied.
- Inorganic geochemistry and whole-rock and pore fluid chemistry; inductively coupled plasma–mass spectrometry (ICP-MS) and X-ray fluorescence (XRF); and carbonate and total organic carbon content (Leco).

- X-ray diffraction analysis (XRD): bulk mineralogy (e.g., carbonate mineralogy, etc.).
- Petrophysical measurements:
  - Selected repeat whole-core measurements for QA/QC if required.
  - Split-core multisensor core logger if required.
  - Physical properties of discrete samples (moisture/sample density): Determination of index properties (velocity, wet bulk density, grain density, porosity, and void ratio). Following IODP procedure, core samples will be oven-dried, the dried sample volume quantified using a Quantachrome penta-pycnometer, and masses using a high-precision balance.
  - Color reflectance measurements (Minolta spectrophotometer).
  - Digital line-scan camera on split core multisensor core logger track.
  - X-ray CT scanning before the OSP (on special request and on selected core sections only).

Figure AF1. Offshore core flow. (1) If no core catcher is collected, a sample from the lower end of the section will be taken for shipboard lithological and macropaleontological analysis. If the lower end of the section is a massive coral, no sample will be taken. (2) Depending on the length of the core catcher, additional material from the archive half of the core catcher can be used for sampling for shipboard lithological description and preliminary shore-based studies. (3) If space allows, a separate container from Bluestone will be designated for lithological description work to provide protection for the cores and scientists working on them. If this is not possible, space will be made available in an ESO/Bremen container. This will be decided at mobilization.

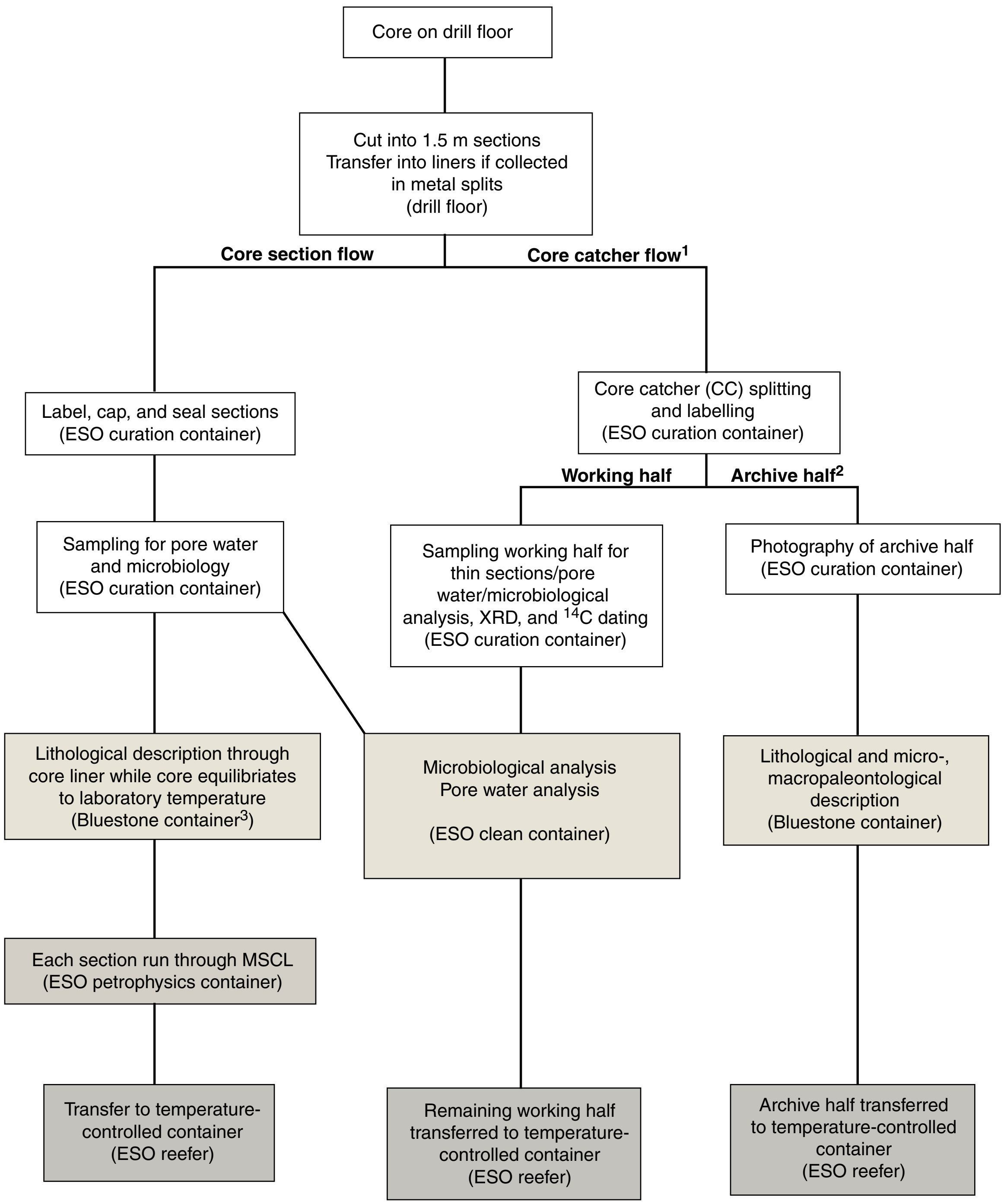
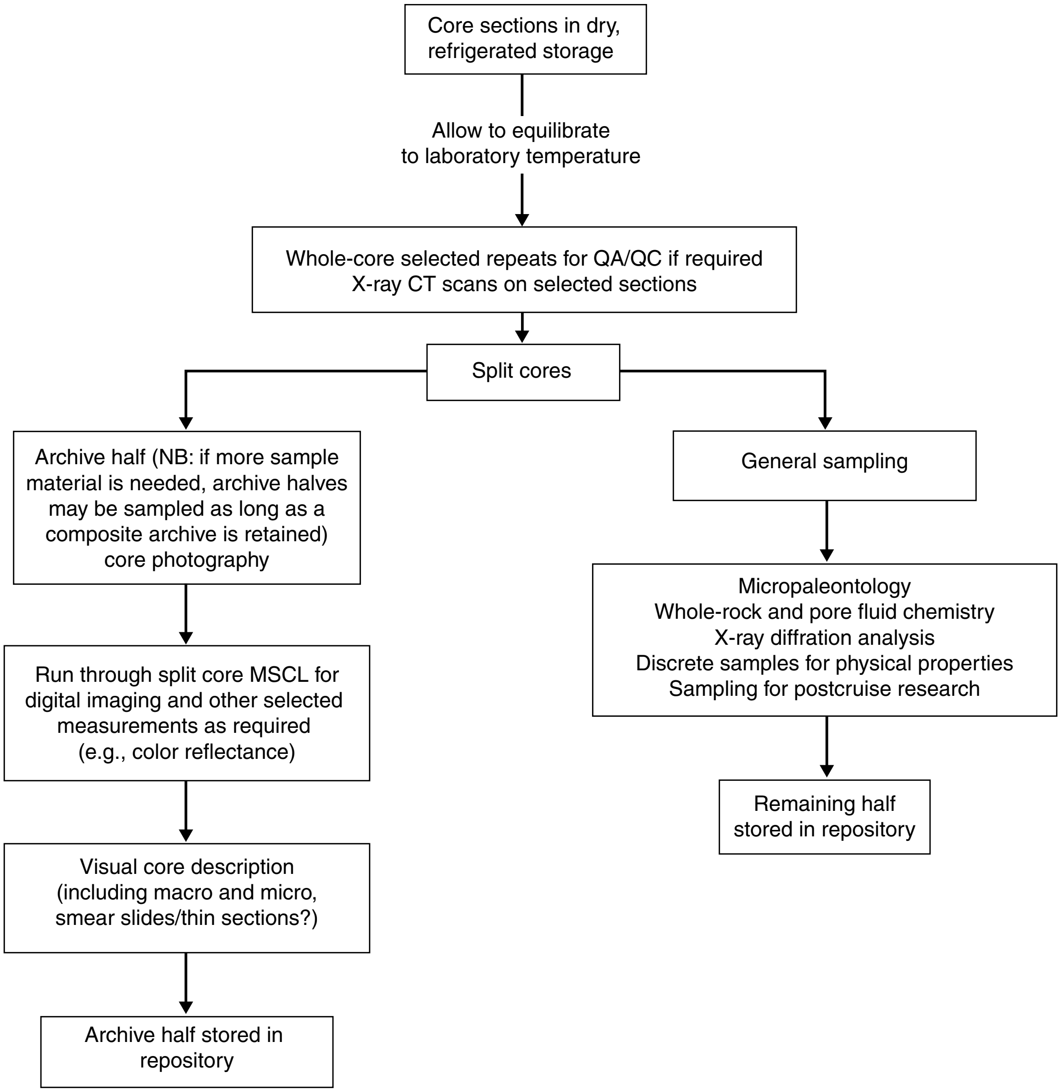


Figure AF2. Onshore core flow. Directions of splitting cores will depend on growth directions of coral colonies, if any. QA/QC = quality assurance/quality control, CT = computed tomography, MSCL = multisensor core logger.



Expedition scientists and scientific participants

The current list of participants for Expedition 325 can be found at **www.eso.ecord.org/expeditions/325/325.htm.**