IODP Expedition 371: Tasman Frontier Subduction Initiation and Paleogene Climate

Site U1511 Summary

Background and Objectives

International Ocean Discovery Program (IODP) Site U1511 (proposed Site TASS-2A; 37.5611°S, 160.3156°E, 4858 m water depth) is located on the Tasman Sea abyssal plain, ~945 km east of Australia and ~990 km northwest of New Zealand. Site U1511 lies adjacent to the Lord Howe Rise on oceanic crust of Late Cretaceous age that is thought to have formed during Chron 33 (74–83 Ma). Regional seismic reflection data reveal a thick (>800 m) sequence of sediments that are deformed by reverse faults and folds. Site U1511 was chosen to find the age of this deformation and to provide one of the first comprehensive records of sedimentation on the Tasman Sea abyssal plain. The primary drilling objectives at Site U1511 were to sample (a) the top of the middle seismic unit, to constrain the age of folding; and (b) the rest of the sedimentary sequence, to develop an understanding of this significant abyssal location. The only previous scientific borehole into Tasman Sea abyssal plain sediments was drilled in 1973 at DSDP Site 283, 870 km to the southwest on conjugate crust of Late Cretaceous age near southeast Australia.

Operations

Hole U1511A (37°33.6665'S, 160°18.9380'E, water depth 4847 m)
Hole U1511B (37°33.6656'S, 160°18.9379'E, water depth 4847 m)

The ship completed the transit from Site U1510 and arrived at Site U1511 at 1248 h on 16 September (UTC + 11 h). Rotary core barrel (RCB) coring in Hole U1511A began at 0425 h on 17 September. After retrieving Core 3R, the drill string had to be pulled clear of the seafloor due to excessive heave and wind. Cores 1R through 3R penetrated from 0 to 26.6 m and recovered 7.9 m (30%). A total of 19.25 h or 0.8 d were spent on Hole U1511A.

After waiting for 17 h, Hole U1511B was initiated at 0145 h on 18 September by washing down (i.e., drilling without coring and without a center bit installed) to 19.8 m. Coring resumed at 0215 h on 18 September and Cores 2R to 7R penetrated from 19.8 to 77.2 m. A center bit was deployed and the interval 77.2 to 192.2 m was drilled without coring to ensure we could reach the target depth in the remaining time of the expedition. Coring resumed at 1500 h on 18 September and Cores 9R to 41R penetrated from 192.2 to 508.8 m. At 1600 h on 20 September coring was suspended due to excessive heave and the drill string was raised above the bottom of the hole. As the swell began to subside at 1030 h on 21 September, the drill string was lowered back to the bottom of the hole. After pumping a 25 barrel mud sweep, coring resumed at 1600 h on 21 September and continued until at 0450 h on 22 September with Core U1511B-47R

reaching 566.2 m. The total cored interval in Hole U1511B was 431.4 m and recovery was 279.3 m (65%). Two intervals were drilled without coring for a total of 134.8 m.

The rig floor was secured for transit to Hobart at 1630 h on 22 September, ending Hole U1511B and Site U1511. A total of 110.75 h or 4.6 d were spent at Hole U1511B. Total time at Site U1511 was 130.0 h or 5.4 d. This included 40.5 h spent waiting on weather.

Principal Results

Three lithostratigraphic units were described and are differentiated by the presence or absence of microfossils. Unit I (0–77.2 m) is ~80 m of gray to brown clay, with calcareous nannofossils restricted to the lowermost 40 cm of the unit. Unit II (201.9–403.4 m) is separated from Unit I by an ~120 m interval that was penetrated without coring. Unit II consists of ~200 m of greenish gray to yellowish brown diatomite with minor abundances of clay and other siliceous microfossils (radiolarians, sponge spicules, ebridians, and silicoflagellates). Unit III (403.4–560.7 m) is ~150 m of claystone. A ~30 m reddish brown interval near the top of Unit III contains minor abundances of radiolaria. A ~40 m grayish green interval near the bottom of the unit contains minor abundances of calcareous nannofossils.

A variety of secondary minerals are present throughout Site U1511, attesting to diagenesis and alteration. Manganese nodules and black specks of sulfides occur in Unit I, whereas sporadic centimeter-scale nodules and specks of pink rhodochrosite occur in Unit II. Several centimeter-scale intervals of greenish gray claystone within Units II and III contain sand-sized grains of native copper surrounded by dark green haloes. The lower part of Unit II also contains cristobalite and an interval of red and pink flouroapatite. Furthermore, a color gradient across Unit III from red and reddish brown at the top of the unit to greenish gray towards the base, with alternations of the two colors in the intervening interval, seems to be related to trace amounts of redox-sensitive metal oxides. These minerals suggest a complex history of diagenesis and alteration, the latter likely mediated by fluid flow.

Calcareous nannofossils and planktic foraminifera are generally absent throughout Site U1511. When present, their abundances and preservation states are varied. Radiolaria are present from 192 to 547 m, and are abundant from 209 to 394 m, with good preservation. Below, radiolaria are less abundant and poorly preserved.

Benthic foraminifera are sparse in the Pliocene to lower Eocene interval, where a low diversity agglutinated assemblage was recognized. The transition to a higher diversity, Paleocene to lowermost Eocene assemblage was observed at the contact between Lithostratigraphic Units II and III. The Paleocene interval contains both agglutinated and calcareous taxa. Samples are barren of ostracods and palynomorphs. Given the overall microfossil assemblages, the location of Site U1511 has probably been abyssal, and beneath or near the CCD since the Paleocene.

Biostratigraphic data are based primarily on radiolaria datums. Rare nannofossils and planktic foraminifera found through the Pliocene, Miocene, lower Oligocene, and Paleocene intervals were used to constrain age where possible. Based on planktic foraminifera, Pliocene (7.5–7.6 m), lower Pliocene to upper Miocene (7.5–47.6 m) and possible Miocene (65.6–65.7 m) strata were recognized. Based on calcareous nannofossils, lower Oligocene (192.2–204.0 m) was identified, however this section is part of the drilled interval and may not be in situ.

Based on radiolarian biostratigraphy, upper Eocene (209–235 m), lower to middle Eocene (235–389 m), and Paleocene (432–539 m) strata were recognized. Lower to middle Paleocene (538.8–539.4 m) was also identified based on nannofossil biostratigraphy.

High-quality paleomagnetic data were obtained across intervals of Units II and III. From Cores 14R to 30R (~240–400 m), all polarity reversals from the base of Chron 17n.3n to Chron 21n are identified, indicating that Unit II at Hole U1511B spans from ~38 to 47.5 Ma (Bartonian–Lutetian). Four magnetic polarity reversals within Core 38R can be successfully correlated with Chron C24n.1n to 2n (~53 Ma).

The remanence intensity of sediments from Units II and III exhibits possible cycles. These variations appear related to lithological color changes, where brown intervals generally have a higher magnetization, compared to the lower magnetization in the gray sediment intervals. Such changes may be related to magnetic mineral diagenesis. Many samples in Unit III show magnetically hard natural remanent magnetization behavior that is resistant to alternating field demagnetization. Such hard remanence component is carried by hematite, which probably contributes to the reddish sediment color in Unit III.

Cube samples from Unit II and III show reliable anisotropy of magnetic susceptibility (AMS) data, and distinct patterns for Units II and III. Samples from Unit II indicate a random orientation of AMS tensor, which probably reflects a random deposition of minerals without sediment compaction. In contrast, sediments from Unit III exhibit a well-defined oblate AMS fabric, as typical for undeformed but compacted sedimentary rocks.

Porosity decreases downhole from 80% to 65% in Unit I, along a trend typical for pelagic clay. This trend continues in Unit III (60% to 45%). However, in Unit II porosity is offset to extremely high values (70% to 83%). This general profile is mirrored in bulk density and is attributed to the diatomite with clay in Unit II. *P*-wave velocity increases downhole on a linear trend, with the exception of two peaks in the lower part of Unit II (1750 m/s) and middle part of Unit III (1850 m/s). Magnetic susceptibility (MS) values vary between 5 and 50 IU in Unit I and near the top of Unit III, and are much lower in Unit II and in the lower part of Unit III. Natural gamma radiation (NGR) shows a similar trend and both MS and NGR appear to correspond to clay content. All color reflectance parameters (L*, a* and b*) increase downhole from 200 m to 300 m, and then decrease from 300 to 400 m, corresponding to the diatomite in Unit II. A step increase in bulk density (1.50 to 1.75 g/cm^3), MS, NGR, and a* and b*, associated with a

decrease in porosity (70% to 52%), is attributed to a red claystone interval in the top of Unit III (~410 m).

Headspace gas concentrations were all below the detection limit. Low contents of carbonate (<15%) and organic carbon (<0.4%) prevail throughout the sedimentary column at Site U1511. Carbonate contents only rise above 1% in samples from two intervals: at the bottom of Unit I (71–77 m) and within the lower half of Unit III (490–539 m).

A total of 50 interstitial water (IW) samples were collected at Site U1511 by two methods: squeezing and Rhizon. At the precision required to understand basic processes at Site U1511, squeeze and Rhizon samples give similar profiles for most dissolved species. These profiles show some general trends as well as some unusual features, and this reflects a combination of lithology and multiple processes.

As also observed at other Expedition 371 sites, modest oxidation of particulate organic carbon leads to production of alkalinity and NH_4^+ and removal of SO_4^{2-}. Limited dissolution of biogenic silica occurs which increases dissolved H_4SiO_4 (particularly in Unit II). Dissolved Ca increases, and Mg and K decrease downhole, suggesting reaction with silicate minerals. However, the change in Ca relative to Mg with respect to depth is much greater at Site U1511 than at other Expedition 371 sites, which probably results from reactions with underlying basalt rather than continental crust. Many species display an inflection in concentrations at ~200 m and a major drop in concentrations at ~400 m. The first change probably results from the major increase in porosity associated with diatomite; the latter change probably represents the conversion of biosilica to cristobalite and the release of water. Dissolved Mn increases slightly in the upper 80 m but sharply below 200 m, reaching an extreme of 357 μM at 421 m. Such high values suggest dissolution of Mn oxides in the lower layer of the sediment column. Ammonium concentrations are below the detection limit across the uppermost 20 m, which may indicate a deep horizon of ammonia oxidation.

Physical properties and paleomagnetic and biostratigraphic data were compiled to locate middle Eocene climate events in Hole U1511B. Interpretation of magnetic inclination and radiolarian assemblage data indicate the Middle Eocene Climatic Optimum (MECO) was recovered in sediment of Core U1511B-16R. The putative C19r event may be present in sediment of Core U1511B-18R, based on natural magnetic remanence data.