IODP Expedition 371: Tasman Frontier Subduction Initiation and Paleogene Climate

Site U1508 Summary

Background and Objectives

International Ocean Discovery Program (IODP) Site U1508 (proposed Site REIS-2A) is ~130 km west of Cape Reinga, the northern tip of Northland New Zealand. The location is on the northeast margin of Reinga Basin, which contains folded Eocene strata that have been dredged but never drilled. The site was chosen to sample a record of deformation, uplift, subsidence, and early arc volcanism in a southern region proximal to Tonga-Kermadec subduction initiation. The overall objective was to sample Miocene–Eocene strata, which includes an onlap surface that marks the onset of deformation. A high-amplitude seismic reflector near the base of the borehole has regional significance for stratigraphic correlation, and was hypothesized to represent a major change in sedimentation during the Eocene.

Operations

Hole U1508A (34°26.8902'S, 171°20.6073'E, water depth 1609 m)
Hole U1508B (34°26.8975'S, 171°20.5990'E, water depth 1609 m)
Hole U1508C (34°26.8905'S, 171°20.5889'E, water depth 1609 m)

We completed the 546 nmi transit from Site U1507 to Site U1508 (proposed Site REIS-2A) and arrived at 2300 h on 20 August. An advanced piston corer (APC)/extended core barrel (XCB) bottom-hole assembly (BHA) was made up and APC coring in Hole U1508A started at 0900 h on 21 August. Temperature measurements were taken on Cores 7H, 9H, 10H, 12H, 14H, and 17H. Core 23H had to be drilled over for 40 min to release it from the formation and Hole U1508A was ended at 1140 h on 22 August. Total recovery for the 210.3 m cored was 201.13 m (96%). The time spent on Hole U1508A was 36.0 h or 1.5 d.

The ship was offset by ~20 m to the southwest. A rotary core barrel (RCB) BHA was made up and drilling without coring in Hole U1508B started at 1745 h on 22 August, reaching the target (186.6 m DSF) at 2245 h on 22 August. Coring began with Core U1508B-2R. While retrieving Core 38R (503.4 m DSF) at 0700 h on 24 August, we stopped operations due to a medical emergency and began recovering the drill string. Cores U1508B-2R through 38R penetrated from 186.6 to 503.4 m DSF and recovered 133.32 m (42%). Time spent on Hole U1508B was 49.5 h or 2.1 d.

The 302 nmi transit to Auckland began at 1354 h on 24 August, and the trip back to Site U1508 was completed at 0600 h on 27 August. An RCB BHA was deployed and Hole U1508C was initiated ~20 m northwest of Hole U1508B at 1150 h. The top 450 m were drilled without coring, except for two spot-cored intervals, 278.0 to 292.6 m DSF (Cores U1508C-2R to 4R) and 316.0 to 330.7 m DSF (Cores 6R and 7R). At 0730 h on 28 August we resumed RCB coring until penetration rates slowed to ~2 m/h. Although short of the desired target depth, we decided to stop coring and conduct wireline logging at 0300 h on 31 August. Collectively, Cores U1508C-2R to 38R, and the two interspersed drilled intervals, penetrated from 278.0 to 704.5 m and recovered 185.04 m of sediment (65% of cored intervals).

The bit was dropped at the bottom of the hole at 0325 h on 31 August, the hole was displaced with 194 barrels of 11.0 ppg mud, and the end of the open end of the drill string was set at 86.7 m. At 0900 h we deployed the same modified triple combo logging tool string configuration as used in Hole U1507B with the exception that no source was installed in the density tool. Logging went well until ~1230 h when the tool string became stuck at ~270 m WSF (wireline depth below seafloor). The logging line was cut at the rig floor and terminated with connectors that would allow assembly of drill pipe over the logging line to wash down and over the logging tools with the open-ended BHA. After the logging tools were free at 2105 h, the tool string arrived back on the rig floor at 0315 h on 1 September. After the drill string was recovered, the ship started the transit to Site U1509 at 0730 h on 1 September.

Principal Results

Lithostratigraphy

The sedimentary sequence at Site U1508 consists of ~700 m of heterogeneous strata divided into three lithostratigraphic units (Units I, II, and III).

Unit I (0.0–90.1 m CSF-A) consists of ~90 m of foraminiferal ooze with varying amounts of nannofossils and coarse-grained bioclasts. An increase in the occurrence of millimeter-sized bioclasts comprised mainly of bryozoans starts at ~49 m and extends to the bottom of this unit. The Unit I/II boundary at 90.1 m is defined by an abrupt change from foraminiferal ooze with bioclasts to clayey nannofossil ooze with biosilica.

Unit II (90.1–379.3 m) consists of ~290 m of calcareous biogenic ooze and chalk divided into two subunits: Subunit IIA (90.1–200.6 m) is comprised of light greenish foraminiferal nannofossil ooze with varying contents of foraminifers and sponge spicules; and Subunit IIB (200.6–379.3 m) is nannofossil-rich foraminiferal ooze and chalk with lithic and volcanic grains increasing to ~336 m and then decreasing downhole, resulting in a pure foraminiferal chalk in the lowermost 30 m of the subunit.

The Unit II/III boundary at 379.3 m is identified by an abrupt downhole decrease in grain size to nannofossil chalk with varying amounts of foraminifers. Unit III (379.3–701.9 m) is composed of moderately bioturbated nannofossil chalk, which is further divided into two subunits. Subunit IIIA (379.3–491.6 m) consists of moderately to heavily bioturbated clayey nannofossil chalk and contains at least 50 sporadic centimeter-scale siliceous intervals (cherty limestone). Subunit IIIB (493.8–701.9 m) is characterized by a downhole decrease in clay content and color brightening, with cherty limestone nodules last observed at ~503 m. Subunit IIIB is comprised of nannofossil chalk, and from ~685 m downhole it is sufficiently lithified to be classified as a nannofossil limestone.

Biostratigraphy and Paleoenvironment

Calcareous nannofossils are abundant in most of the studied samples. Planktic foraminifera dominate over benthic foraminifera, which are present in most samples. Radiolarians are few to rare in most samples, barren in some samples from Holes U1508A and U1508B, and abundant in the lower half of Hole U1508A. Ostracods are barren to abundant. Preservation of all fossil groups decreases downhole, ranging from excellent to good in the upper part of Hole U1508A, to poor to moderate in Hole U1508C.

Calcareous nannofossil and planktic foraminiferal datums, occasionally supplemented by radiolarian biostratigraphy, allow age assignments to all studied samples. Lithostratigraphic Unit I is Pleistocene–Pliocene in age. The interval between 96 and 210 m, nearly coincident with Lithostratigraphic Subunit IIA, is Miocene. Samples between 187 and 373 m are Miocene to Oligocene in age. Nannofossil biostratigraphy points to an early Miocene to late Oligocene hiatus (Zones NN4 to NN1) of ~6 My in both Holes U1508B (312–321 m) and U1508C (316–321 m). The interval 379 to 497 m in Hole U1508B is late to middle Eocene. In Hole U1508C, the interval 450 to 480 m is late Eocene and the interval 484 to 686 m is middle Eocene. Nannofossil, planktic foraminifera and radiolaria indicate an early Eocene age near the bottom of the sequence (686–702 m). Age-diagnostic dinocyst species corroborate the age constraints determined by nannofossils and planktic foraminifera.

Benthic microfossils (ostracoda and foraminifera) indicate a bathyal paleoenvironment throughout the sedimentary sequence. Palynological assemblages contain moderately- to well-preserved palynomorphs, predominantly inner neritic to pelagic dinocysts. Terrestrial palynomorph content is much higher in the Pliocene to late Oligocene than in the early Oligocene to Eocene, indicating a significant change in offshore transport. Reworked microfossils, in particular of early Paleogene age, commonly occur downhole from the mid-Miocene in all fossil groups.

Paleomagnetism

Pass-through paleomagnetic measurements from Unit I (0–90 m) are affected by core disturbance and have extremely weak magnetization (~10^{-5} to 10^{-3} A/m), resulting in random natural remanent magnetization (NRM) inclinations. NRM inclinations in Subunit IIA (~90–210 m) after 20 mT alternating field (AF) cleaning show a series of swings between positive and negative values, but without a clear polarity pattern. In contrast, high quality paleomagnetic data were obtained from Subunit IIB, from ~250 to 380 m, with well-defined geomagnetic reversals and bimodal inclination clustering. This interval is also characterized by higher NRM intensity, mostly ~10^{-2} A/m. From lithostratigraphic Subunit IIB to Unit III, the NRM intensity drops to ~10^{-4} to 10^{-3} A/m, resulting in poor paleomagnetic behavior for many cores. Reliable paleomagnetic data were obtained from some intervals in Hole U1508C, including 278–324 m and ~650–700 m. Integration with biostratigraphy allows series of paleomagnetic reversals in Holes U1508B and U1508C (Subunit IIB and Unit III) to be correlated with the geomagnetic polarity timescale (GPTS) back to ~48 Ma.

Samples from Hole U1508A have a poorly defined orientation of anisotropy of magnetic susceptibility (AMS) tensor, whereas most samples from Holes U1508B and U1508C exhibit a well-defined oblate AMS fabric with the minimum axis of the AMS ellipsoids statistically oriented perpendicular to the bedding plane.

Petrophysics

Variations in physical properties define three distinctive boundaries at ~90 m, ~200 m and ~500 m, and are correlated with two strong reflections on multichannel seismic data and three lithostratigraphic boundaries. The upper interval that corresponds to Lithostratigraphic Unit I is characterized by low density of ~1.5 g/cm^3, high porosity of ~65%–75%, and increasing velocity from ~1500 to ~1700 m/s. All of these values show a baseline shift at the Unit I/II boundary (~90 m) to higher bulk density values (~1.65 g/cm^3), lower porosity values (~60%–65%), and lower velocity values (~1600 m/s), which remain constant throughout Subunit IIA down to ~200 m. Within the uppermost part of Subunit IIB (~200–250 m), where the ooze to chalk transition occurs, bulk density drops from ~1.75 to ~1.55 g/cm^3, porosity increases from ~60% to ~70%, and shear strength drops from ~100 kPa to ~30 kPa, while *P*-wave velocity increases from ~1600 to 1900 m/s. Below 500 m, bulk density gradually increases from 2.0 to 2.3 g/cm^3, porosity gradually decreases to ~25%, and *P*-wave velocity increases from ~2200 to 2600 m/s. At the very base of Subunit IIIB where the transition from chalk to limestone occurs (680–700 m), velocity and bulk density sharply increase to ~3600 m/s and 2.45 g/cm^3, respectively.

Natural gamma radiation (NGR) and color reflectance data reveal complementary trends to the density, porosity, and velocity measurements, including the three distinctive boundaries at ~90 m, ~200 m, and ~500 m. NGR increases and the color changes at ~90 m. NGR decreases and then increases around ~200 m. Magnetic susceptibility from wireline logging and core measurements are low throughout the entire section, except for the interval ~240 m to ~380 m (Subunit IIB), which contains lithic constituents. This interval also has higher amplitude (up to ~20 counts/s) NGR variations.

Five in situ temperature measurements in Hole U1508A revealed a gradient of ~55°C/km.

Geochemistry

Headspace gas samples were routinely collected from each core at Site U1508. Methane was detected in samples from ~460 m downhole in Hole U1508B and from ~490 m to the bottom of Hole U1508C. Small amounts of ethane were detected near the base of Hole U1508C.

A total of 75 interstitial water samples were collected from Site U1508 by three different methods: whole-round squeezing, rhizon sampling, and half-round squeezing. The latter were ~15 cm intervals taken from core working halves 1–2 d after recovery and crushed in plastic bags. These half-round samples yield reasonable results for some dissolved species, notably sulfate, but not for others. Rhizon results generally lie close to those from squeezed samples at nearby depths. The manganese concentration profile does not show a peak within the uppermost meter or so, which suggests the true mudline is missing. Adjacent samples from the upper ~100 m of section show large variance because the sediment is unconsolidated foraminiferal sand, which makes collection of uncontaminated pore water difficult. Nonetheless, most constituents do not vary much in concentration over the uppermost 275 m. Below 275 m, sulfate concentrations decrease downhole linearly, and concentrations of ammonium, barium, and strontium increase linearly or exponentially. The concomitant loss of sulfate and rise in methane at ~500 m suggests a deep zone of oxidation of methane coupled to sulfate reduction, which may explain the abundant macroscopic pyrite at this depth interval.

Bulk sediment carbonate content varies considerably with depth, having 100 m scale fluctuations between highs of ~95 wt% and lows of ~40 wt%, which relate to the lithostratigraphic units. TOC contents are 0.76 ± 0.36 wt%, without any consistent downhole trend.

Stratigraphic Correlation

NGR records were used to tie the base of Hole U1508A to Hole U1508B (one tie point) and the base of Hole U1508B to Hole U1508C (three tie points). These tie points are further supported by calcareous nannofossil data, reflectance data (L*, a*, b*), and core images. No core composite depth scale was established based on these correlations.

All cores from Holes U1508A, U1508B, and U1508C were correlated to the downhole logging wireline matched depth below seafloor (WMSF) using one tie per core. An offset table allows users to approximate depths of core data at the CSF-A scale to the WMSF depth scale of the downhole logging data.

Age model and sedimentation rate

Linear sedimentation rates (LSRs) were calculated for Site U1508 using calcareous nannofossil datums and polarity chron boundaries on the CSF-A depth scale from 0 to 48 Ma. LSRs in the Pliocene–Pleistocene vary between ~10 and 80 m/My, and average ~20 m/My during the early to late Miocene. The succession is condensed for most of the Oligocene despite a short interval from 23 to 26 Ma. LSRs for the late to middle Eocene are steady ~20 m/My.