IODP Expedition 375: Hikurangi Subduction Margin

Site U1526 Summary

Background and Objectives

The primary objective of drilling at Site U1526 was to sample the thin sediment section (~30 m) and ~100–150 m of underlying volcaniclastics or basement on the western flank of Tūranganui Knoll seamount, at 2908 m water depth. The scientific aim of coring was to characterize the seamount's composition, physical properties, extent of alteration and hydration, and structure and hydrogeology prior to transport into the slow slip event (SSE) source region. Seismic imaging shows that subducted seamounts are present in the source region of SSEs along the drilling transect, and that they may represent barriers to SSE propagation, as well as potentially be related to the location of historical tsunami earthquakes. Priorities for postexpedition analysis of cores include measurement of the mechanical, elastic, frictional, and hydrological properties of the incoming sediment and basement, along with detailed analyses of composition and alteration.

Operations

Transit to Site U1526

The vessel arrived at Site U1526 (proposed Site HSM-08A) located on Tūranganui Knoll at 1700 h (UTC + 12 h) on 22 April 2018. Upon arrival, the thrusters were lowered and the dynamic positioning (DP) system was engaged.

Hole U1526A

A rotary core barrel (RCB) bottom-hole assembly was assembled and the drill string was lowered to the seafloor. Hole U1526A (39°1.3203′S, 179°14.7594′E, 2890.1 m below sea level [mbsl]) was started at 0150 h on 23 April 2018. Cores 1R to 14R advanced from 0 to 83.6 m and recovered 29.26 m (35%). Nonmagnetic core barrels were used for all RCB cores. The time spent at Hole U1526A was 2.13 d. At the completion of coring, the drill was partially raised and the ship started moving toward nearby Site U1520 in DP mode.

Hole U1526B

Following an 8 h transit from Site U1520 in DP mode, the ship was offset 20 m to the west–northwest from Hole U1526A, and Hole U1526B (39°1.3146′S, 179°14.7481′E, 2888.4 mbsl) was started at 2015 h on 2 May 2018. Advanced piston corer (APC) Cores 1H to 4H and extended core barrel (XCB) Core 5X advanced from 0 to 33.5 m and recovered 31.56 m (94%).

Nonmagnetic core barrels were used for all APC cores. The *JOIDES Resolution* started the transit to Auckland at 1200 h on 3 May.

Principal Results

Lithostratigraphy

We identified two lithologic units at Site U1526. Unit I is characterized by fine-grained mixed sediment (i.e., siliciclastic-calcareous) to biocalcareous sediment. Unit II comprises volcaniclastics. Unit I extends from 0 to 30.23 m below seafloor (mbsf) and is composed of mud, calcareous mud, and nannofossil-rich ooze. The upper greenish gray mud contains foraminifer-rich silt and ash layers. Between 26.91 and 30.23 mbsf, the lithology changes from greenish gray mud to light green calcareous mud with nannofossils and then to whitish-brown nannofossil ooze. Unit I ranges from Holocene to Late Cretaceous.

The boundary between Units I and II at 30.23 mbsf is characterized by a 20 cm interval rich in manganese concretions. Unit II is Cretaceous in age. Below the manganese-rich layer, we observe a volcaniclastic sandstone to conglomerate with variably altered basalt clasts in a sand-sized matrix composed of shell and basalt fragments. The top of the volcaniclastic conglomerate is characterized by abundant intact shells. Due to the sharp contact between the dramatically different lithofacies of Units I and II, the presence of the manganese crust at the top of Unit II, and the Cretaceous macrofossils found in the volcaniclastic conglomerate, we interpret this boundary as an unconformity. Below the shell-rich layer, basalt clasts generally range from centimeter to decimeter scale, with some basalt intervals extending for 1–2 m.

Biostratigraphy

The sedimentary succession cored at Site U1526 ranges in age from Holocene to Late Cretaceous. High foraminiferal abundances and good preservation were observed throughout the upper sedimentary cover (lithologic Unit I). Below this, within lithologic Unit II, volcaniclastic coarse sandstones and conglomerates were barren of microfossils, although macroinvertebrate remains provided broad biostratigraphic and paleowater depth constraint.

Planktonic foraminifers and calcareous nannofossils indicate that Holes U1526A and U1526B recovered a succession of Holocene (<0.009 Ma) and Pleistocene (0.44–2.17 Ma) sediments from 0.07 to 19.95 mbsf, overlying late Miocene (5.33–5.44 Ma) sediments from 20.47–21.07 mbsf, and Late Cretaceous (~66–74 Ma) sediments observed at a depth 30.20 mbsf. Planktonic foraminifer abundances and benthic foraminifer assemblages throughout Unit I are indicative of open oceanic settings and mid to lower bathyal water depths (>600 m), respectively. Macroinvertebrate remains in Unit II are consistent with Late Cretaceous shallow water bioclastic material transported downslope.

The underlying volcaniclastic section recovered in Hole U1526A (29.1–81.39 mbsf) was generally barren of microfossil remains; however, a coarse sand-size volcaniclastic sandstone to conglomerate in the upper portion (29.1–38.8 mbsf) of Unit II contained abundant bivalve shells. Below this interval, large subrounded to subangular pebbles and boulders of variably altered to fresh basalt are embedded in a coarse volcaniclastic sand matrix, which contains remobilized shell material, echinoid spines, and coralline algae.

Paleomagnetism

Paleomagnetic investigations at Site U1526 focused on (1) producing a preliminary magnetostratigraphy for the sedimentary cover sequence sampled in Hole U1526B, (2) resolving remanence intensities and demagnetization behavior of volcaniclastic material recovered below 24 mbsf, (3) providing constraints on the emplacement temperatures of the volcaniclastic material, and (4) exploring the possibility that in situ lava flows are present. Analyses included the continuous measurement of the natural remanent magnetization (NRM) of archive-half sections prior to and following alternating field (AF) demagnetization. An additional 14 discrete samples from individual basaltic clasts were subjected to thermal demagnetization experiments.

The pelagic sediments from Hole U1526B yield NRM in the range of ~0.005 to 0.5 A/m that decay rapidly during the removal of a steep drilling overprint. Following AF treatment to 10 or 20 mT, inclination records display a well-defined pattern with multiple switches from negative (normal polarity) to positive (reversed polarity) inclinations characterized by sharp transitions.

The NRM of the volcaniclastic materials in lithostratigraphic Unit II ranges from ~0.2 to 13.0 A/m. The NRM directions have inclinations that usually differ from clast to clast, suggesting that the clastic material was emplaced in the deposit at ambient ("cold") temperatures. Characteristic remanent magnetization directions from discrete samples are coherent with the directions measured on the archive-half sections. Samples generally yield high quality demagnetization behavior and primarily demagnetize in the blocking temperature range 250° to 350°C, suggesting that titanomagnetite is the main remanence carrier.

Basalts recovered between 57.2 and 64.8 mbsf yield consistent steep and negative NRM inclinations similar to the inclination of a ~1.5 m long and mostly intact piece of basalt recovered between 24.6 and 26.03 mbsf. This leads to the possibility that in situ lava flows may be present, although heavily fractured, in the sequence.

Structural Geology

Bedding planes are difficult to resolve throughout the cored interval at Site U1526, although local distinctive sedimentary structures are noted. Brecciated clasts are scattered throughout, exhibiting possible shear fabrics. Fractures and veins are the most common structural features, and are observed within both clasts and matrix. Both fracture-filled and diffuse veins are present in the volcaniclastic deposits. We define two distinct structural domains at this site. Domain 1

contains fine-grained sediments with no veins. Domain 2 contains volcaniclastic sediments and basalt, and is distinguished by varying degrees of cementation and veining throughout.

Geochemistry

The main objective of the inorganic geochemistry program at Site U1526 is to identify diagenetic reactions and to evaluate the possibility of vertical recharge of seawater through the Turanganui Knoll seamount. A total of 11 routine pore water whole-round (WR) samples were collected from APC cores in Hole U1526B, and squeezed for shipboard and shore-based pore water chemical analyses. All samples were thoroughly cleaned in an effort to remove drilling fluid contamination, and then pressed in titanium squeezers at gauge forces up to a maximum of 30,000 lb. The volume of recovered pore water varied with lithology, and depth, and ranged between 15–58 ml. The geochemical profiles at Site U1526 reflect the combined effects of early organic matter diagenesis and carbonate/silicate mineral diagenesis. There is a sharp gradient in the profiles of many solutes approaching the volcaniclastic sediments of Unit II to a modified fluid composition similar to that of the volcaniclastic unit (Unit V) at Site U1520.

Hydrocarbon gases were not detected at Site U1526. Calcium carbonate ($CaCO_3$) in lithologic Unit I (0–29.1 mbsf), which consists of fine-grained mixed to biocalcareous sediment, exhibits a large degree of scatter (ranging from 1.26 to 69.99 wt%). The calcium carbonate content increases with depth and reaches its highest value of 69.99 wt% at 21 mbsf, which corresponds to nannofossil-rich ooze. In lithologic Unit II (29.1–81.39 mbsf), which is composed of coarse volcaniclastic sandstone and volcaniclastic conglomerate, $CaCO_3$ concentrations also exhibit a large degree of scatter and range between 0.25 to 68.30 wt%. The highest value (68.30 wt%) is indicative of incorporation of bivalve shells and calcite cement in the shell-rich bed at the top of the volcaniclastic sequence. Organic carbon values are low in Units I and II (ranging from 0.00 to 0.61 wt%). The highest values are above 21 mbsf and correspond to calcareous mud. The carbon/nitrogen ratios range from 20.89 (possibly due to a terrestrial influence of organic matter) to 190.91 due to a low nitrogen value.

Physical Properties

Porosity values are 62%–68% between the seafloor and 21 mbsf in lithologic Unit I. Porosity decreases abruptly to 18% at ~30 mbsf at the top of Unit II. From 39 mbsf to the bottom of Hole U1526A in lithologic Unit II, porosity values exhibit large scatter (2%–44%) and average 20% with no significant downhole trend. In Unit I (between 0 and 30 mbsf), *P*-wave velocity ranges from 1450 to 1570 m/s. Below 30 mbsf in Unit II, *P*-wave velocity ranges from 1700 to ~6000 m/s, with significant scatter arising from the heterogeneous nature of the conglomerates and basalt. Thermal conductivity values range between 1.2 and 1.6 W/(m·K) and have a mean value of 1.5 W/(m·K). Undrained shear strength increases with depth, ranging from 0 to ~100 kPa between 0 and 30 mbsf. Natural gamma radiation (NGR) values within lithologic Unit I mostly range between 20 and 40 counts/s, except for lower values of 2–8 counts/s between 27 and 30 mbsf where nannofossil-rich ooze is present. NGR values within Unit II increase from

~29 counts/s at the top of the unit to ~36 counts/s at ~50 mbsf, and then decrease gradually to 27 counts/s at the bottom of the cored interval. Magnetic susceptibility (MS) mostly ranges from 10×10^{-5} to 200×10^{-5} SI in Unit I, above ~30 mbsf. Below this, MS ranges from $\sim 100 \times 10^{-5}$ to 3000×10^{-5} SI, with an average value of $\sim 1400 \times 10^{-5}$ SI.

Core-Log-Seismic Integration

Core-based observations and measurements from Hole U1526A and U1526B were integrated with seismic reflection data from Tūranganui Knoll. In the absence of logging data, we used *P*-wave velocity and density measurements from cores to construct a lithological model and produce a seismic-well tie. Measurements of *P*-wave velocity in the pelagic sediments of Hole U1526B indicate the velocities in this interval are low, typically ranging from ~1500 to 1530 m/s. This is consistent with a strong reflection at the base of lithologic Unit I that separates the pelagic sediments from the cemented volcaniclastic sandstones below. In order to depth convert the seismic data below Unit I, we used a mean *P*-wave velocity of 3805 m/s from laboratory measurements on core samples.

Two seismic units are identified at Site U1526. Seismic Unit 1 corresponds to lithostratigraphic Unit I and is represented by a weakly reflective interval that is 30.2 m thick at Hole U1526B. However, the thickness varies significantly away from the site, reaching thicknesses of over 140 m elsewhere on Tūranganui Knoll. Cores show that seismic Unit 1 (0–30.2 mbsf) comprises predominantly light greenish gray calcareous mudstone over brownish white nannofossil-rich ooze, with thin layers of volcanic ash, and represents a highly condensed section that spans from Holocene to Cretaceous. Seismic Unit 2 corresponds to lithostratigraphic Unit II and represents the lower 44 m drilled at Hole U1526A, but extends below the depth of drilling. The upper part of the unit is strongly reflective, comprising planar to irregular, discontinuous high-amplitude reflections. Cores show that seismic Unit 2 comprises large, subrounded to subangular pebbles and boulders of variably altered to fresh basalt embedded in a heavily cemented coarse-grained volcaniclastic sand matrix.