IODP Expedition 372: Creeping Gas Hydrate Slides and Hikurangi LWD

Site U1520 Summary

Background and Objectives

Site U1520 (proposed Site HSM-05A) is located on the floor of the Hikurangi Trough between the deformation front and the Tūranganui Knoll. The site lies ~95 km from shore and 16 km east of the deformation front at 3521 m water depth. The seafloor in this location is a flat turbidite plain underlain by ~1 km of sediment overlying the inferred volcanic rocks of the Hikurangi Plateau. This sequence of sedimentary and volcanic rocks collectively represents the "inputs" to the subduction zone. The cover sedimentary sequence in this area is condensed relative to southern Hikurangi Margin, where up to 9 km of total sedimentary section, including 6 km of Miocene to recent turbidites, overlies the plateau.

Regional bathymetric data show that the Tūranganui Knoll is one of numerous seamounts that characterize the northern Hikurangi Plateau. Predrilling interpretations of regional seismic reflection lines and gravity anomaly data indicate irregular crustal relief with seamounts and ridges of various scales buried beneath the sedimentary sections. At the deformation front west of Site U1520, practically the entire sedimentary cover sequence is accreting, with the plate interface décollement located close to the top of the plateau volcanics.

The primary objective at Site U1520 was to acquire logging-while-drilling (LWD) data to 1200 m to constrain the accreting sequence and upper part of the subducting volcanic section. This site is the first ever drilling in the Hikurangi Trough. Through the correlation of the sequences away from the site to the deformation front using seismic sections, it was expected that the LWD data would provide insight into the lithologies and conditions at the subduction plate interface where slow slip earthquake events (SSEs) are believed to occur close the trench. The site was intentionally located adjacent to Tūranganui Knoll, where the turbidite trench section is relatively condensed compared to the area closer to the deformation front. In addition to LWD data we acquired at Site U1520, the site will be cored during Expedition 375.

Site-specific objectives include the following:

- Characterize the lithological composition and geophysical properties of the Hikurangi Trough inputs sequence to provide insights into possible interplate thrust fault zone and host rock properties. This includes formation density, resistivity, porosity, natural gamma radiation, and sonic velocities.
- Identify the distribution and density of fractures visible in borehole images to evaluate the deformation and stress state of the input section east of the deformation front at subseismic scale.

- Identify the present maximum and minimum stress orientations from borehole breakouts and compare these with data from the other sites to evaluate regional variations in contemporary stress across the margin.
- Cores collected during Expedition 375 will provide additional information on lithology, porosity, permeability, density, meso- and micro-scale structure, shear strength, age, thermal conductivity, natural gamma radiation, sonic velocities, and geochemical compositions of present and past pore fluid, and information of sediment source and depositional process. Pore fluid analysis of samples will help to evaluate the source of fluids, while geotechnical measurements undertaken on core samples will provide information on fault-zone formation permeability, consolidation state, frictional properties and strength. The combined LWD and core data will enable the refined depth conversion of the existing 2-D and planned 3-D seismic data. They will also extend knowledge of in situ conditions (stress, fault zone properties, and pore pressure) away from the boreholes over a much broader region.

Overall, these objectives will constrain (1) the composition and frictional properties of subduction inputs and the shallow plate interface, (2) the hydrologic and thermal conditions of the incoming plate and shallow fault, and (3) the structural character, stress conditions, and mechanical properties of the main active thrust and subduction inputs.

Operations

Site U1520 (38°58.16′S, 179°7.93′E; water depth 3520 mbsl) consisted of two LWD holes that were drilled to 97.9 and 750 m. The total time spent at Site U1520 was 2.9 d, including 45.8 h spent waiting for severe weather to subside.

Hole U1520A

The vessel arrived at Site U1520 at 1302 h (UTC + 13 h) on 26 December. The 210.30 m long LWD bottom-hole assembly (BHA) was assembled, including the geoVISION, NeoScope, StethoScope, TeleScope, SonicScope, and proVISION tools. Hole U1520A began at 0845 h on 27 December. The weather and sea conditions began to deteriorate and the drill string had to be pulled out of Hole U1520A after reaching only 97.9 m. Hole U1520A ended when the bit cleared the seafloor at 1410 h on 27 December.

Hole U1520B

The vessel waited on the weather to clear for 45.75 h (1.91 d). During this time the ship was offset 20 m to the northwest of Hole U1520A. Hole U1520B began at 1245 h on 29 December. The hole was washed down to a depth of 80 m and LWD measurements were taken from 80 to 750 m. After reaching the total depth of 750 m at 0430 h on 31 December, the hole was cleaned with mud and the drill string was pulled out of the hole. The bit cleared the seafloor at 0715 h and the rig floor at 1930 h. The LWD tools were broken down and the vessel began the 32 nmi transit to Site U1517 at 1954 h, ending Site U1520.

Principal Results

Logging While Drilling

Six LWD tools were deployed in Holes U1520A and U1520B to constrain the stratigraphic architecture of the sedimentary section entering the Hikurangi convergent margin. Nine logging units were identified in Hole U1520B, reflecting significant changes in the sediment physical properties recorded by the logs. Major reflectors in the seismic reflection data were also used to help define these logging units. The uppermost 100 m are interpreted to be coarse sediments that represent turbidite deposits. These overlie ~110 m of finer sediments that are interpreted as belonging to the Ruatoria mass transport deposits (MTD). The sediments beneath the Ruatoria MTD comprise both fine and coarser grained sedimentary packages that show progressive compaction with depth down to a boundary at around 510 m. This boundary marks a change to sediments that have a different acoustic character, and have markedly lower gamma ray. Several units with distinct logging character are identified down to the base of the hole at 750 m. Although the logs do not enable the direct identification of the rock type, the petrophysical characteristics and the tie to seismic reflectivity would indicate that the pelagic sequence overlying the Gisborne Knoll was reached by drilling. Owing to generally poor hole conditions and a fast rate of penetration, the image logs are of poor quality through much of the drilled section, but dipping beds were identified in many of the logging units. Above ~510 m, there appears to be little or no organization in the pattern of dip inclination or azimuth, attesting to the chaotic nature of the MTDs. In the underlying sequence the bedding dips are most commonly at low angles to the east or northeast. Several high angle resistive fractures were identified in the sediments between 660–710 m in Hole U1520B.

Log-Seismic Integration

The seismic data available for Site U1520 allows for correlation with the LWD data. The upper 406 m are characterized by generally low seismic amplitudes. The Ruatoria MTD, buried under 102 m of sediment, stands out as a 126 m thick package composed of chaotic and mottled reflections. The sequences below 406 m are characterized by markedly higher amplitudes associated with turbidite deposits. Towards the bottom of the well there is an increasing occurrence of disturbed high amplitude reflections. The basin-filling strata generally onlaps a low amplitude package with chaotic reflections located along the flank of the Tūranganui Knoll. Seven seismic-stratigraphic units have been defined based on the reflection geometry and amplitude patterns. Several of the unit interfaces correspond to either erosion by landslides or to regional unconformities. At this site there is a very good correlation between the LWD logging units and the seismic-stratigraphic units. Density, gamma ray, and resistivity curves show pronounced shifts in their curve trends at depths concordant with seismic unit boundaries. Synthetic seismograms produced from the density and velocity logs generally show good correlations with the seismic data analyzed.