IODP Expedition 372: Creeping Gas Hydrate Slides and Hikurangi LWD

Site U1518 Summary

Background and Objectives

Site U1518 (proposed Site HSM-15A) is located on the lower continental slope, ~62 km from shore. The site lies on the frontal accretionary wedge, ~6.5 km west of the deformation front, at 2636 m water depth. Site U1518 targeted a major west-dipping thrust fault that ramps from the interplate thrust and reaches the seafloor along an escarpment about 500–1000 m east of the drilling site. The geological and contemporary rate of activity on the thrust has not yet been established, but predrilling estimates suggest it may accommodate a significant proportion of the plate convergence across the margin. Seafloor geodetic data indicate that slow slip earthquake events (SSEs) on the interplate thrust extend offshore (trenchward) into the vicinity of Site U1518.

The primary objective at Site U1518 was to acquire logging-while-drilling (LWD) data to help characterize the structure and location of the shallow part of the fault and the nature of the sedimentary sequences that host it. These data will be integrated with cores collected at Site U1518 during Expedition 375, which will be used to identify suitable formations and fault rock for hosting a borehole observatory that will be installed during Expedition 375. With very shallow SSEs on this northern segment of the Hikurangi Margin recurring every 1.5–2.0 y, it is anticipated that the borehole observatory will record pressure, temperature, and fluid flow transients associated with SSE-propagated strains within the frontal accretionary wedge.

Based on predrilling interpretation of the seismic data at Site U1518, the thrust fault was expected to lie between 295 and 325 m. The hanging wall sequence (i.e., the sediment above the fault) was expected to include 65–82 m of moderately reflective sediment, overlying a relative weakly reflective interval characterized by irregular reflections, and assumed to be Pliocene to Pleistocene in age. The hanging wall sequence dips easterly, within the forelimb of an anticlinal fold associated with the thrust fault. The footwall sequence (i.e., below the fault) down to the 600 m target drilling depth was expected to include a relatively strongly reflective interval about 145–180 m thick immediately below the fault that overlies a relative weakly reflective lower sequence. The entire footwall sequence drilled has a westerly dip on the seismic profile. The entire borehole was expected to encounter predominantly tectonically accreted muddy and sandy lithologies, including turbidites.

Site specific objectives include the following:

- Identify the location of the primary thrust fault, including the distribution and density of fractures visible in borehole images, and any associated structure that can be inferred from bedding dips. These data will help to constrain fracture permeability, as well as kinematic models of thrust and fold development.

- Characterize the lithological composition and geophysical properties of the footwall and hanging wall sedimentary sequences including their density, resistivity, porosity, natural gamma radiation, sonic velocities, consolidation state, and gas hydrate content.
- Acquire downhole temperature data that will inform interpretations of future borehole observatory measurements, and help to constrain the loci of thermally driven dehydration reactions and their relationship to SSE source regions.
- Identify the present maximum and minimum stress orientations from borehole breakouts. In combination with rock physical properties data, these data will be used to constrain stress magnitudes that may reflect variations in absolute strength of the plate boundary fault.
- When core is collected on Expedition 375, they will provide additional information on meso- and microscale structure, lithology, porosity, permeability, density, shear strength, age, thermal conductivity, natural gamma radiation, sonic velocities, and geochemical compositions of present and past pore fluid. Pore fluid analysis of samples will help to evaluate the source of fluids above and surrounding the region of SSE, while geotechnical measurements undertaken on core samples will provide information on fault and host formation permeability, consolidation state, frictional properties, and strength.

Operations

Site U1518

Site U1518 (38°51.54′S, 178°53.76′E; water depth 2636 mbsl) consisted of two LWD holes that were drilled to 117.8 and 600 m. The total time spent at Site U1518 was 3.4 d with 21 h of that time spent waiting on weather.

Hole U1518A

The vessel arrived at Site U1518 at 1635 h on 19 December after a 20 nmi transit from Site U1517. The LWD tool string for Site U1518 contained the geoVISION, NeoScope, StethoScope, TeleScope, SonicScope, and proVISION tools.

The LWD tools and drill string were run to a depth of 2460 mbsl and the subsea camera was deployed to determine the depth of the seafloor. Hole U1518A began at 0855 h on 20 December. Weather conditions and sea state deteriorated over the next few hours and the logging tools had to be pulled out of the hole at 1605 h, ending Hole U1518A. LWD data was collected from 0 to 117.8 m. The ship began waiting on weather and was offset 20 m to the southeast of Hole U1518A.

Hole U1518B

At 1310 h on 21 December, an attempt was made to begin Hole U1518B; however, the sea conditions were still too rough and prevented the start of the hole. After an additional 3 h of waiting on weather, Hole U1518B successfully began at 1600 h. In total, 21 h were spent waiting on weather. LWD operations continued to a depth of 372.7 m. After logging a portion of the thrust fault zone, the tools were pulled up to 334.7 m. Three pore pressure measurements were attempted using the StethoScope tool, all with poor results. The tools were then pulled up to 234.0 m to try three additional StethoScope measurements; these were unsuccessful as well. The tools were lowered back to the bottom of the hole, a mud sweep was used to clean the hole, and the tools were advanced to 372.7 m. LWD continued to a total depth of 600 m. After finishing the hole, mud was circulated to clean out the hole. The LWD tools and drill string were pulled out of the hole with the bit clearing the seafloor at 1825 h on 23 December. The ship was secured for transit at 0257 h on 24 December, ending Site U1518.

Principal Results

Logging While Drilling

Six LWD tools were deployed on the bottom-hole assembly while drilling Holes U1518A and U1518B, providing both real-time and recorded mode data through the northern Hikurangi Subduction Margin. Based on the LWD measurements, six main logging units were identified and were further divided into subunits based upon the observed LWD physical property characteristics of the formation. Numerous significant features were interpreted from the logs, such as the thrust fault zone and associated sand/silt units. The fault plane at ~320 m is more resistive than the background sediment. The hanging wall of the thrust fault is characterized by high V_p and V_s and the footwall is characterized by lower velocities. The contact between the hanging wall and footwall of the thrust fault is characterized by a porosity inversion. Fractures and borehole breakouts are observed in the resistivity images. The StethoScope tool was deployed six times at two stations to conduct formation pressure measurements; however, none of the runs was successful as the tool was unable to make a seal with the borehole wall.

Log-Seismic Integration

LWD measurements of Site U1518 were integrated with seismic line 05CM04 that crosses the site at CDP4319. Five seismic units (SU) defined from reflection characteristics were correlated with logging units through a time-depth relationship derived from the high quality LWD sonic V_p data. Of particular interest, the ~70 m thick, highly reflective SU3 (300–370 m) encompasses the major thrust and the rock units in the hanging wall and footwall directly adjacent to the fault trace. The strong reflections in this SU are likely caused by the large impedance variations among condensed units, the likely fluid-rich units, and units with increased bed thickness and coarser sediments.