IODP Expedition 344: Costa Rica Seismogenesis Project (CRISP-A2)
Site U1412 Summary

Background and Objectives

The primary objective of Expedition 344 is to sample and quantify the material comprising the seismogenic zone of an erosive subduction margin. Site U1412 (proposed Site CRIS-9A, located on seismic line BGR99-7) targeted the frontal sedimentary prism at the base of the slope near the toe, the main subduction thrust, the underthrust sedimentary section beneath the subduction thrust and the upper oceanic crust. The scientific objectives were to (1) characterize the frontal sedimentary prism by documenting its lithology and age; (2) sample the décollement at a shallow depth to define the deformation style, stress, fault friction and behavior; (3) characterize any diagenetic processes, microstructures, and potential sealing/healing processes; (4) characterize the physical properties of the subducting incoming and frontal prism sediments that are thought to mix with eroded upper plate material; and (5) determine the chemistry of pore waters within the wedge, décollement, and underthrust sections and characterize the fluid pathways.

Principal Results

After a 7.0-nmi transit from Site U1380, the vessel stabilized over Site U1412 at 0200 h on 14 November 2012 (all times in this report are ship local time which is UTC – 6). The original operations plan for Site U1412 (proposed Site CRIS-9A) called for two holes, an APC/XCB hole to a depth of ~500 mbsf and an RCB hole to a depth of 980 mbsf. Eventually, four holes were cored at this site. Coring conditions at this site were extremely difficult with below average recovery and all four cored holes were abandoned short of the targeted depths because of poor hole conditions. Hole U1412A (8°29.3294'N, 84°7.6686'W, 1921 m water depth) was spudded at 1520 h on 14 November. This was an APC/XCB hole to a depth of 200.3 mbsf. APCT-3 formation temperature measurements were taken with Cores 3H, 5H, 7H, and 8H. The FlexIt orientation tool was deployed with Cores 1H through 15H. Core U1412A-25X reached 200.3 mbsf before the hole became too unstable to continue coring. The vessel was offset 350 m in a south-southwest direction in an attempt to find a more favorable coring location. Hole U1412B (8°29.1599'N, 84°7.7512'W, 1965 m water depth) was spudded at 2350 h on 16 November. This hole was drilled without

recovery to 149.1 mbsf and Core U1412B-20X reached 304.3 mbsf before deteriorating hole conditions forced us to stop coring. Logging with the triple combo tool string was attempted on 20 November but the tools could not exit the BHA and the drill string became stuck. After freeing the drill string, the logging tools were laid out and the hole was abandoned. Because this hole did not reach the depth objective, a third hole was attempted 50 m to the northeast. Hole U1412C (8°29.1700'N, 84°7.7467'W, 1965 m water depth) was spudded at 0730 h on 21 November. This hole was drilled without recovery to 300 mbsf and Core U1412C-10R reached 387 mbsf. After several hours spent trying to clean the hole and getting stuck, the decision was made to abandon Hole U1412C and proceed to Site U1413. After coring objectives were completed at Site U1413, the vessel returned to Site U1412. Hole U1412D (8°29.1402'N, 84°7.7793'W, 1973 m water depth) was spudded at 0850 h on 1 December. This hole was drilled without recovery to 350.4 mbsf. We were only able to recover Cores U1412D-2R and 3R before the hole collapsed.

A total of 55 cores were recovered at the site: 16 APC cores, 28 XCB 28 cores, and 11 RCB cores. The APC cored interval was 114.9 m with 115.5 m recovered (101%), the XCB cord interval was 240.6 m with 82.8 m recovered (34%), and the RCB cored interval was 105.8 with 48.8 m recovered (46%). The overall recovery for Site U1412 was 54%. The total time spent on Site U1412 was 277.5 h or 11.56 days (60.25 h at Hole U1412A, 104.5 h at Hole U1412B, 71.25 h at Hole U1412C, and 41.5 h at Hole U1412D).

Site U1412 was drilled to investigate the lithostratigraphy and structural geology of the slope-toe sequence and the uppermost portions of the basement, as interpreted in multichannel seismic reflection data. The primary goal of this site was to penetrate the décollement and investigate the fluid flow regime within the sediments as well as the oceanic crust. Four holes were cored at Site U1412, from 0 to 108.2 mbsf with APC (Cores 344-U1412A-1H to 15H), from 108.2 to 304.3 mbsf with XCB (Cores 344-U1412A-16X to 25X and 344-U1412B-3X to 20X), from 300.0 to 387.0 mbsf with RCB (Cores 344-U1412C-1R to 10R) and finally, 50 m downslope, from 350.4 to 364.0 mbsf with RCB (Cores 344-U1412D-2R to 3R). Overall core recovery at this site was moderate (average of 59%) but became poor (<20%) toward the bottom of Holes U1412B, U1412C, and U1412D.

Three units were distinguished in the sedimentary rocks. Unit I is predominantly a dark greenish to greenish gray clay (33%) with small variations in grain size to silt (16%) and silty clay (17%), and contains seven tephra layers. This is terrigenous-influenced sediment. Unit I shows strong indications for gas expansion and gas hydrate disassociation. Unit II is a light to dark grayish brown calcareous nannofossil ooze with varying amounts of diatoms and sponge spicules. Primary sedimentary structures could not be observed due to very strong drilling disturbance. Unit III is a sequence of grayish-green clayey siltstone with minor interlayered sandstone and contains two dark grayish tephra layers. The Unit III matrix composition is dominated by terrigenous (clay) and it contains nannofossils as well as radiolarian and diatom fragments. The sediment of Hole U1412D is slightly more clayey, highly bioturbated, and shows a decrease in the biogenic components.

Nannofossil biostratigraphy indicates that the upper portion of Hole U1412A is Zone NN19 (0.4–1.89 Ma). A major change from Pleistocene to Miocene is recorded in Core U1412B-8X, consistent with the lithostratigraphic boundary between Units II and III. In Hole U1412C, Samples U1412C-2R-CC to 5R-CC are indicative of a Middle Miocene age. A major age inversion is recorded between Cores U1412B-5R and 6R, with the reappearance of Pleistocene assemblages. Benthic foraminifers are common in the upper sections of Hole U1412A and include *Uvigerina peregrina*, *U. auberiana* and *Cibicidoides pachyderma*, *Melonis affinis*, and *Cassidulina carinta*. A substantial change in foraminiferal assemblages occurs starting with Core U1412B-7X and is characterized by *Globocassidulina subglobosa*, *Cibicidoides pachyderma* var. *bathyalis*, *Hansenisca altiformis* and *Planulina renzi*. The latter species last appeared in the middle Miocene, which agrees with the nannofossil and radiolarian biostratigraphy.

Hole U1412A has subhorizontal to gently dipping bedding at the very top of the drilled section. Steeply dipping normal faults are common in the lower part of the section. Hole U1412C has steeply dipping bedding, normal and reverse faults, and intervals of brecciated sediments, in some cases with fragments where striated and polished surfaces are developed.

The upper sections of the sediment reflect changes associated with organic matter diagenesis. The sulphate-methane transition (SMT) occurs at 14.73 mbsf, and high-resolution headspace samples were collected below this depth for shore-based geomicrobiology studies. The decrease in calcium and magnesium concentrations at the SMT depth reflects precipitation of authigenic carbonates. The presence of gas hydrate in the sediment was inferred from discrete chloride anomalies and excursions to low C_1/C_{2+} ratios between 60 and 85 mbsf, consistent with observations of mousse-like texture in sediments. We observe decreasing concentrations in alkalinity, boron and magnesium, whereas calcium, barium, strontium and lithium concentrations increase with depth. There is, however, not enough resolution in the sample coverage from lithologic Units II and III to delineate in situ diagenetic reactions or fluid migration pathways. There is no significant change in the chloride values below the gas hydrate stability zone.

In general, the methane concentration increases rapidly below 14.1 mbsf, consistent with the depth of the SMT at this site. The gas composition of the headspace and void gas is consistent with a biogenic methane source. However, the decrease in the C_1/C_{2+} ratios of headspace and void gas samples to ~400 and a few occurrences of propane in Unit III point to a mixture of biogenic gas and thermogenic hydrocarbons that migrated from depth.

Bulk density values increase and porosity values decrease in the upper 30 m. Both properties remain stable to the base of Hole U1412A, with average bulk density and porosity values of 1.69 g/cm^3 and 60%, respectively. Bulk density and porosity values in Unit III show considerable variability but suggest slightly more compaction (higher bulk density and lower porosity) than at the base of Unit I. In Unit I, background magnetic susceptibility is low with some high excursions within Unit I. NGR is relatively stable throughout Unit I and higher and more scattered within Unit III. Strength increases in the upper 30 m, then remains stable until Unit III, where it is higher and more scattered. Formation factor values vary between 1.5 and 4. Thermal conductivity and *P*-wave measurements were rare and scattered due to gas disturbance. Measured *P*-wave velocities are low, varying between 1500 and 1600 m/s. Thermal conductivity ranges from 0.7 to 1.3 W/m·K. A least-squares linear fit to the downhole temperature data yields a gradient of 114°C/km.

We measured the natural remanent magnetization (NRM) of archive section halves and demagnetized them in an alternating field up to 40 mT. There are more significant variations in NRM intensity within lithostratigraphic Unit I than in Units II and III. We demagnetized 61 discrete samples to verify the section data. We recognized seven magnetozones in Hole U1412A and interpreted them to include the Brunhes Chron and the Jaramillo, Cobb Mountain, and Olduvai Subchrons. Our magnetostratigraphic data suggest extremely high sedimentation accumulation rates for Hole U1412A, similar to those found in Hole U1379C during Expedition 334.