IODP Expedition 344: Costa Rica Seismogenesis Project (CRISP-A2)
Site U1413 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 U1413 (proposed Site CRIS-13B) targeted the upper slope of the Costa Rica margin. The primary purpose of drilling Site U1413 is to determine the nature, composition, and physical properties of the slope sediment. This site is also designed as a "pilot hole" in preparation for proposed CRISP Program B deep drilling at this location. Science objectives at Site U1413 included (1) documenting the lithology and structural geology of the upper slope sequence, (2) determining the stress orientation of the margin above the seismogenic zone; and (3) constraining the fluid-flow regime and role of slope sediments in fluid flow. Documenting the periods of subsidence and uplift provides important information about the process of tectonic erosion that characterizes the Costa Rica margin. One technique for estimating the relative motion of the margin is through stratigraphic correlations of multiple sites.

Principal Results

After a 15.0-nmi transit from Site U1412, the vessel stabilized over Site U1413 at 2330 h on 23 November 2012 (all times in this report are ship local time which is UTC – 6). The original operations plan for Site U1413 (proposed Site CRIS-9A) called for two holes: an APC/XCB hole to ~600 m below seafloor (mbsf) and an RCB hole to 1430 mbsf. Eventually three holes were cored at this site. Coring conditions varied from expectations but in general were quite good. Hole U1413A (8°44.4593'N, 84°6.8095'W, 540 m water depth) was spudded at 0635 h on 24 November. This was an APC/XCB hole to 189.1 mbsf. APCT-3 formation temperature measurements were taken with Cores 3H, 5H, 6H, 7H, and 8H. The FlexIt orientation tool was deployed with Cores 1H through 18H. Hole U1413B (8°44.4593'N, 84°6.7992'W, 540 m water depth) was spudded at 0055 h on 26 November. This was a shallow hole to 25.6 mbsf drilled primarily for geochemical analyses. Hole U1413C (8°44.4482'N, 84°6.7993'W, 540 m water depth) was spudded at 0940 h on 26 November. This hole was drilled without recovery to 178.0 mbsf, was cored with the RCB system to 582.2 mbsf, and logged. Coring was terminated to allow time to complete other expedition objectives.

Three logging runs were conducted on 30 November with the triple combo, UBI (Ultrasonic Borehole Imager), and FMS (Formation MicroScanner) tool strings but because of poor hole conditions the logged interval extends only from 103 to ~187 mbsf.

A total of 71 cores were recovered at this site: 21 APC cores, 8 XCB cores, and 42 RCB cores. The APC cored interval was 166.2 m with 171.2 m recovered (103%). The XCB cored interval was 48.5 m with 43.7 m recovered (90%). The RCB cored interval was 404.2 m with 313.9 m recovered (78%). The overall recovery at Site U1413 was 85%. The total time spent on Site U1413 was 170.25 h or 7.1 days (48.5 h at Hole U1413A, 5.75 h at Hole U1413B, and 116.0 h at Hole U1413C).

Site U1413 was drilled to investigate the lithostratigraphy and structural geology of the upper slope sequence as a preliminary study for future deep riser drilling. Three holes were drilled to recover sediment and sedimentary rocks. Sediments were drilled with the APC (0 to 140.60 mbsf; Cores 344-U1413A-1H to 18H and Cores 344-U1413B-1H to 3H), XCB (140.60 to 186.91 mbsf; Cores 344-U1413A-19X to 26X), and RCB (0 to 578.84 mbsf; Cores 344-U1413C-1R to 43R) coring systems. Core recovery was excellent for Holes U1413A and U1413B with 99% and 107% recovery, respectively, and good for Hole U1413C with 78% recovery.

Three lithologic units can be distinguished in the sediments of Holes U1413A, U1413B, and U1413C, with an overall abundance of silty clay to clay (32.1%), clayey silt to sandy silt (53.3%), silty sand to sand (14.4%), and tephra (0.2%). The 44.6 m thick Unit I recovered at Holes U1413A and U1413B is dominated by a dark greenish gray silty clay with multiple centimeter-sized turbidite sequences of fine-sand laminae. A slump/slide event was identified in the uppermost ~3.5 m of this unit. The lithology changed into a brownish green chaotic mixture of silty clay and dark gray sands in the lowermost part of Core U1413A-5H. Ten tephra layers were identified in Unit I. Lithologic Unit II, starting at 44.60 mbsf, is characterized by a well-consolidated light greenish gray calcareous clayey silt(stone) with occasional variations to silty clay, and minor sand(stone) layers. Unit II exhibits moderate variability in the amount and extent of calcareous cementation with depth. In addition, this unit contains several horizons of lithified and reworked, rounded carbonate mud clasts. Fourteen tephra layers were identified in Unit II. Near the bottom of Hole

U1413A (Section U1413A-20X-1) a chaotic layer of intermixed sand and calcareous clayey silt, not associated with a lithologic change, most likely represents a Mass Transport Deposit (MTD) interval. Unit II continues in Hole U1413C until 366.45 mbsf with the same lithology, but heavy minerals, shell fragments, and occasional sandstone layers with sapropel and leaf fragments become more abundant with depth. The boundary between Units II and III (Section U1413C-21R-3, 117 cm) is marked by the first appearance of an 18 m thick package of alternating sandstones and siltstones with common to abundant organic matter (sapropel) and shell and gastropod fragments. The matrix of the siltstone and sandstone is characterized by abundant magmatic and sedimentary lithic fragments, common feldspar, and volcanic glass fragments. Foraminifers are the most abundant components of the biogenic material. After a relatively thin siltstone interval (~42 m) the remainder of the hole (426.8–578.8 mbsf) consists of massive, fine- to medium-grained sandstones that contain three tephra layers. The sandstones are normally graded and range from decimeter- to meter-thick layers with occasional internal laminations, particularly in the uppermost part of the section. Some cores in Unit III are particularly rich in gastropods and reworked, well-rounded carbonate clasts. These lithologic units can be correlated to some of the units found at Sites U1378 and U1379 during Expedition 334.

Biostratigraphy at Site U1413 was mainly constrained by calcareous nannofossils. Radiolarians are present in the upper section of Hole U1413A but very few useful species were found. The upper section of Hole U1413A (Samples U1413A-1H-CC to 14H-CC) is assigned to Zone NN21. From Sample U1413A-15H-CC to 19X-CC the age is less well constrained and is assigned to Zones NN20-NN21 (1.89 Ma to present). The first appearance of *Pseudoemiliania lacunose*, which defines the top of Zone NN19, is found in Sample U1413A-20X-CC. The LO of *Helicosphaera sellii* is observed in Sample U1413C-15R-CC and is assigned to 1.34 Ma.

Benthic foraminifers were dominant and well preserved from Section U1413A-1H-1 to Sample U1413A-19X-CC but they range from “common” to “few” in the lower sections of Hole U1413A and throughout Hole U1413C, with most of the foraminiferal samples showing signs of mechanical breakage. Benthic foraminiferal assemblages show remarkable changes downhole. The upper 150 m of sediment is characterized by an assemblage composed of *Brizalina bicostata*, *Cassidulina tumida*,

and *Cancris inflatus*. These species are absent in the rest of the cored interval. From 160 mbsf (Sample U1413A-20X-CC) to 478 mbsf (Sample U1413C-32X-CC) there is a completely different assemblage composed of *Brizalina spissa*, *Epistominella smithi*, *Uvigerina* cf. *excellens*, and *Hansenisca altiformis*. The lower part of Hole U1413C (Samples U1413C-36R-CC to 42R-CC) is characterized by the appearance of *Brizalina* cf. *dilatata*, which together with *Uvigerina peregrina,* dominates the assemblages and constitutes up to the 80% of all foraminifers.

Faulting related deformation starts to be present and abundant below 180 mbsf. Deformation is additionally localized along brecciated fault zones at 181, 230, 237–239, 365, 529–532, and 567 mbsf. Both normal and reverse faults were observed. Dip angles of these vary from subhorizontal to subvertical.

We collected 106 interstitial water samples from Site U1413. Hole U1413B was dedicated to high-resolution studies of the biogeochemical processes just below the sulfate-methane transition (SMT), which at this site occurs at 16 mbsf. The pore fluid profiles of sulfate, alkalinity, and ammonium concentrations in the uppermost ~150 m of Holes U1413A and U1413B reflect organic matter remineralization, but are significantly impacted by sediment slumps at ~45 and ~150 mbsf. Calcium and magnesium concentrations decrease from seawater values at the seafloor to minima of 1.1 and 39.8 mM, respectively, at the lithologic Unit I/II boundary, reflecting precipitation of authigenic carbonates. The Cl concentrations decrease with depth to ~500 mbsf, but below this depth the Cl profile shows a trend of increasing concentrations ~96% seawater value. The reason for the lower than modern seawater Cl value throughout the cored section but in particular in the upper ~150 m is as yet unclear. Methane increases below the SMT, and the C_1/C_2 ratio in the upper 50 m indicates a biogenic origin for the gas. Below this depth, the C_1/C_2 ratio decreases steadily with depth, and shows a marked decrease to values <100 below 480 mbsf, indicating a thermogenic component from a deeper source.

Site U1413 porosity values decrease (and bulk densities increase) rapidly from 0 to 180 mbsf and more gradually below 180 mbsf. Both trends have different slopes than that found in porosity data from Site U1379. Magnetic susceptibility excursions appear to coincide with sand-rich layers that contain detrital magnetite. *P*-wave velocities average 1600 m/s above 20 mbsf. We have only a few scattered

measurements between 20 and 200 mbsf due to core disturbance, and values average 1960 m/s below 200 mbsf. Thermal conductivity increases from 0.9 to 1.25 W/(m·K) from the seafloor to 200 mbsf and then gradually increases to 1.35 W/(m·K) at the bottom of Hole U1413C. Three temperature measurements yield a gradient of 49°C/km and a heat flow of 0.056 W/m^2. Sediment strength generally increases from the seafloor to 140 mbsf. Below 140 mbsf, values are scattered but show an overall gradual increase. Formation factor increases rapidly within the upper 20 m and more gradually below 20 mbsf.

We performed split-core measurements of natural remanent magnetization (NRM) and alternating-field demagnetization of discrete samples to observe the magnetic properties of each lithostratigraphic unit recovered at Site U1413. Based on biostratigraphic data, we were able to tentatively correlate certain parts of the magnetic polarity interval recorded in the sediments with the geomagnetic polarity timescale. In particular, the polarity shift from reversed to normal at 485 mbsf in Section U1413C-42R-4 may represent the beginning of the Olduvai normal polarity Subchron (1.778 Ma), implying a sediment accumulation rate of 270 m/my.

Downhole logging at Hole U1413C took place between 1045 and 2300 h on 30 November. Three tool strings were deployed: a slick triple combo (without the radioactive source because of poor hole conditions), a UBI, and an FMS tool string. The tool strings could not be lowered below 187 mbsf because of a borehole obstruction; the last two tool strings were chosen to focus on the ultrasonic and resistivity imaging of borehole breakouts. Three logging units can be distinguished. Logging Unit 1 (93–148 mbsf) contains clear borehole breakouts imaged by low reflection amplitudes and large traveltimes in the UBI ultrasonic log, and by the orientation of the FMS pair of arms that measure the larger borehole radius. The orientation of the breakouts shows that the minimum principal horizontal stress is oriented approximately N–S. In contrast, the borehole is nearly circular and in gauge (~10 in diameter) in logging Unit 2 (148–169 mbsf), which also has a higher natural radioactivity and higher resistivity than Unit 1, suggesting a more consolidated formation. The borehole is washed out in all directions in logging Unit 3 (169–184 mbsf), and low values of natural radioactivity and resistivity are likely artifacts caused by hole enlargement.