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

Week 7 Report (2–9 December 2012)

Operations

Week 7 of Expedition 344 (Costa Rica Seismogenesis Project, Program A Stage 2) began with drilling without recovery from 272.8 to 305.4 mbsf in Hole U1412D in an effort to reach the décollement. Coring continued with non-magnetic RCB core barrels from Core U1412D-2R to 3R to a final depth of 369.2 mbsf. The two RCB cores were taken over an 18.8 m interval with 12.3 m recovered (65%). Hole conditions deteriorated drastically and we had to offset the vessel 60 m from the hole location in order to free the stuck drill string. All efforts to condition the hole and continue coring failed and the decision was made to abandon the hole. The seafloor was cleared at 1630 h and the beacon was recovered at 1735 h on 2 December. After recovering the beacon, the vessel began a slow move to Site U1414. The remainder of the drill string was recovered during the transit to the next site. The bit cleared the rotary table at 2105 h on 2 December, ending Hole U1412D. The total time spent on Hole U1412D was 41.5 h.

After a 5.8-nmi transit from Site U1412, a positioning beacon was deployed at 0010 h and the vessel stabilized over Site U1414 (proposed Site CRIS-19A) at 0015 h on 3 December. Hole U1414A (8°30.2304'N, 84°13.5298'W, 2459 m water depth) was spudded at 0805 h. APC Cores U1414A-1H to 22H were taken from 0 to 200.1 mbsf. APCT-3 formation temperature measurements were taken with Cores 3H, 5H, 7H, and 9H. The coring system was switched to the XCB system after having to drill over Core 22H. XCB Cores 23X to 35X were taken from 200.1 to 311.9 mbsf, and XCB coring was terminated after penetration rates and recovery drastically decreased. The APC/XCB assembly was raised to just below seafloor, a free fall funnel was deployed, and the remainder of the drill string was brought to the surface. An RCB bottom-hole assembly was then assembled with a new bit and lowered to just above the seafloor. Hole U1414A was re-entered and RCB Cores 36R to 63R were recovered by 1205 h on 9 December, including 96 m of igneous basement. Coring was terminated so that logging could begin. The logging program at Hole U1414A includes two runs with the triple combo and Formation Microscanner (FMS) tool strings. The vessel is scheduled to depart Site U1414 for Puntarenas around 2100 h on 10 December.

Science Results

Limited geochemical, physical properties, and paleomagnetic measurements were conducted on Cores U1412D-2R and 3R. The sediment of Hole U1412D is slightly more clayey, highly bioturbated, and shows a decrease in biogenic components. There is no clear correlation between the sediments recovered at the base of Hole U1412C and Hole U1412D.

The majority of the week was spent at Site U1414. The upper part of Hole U1414A is characterized by a predominantly monotonous, terrigenous sequence of soft, light greenish gray hemipelagic silty clay to clay with some small sand layers in the uppermost part of Unit I (Subunit IA) and an increasing amount of calcareous nannofossils in the lower part (Subunit IB). Terrigenous material (lithic fragments, glass shards, and minerals) decreases with depth. The Unit I/II boundary at 145.34 mbsf separates greenish gray nannofossil-rich clay sediments from

calcareous ooze. Unit II (145.3–309.4 mbsf) is a 164.03 m thick, moderately consolidated, interval that is characterized in the upper part by nannofossil calcareous ooze. In the lower part it is alternating calcareous nannofossil ooze and biosilica-rich calcareous ooze. Unit III (309.4–375.3 mbsf) is a 65.88 m thick interval that is characterized by a sequence of lithified, calcareous and siliceous, cemented silt- and sandstone that probably lost biogenic components as a result of diagenetic remobilization but still preserves the original sedimentary structures such as bedding and bioturbation. Tephra layers and pods are rare (1%) but, despite their dark brown to black macroscopic appearance, the glass shards are mainly transparent under the microscope, implying a rather evolved than a mafic volcanic origin.

Igneous basement, encountered at 375 mbsf, comprises a ~65 m thick sequence of massive basalt (Cores 344-U1414A-45R to 59R) overlying a 1.5 m thick interval of intercalated sediment. Below the sediment is a second (at least ~30 m thick) massive basaltic unit. We tentatively identify two units based on the presence of the intercalated sediment interval, which defines a clear boundary between these two units.

Unit 1 is primarily massive and microcrystalline. Phenocryst abundance ranges from aphyric to highly plagioclase phyric. Olivine and clinopyroxene phenocrysts are also tentatively identified by hand-specimen observation. Increased phenocryst abundance and size are typically associated with increased grain size, ranging from nonvesicular to highly vesicular. Most vesicles (~98%) are filled with an unidentified green secondary mineral and occasionally carbonate, pyrite, and silicates. Highly vesicular intervals exhibit finer groundmass (micro- to cryptocrystalline). Two unusual cryptocrystalline “tubes” were observed within Cores U1414A-51R and 57R, which we interpret as a possible pressure-induced intrusion. Groundmass alteration is slight to moderate with partial replacement of plagioclase and partial to complete replacement of olivine and clinopyroxene. Veins are composed of carbonate, sulfides, silicates, and unidentified green minerals that are evenly distributed throughout. Larger veins exhibit evidence of multiple filling episodes, with carbonate and silicates typically observed in the central portion of the veins. The presence of partially recrystallized sediments above Unit 1 could suggest that the basalt intruded into the sediment as a sill. However, the upper and lower contacts were not recovered.

Unit 2 exhibits similar groundmass textures (i.e., phenocryst variation, vesicle distribution, and grain size) as Unit 1. The uppermost part of Unit 2 is composed of devitrified glass followed by a 70 cm thick interval of basalt clastic breccia with an unidentified dark gray/olive green mineral forming the matrix. Clasts are moderately to highly altered and exhibit a partially preserved jigsaw-puzzle morphology that indicates that the breccia formed in situ with no mass transport. Overall groundmass alteration is slight to moderate with partial replacement of plagioclase and partial to complete replacement of olivine and clinopyroxene. Veins are composed of carbonate, sulfides, silicates, and unidentified green minerals that occur in the upper two thirds of Unit 2. Larger veins exhibit evidence of multiple filling episodes, with carbonate and silicates typically observed in the central portion of the veins. In the lower portion of Unit 2 (Cores U1414-59R and 60R) veins are predominantly composed of carbonate with minor silicates and pyrite. Narrow sub-millimeter veins with a dark mineral are present.

Biostratigraphy at Hole U1414A is constrained by radiolarians and nannofossils. Nannofossils have “moderate” preservation overall, with evidence of recrystallization downhole. Radiolarians are well preserved overall, with intervals of poor preservation between Samples U1414A-17H-CC and 21H-CC. The presence of *Pseudoemiliania lacunosa* and *Collosphaera tuberosa*

indicates that the upper ~120 m was deposited in the Pleistocene. Radiolarian and nannofossil assemblages at the base of Hole U1414A constrain the age of the oldest sediments to the middle Miocene.

Foraminiferal work was conducted on 34 core catcher samples. Generally, the abundance of benthic foraminifers varied from "common" to "few" with a few particular intervals where benthic foraminifers were only "present." Preservation was good to moderate except for some samples contained in lithologic Subunit IIB where foraminiferal preservation was poor with tests showing signs of recrystallization.

Overall, two main benthic foraminiferal assemblages can be distinguished in this hole. The upper assemblage (0–140 mbsf) includes "*Globobulimina*" group species, *Uvigerina auberiana* and, as accessory species, *Uvigerina* cf. *senticosa*, *Cassidulina carinata* and *Melonis affinis*. The lower assemblage (140–320 mbsf) is composed of species belonging to the "*Cibicides*" group, *Globocassidulina subglobosa*, *Pullenia* spp. and *Uvigerina* cf. *senticosa*. In Sample U1414A-12H-CC we found the last appearance of the *Stilostomella* group species, which indicates an age older than 0.6 Ma for that. The base of the hole (Samples U1414A-30H-CC to 34H-CC) contains specimens of *Planulina renzi*. This species died out during the middle Miocene. This age is in agreement with the biostratigraphic constraints for that interval.

Site U1414 has sub-horizontal to gently dipping bedding. Few faults, generally normal, were observed in Units I and II. Unit III is characterized by strong foliation and veins. Unit III is slightly metamorphosed. Some shear zones were also recognized.

We completed the chemical analyses for 61 interstitial water samples collected from Site U1414. The pore fluid composition in the uppermost 80 m shows trends characteristic of organic matter remineralization. In addition, coincident minima in ammonium and sulfate concentrations at 37 mbsf suggest that there may be favorable conditions for sulfate-reducing ammonium oxidation. The feasibility of this metabolic pathway in marine sediments was recently documented for the first time in sediments from the Bay of Bengal, India.

The sulfate concentration-depth profile at this site is also unusual in that it displays a second minimum at 330 mbsf, which corresponds to a sharp minimum in calcium and a maximum in barium concentrations. These data suggest lateral flow of a sulfate-depleted fluid, which originated from microbial oxidation of methane and/or other organic carbon sources, landward of Site U1414, and migrated up-dip through the upper sediments of Unit III. The calcium minimum thus likely reflects a combination of in situ carbonate formation caused by the ongoing sulfate reduction and a contribution from the laterally migrating fluid having low calcium concentration. Similarly, the barium concentration, which mirrors the sulfate profile at depth, is controlled by the stability of the mineral barite ($BaSO_4$), thus the increase in barium may reflect both in situ marine barite dissolution at the sulfate minimum plus barium contribution from the laterally migrating low-sulfate fluid. Postcruise isotopic analyses of the carbon species, solid-phase barite and carbonate analyses, and numerical modeling will be required to determine the origin and history of the fluid flow at depth in this input sediment section.

The incoming sediments also display changes in composition driven by the nature of the lithology and associated diagenetic reactions. Both major and minor element profiles show a marked discontinuity at ~195 mbsf, which corresponds to the lithologic Subunit IIA/IIB

boundary. These strong discontinuities can only be maintained by a diagenetic diffusion barrier, which was not observed in the cores. However, it coincides with the change from APC to XCB cores triggered by APC refusal, and a 4-m thick interval of sediment that was not recovered.

Lithologic changes at this site are apparent in the silica profile, which is characterized by typical silicate mineral diagenesis. The gradual increase in the amount of biogenic opal in the sediments from the silty clay/sand-dominated Unit I through the nannofossil-rich clay in Subunit IB is apparent as a monotonic increase in dissolved silica. The change from the nannofossil-rich clay of Subunit IB to the nannofossil-rich calcareous ooze of Subunit IIA coincides with a sharp decrease in Si concentrations. Another marked increase in Si concentrations across the lithologic Subunit IIA/IIB boundary reflects a change in fluid-rock reactions in Subunit IIB that are dominated by the opal-A solubility at the in situ temperature of ~35°–45°C. Near the base of Subunit IIB there is a distinct decrease in Si concentrations, which coincides with a clear decrease in the dissolved K concentrations, consistent with clinoptilolite formation, a K-Si-rich zeolite, which is also apparent in the XRD data.

All Site U1414 physical properties measurements on sediments were completed. Bulk density and porosity data are complicated by the combination of lithologic changes and variations in diagenesis. Compaction is very slight in Unit I, with porosity values of 69% at 145 mbsf. Porosity decreases to 54% and then gradually increases to >75% near 225 mbsf, before decreasing to the base of the hole. Background magnetic susceptibility values generally decrease with depth, reaching near-zero values below 350 mbsf. Excursions generally correspond to tephra layers. Natural gamma ray values are generally stable in the upper 110 m, rise to a peak at 130 mbsf, and then decrease down to the Unit II/III boundary. NGR values are scattered in Unit III, with a peak near 350 mbsf. *P*-wave velocities from the split cores decrease in the upper 25 m and then gradually increase with depth. Overall, *P*-wave velocities in Unit I are low, averaging 1520 m/s. A local maximum at ~190 mbsf corresponds to a bulk density maximum and porosity minimum. *P*-wave velocities between 300 and 340 mbsf average 1850 m/s and then sharply increase to 3260 m/s below 340 mbsf. Thermal conductivity shows variations consistent with bulk density. Strength values rise steadily in Unit I and Subunit IIA. Four downhole temperature measurements yield a thermal gradient of 168°C/km. Due to little time remaining, physical property measurements of basalt were limited to those on the WRSML and SHMSL.

During the last week of Expedition 344, we have been concentrating our efforts on measuring and demagnetizing core sections and discrete samples from Sites U1413 and U1414. In general, variations in NRM intensity follow changes in lithology, especially in the sandy layers of Hole U1413B and light green calcareous ooze of Hole U1414A. Our magnetostratigraphic data suggest high sedimentation-accumulation rates (~270 m/my) for the upper 480 m of sediment in Hole U1413C, similar to those in Holes U1379C and U1412A.

Education and Outreach

Blogs and photos were added to joidesresolution.org, Facebook, and Twitter. Eleven video conferences were held with high school students in Lakeside, California, Toledo, Ohio, Jefferson, Georgia, and France; and middle school students in St. Petersburg, Florida, and Washington, DC. CRISP-2 Episode 2 with a focus on paleontology and paleomagnetism was completed. Work continued on Episode 3.

Technical Support and HSE Activities

The following technical support activities took place:

- Labs processing core
- End of Expedition preparations on going

The following HSE activities took place:

- Vessel boat and security drill held on Friday, 7 December
- Eyewash stations tested