IODP Expedition 344: Costa Rica Seismogenesis Project (CRISP-A2)
Site U1381 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. Fundamental to this objective is an understanding of the nature of the sediments and oceanic crust entering the seismogenic zone, and the hydrologic and the thermal state of the igneous oceanic crust. Site U1381 serves as a reference site on the subducting aseismic Cocos Ridge.

Site U1381 is ~4.5 km seaward of the deformation front offshore Osa Peninsula and Caño Island, Costa Rica. This site was chosen for multiple reasons. First it is located on a local basement high. Basement relief often focuses fluid flow so data from this site has a high likelihood of documenting the vigour of fluid flow in this area. Secondly, a clear seismic record of the plate stratigraphy is present at this site. The seismic section shows a 100-m-thick sediment section resting on reflective basement interpreted as Cocos Ridge igneous crust. The sedimentary section is composed of pelagic and hemipelagic sediments (Vannucchi et al., 2012). Thirdly, Site U1381 is far enough away from the frontal thrust that it is expected to be reasonably free from the influence of downslope debris flows that might emanate from the convergent margin slope. Finally, Site U1381 is located on the same seismic line as Sites CRIS-9A, U1380, and U1379. Paleomagnetic data constrain the age of this portion of Cocos Ridge to be 14 Ma (Barckhausen et al., 2001).

During the previous CRISP Expedition (334) in 2011, Site U1381 was cored using the rotary core barrel (RCB) system because the primary objective was oceanic crust and time constraints precluded APC drilling through the sediment section (Vannucchi et al., 2012). However a disadvantage of the RCB system is that soft sediments recovered with it are usually highly disturbed. Thus a primary goal for revisiting this site was to advance piston core (APC) the sediment section to obtain more pristine samples to document the nature of the sediments entering the seismogenic zone.

Principal Results

After a 403-nmi transit from Panama, the vessel stabilized over Site U1381 at 0620 h on 26 October 2012 (all times in this report are ship local time which is UTC-6). Hole U1381C was spudded at 2015 h on 26 October (8°25.7027'N, 84°9.4800'W, 2064.6 m water depth). Advancement for Hole U1381C was 103.8 mbsf, with 103.5 m cored with the APC system and 0.3 m cored with the XCB system. Recovery with the APC system was 108.68 m (105%) and recovery with the XCB system was 0.33 m (110%). The APCT-3 temperature measurement tool was deployed on Cores U1381C-3H, 5H, 6H, and 7H and four good temperature curves were recorded. The FlexIt orientation tool was deployed on Cores U1381C-1H through 9H with good results. After reaching basement, the APC system was changed to the XCB system and a single short core was cut to confirm and recover basement material. Hole U1381C ended at 1545 h on 27 October, and a total of 33.5 h was spent at Site U1381.

The cored interval in Hole U1381C comprises five units. The top of the hole contains hemipelagic sediments that are typical of an incoming plate location near a terrigenous source. The Unit I/II boundary is present in Core U1381C-7H and is characterized by a change between greenish grayish silty clay with some nannofossils and terrigenous minerals to a brownish grayish nannofossil-dominated ooze with abundant to common foraminifers and sections with predominant sponge spicules. This boundary is also seen in smear slide and XRD data. The top of Unit II is also characterized by a high abundance of tephra layers that are up to 42-cm thick. Judging from core description and smear slide data, a lithologic change in Core U1381C-11H to finer grained nannofossil-rich clay with only some glass and feldspar components marks the Unit II/III boundary. The Unit III/IV boundary in Core U1381C-12H again shows a drastic change in lithology to a pure clay/claystone. XRD data indicate a mixing of smectite, probably saponite, pyrite, and to a less extent plagioclase. Sphalerite, calcite, and anhydrite are present as minor phases. Unit V starts in Core U1381C-13X and consists of brecciated basalt. Overall alteration of the basaltic groundmass is slight to moderate with smectite replacing interstitial glass and partially corroding plagioclase and clinopyroxene phenocrysts.

The biostratigraphic characterization of Hole U1381C was constrained from calcareous nannofossils and radiolarians identified in core catcher samples from Cores U1381C-1H to 11H. Biostratigraphic zones indicate that Unit I is of Late Pliocene to Pleistocene age (~2 Ma). Unit II represents the middle Miocene (~11 to 13 Ma). Thus, the hiatus between Units I and II is ~9–11 m.y.

Benthic foraminifers are present throughout the core, ranging from 1% to 5% of the total 125 µm fraction. Preservation is good with little evidence of dissolution or breakage. Benthic foraminiferal assemblages from Unit I are substantially different from the ones of Unit II, indicating large paleoenvironmental changes related to organic carbon flux and bottom water ventilation. Of particular interest is the substantial presence of representatives of the *Stilostomella* extinction group in Section 344-U1381C-6H-CC. This provides an alternative biostratigraphic datum to the calcareous nannofossils.

Thirty-five measurements of bedding were taken principally from tephra layers in Hole U1381C. Bedding is generally sub-horizontal to gently dipping. In Unit III, toward the bottom of the sedimentary succession, we observed a few deformation bands and mineral-filled extensional and shear fractures, which have a normal displacement component.

We collected and processed 28 whole-round (WR) core samples for interstitial water analyses and an additional 3 WR samples for helium analyses. In all cases enough fluid was collected for shipboard and shore-based requests with 10-cm-long WRs. Similar to the data from Expedition 334 Hole U1381B, there is little variation in salinity, chloride, sodium, and potassium downhole. Diagenesis of organic matter in the upper sediments is indicated by increases in alkalinity, ammonium, and phosphate and consumption of sulfate, which reaches a minimum value of 11 mM at ~40 mbsf. A concomitant calcium decrease is indicative of carbonate precipitation driven by the alkalinity increase. The sulfate profile shows a reversal below ~40 mbsf, with a steady increase in concentration with depth. This observation is similar to that previously reported for Hole U1381B and for the incoming sediment section off the Nicoya Peninsula. In summary, the concentration-depth profiles of Ca, SO_4, Li, Mn, and possibly Si, indicate diffusional communication with an altered seawater fluid in the oceanic basement.

For organic geochemistry, we collected and analyzed 29 headspace (HS) samples. Except for elevated values of hydrocarbons in the uppermost sample (at 1.5 mbsf), which has been attributed to drilling contamination, methane occurs only in trace amounts and no heavier hydrocarbons were detected. CO_2 concentrations in the HS samples range from 555.5 to 1846.3 ppmv and show no change with depth.

Inorganic carbon distribution increases with depth in Hole U1381C, consistent with a change in lithology from the silty clay sediments of Unit I to the foraminiferal carbonate ooze of Unit II. The total carbon concentration also increases from about 3% to less than 7% at that depth. The total organic carbon (TOC) concentration ranged from 0.967 to 2.082 wt%. The total nitrogen (TN) concentration ranged between 0.049 and 0.197 wt%.

Physical property measurements show high porosities (Unit I: 75%, Unit II: 78%) and low bulk densities (Unit I: 2.5 g/cm^3, Unit II: 2.7 g/cm^3), with little evidence for compaction. Magnetic susceptibility values stay fairly constant with depth but have intermittent peaks in Unit I (>100 x 10^{-3} SI) and Unit II (>25 x 10^{-3} SI) that correlate with tephra layers. NGR gradually increases with depth and is highly variable around the Unit I/II boundary. Electrical conductivity values appear generally consistent with porosity trends. P-wave velocity measurements indicate slightly higher values in Unit II (1540 m/s) than in Unit I (1520 m/s), despite elevated porosities in Unit II, and are highest in Unit III (1620 m/s). Vane shear and penetrometer measurements show values generally increasing downhole throughout Units I and II. Thermal conductivity results are inversely correlated with porosity. Downhole temperature measurements are consistent with those obtained previously on Expedition 334 and suggest a thermal gradient (231°C/km) that is higher than predicted for conductive cooling. The calculated heat flow of 185 mW/m^2 is larger than that predicted for 15 Ma crust, suggesting significant fluid flow in the underlying ocean crust.

Downhole variations in the natural remanent magnetization (NRM) intensity for archive-half cores correlate well with lithology in Hole U1381C. Paleomagnetic measurements indicate that the silty clay of Unit I (0–55.93 mbsf) has a mean NRM intensity on the order of 10^{-2} A/m, whereas the foraminifer-rich ooze in Unit II has a lower NRM intensity of 10^{-2}–10^{-3} A/m. A number of higher NRM peaks appear in both Units I and II, and can be tied directly to the presence of tephra layers. The measured NRM declinations of different cores are scattered but upon correction with the FlexIt orientation data, declinations become close to magnetic north, indicating the remanence is of geomagnetic origin. The magnetic properties obtained from the archive section halves were confirmed by discrete sample measurements.

We used characteristic remanent (ChRM) declinations and inclinations from discrete measurements to define magnetic polarity sequences for the oriented core section in Hole U1381C. At a low latitude area such as Site U1381, a near 180° shift in declination in the cores is a more reliable sign of a polarity transition than a change in the magnetic inclination. For the upper part of Unit I, both pass-through and discrete sample measurements show signs of dominantly normal polarity of ChRM. An additional constraint is provided by an ash layer at ~25 mbsf, which is inferred to be the Ar-Ar dated (320 ka) Tiribi Tuff ash layer. Thus, we interpret that the sediments from 0 to 49 mbsf were deposited within the Brunhes Chron (<0.78 Ma). From Section 344-U1381C-6H-5 through Section 6H-7 we see a dominantly reversed polarity in the section-half measurements. Discrete samples from this interval also show negative inclinations and corrected declinations show a ~180° shift, consistent with the magnetization acquired in a reversed field. Thus, we tentatively conclude that the Brunhes/Matuyama boundary is at a depth of 49 mbsf in Section U1381C-6H-3.

References

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