IODP Expedition 390C: South Atlantic Transect Reentry Systems

Site U1556 Summary

Background and Objectives

International Ocean Discovery Program (IODP) Site U1556 (proposed Site SATL-53B) is in the central South Atlantic Ocean, ~1250 km west of the Mid-Atlantic Ridge. The objective for Expedition 390C was to core one hole with the advanced piston corer/extended core barrel (APC/XCB) system to basement for gas safety monitoring, and to install a reentry system with casing through the sediment to ~5 m into basement in a second hole, to expedite basement drilling during South Atlantic Transect Expeditions 390 and 393.

Site U1556 is located on seismic line CREST1A/B at position CDP 3410 near the CREST05 crossing line. A reflector at ~6.9 s two-way traveltime (TWT) was interpreted as the top of basement and estimated to be 180 m below seafloor (mbsf). The reflector marks a change in seismic character from high-frequency layered energy to low-frequency chaotic energy. This site is located only 6.7 km from Site U1557 (proposed Site SATL-56A), and the basement at both sites is predicted to be ~61.2 Ma, formed at a half spreading rate of ~13.5 mm/y. Oceanic crust at these sites is the oldest that will be drilled as part of the South Atlantic Transect expeditions and will be compared to younger crustal material. The contrasting sediment thicknesses at these closely spaced sites, with Site U1556 being less heavily sedimented, will allow exploration of the effect of sediment thickness on crustal evolution. Overlying sediment from Site U1556 is expected to be primarily carbonate ooze, and will be used in palaeoceanographic and microbiological studies. Average sediment accumulation rate at this site is predicted to be only 2.9 m/my, the lowest of all sites along the proposed South Atlantic Transect. As such, microbiological research at this site will provide insight into how subsurface microbial communities underneath the low-nutrient South Atlantic Gyre survive.

Operations

The *JOIDES Resolution* completed its 3608 nmi transit from Las Palmas, Canary Islands, at an average speed of 12 kt, and arrived at Site U1556 (proposed Site SATL-53B) at 0206 h on 28 October 2020. We switched from cruise mode to dynamic positioning (DP) mode at 0230 h and started operations for Hole U1556A. No acoustic beacon was deployed. Hole U1556A is located at 30°56.5244′S, 26°41.9472′W and the water depth is 5006.4 m below sea level (mbsl).

The APC/XCB bottom-hole assembly was made up and deployed. A nonmagnetic drill collar was used above the outer core barrel to improve the quality of magnetic orientation data collected during APC coring. We lowered the drill bit to 5006 mbsl and pumped a “pig” (pipe cleaning device) through the drill string to remove rust. At ~2200 h on 28 October, the sinker bars and core orientation tool were installed and the core barrel lowered. We spudded Hole U1556A at 2300 h. Mudline Core U1556A-1H arrived on deck at 2335 h and recovered 9 m.

Cores 1H through 16H advanced to 151.4 mbsf and recovered 155.13 m (103%). All APC cores were oriented with the Icefield MI-5 core orientation tool, following new procedures to identify any rotation relative to the core barrel during deployment. Formation temperatures were measured on Cores 4H, 7H, 10H, and 13H with the advanced piston corer temperature (APCT-3) tool. Cores 11H to 13H were partial strokes due to the stiffness of the sediment but had good recovery; Cores 14H and 15H were full strokes. Core 16H experienced 60,000 lb overpull and had to be drilled over to release it from the formation. Consequently, we changed to the XCB coring system using the polycrystalline diamond compact (PDC) cutting shoe. Cores 17X through 29X advanced from 151.4 to 273.6 m and recovered 79.53 m (65%). The rate of penetration was <10 m/h for Cores 17X to 20X, and increased to an average of 15.2 m/h for Cores 21X to 29X.

Core U1556A-30X encountered a hard layer that decreased the rate of penetration dramatically. Upon recovery, this layer was confirmed to be hard rock and was determined to be at 278 mbsf. Cores 31X to 33X attempted additional coring of the altered basalt and volcaniclastic material. In total, Cores 30X to 33X advanced 5.8 m into basement and recovered 4.33 m (75%), reaching a total depth of 283.8 mbsf. The sediment/basement interface in Core 30X had the lowest recovery (23%), but we experienced higher recovery in subsequent cores (90% for Cores 31X to 33X). Core quality was also high, with the XCB PDC cutting shoe returning nicely trimmed and relatively large pieces, indicating that the PDC cutting shoe performs well for short durations in altered basalt material. We observed minimal wear on the cutting shoe. Prior experience with tungsten carbide insert (TCI) XCB cutting shoes has shown that we would have required shoe replacement after each core in basement material.

In summary, Hole U1556A reached a total depth of 283.8 mbsf and recovered 243.78 m (86%), taking 4.1 d of expedition time. Following recovery of Core 33X, we raised the pipe to ~20 m above seafloor. The seafloor was cleared at 0410 h, ending Hole U1556A. We then transited in DP mode to nearby Site U1557 to conduct APC/XCB coring there. The intention was to core to basement at Site U1557 and then return to Site U1556 to install a reentry system with casing. However, the failure of the subsea camera system at Site U1557 made it impossible to complete the planned reentry system installation at Site U1556. Thus, the end of Hole U1556A was also the end of Site U1556 for Expedition 390C.

Principal Results

Basement was found to be deeper at Site U1556 than expected based on the initial interpretation of seismic data (278 instead of 180 mbsf). A lower reflector at ~6.95 s TWT is now identified as the sediment/basement interface. This basement depth also increases the average sediment accumulation rate to 4.5 m/my from the original estimate of 2.9 m/my.

Cores U1556A-1H through 29X were measured on the whole-round (WR) and split-core track systems. We collected physical properties data, line scan optical images, X-ray images, and paleomagnetic measurements. Basement Cores 30X through 33X were measured on the WR track systems but were not split, and are being preserved in nitrogen gas-flushed bags for description and analysis during Expeditions 390 and 393. Core catcher samples were collected for postexpedition biostratigraphic dating. In addition, we collected one sample per core for headspace gas analysis as well as 1–2 WR samples per core for chemical analysis of interstitial water (IW). Starting with Core 17X, we collected 10 cm instead of 5 cm WR samples to ensure enough water was available for standard analyses. No systematic core description took place during Expedition 390C. Sediment lithology in Hole U1556A alternates between 1–10 m thick layers of red-brown clay and carbonate ooze with sharp contacts between these lithologies. Analysis of calcium carbonate content conducted on samples from IW squeeze cakes also demonstrates this alternation. Calcium carbonate content ranges from a minimum of 0.08 wt% in clay to 92.08 wt% in carbonate ooze. Physical properties data reflect similar lithological changes, with higher magnetic susceptibilities and counts of natural gamma radiation (NGR) in the clay layers. *P*-wave velocity and gamma ray attenuation (GRA) density increase downhole with a significant increase in both in basement cores.

Alkalinity generally decreases downhole, although a broad peak in concentration at intermediate depths (~150 mbsf) and a secondary peak at ~220 mbsf may reflect sulfate reduction. Total dissolved sulfur concentrations, as measured by inductively coupled plasma–atomic emission spectrometry (ICP-AES) of IW samples, decrease towards this depth and then level out, not decreasing below 22 mM even at the bottom of the hole. Sulfate concentrations measured by ion chromatography reveal the same trend but are noisier than the ICP-AES data. Peaks in dissolved manganese and ammonium in the top half of the hole also indicate active reductive processes and heterotrophic metabolisms. Dissolved iron was below the detection limit, likely because it reoxidized and precipitated during the WR squeezing process. Dissolved silicon and boron are inversely correlated, with a sharp peak in silicon concentrations at an intermediate depth (~151 mbsf) coinciding with a sharp decline in boron. Calcium and strontium concentrations reach a broad peak at an intermediate depth and are lower in the upper and lower parts of the hole. Magnesium and potassium, conversely, are highest in surface samples, decrease with depth, and then increase again slightly near basement. This increase may suggest fluid flow along or near the sediment/basement interface.

All cores excluding the unsplit basement sections were measured on the superconducting rock magnetometer (SRM) for natural remanent magnetization (NRM) and then at alternating field (AF) demagnetization levels of 5, 10, and 20 mT. Vertical drilling overprints were ubiquitous but were generally removed by the 5 mT demagnetization step. Many samples appear to show a characteristic remanent magnetization (ChRM) after 20 mT demagnetization, although some likely have a higher coercivity component that will need to be examined during postexpedition research. APC cores were magnetically oriented and a correction applied to the SRM data for each core. Corrected declinations roughly cluster around two antipodal locations, assuming a geocentric axial dipole and some level of paleosecular variation.

Additional analyses and data interpretation will occur during Expeditions 390 and 393, which are expected to take place in 2022.