IODP Expedition 390C: South Atlantic Transect Reentry Systems

Site U1557 Summary

Background and Objectives

International Ocean Discovery Program (IODP) Site U1557 (proposed Site SATL-56A) is in the central South Atlantic Ocean, ~1250 km west of the Mid-Atlantic Ridge. The objective for Expedition 390C is 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 above basement in a second hole, to expedite basement drilling during South Atlantic Transect Expeditions 390 and 393.

Site U1557 is located on seismic line CREST1A/B at position CDP 4470 near the CREST05 crossing line. A reflector at ~7.2 s two-way traveltime (TWT) was interpreted as the top of basement and estimated to be 510 m below seafloor (mbsf). This site is located only 6.7 km from Site U1556, and the basement at both sites is estimated 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 U1557 being more heavily sedimented, will allow exploration of the effect of sediment thickness on crustal evolution. Overlying sediment from Site U1557 is expected to be primarily calcareous ooze, and will be used in palaeoceanographic and microbiological studies. The thick sediment layers at this site in particular will allow for paleoceanographic records covering the entire Cenozoic to be developed, including reconstruction of Atlantic Ocean circulation patterns during periods of elevated carbon dioxide during the Cenozoic.

Operations

We opted to core and install a reentry system at proposed alternate Site SATL-56A instead of proposed primary Site SATL-54A as the thinner sediment layer (estimated at 510 m at Site SATL-56A instead of 640 m at Site SATL-54A) would allow installation of casing to basement. Stress calculations indicated that casing could only be installed to 600 m without exceeding the safe utilization threshold of the drill pipe. The reentry system and casing installation was planned as two stages. First, the reentry cone and five joints of 16 inch casing would be jetted in to ~60 mbsf. Then, 10¾ inch casing string would be drilled into basement.

Hole U1557A

We arrived at Site U1557 on 1 November 2020 after moving the ship in dynamic positioning (DP) mode 6.7 km from Site U1556 at an average speed of 0.9 kt with the APC/XCB bottom-hole assembly (BHA) and bit suspended ~20 m above seafloor. There was no acoustic beacon deployed. Hole U1557A is located at 30°56.4549′S, 26°37.7912′W. The bit was lowered to 5003.9 m below sea level (mbsl) for the first core, based on the expected precision depth recorder (PDR) seafloor depth of 5011.3 mbsl. The first mudline core came back empty. A second mudline core was attempted from a water depth of 5009.9 mbsl and also came back empty. The drill string was lowered to 5011.9 mbsl for a third attempt. Core U1557A-1H over-penetrated and came back with a full core barrel. We thus ended Hole U1557A and offset the ship 20 m east to begin Hole U1557B.

Hole U1557B

Hole U1557B is located at 30°56.4547′S, 26°37.7775′W. The hole was spudded at 1615 h on 1 November from a drill string depth of 5006.9 mbsl. Core U1557B-1H recovered 4.1 m of sediment and established the seafloor depth as 5012.3 mbsl. Cores 1H to 11H advanced to 99.1 mbsf and recovered 90.95 m (92%). All APC cores were taken with a nonmagnetic core barrel and 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, and 10H using the advanced piston corer temperature (APCT-3) tool. Cores 2H and 3H had lower recovery than expected for APC coring of surface sediment (68% and 43%, respectively); this result may be explained by one or more hard layers near the surface that we were not able to recover. Core 11H had to be drilled over to release it from the formation. Consequently, the decision was made to switch to the XCB coring system with the polycrystalline diamond compact (PDC) cutting shoe.

XCB coring continued smoothly. Cores U1557B-12X to 62X advanced from 99.1 to 562.4 mbsf and recovered 317.35 m (68%). The sinker bars were removed after a hard layer was encountered at 239 mbsf. The rate of penetration for Cores 12X to 44X averaged 14.6 m/h. Starting with Core 45X, the rate of penetration decreased substantially in increasingly hard sediment, averaging 5.8 m/h for Cores 45X to 62X. We began conducting mud sweeps with Core 61X and continued mud sweeps on every core thereafter. Hard rock was encountered at 564 mbsf in Core 63X. Three additional XCB cores were taken to achieve 10 m penetration into basement. Cores 64X and 65X had low recovery (<50%) and Core 64X consisted of small rubbly pieces that appeared to jam in the core liner and core catcher. Core 66X had 100% recovery on a 2.1 m advance (drilled by time) and returned cohesive pieces of basalt/breccia. Overall, coring in Hole U1557B advanced to 574.0 mbsf and recovered 414.94 m (72%), taking 7.5 d of operational time. As at Site U1556, the XCB PDC cutting shoe performed extremely well, returning cohesive pieces of hard rock and showing minimal wear. Coring in basement was deliberately kept to 2 h per core, after which the core was pulled and the cutting shoe inspected for integrity. No cutters were observed to be lost or damaged.

After Core 66X was recovered, we began preparations for a jet-in test to determine whether sediment at Site U1557 was appropriate for the installation of a reentry cone and five joints of 16 inch casing (~60 m) prior to installation of 10¾ inch casing to basement. We pulled out of the hole to ~30 m above seafloor and the bit cleared the seafloor at 0210 h, ending Hole U1557B.

Hole U1557C

The ship repositioned 20 m south for the jet-in test and Hole U1557C was spudded at 0345 h on 9 November 2020 with the APC/XCB BHA. The jet-in test advanced to 3 m before contacting a hard layer, and we were unable to jet in further despite increasing the flow rate. The ship was repositioned 20 m west for a second jet-in test that was also unable to penetrate the seafloor. Because the jet-in tests were unsuccessful, the top drive was set back and the drill string pulled back to the surface. The bit cleared the rig floor at 1930 h, ending Hole U1557C. This experience provides additional evidence for one or more surface hard layers at this site.

Hole U1557D

A revised plan was made to drill in the reentry cone with five joints of 16 inch casing (~60 m) using a stinger with a mud motor, underreamer, and drill bit. In preparation for assembling the casing string, the mouse hole and upper guide horn (UGH) were removed and the reentry cone was moved under the rotary table on top of the moonpool doors. The casing was made up, lowered through the reentry cone, and latched into the hanger. The first three joints were locked and welded. Then, we tested the mud motor and underreamer to determine the pump rate required to open up the arms of the underreamer (50 strokes/min and 350 lb/inch^2). The full casing stinger was assembled with a 14¾ inch bit and lowered through the reentry cone. The Dril-Quip running tool at the top of the stinger was latched into the reentry cone. The driller lifted the assembly measuring the weight of the reentry system and checking the engagement of the running tool. The moonpool doors were opened and the reentry cone, casing, and stinger assembly were lowered through the splash zone at 1045 h on 10 November. The reentry system was lowered using a controlled descent to 729.0 m below rig floor (mbrf) while filling the drill pipe with water every ten stands, and the UGH was reinstalled before we continued lowering the drill string.

When the reentry cone reached ~4020 mbsl, the subsea camera system was deployed and lowered quickly until it caught up with the cone. The camera then began following the cone down. At 0615 h on 11 November and at ~4900 mbsl, video feed and communication from the subsea camera system was lost and the system was pulled back to the surface to diagnose and repair the issue. The telemetry pod was swapped out for a spare and the system was redeployed. At the same depth (~4900 mbsl) video and communication were again lost and the system was pulled back to the surface. In the meantime, Hole U1557D was spudded at 1050 h on 11 November and the reentry cone and five joints of 16 inch casing were successfully drilled into the sediment to a depth of 64.2 mbsf. The driller lost the weight of the reentry system with casing at 5010.7 mbsl, establishing that as the seafloor depth for Hole U1557D. The Dril-

Quip running tool was disconnected from the reentry cone at 1400 h, without the ability to observe this operation on the subsea camera.

We determined that the problem with the subsea camera system is pressure related. Consequently, we were not able to complete the installation of 10¾ inch casing to basement in Hole U1557D. Instead, we decided to transit to Site U1558 (proposed Site SATL-43A) and continue coring and reentry system installations at the other planned sites, where the water depth is shallower and pressure was not expected to limit use of the subsea camera.

The drill string was pulled back to the surface. The UGH was removed to recover the Dril-Quip running tool, and was then reinstalled after recovery of the running tool and the BHA. The rig floor was secured at 0908 h on 12 November for the transit to Site U1558 (proposed Site SATL-43A). Overall, Hole U1557D took 2.6 d of expedition time.

Principal Results

After basement at Site U1556 was found to be substantially deeper than predicted, the seismic data for Site U1557 were also reinterpreted. The revised estimate was 585 mbsf instead of 510 mbsf. Basement was encountered at 564 mbsf, providing a tie point for future seismic interpretations.

Cores U1557A-1H and U1557B-1H through 62X 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 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 one WR sample per core for chemical analysis of interstitial water (IW). Starting with Core U1557B-19X, 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 alternates between 1–10 m thick layers of clay and carbonate ooze with sharp contacts in between. Compared to Hole U1556A, clay layers are generally thinner and carbonate ooze layers slightly thicker. After Core 32X (bottom depth 296.1 mbsf), lithology transitioned toward predominantly carbonate ooze with an average calcium carbonate content of 86 wt%. Rare clay layers are <1 m in thickness. Physical properties such as magnetic susceptibility (MS) and counts of natural gamma radiation (NGR) generally correlate with lithology, with higher MS values and NGR counts in the clay layers and in the hard rock sections. *P*-wave velocity and gamma ray attenuation (GRA) density increase downhole with a significant increase in both values in basement cores.

Alkalinity is high near the top of Hole U1557B, decreases down to ~75 mbsf, and then shows a generally increasing trend toward the bottom of the hole. Near basement, alkalinity spikes to 12.3 mM but declines again in the final IW sample collected before reaching hard rock material.

Total dissolved sulfur concentrations, as measured by inductively coupled plasma–atomic emission spectrometry (ICP-AES) of IW samples, decrease downhole from surface levels then level out. A sharp decrease in concentration (from ~24 mM down to 19.5 mM) is associated with the increase in alkalinity near the bottom of the hole. Sulfate concentrations measured by ion chromatography closely match the sulfur data measured via ICP-AES. Nonetheless, sulfate concentrations remain above 20 mM even at the bottom of the hole. Peaks in dissolved manganese and ammonium in the top half of Hole U1557B also indicate active reductive processes and heterotrophic metabolisms. A secondary dissolved manganese peak occurs at an intermediate depth. 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 throughout most of the hole, with a sharp peak in dissolved silicon concentrations in the top half of the hole coinciding with a sharp decline in boron. The depth of this peak (~168 mbsf) is approximately the same as the depth of the peak in silicon concentrations observed in Hole U1556A (~151 mbsf). Near the bottom of the hole, both dissolved silicon and boron concentrations increase sharply but decline again immediately before reaching basement. Calcium and strontium concentrations reach a broad peak at an intermediate depth and are lower in the upper and lower parts of the hole top. 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 appeared 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 was applied to the SRM data for each core.

The first deployment of the subsea camera system was also the inaugural deployment of the newly acquired conductivity-temperature-depth (CTD) sensor, which was attached to the subsea camera frame. The deployment was successful and produced quality water column data that will aid in identification of water masses.

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