IODP Expedition 393: South Atlantic Transect 2

Site U1583 Summary

Background and Objectives

International Ocean Discovery Program (IODP) Site U1583 (proposed Site SATL-33B) is located ~652 km west of the Mid-Atlantic Ridge at 30°42.6175′S, 20°26.0336′W (Hole U1583F) in 4210 m of water. The basement at Site U1583 was predicted to have formed at ~30.6 Ma at a half spreading rate of 24 mm/y (Kardell et al., 2019; Christeson et al., 2020). The site is located on the north–south-trending (355) CREST 03 seismic crossing line at common depth point (CDP) 12300 about 3.3 km south of the main east–west (085) CREST 1C/D seismic line. A reflector at ~5.73 s two-way traveltime (TWT) was interpreted to be the top of basement and estimated to be 138 meters below seafloor (mbsf).

Site U1583 is a new site that has not been previously occupied. The original operational objectives of Expedition 393 at Site U1583 were to core two advanced piston corer/extended core barrel (APC/XCB) holes to basement and to core and log ~250 m of basement volcanic rocks. At 30.6 Ma, Site U1583 is located in the middle of the South Atlantic Transect and will be compared to older and younger sediments and igneous rocks cored during Expedition 390 and 393. Science objectives at Site U1583 are: 1) investigate the history of the low-temperature hydrothermal interactions between the aging ocean crust and the evolving South Atlantic Ocean and quantify past hydrothermal contributions to global geochemical cycles; 2) collect samples of the sediment- and basalt-hosted deep biosphere beneath the low-productivity South Atlantic Gyre which will be used to refine global biomass estimates and investigate microbial ecosystems' responses to variable conditions; and 3) construct paleoceanographic records of carbonate chemistry and deepwater-mass properties across the western South Atlantic Ocean through key Cenozoic intervals of elevated atmospheric CO_2 and rapid climate change.

While the *JOIDES Resolution* was operating at Site U1583 at 1030 h on 6 July 2022, a tribute was held for Professor Dirk "Dick" Kroon, Regius Professor of Geology at the University of Edinburgh, and former IODP Science Evaluation Panel Co-Chair and until recently Chair of the IODP Forum. Many colleagues from the international scientific ocean drilling community around the world joined the shipboard party in a minute's silence. A free-fall funnel labelled "Dick Kroon 1957–2022" was dropped over Hole U1583F to enable coring and wireline logging operations during Expedition 393.

Operations

Transit

At 0530 h on 5 July 2022 we started the 227 nmi transit to Site U1583. The transit took 21.5 h at an average speed of 10.6 kt and we arrived on site at 0300 h on 6 July.

Site U1583 (SATL-33B)

The ship switched to dynamic positioning (DP) mode at 0315 h, beginning operations in Hole U1583A. On site, we noted a 41 m seafloor depth discrepancy between the ship's precision depth recorder (PDR) 12 kHz estimate of 4234 meters below sea level (mbsl) and the prospectus estimate from the preexpedition seismic survey of 4193 mbsl. Sea conditions were rough and ship heave was 3–4 m. The APC/XCB bottom-hole assembly (BHA) was made up and lowered down to 4228.5 mbsl, 4.5 m above the PDR estimated depth.

Holes U1583A and U1583B

At 1545 h we started Hole U1583A, but Core U1583A-1H recovered 9.14 m of sediment, indicating that the bit was below the seafloor when the piston was shot, so the mudline depth could not be determined. At 1715 h we started Hole U1583B at approximately the same geographic location with the drill bit 5 m shallower. Core U1583B-1H was similarly full, recovering 9.38 m of sediment, so the mudline depth again could not be determined.

Hole U1583C

The bit was raised 10 m shallower than the Hole U1583B shooting depth to 4213.5 mbsl and the ship moved 10 m to the north. At 1845 h we started Hole U1583C and Core U1583C-1H recovered 8.5 m of sediment, giving an apparent mudline at 4214.6 mbsl (we did not know at the time that this core was also shot from below the mudline). Coring continued with the full-length APC system with the Icefield orientation tool run on each core. Temperature measurements were taken on Cores U1583C-4H, 7H, and 10H. Core U1583C-12H hit hard rock when it was fired, based on some damage to the cutting edge of the APC shoe. The basement contact was subsequently confirmed when the bit encountered hard formation 2 m below the top of Core 12H at 104.5 mbsf. Core U1583C-12H recovered 8.02 m of sediment, an apparent 401% recovery, most of which was disturbed sucked-in sediment and is not in place. This basement depth was ~33.5 m shallower than expected from the site survey seismic interpretation of basement depth at ~138 mbsf. Cores U1583C-1H to 12H penetrated from 0 to 104.5 mbsf and recovered 108.3 m (103%).

The XCB coring system was then deployed for Core U1583C-13X, which penetrated 3 m to 107.5 mbsf and recovered 1.9 m of fresh microcrystalline basalt (63%). The bit was then pulled out of the hole, clearing the seafloor at 1540 h on 7 July, ending Hole U1583C.

Hole U1583D

We started Hole U1583D 50 m to the south of Hole U1583C and 20 m to the south of the preexpedition site coordinates, which we reserved to be the location for hard rock coring in Hole U1583F. All holes at this site are located on a north–south line because the site sits on the edge of a north–south trending basin and the basement depth was anticipated to be more uniform in this direction compared to the east–west direction. Core U1583D-1H recovered 10.04 m of sediment and the mudline depth could not be determined. Coring was terminated and Hole U1583D ended at 1730 h.

Hole U1583E

We raised the bit by 5 m to 4204.5 mbsl and at 1835 h we started Hole U1583E in the same location as Hole U1583D. Core U1583E-1H recovered 4.03 m of sediment, placing the mudline at 4210.0 mbsl. This seafloor depth was 24 m shallower than the PDR depth and 17 m deeper than depth predicted from the preexpedition seismic survey. The difference from the seismic survey depth is consistent with observations at Sites U1556 to U1560 along the transect, where mudline seafloor depths are deeper by 8–21 m than the depth estimated from the seismic survey. While retrieving Core U1583E-2H, the core winch weight indicator showed that the core barrel became detached from the core winch line. An overshot was made up using a core catcher and a rotary core barrel (RCB) core barrel. The barrel was lowered and the APC core barrel was retrieved. Coring continued to Core U1583E-12H to a depth of 105.2 mbsf. All cores were full length APC cores with the Icefield orientation tool run on all but two cores (Cores U1583E-3H and 4H). Temperature measurements were taken on Cores U1583E-3H and 8H.

After cutting Core U1583E-12H, the APC core barrel could not be pulled back into the BHA. From 1230 to 1545 h on 8 July we tried to free the barrel by pumping and washing over it, but it would not move. We decided to deploy the Kinley wireline cutter and crimper tool to cut the winch core line just above the APC corer. The Kinley cutter was deployed at 1610 h and the hammer/actuator was deployed at 1640 h. However, based on the core winch line tension, the Kinley cutter had stopped before reaching the bottom of the drill string and cut part way down. Approximately 1560 m of core winch line was pulled up to the ship and then we started to raise pipe. The drill pipe was pulled out of the hole to a depth of 2562 meters below rig floor (mbrf) when the severing tool was found in stand number 83. A second Kinley cutter was deployed in an effort to sever the remaining core winch line from the sinker bar assembly. This was unsuccessful and the rig crew continued to pull the drill string out of the hole, cutting and removing the remaining core winch line at each stand. The second severing tool was found at the top of stand 55. The rig crew continued to pull the drill string to surface, cutting and removing the core winch line as before. The bit reached the rig floor at 0435 h on 10 July, ending Hole U1583E. The rig floor team then disassembled the lower part of the BHA and found that the APC core barrel assembly had stuck in the landing saver sub because a shear pin had become wedged between the landing seat and the core barrel. The APC cutting shoe was undamaged, showing that it had not hit basement, and Core U1583E-12H recovered 6.1 m of sediment after a

long trip to the surface. Cores U1583E-1H to 12H penetrated from seafloor to 105.2 m and recovered 105.2 m (100%).

Hole U1583F

At 1000 h on 10 July we began assembling the RCB BHA with a C-7 bit and then lowered it down to 4174 mbsl, where we paused to slip and cut the drill line and pick up the top drive. At 0030 h on 11 July we started Hole U1583F and washed down through most of the sediment column to 101 mbsf (Drilled Interval U1583F-1-1). Core U1583F-2R penetrated from 101.0 to 109.5 mbsf and recovered 6.4 m (76%) of clayey nannofossil ooze. At the start of drilling Core U1583F-3R a hard formation was noted by the drillers at 109.7 mbsf, and the formation was subsequently confirmed to be basalt. Coring continued to Core U1583F-8R at depth of 142.9 mbsf. With a hole in basement established, a free fall funnel was deployed at 1450 h on 12 July to aid in reentry for downhole logging or for a bit change, which was still a possibility at the time. Coring continued with a typical RCB half-core advance of 4.8 m. To test for microbiological contamination, perfluoromethyldecalin (PFMD) tracer was run continuously in the drilling fluid until the supply was exhausted on Core U1583F-12R. From Core U1583F-12R there was up to 3 m of backfill in the hole after each core, and the drill string experienced high torque at times. It was uncertain if the fill resulted from cuttings not being completely cleared from the hole or if new material was falling down from the borehole wall. We ran 30–60 barrel mud sweeps after every core to flush out the cuttings. The last five cores (Cores U1583F-25R to 29R) averaged only 7% recovery and the bit had been run for ~73 hours of drilling time, so coring was terminated at 1230 h on 16 July after recovering Core U1583F-29R. Basement Cores U1583F-3R to 29R penetrated from 109.5 to 239.5 mbsf and recovered 39.4 m (30%).

To prepare for wireline logging in Hole U1583F we ran a 75 barrel mud sweep and released the RCB bit at the bottom of the hole. We set the end of the pipe at 102.8 mbsf in sediment ~7 m above the basalt flow that forms the uppermost basement to avoid of the risk of dislodging rock pieces while the logging tools were below that depth. At 1730 h we began to rig up the triple combo logging tool string, consisting of natural gamma radiation, neutron porosity, density, and electrical resistivity tools. Because of the hole conditions and also because of ~3 m ship heave, which is high for logging, the density tool source and the magnetic susceptibility (MS) tool were not included in the tool string, and the density tool was used only for the caliper log of borehole diameter. The tool string was lowered down the pipe, but at ~540 mbsl it developed an electrical fault and had to be raised back to the ship. The fault was found in the electrical resistivity tool (the lowermost tool of the tool string), which was then replaced with the backup resistivity tool.

We started to lower the triple combo from the rig floor again at 0045 h on 27 July. Logs were recorded on the downward pass and the tool string reached to 237 mbsf, within 3 m of the bottom of the hole. Two logging passes were run in the open hole. During the first pass, the wireline heave compensator cut out about halfway up the open hole, but logging continued to the top of basement. While descending for the second pass, the tool string encountered an obstruction at 182 mbsf and could not pass below it. We raised the triple combo to the rig floor,

disassembled it, and assembled the Formation MicroScanner (FMS)-sonic tool string. We lowered the FMS-sonic tool string down to 182 mbsf and made a logging pass up to the top of basement at 109.5 mbsf. At that point we found that the tool string could not go back down into basement, and overpull of approximately 8,000 lb was observed when trying to pull the tool string back into drill pipe. After pumping to remove any potential obstruction, the tool string still could not enter the pipe. Finally, we rotated the pipe 180° and the tool string could be pulled in. When the tool string reached the rig floor, it was discovered that the FMS tool caliper arms had been damaged and one was missing. By midnight we had disassembled the FMS-sonic tool string, ending downhole logging operations at Hole U1583F. The difficult borehole conditions and continuing high heave did not allow for the planned logging with the Ultrasonic Borehole Imager (UBI) tool string. We raised the pipe from 102.8 mbsf, clearing seafloor at 0035 h on 18 July. The BHA reached the ship at 0645 h and was disassembled. The rig floor was secured for transit by 0840 h, and we raised the thrusters and began the transit to Site U1560.

Principal Results

Site U1583 targeted 30.6 Ma upper oceanic crust along the South Atlantic Transect. A near-complete sedimentary sequence was recovered from the combination of Holes U1583C and U1583E, and uppermost basement rocks were recovered in Hole U1583C as well as Hole U1583F. Hole U1583F advanced to a total depth of 239.5 m, ~130 m into volcanic rocks of the ocean crust, and recovered >39 m of basalt lavas and breccias with a recovery rate of ~30%.

Sediments

Sedimentology

Drilling at Site U1583 recovered 108.3 m of sediment and 1.89 m of volcanic rock in Hole U1583C and 105.2 m of sediment in Hole U1583E. The cores recovered from Holes U1583A to U1583F record four major sedimentary lithologic Units (I–IV). Biogenic sediments consist primarily of calcareous nannofossil ooze with varying amounts of clay and foraminifers. Intervals with siliciclastic sediments have abundant clays with variable nannofossil and foraminifer content. Lithologic Unit I is composed of 3 m of Pliocene/Pleistocene sediments, consisting of interbedded nannofossil-rich clay with foraminifers and clayey nannofossil ooze, and was only recovered in Hole U1583E. Lithologic Unit II is composed of up to 11.3 m of Pliocene/Pleistocene sediments, predominantly beds of nannofossil ooze with clay and foraminifers interbedded with beds of nannofossil ooze with clay. Unit III consists of up to 11.9 m of clay and nannofossil ooze with varying amounts of clay. Unit IV is subdivided into three subunits (IVA–IVC). Subunit IVA is up to 64.4 m thick and consists of nannofossil ooze with clay and varying amounts of foraminifers. Subunit IVB comprises up to 6.1 m of nannofossil ooze with clay and decimeter-thick beds of calcareous ooze. Subunit IVC is up to 24.4 m thick and consists of nannofossil ooze with clay and varying amounts of foraminifers.

Biostratigraphy and Age-Depth Model

Calcareous nannofossil and planktic foraminifer biostratigraphy of Site U1583 was performed primarily on core catcher samples examined onboard the *JOIDES Resolution* during Expedition 393. The mudline sample in Hole U1583E contains modern assemblages of planktic foraminifers and calcareous nannofossils. In contrast, the uppermost sediments in Hole U1583C contain a collection of Recent to Late Pleistocene planktonic foraminifers, accompanied by Early Pleistocene calcareous nannofossils, confirming that the mudline was missed in this hole.

Biostratigraphic analyses indicate that the Pliocene/Pleistocene boundary occurs above 11.1 m core depth below seafloor, method B (CSF-B) in Hole U1583C, and above 13.5 m CSF-B in Hole U1558E, which corresponds to the sequence of brown nannofossil-rich clays and pink nannofossil oozes (Lithologic Units I and Unit II, respectively). Dark clay sediments (Lithologic Unit III) below the Pliocene–Pleistocene sediments are ~6.6 m thick in Hole U1583C and 11.8 m thick in Hole U1583E, and represent a condensed interval spanning roughly ~9 My across the Miocene/Pliocene boundary.

Biostratigraphic data indicate Early-Middle Miocene sediments occur between 14.8 and 36.0 m CSF-B in Hole U1583C, and between 23.0 and 42.0 m CSF-B in Hole U1583E. The Oligocene is ~71.5 m thick in Hole U1583C, and ~54.8 m thick in Hole U1583E, and corresponds to the sequence of calcareous and nannofossil oozes (combined Lithologic Unit IV).

The most accurate determination for the age of sediment/basement interface comes from the deepest sediment samples from Holes U1583C (Sample 393-U1583C-12H-CC, 12–17 cm) and U1583E (Sample 393-U1583E-12H-CC, 0–1 cm) that both contain *Sphenolithus distentus*, suggesting an age younger than 30.0 Ma. Planktic foraminifer assemblages in the same two samples contain *Subbotina angiporoides* and record the disappearance of *Paragloborotalia opima*, suggesting an age older than 30.8 Ma. These results are generally in good agreement with the projected crustal age of ~30.6 Ma at Site U1583.

Calcareous nannofossil and planktic foraminifer bioevents, in conjunction with paleomagnetic data, allowed for comprehensive hole age-depth models and calculation of linear sedimentation rates (LSRs). LSRs range from 0.13 cm/ky to 4.08 cm/ky in Hole U1583C, and from 0.06 cm/ky to 7.29 cm/ky in Hole U1583E. In both holes, the highest LSRs consistently occurred within the Oligocene, with values ranging from 0.29 to 4.08 cm/ky in Hole U1583C, and from 0.17 to 7.29 cm/ky in Hole U1583E. In contrast, the Neogene and Quaternary in both holes record the lowest sedimentation rates.

Sedimentary and Pore Water Geochemistry

Samples from Site U1583 were mostly collected from Hole U1583C, with one additional water sample each from Holes U1583E (mudline) and U1583F (sediment/basement interface). Shipboard analyses included fluid chemistry, sediment geochemistry, and measurements of headspace gas. Pore fluid salinity is uniform at the seawater value (35) throughout Hole U1583C,

although concentrations of Na, Cl, and Br are higher than in seawater below ~5 m core depth below seafloor, Method A (CSF-A). Measured pH is uniformly (7.5 ± 0.1, 2σ, n = 13) lower than local bottom seawater between ~3 m and 56 m CSF-A and gradually increases (up to 7.8) between ~60 m and 100 m CSF-A. Alkalinity values are much more variable and show a number of inflection points, including increases at the boundaries between lithostratigraphic Units II (nannofossil ooze with clay and foraminifers) and III (clay with nannofossils and clayey nannofossil ooze; 2.0 to 2.5 mM) and between Subunits IVA (nannofossil ooze with clay and foraminifers) and IVB (calcareous and nannofossil oozes with clay and foraminifers; 2.2 to 2.5 mM). The transition from Units II to III is also marked by (1) an increase in Ca, Sr, and Sr/Ca and a decrease in Mg concentrations in pore fluids, consistent with the dissolution of biogenic carbonate and recrystallization of high-Mg inorganic calcite, and (2) significant increases in B (67%), Li (10%), Si (78%), and K (17%) concentrations, which are likely a result of diagenetic reactions involving detrital silicates and biogenic silica. The weak positive trend between SO_4 and Ca concentrations in Hole U1583C hints at a potential role for sulfate reduction within these sediments, which may also explain the concomitant downhole decrease in SO_4 and total organic carbon (TOC) content. NH_4 (3 to 17 μM) and Mn (0.63 to 2.86 μM) concentrations remain low throughout the sediment column, with the exception of two peaks observed in Unit III (clay with nannofossils and clayey nannofossil ooze) and Subunit IVB. Oxygen concentrations decrease between Units II and IVA and reach a minimum value of 10.5 μM at ~22 m CSF-A before gradually increasing to 207.4 μM at ~99 m CSF-A. Calcium carbonate content is generally high throughout the hole, with the exception of Unit III, which has a difference of ~80 wt% between the top and bottom of the unit. Conversely, low TOC concentrations (<0.36 wt%) are measured in Hole U1583C and values gradually decrease towards the bottom of Unit IVC (nannofossil ooze with clay and foraminifers), consistent with organic matter oxidation. A spike in TOC is seen in Unit IVB, which coincides with increases in SO_4, NH_4, and Mn geochemical profiles. In Hole U1583C, headspace gas measurements for methane, ethane, propane, and higher molecular weight hydrocarbons were below detection limits.

Paleomagnetism

Continuous measurements of remanent magnetization were conducted on sediment cores from Hole U1583C and Hole U1583E using the superconducting rock magnetometer (SRM) at 2 cm intervals before and after progressive alternating field (AF) demagnetization of three steps (5, 10, 20 mT fields). Discrete measurements including anisotropy of magnetic susceptibility (AMS) and remanence after AF demagnetization were conducted on 25 cube samples. Isothermal remanent magnetization (IRM) acquisition experiments were performed on eight selected samples, which is at least one per lithological unit. Paleomagnetic measurements provide constraint on the magnetostratigraphy for the entire sediment sequence at Site U1583.

Viscous overprints are almost completely removed at 20 mT demagnetization and characteristic components can be observed at this stage. Inclination values of the revealed characteristic

components (a.k.a. 20 mT inclination) show a bimodal distribution in both holes, where values are clustered around +57° and −54° in Hole U1583C and around +59° and −51° in Hole U1583E. Well defined normal and reversed polarities in the 20 mT inclination are present in both Holes U1583C and U1583E, enabling age determinations by magnetostratigraphic correlations with polarity chrons in the geomagnetic polarity timescale (GPTS). The topmost sediment sequence in Hole U1583E contains the Brunhes, Matuyama, and Jaramillo Chrons, which are absent in Hole U1583C. The Oligocene/Miocene boundary occurs within Unit IVA at ~40 m CSF-A in Hole U1583C and at ~45 m CSF-A in Hole U1583E. Paleomagnetic results at the bottom of the sediment sequence, above the sediment/basement interface (between 100 and 110 m CSF-A), were placed in Chron C11r for Hole U1583C and Cr11.2n in Hole U1583E. The relative ages of those Chrons agree with the estimated basement age of ~30.6 Ma (Kardell et al., 2019).

Discrete samples were subjected to AF demagnetization up to a maximum of 130 mT. Most of the samples reveal a single remanent magnetization component after the 5 mT AF demagnetization step with maximum angular deviation (MAD) angles spanning from 2.2° to 14.8°. Inclinations of characteristic remanent magnetization (ChRM) components calculated from discrete sample measurements are consistent with the values measured from the SRM.

Mineralogy-related measurements (IRM and AMS) were conducted on one to two discrete samples per each lithological unit. IRM measurements reveal the dominance of low-coercivity minerals throughout the cored interval with no variations with depth or between lithological units. AMS measurements show two different trends in the magnetic fabric with either a subvertical or a subhorizontal magnetic foliation. Samples showing subhorizontal magnetic foliation correspond to typical oblate sedimentary fabric. In contrast, the presence of samples characterized by a subvertical magnetic foliation might be related to either soft sediment deformation or drilling disturbance.

Physical Properties

Characterization of the sediment physical properties at Site U1583 was primarily based on cores from Hole U1583C, with additional information from Hole U1583E. Whole-round, section-half, and discrete measurements were considered together to characterize the petrophysical signatures for the different lithologic units. All archive halves were imaged using an X-ray image logger. A correlation framework and a semicontinuous splice was developed for the site that considers natural gamma radiation (NGR), gamma ray attenuation (GRA), MS, and magnetic inclination from each hole.

Whole-round measurements of NGR range from 1 to 42 counts/s through the sedimentary section in Hole U1583C. NGR is relatively low in the nannofossil ooze (Units II and IV; ~5 counts/s) and high in the clay-rich Unit III (15 to 42 counts/s, mean 27 counts/s). Similarly, MS ranges from 1 to 126 instrument units (IU) and shows a downhole trend similar to the NGR record over the entire hole, with the highest values in Unit III (ranging from 30 to 122 IU, mean 78 IU). Bulk density based on GRA ranges from 1.4 to 2.5 g/cm^3 over the interval measured and

shows an overall gradual increase downhole due to increasing consolidation of sediments with depth. In moisture and density analyses, porosity shows an overall decreasing trend from 65% at the top of Unit II to 55% in the bottom of Unit IVA, then remains relatively constant through the bottom of Hole U1583C, and bulk density measured generally follows the GRA record. *P*-wave velocity ranges from 1.45 km/s to 1.72 km/s with a mean value of 1.54 ± 0.03 km/s, and increases downhole, which is likely due to sediment compaction. Shear strength is relatively uniform in nannofossil ooze with a value of 15–16 kN/cm^2, and shows its highest value of 42 kN/cm^2 in the clay rich Unit III. Compressional strength is scattered between 0.1 kg/cm^2 and 1.0 kg/cm^2 (mean 0.6 ± 0.3 kg/cm^2) throughout the sedimentary sections with no apparent downhole trend. Most samples have a thermal conductivity of ~1.3 W/(m·K), and the lowest measurements come from Unit III (0.93 W/[m·K]). The vertical conductive heat flow for Site U1583 was estimated to be 31 mW/m^2, based on three advanced piston corer temperature (APCT-3) measurements and thermal conductivity. This value is lower than the modeled heat flow values for ocean crust of this age, requiring significant regional advection of heat by hydrothermal fluid circulation (cf., Kardell et al., 2022)

Microbiology

Microbiology sampling of sediments in Hole U1583C was focused on exploring evidence for microbial life using microscopy, culture-based, and culture-independent approaches. One microbiology whole-round sample (between 5–10 cm long) was collected from each 9.5 m core. One additional sediment sample was taken from near the sediment/basement interface in Hole U1583F. A total of 13 routine microbiology whole-rounds were taken and subsequently subsampled for different ship- and shore-based scientists, and an additional 33 whole-rounds were taken for personal, specialized, shore-based analyses.

Two microbiology experiments were started shipboard during Expedition 393 on sediment samples from Site U1583. To study the extent of viral activity and dynamics between viruses and other microbial life (Bacteria and Archaea), virus-induced microbial mortality and prophage induction experiments were performed on subsamples taken from five microbiological whole-round cores throughout the sediment column. To study the microbial activity at the sediment/basement interface, ammonium enrichment incubation experiments were started with the deepest sediment cores in Holes U1583C and U1583F, along with the uppermost basement samples.

Volcanic Rocks

Igneous Petrology

Site U1583 was established above ~30.6 Ma ocean crust by Expedition 393 and Holes U1583C and U1583F recovered volcanic basement. The uppermost igneous rock encountered was an ~11 m thick massive basalt lava flow intersected by Holes U1583C and U1583F at 107.5 mbsf and 109.7 mbsf, respectively, some 30 m shallower than predicted by seismic site surveys

(Kardell et al., 2019; Christeson et al., 2020). Only Hole U1583F advanced deeply into basement, reaching 239.6 mbsf or 129.8 m subbasement (msb) with ~30% recovery.

Hole U1583F intersected three volcanic sequences: A, B, and C with 62 m, 35 m, and 33 m expanded thicknesses, respectively, separated by two sedimentary breccia units (Unit 4 and Unit 6) with thicknesses estimated between 0.8–3.4 m. The upper Sequence A (109.7–171.6 mbsf) consists of Unit 1, an 11 m thick massive lava flow, Unit 2 made of moderately plagioclase-olivine-augite phyric pillow lavas and sheet flows, and the aphyric Unit 3, which is markedly more primitive than all the other lavas in the hole. The middle Sequence B is capped by sedimentary breccia Unit 4 and consists of moderately plagioclase-olivine (± augite) phyric pillow basalts and another thin breccia horizon. The lower Sequence C is again capped by a sedimentary breccia (Unit 6) above sparsely to moderately plagioclase-olivine phyric pillow basalts that are chemically and lithologically similar to Sequence B.

Lava compositions assessed by pXRF downhole vary both gradationally and in a stepwise fashion across petrologically defined unit boundaries. Incompatible element concentrations and Zr/Ti ratios are consistent with a relatively primitive N-MORB-like lava composition at Site U1583. In contrast to the Sequence stratigraphy defined by the presence of sedimentary breccias, pXRF measurements reveal that Unit 3 has a uniquely primitive composition in Hole U1583F, splitting the Hole into three major chemostratigraphic units: Units 1–2, Unit 3, and Units 4–7.

Alteration Petrology

Hole U1583F records fluid/rock reactions over the full range of spatial contexts expected for uppermost basement. The secondary minerals forming are predominantly various clay minerals, calcium carbonate, iron oxyhydroxides, and zeolites that are consistent with reactions at low temperatures between basalt and seawater or seawater-derived ridge flank hydrothermal fluids. Within Hole U1583F it is possible to identify zones of alteration that have distinctive characteristics. The uppermost 70 m of the hole are characterized by the presence of green clay filling vesicles (in background and in alteration halos) and a generally low abundance of alteration halos (<30% of core surface) and background alteration dominates. This zone also hosts the most calcium carbonate and carbonate abundance increases downhole through this zone. From 40–70 msb, complex multicolored halos occur that exhibit both diffuse and sharp halo sequences that are variably mutually overprinting. These multi-halos are best observed through the changing sequences of vesicle fillings. From 70 msb, green clay in vesicles is absent and the abundance of carbonate filled veins decreases. These changes are accompanied by an increased modal proportion of alteration halos, with the prominence of brown halos increasing downhole. From 95 msb halos are most commonly orange and there is a slight increase in carbonate veins.

Igneous Geochemistry

For Hole U1583F basement cores, representative samples were taken from the freshest portions of each lithological subunit to obtain a downhole record of the primary magmatic conditions, along with one sample near the sediment/basalt contact. In addition, one sample of the intercalated indurated calcareous sediment/breccia matrix was taken to better understand the sediment-basalt chemical exchanges that occurred as new lavas erupted. Seventeen samples were measured for loss on ignition (LOI) and bulk rock geochemical analysis via inductively coupled plasma–atomic emission spectroscopy (ICP-AES). The unoxidized powders of these samples were characterized for elemental abundances via pXRF to complement additional pXRF measurements made directly on the cut core surfaces.

The Hole U1583F basalts are moderately altered, with elevated abundances of K_2O and Rb. Basalt compositions show variability downhole that is most evident in the pXRF surface data. TiO_2 contents vary between 1.3–1.5 wt%, consistent with a moderate amount of magmatic crystallization before eruption. K_2O shows a gradual increase downhole, from 0.1 wt% to as high as 0.48 wt%. MgO shows clear evidence for Mg removal from the rocks via seafloor weathering, with the lowest MgO samples clustered near horizons of volcano-sedimentary breccias, suggesting locally more intensive reactions with seawater. In terms of basaltic rock type, the freshest Site U1583 basalts classify as olivine tholeiites following the Yoder and Tilley (1962) normative classification scheme. K/Zr ratios are overall lower than seen in the older South Atlantic Transect sites, ranging to values similar to those seen at Site U1559 (≈6.6 Ma).

Paleomagnetism of Volcanic Rocks

Continuous measurements of remanent magnetization were performed at a resolution of 2 cm intervals on basement cores of Hole U1583F using the SRM before and after progressive AF demagnetization at 5, 10, and 20 mT fields. Only core pieces longer than 9 cm were measured. Discrete magnetic measurements performed on 20 cube samples taken predominantly from fresh background basalts with some samples displaying different styles and intensities of hydrothermal alteration.

The SRM results indicate that viscous overprints are mostly removed and primary components can be clearly observed at the 20 mT demagnetization step. The primary components predominantly show positive inclination, which indicates reversed geomagnetic polarity at this latitude (30°S). Inclination values are clustered around 45.4°, agreeing with the calculated geocentric axial dipole (GAD; ±49.1°). Based on the age of the sediments at the sediment/basement interface, the basement at Site U1583 can be placed in the reverse Chron C11r with a basal age of 30.59 Ma (Gradstein et al., 2020). However, in brecciated intervals some rocks present negative inclinations, suggesting either the extensive overprinting of the primary remanent magnetization by a secondary component or rotation of the clasts.

A subset of 20 discrete samples were subjected to AF demagnetization up to 190 mT step to isolate the ChRM. Discrete sample measurements mostly revealed well-defined ChRM with MAD between 0.3° and 14.8°. A few samples show a more stable secondary component, as the ChRM is revealed after the 25 mT step. Experiments to determine the magnetic mineralogy were conducted on a selected number of samples to define the possible relationships with igneous units and alteration types. Most of the samples show the dominance of low-coercivity minerals as titanomagnetite. A few altered basalts and the breccias do not reach saturation at the maximum applied field of 1200 mT, implying a significant contribution of high-coercivity minerals such as hematite. Anisotropy of magnetic susceptibility measurements reveal different magnetic fabric shapes depending on the emplacement style of igneous units.

Physical Properties

Whole-round, section-half, and discrete measurements characterize the petrophysical signatures for the different igneous units. In addition to these measurements, ~77% of the recovered material was scanned using the Deutsche Montan Technologie (DMT) core scanner after identifying oriented core pieces with relatively cylindrical shapes. Selected archive-half sections with breccia were imaged using an X-ray image logger.

NGR in Hole U1583F is relatively low in the basalts (Unit 2, 3, 5 and 7), around 2 counts/s, and higher in the sedimentary breccias: 5.1 ± 2.7 counts/s in Unit 4 and 4.0 ± 1.5 counts/s in Unit 6. Discrete point contact measurements of MS range from 1 to 2910 IU and are highest in the massive flows of Unit 1 (mean 610) and sheet flows of Unit 3 (mean 196). A total of 23 discrete sample cubes were used for *P*-wave velocity and moisture and density analyses and were described in terms of their alteration, emplacement style, and groundmass grain size. Bulk density ranges from 2.05 to 2.90 g/cm^3 with the breccia samples having lower densities than the basalts. Breccias also have the lowest *P*-wave velocity and the highest porosity. Basalts with stronger alteration have higher porosity, lower *P*-wave velocity, lower bulk density, and lower grain density. Most basalt samples have a porosity <10%, although one sample of a strongly altered basalt from a brown halo has a porosity of 12.1%. *P*-wave velocity shows a general decreasing trend with depth in Hole U1583F and ranges from 4.87 to 6.00 km/s. Lower *P*-wave velocity towards the bottom of the hole is likely driven by the higher prevalence of altered basalts in Units 5 through 7. Thermal conductivity in the basement at Site U1583 ranges from 1.23 to 2.00 W/(m·K), with lowest values found in Unit 4 and Unit 6 (sedimentary breccias), and higher mean values between 1.6 and 1.7 W/(m·K) in basalt flows.

Downhole Logging

After completion of coring, two downhole logging tool strings were deployed in Hole U1583F (see Operations, above). Sea state was marginal for logging (up to 3 m heave) and affected the operations. However, the logging data, in particular the resistivity log, are still of good quality and will help constrain the major units identified in the volcanostratigraphy.

Microbiology

Microbiology sampling from volcanic rocks in Hole U1583F was focused on exploring evidence for life in the basement, especially at the sediment/basement interface using microscopy, culture-based, and culture-independent approaches. Nine whole-round samples (10–17 cm long) from Hole U1583F, and one whole-round sample (15 cm) from Hole U1583C, reflecting all the major igneous characteristics and units, were collected for microbiological analyses. Following the careful removal of potentially contaminated core exteriors, the remaining material was split into subsamples that were prepared for different microbiology analyses. Experiments were started shipboard to study microbial activity at the sediment/basement interface using ammonium enrichment incubations. These incubations focused on the uppermost basement samples to correspond with the deep sediment column samples described in the sediment section.

To determine the extent of contamination of microbiology samples, the perfluorocarbon tracer perfluoromethyldecalin (PFMD) was injected into drill fluids during Hole U1583F coring until the tracer ran out after Core U1583F-12R. Microbiologists then collected samples from both the exterior and interior of core intervals selected for microbiology analysis, as well as core catcher rubble, to quantify the presence of PFMD. PFMD was detected from a majority of the exterior samples, with an average concentration of 46 ppb/g and a median concentration of 48 ppb/g of rock when detected. The tracer was not detected in the interior microbiology samples, suggesting no to minimal drilling contamination of the samples.

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