IODP Expedition 393: South Atlantic Transect 2

Site U1558 Summary

Background and Objectives

International Ocean Discovery Program (IODP) Site U1558 (proposed Site SATL-43A) is located ~1067 km west of the Mid-Atlantic Ridge at 30°53.78′S, 24°50.48′W, in 4334 m of water. The basement at Site U1558 was predicted to have formed at ~49.2 Ma at a half spreading rate of 19.5 mm/y (Kardell et al., 2019). The site is located on seismic line CREST1B/C at position CDP 3252 about 3.4 km west of the crossing line CREST 04, where a reflector at ~5.94 s two-way traveltime (TWT) was interpreted to be the top of basement and estimated to be 148 m below seafloor (mbsf).

Site U1558 was previously occupied in November 2020 during Expedition 390C with objectives to confirm the depth to basement by coring, conduct gas safety measurements, and set a reentry system consisting of a reentry cone and 13⅜ inch casing (Estes et al., 2021). Hole U1558A was cored by advanced piston corer/extended core barrel (APC/XCB) to 163.9 mbsf, finding the sediment/basement contact at 158.9 mbsf. Holes U1558B and U1558C marked unsuccessful attempts to drill in and release the reentry system using the Dril-Quip running tool. While lowering the reentry system for Hole U1558D, the reentry cone and mudskirt became detached from the casing and fell to the seafloor the right way up and within a few meters of the intended location. The drill bit and casing assembly were lowered through the cone and drilled into Hole U1558D, setting the casing shoe at 146.1 mbsf and the base of the hole at 150.0 mbsf.

The original operational objectives of Expedition 393 at Site U1558 were to core a single APC/XCB hole to basement and to core and log ~250 m of basement volcanic rocks in Hole U1558D.

At 49.2 Ma, Site U1558 is the second oldest location of the South Atlantic Transect and will be compared to older and younger crustal material cored at Expedition 390/393 sites. Science objectives at Site U1558 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.

Operations

During Expedition 393, three holes were cored at Site U1558. Hole U1558E consisted of one APC core, which missed the mudline. Hole U1558F was cored by APC/XCB to 177.2 mbsf, with the sediment/basement contact at 176.0 mbsf. In Hole U1558D, the sediment/basement contact was found at 166.8 mbsf and the volcanic sequence was cored by rotary core barrel (RCB) to 370.2 mbsf (203.4 meters subbasement). Unfortunately, while withdrawing the bit out of Hole U1558D to prepare for wireline logging, the reentry cone and some casing were pulled out the seafloor by the bottom-hole assembly (BHA), ending operations in that hole. The cased South Atlantic Transect holes were intended to be legacy holes for potential future deepening or other operations, but this is no longer possible at this site. This damage also precluded wireline logging of the volcanic sequences.

Transit

The ship completed the 508 nmi transit from Site U1559 to Site U1558 in 46.5 h (1.9 days), arriving on site at 1125 h on 25 June 2022. The ship was switched to dynamic positioning (DP) mode, beginning operations at Site U1558.

Hole U1558E

An APC/XCB BHA was assembled and deployed to 4321 meters below rig floor (mbrf). A pipe "pig" was circulated down through the drill pipe to remove any rust from the extra ~1300 m of pipe required to reach the seafloor at Site U1558, compared to the shallower Site U1559 drilled previously. Heavy weather and sea conditions delayed the start of coring in Hole U1558E by 3 h, while we waited for the ship's heave to subside. The ship was positioned 20 m to the south of Hole U1558D. At 0440 h on 26 June, Core U1558E-1H penetrated 9.5 m and recovered 9.97 m (105%), but there was no mudline. Therefore, at 0515 h Hole U1558E was terminated.

Hole U1558F

The ship was offset 10 m to the east of Hole U1558E (50 m southeast of Hole U1558A) and at 0610 h on 26 June we started Hole U1558F. Coring started with the full-length APC and a seafloor depth of 4337.3 meters below sea level (mbsl) was established based on the mudline in Core U1558F-1H. After Core U1558F-3H was drilled ahead by 3 m in an effort to offset gaps in the stratigraphy recovered from Hole 390C-U1558A. APC coring continued to Core U1558F-10H at 86.9 mbsf, where 80,000 lb of overpull was required to free the barrel, marking APC refusal depth. All full-length APC cores were oriented and the advanced piston corer temperature (APCT-3) tool was deployed on Cores U1558F-3H, 6H, and 10H. Unfortunately, the advance in Core U1558F-10H was overdrilled by 4.7 m and core is missing from Hole U1558F from 82.2 to 86.9 mbsf. The half-length advanced piston corer (HLAPC) was deployed for Cores U1558F-11F to 19F. Core U1558F-19F at 129.2 mbsf needed to be freed by drilling over the core barrel, marking HLAPC refusal depth. The XCB coring system was deployed from Cores U1558F-20X to 24X. The driller noted a formation change at 176.0 mbsf, and drilling was terminated at

177.2 mbsf approximately 1.2 m~~eters~~ into volcanic rocks. Cores U1558F-1H to 24X penetrated from 0 to 177.2 mbsf and recovered 164.3 m (94%). The drill string was recovered to the ship, and the drill bit cleared the rotary table at 0035 h on 28 June, ending Hole U1558F.

Hole U1558D

We then made up the RCB BHA with a new TransCo C4 RCB bit, and following a slip and cut, we lowered it down to Hole U1558D, where a reentry system had been installed in November 2020 during Expedition 390C. Guided by the subsea camera video feed, the ship maneuvered over the hole. At first the bit entered the center of the cone but soon met resistance and did not pass down into the casing and had to be pulled back above the cone. The second attempt was successful and the bit reentered Hole U1558D at 1505 h. We lowered the bit to the depth of the existing hole, 150 mbsf, and started coring at 1845 h. The existing hole is designated as drilled Interval U1558D-1-1. Cores U1558D-2R to 3R penetrated from 150 to 166.5 mbsf and recovered 3.27 m (20%) of sediment. The sediment/basement contact was determined to be at 166.8 mbsf based on an abrupt slowing of the rate of penetration at that depth while starting to core Core U1558D-4R. Coring continued, at first alternating between full and half cores based on the rate of penetration and core recovery, and from Core U1558D-16R switching exclusively to half-length cores. Perfluorocarbon tracer (PFT) was run on all cores. Core U1558D-39R reached a healthy 203.4 m into volcanic rock and coring was stopped to enable wireline logging. Basement Cores U1558D-4R to 39R sampled from 166.8 to 370.2 mbsf, recovered 97.53 m of core (~48% recovery), and took 5.0 days to drill.

At 0330 h on 4 July we set back the top drive and pulled the bit up to 126.3 mbsf, observing 20,000 lb drag. At 0445 h we deployed the subsea camera to observe the bit release and guide reentry, in preparation for downhole logging. We pulled the bit out of the hole to 4317 mbsl, 17 m above seafloor. However, at 0615 h the drill pipe was observed by the subsea camera to be still inside the reentry cone, with the cone much higher up than it should be. The extra weight on the drill string confirmed that the cone and some, perhaps all, casing had been pulled out of the hole by the BHA. From 0730 to 0830 h, we attempted unsuccessfully to free the casing by pushing into the seafloor. We raised the camera back up to the ship and from 1030 to 1100 h we attempted to free the drill string from the casing by rotation. During this process, a weight decrease of 30,000 lb was observed on the hook load indicator, showing that at least part of the casing had come free. The subsea camera was deployed again and at 1345 h we observed that the cone had fallen away and that some of the BHA drill collars appeared to be bent, but the casing hanger and casing crossover were still attached. The decision was made to retrieve the drill string and deal with any casing at the surface. When the drill string reached surface, the casing hanger and casing were no longer attached and must have fallen away while being raised. The bit cleared the rotary table on the rig floor at 0215 h on 5 July. We disassembled the BHA and examined it for damage and set aside the bottom three drill collars, one of which was slightly bent. We then secured the rig floor for transit and raised the thrusters, ending operations in Hole U1558D and at Site U1558. The original operations plan had included running three downhole

logging tool strings in Hole U1558D but this could not be undertaken. Unfortunately, Hole U1558D is no longer a legacy hole for potential future operations. At 0530 h on 5 July, we started the 227 nmi transit to Site U1583 (proposed Site SATL-33B).

Principal Results

Site U1558 targeted 49.2 Ma upper oceanic crust along the South Atlantic Transect. A near-complete sedimentary sequence was recovered from the combination of Holes U1558A and U1558F, and uppermost basement rocks were recovered in both holes as well as Hole U1558D. Hole U1558D advanced 203.7 m into basement and recovered a volcanic sequence of moderately altered plagioclase ± olivine ± clinopyroxene phyric pillow lavas and sheet and massive flows with abundant interlava intervals of indurated calcareous sediment.

Sediments

Sedimentology

A near complete 159 to 176 m thick sequence of siliciclastic and biogenic sediments was recovered from two sediment holes cored at Site U1558 (Holes U1558A and U1558F), principally comprising brown Early Miocene nannofossil-rich clay overlying pinkish Middle Eocene to Early Miocene nannofossil ooze and chalk with clay and foraminifers.

Two lithologic Units (I and II) are defined at Site U1558. Lithologic Unit I is composed of up to 10.11 m of Pleistocene to Early Miocene, brown and reddish-brown nannofossil-rich clay containing varying amounts of foraminifers and sponge spicules and subordinate nannofossil ooze with clay and foraminifers. Lithologic Unit II is composed of up to 165.32 m of Middle Eocene to Early Miocene biogenic sediments consisting primarily of pink, pinkish-white, pinkish-gray and light brown nannofossil ooze and chalk with varying amounts of clay and foraminifers. Unit II is subdivided into three subunits based on their composition (clay, $CaCO_3$ and foraminifer content) and color. Differences in constituent mineral assemblages between the units and with increasing burial depth are relatively subtle. There is a discernible increase in $CaCO_3$ content with concomitant decrease in clay content downhole. In lower portions of the sediment section, nannofossil ooze is moderately consolidated and is termed chalk. Overall, clay content decreases downhole.

Biostratigraphy and Age-Depth Model

Calcareous nannofossil and planktic foraminifer biostratigraphy of sediments recovered at Site U1558 were performed primarily on core catcher samples from Holes 390C-U1558A and 393-U1558F, examined both onshore and onboard the *JOIDES Resolution* during Expedition 393.

The mudline sample from Hole U1558A lacks microfossils, preventing an age determination. The mudline sample from Hole U1558F contains Pleistocene planktonic foraminifers, whereas

calcareous nannofossil assemblages are a predominantly modern assemblage with some Miocene and Paleogene taxa present, indicating some degree of reworking and mixing.

Biostratigraphic analyses indicate that Miocene sediments occur above 22.27 m core depth below seafloor-B (CSF-B) in Hole U1558A, and above 13.50 m CSF-B in Hole U1558F. This corresponds to lithologic Unit I and the uppermost part of Unit IIA. Oligocene-aged sediments occur between 31.85–108.90 m CSF-B in Hole U1558A and between 28.83–110.40 m CSF-B in Hole U1558F. Thus, most of lithologic Units IIA and IIB are Oligocene.

The Eocene–Oligocene boundary is inferred to occur within the lowermost part of lithologic Unit IIB (at 108.90 m CSF-B in Hole U1558A, and at 109.45 m CSF-B in Hole U1558F), close to the Unit IIB/IIC transition. Eocene sediments are approximately 48.41 m thick in Hole U1558A, and 50.4 m thick in Hole U1558F, corresponding to lithological Unit IIC.

The most accurate determination of the age of the sediment/basement interface comes from core catcher samples from Sections 390C-U1558A-18X-CC and 393-U1558F-24X-CC, both of which contained *Reticulofenestra umbilicus*, suggesting that sediments near the sediment/basement interface are not older than 42.72 Ma. Planktic foraminifer assemblages in Sample U1558F-24X-CC indicate a minimum basement age of 42.6 Ma. These results combined indicate that the first sediments deposited at this site are almost 6.5 million years younger than 49.2 Ma, the age estimated for ocean crust at Site U1558 (Kardell et al., 2019).

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 0.38 cm/ky to 1.09 m/ky in Hole U1558A, and from 0.34 cm/ky to 1.8 cm/ky in Hole U1558F. Apart from the condensed sedimentation of Unit I, the lowest sedimentation rates occur in the Late Oligoene and Early to Middle Miocene, as well as across the Eocene–Oligocene transition. The highest LSRs occur at the base of the holes, in the Middle Eocene, and throughout the Oligocene.

Sedimentary and Pore Water Geochemistry

Samples from Holes U1558A and U1558F were analyzed for interstitial water (IW) and sediment geochemistry and, in the case of Hole U1558A, for headspace gas. IW geochemical data from Hole U1558F is consistently higher for sulfate, Na, Mg, and Cl concentrations, and lower for Sr than in Hole U1558A. When applying a mudline correction and adjusting Hole U1558A values to expected mudline values, elemental concentrations in Hole U1558A show excellent agreement with data from Hole U1558F. Variations in pore water Ca, Mg, Sr concentrations, and Sr/Ca ratios observed in both holes are consistent with authigenic carbonate formation and recrystallization of a high-Mg calcite phase during sediment diagenesis. Dissolution of biogenic silica, weathering of detrital silicates, and/or ion exchange between sediment and porewaters may explain the sharp increases in fluid B, Li, Si, and K concentrations relative to the mudline in Unit I (nannofossil-rich clay) in both holes. The pH of Hole U1558A

IW is consistent with local seawater pH, with lower values recorded in Hole U1558F. Alkalinity was conversely higher in Hole U1558F and reached seawater values within Unit IIC (nannofossil chalk with clay and volcaniclastics). Calcium carbonate contents in clay-rich lithological Unit I are lower compared to the underlying nannofossil oozes, as expected. The SO_4 minima in both holes roughly coincide with a spike in Mn concentrations and are likely controlled by organic matter remineralization.

Paleomagnetism

Paleomagnetic measurements were undertaken to determine the magnetic polarity stratigraphy and constrain the magnetic mineralogy of sedimentary units at Site U1558. Continuous measurements of the remanent magnetization were conducted on sediment cores from Hole U1558F and the sediment/basement interface in Hole U1558D using the superconducting rock magnetometer (SRM) at a resolution of 2 cm. Remanent magnetization before and after progressive alternating field (AF) demagnetization of three steps (5, 10, 20 mT fields) were measured during this process. Discrete measurements including anisotropy of magnetic susceptibility (AMS) and AF demagnetization were conducted on a total of 38 cube samples. Isothermal remanent magnetization (IRM) acquisition experiments were performed on eight selected samples, which is about two per lithologic unit.

The SRM results from Hole U1558F and the sediment/basement interface in Hole U1558D, along with data obtained from Hole U1558A during Expedition 390C, were used to define the magnetostratigraphy for the entire sediment sequence at Site U1558. Viscous overprints are almost completely removed at 20 mT demagnetization to reveal characteristic components. The distribution of inclination values is bimodal in both Holes U1558A and U1558F, with peaks near ±56° in Hole U1558A and +60° and −51° in Hole U1558F. These values are steeper than indications expected at 30°S in the geocentric axial dipole (GAD; ±49.1°). SRM data record clear polarity reversals for most of the sedimentary sequence in both Holes U1558A and U1558F, giving confidence in the correlation to the geomagnetic polarity timescale (GPTS). Some intervals near the top of each hole reveal indistinct polarities due to core gaps and drilling disturbances. All collected discrete samples were subjected to AF demagnetization up to 100 mT step to derive the characteristic remanent magnetization (ChRM). Thirty-five of the measured samples revealed well-defined ChRM with maximum angular deviations between 1.9° and 14.8°. The inclination of ChRM components mostly coincide with those shown in the SRM data, providing robustness to the results. The proposed correlation with the current GPTS (Gradstein et al., 2020) has the Chattian–Rupelian boundary (28.1 Ma; Gradstein et al., 2020) within Unit IIA (~56 m CSF-B in Hole U1558F) and the Oligocene–Eocene boundary at ~110 m CSF-B, near the base of Unit IIB.

Rock magnetic experiments were conducted on eight samples and reveal the dominance of low-coercivity minerals throughout the cores with no significant variations among different lithological unit/subunits. AMS measurements mainly reveal a subhorizontal magnetic foliation with neutral to oblate ellipsoidal shapes typical of sedimentary fabric.

Physical Properties

Characterization of the sediment physical properties at Site U1558 was primarily based on cores from Hole U1558F supplemented by measurements from Hole U1558A. 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 the X-ray image logger. A correlation framework and splice were developed for Site U1558 that considers natural gamma radiation (NGR), gamma ray attenuation (GRA), magnetic susceptibility (MS), and magnetic inclination from each hole. The correlation resulted in an almost continuous spliced record to 207 m CCSF, although a cumulative total of ~12 m of core gap still persists in the splice section. Stratigraphic correlation also highlighted ~2 m of lateral thickness variation between Holes U1558A and U1558F, with Hole U1558F having an expanded record relative to Hole U1558A.

Whole-round measurements of NGR range from 2 to 50 counts/s through the sedimentary section in Hole U1558F. NGR is highest in the upper 10 m of the section, corresponding to the nannofossil-rich clay and ooze of lithologic Unit I (mean NGR from Unit I in Hole U1558F = 24 ± 7 counts/s, ±1σ). An additional sharp peak in NGR (between 20–29 counts/s) occurs at the boundary between Units IIB and IIC in Holes U1558A and U1558F. In contrast, intervals dominated by carbonate ooze generally have low NGR (<15 counts/s). Pass-through MS follows a similar downhole trend to NGR with an overall range from 0–145 instrument units (IU) (mean = 32 ± 16 IU) in Hole U1558F. The highest values are associated with the clayey nannofossil-rich ooze of Unit I (Ranges 18 to 118 IU, average = 70 ± 22 IU). MS is relatively low through Unit II, with peaks at ~65 m CSF-A (Unit IIA), ~112 m CSF-A (Unit IIB/IIC boundary), and from ~154–160 m CSF-A (Unit IIC). The average GRA bulk density of whole-round cores is lowest in Unit I (mean = 1.6 ± 0.1 g/cm^3) compared to the other three subunits (mean = 1.8 ± 0.1 g/cm^3) and a similar trend is seen in bulk density from discrete samples. Porosity of discrete samples decreases with depth, from ~70% at the seafloor to ~50% close to the sediment/basement interface (173 m CSF-A). *P*-wave velocity measured on whole-round cores ranges from 1.45 to 1.74 km/s (mean = 1.56 ± 0.03 km/s) and generally increases with depth. Compressional strength of the sediments increases with depth, whereas shear strength reaches maximum values (~52 kN/m^2) at 30 m CSF-A before decreasing downhole. Thermal conductivity values range from 1 to 1.61 W/m·K throughout Hole U1558F (mean = 1.34 ± 0.14 W/m·K) and gradually increase downhole. The vertical conductive heat flow for Site U1558 was estimated to be 28–30 mW/m^2, which is lower than modeled heat flow values for ocean crust of this age, requiring significant regional hydrothermal advection of heat to make up the difference (cf., Kardell et al., 2022).

Microbiology

Microbiological analysis of samples from Hole U1558F will focus on microscopy, culture-based, and culture-independent approaches to characterize microbial activity in the sediments. One microbiology whole-round sample (between 5–10 cm long) was collected from each 9.5 m core

and subdivided for shipboard and shorebased studies. Additional whole-round cores for specialized shore-based analyses were also taken. A number of microbiology analyses on sediment samples from Hole U1558F were initiated shipboard during Expedition 393. 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 six microbiology 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 at Site U1558 along with the uppermost basement samples.

Volcanic Rocks

Igneous Petrology

Hole U1558D drilled ~203 m of mid-ocean ridge basalts and intersected two distinct volcanic sequences separated by a ~1 m thick layer of indurated calcareous sedimentary breccia with volcanic debris, possibly indicating a hiatus in volcanism at this site on the order of tens of thousands of years. The upper Sequence A (166.55–234.64 mbsf) includes volcanic Units 1 and 2 that are moderately to highly plagioclase-olivine-clinopyroxene phyric microcrystalline basaltic lavas mostly emplaced as lava pillows of varying comfort (10–130 cm diameter). Extremely sparse but distinctive green clinopyroxene phenocrysts are a characteristic feature of the Sequence A volcanic rocks. In contrast, the underlying Sequence B (234.65–370.20 mbsf) lacks these green phenocrysts, and its uppermost unit contains abundant interflow sediments and breccias, suggestive of a buried seafloor horizon. This change in phenocryst assemblage indicates that some aspect of the magmatic system changed between eruptive sequences. However, lava geochemistry as assessed by Cr/Ti ratios measured directly on the cores by portable X-ray fluorescence spectrometer (pXRF), is relatively consistent downhole with little evidence for fractionated series apart from Unit 4, which has higher Cr concentrations than the other lava units.

Alteration Petrology

The alteration within Hole U1558D can be subdivided into four zones. From the top of the volcanic sequence down to 179 mbsf within Unit 1, there is a dominance of brown halo alteration associated with pillow lava chilled margins. Between 179 and 234 mbsf (part way through Unit 1E to the base of Unit 2B), the second zone is distinguished by a decrease in the abundance of all halo types, and gray background alteration and orange speckled background alteration of the pillow lavas dominate. This shift from brown halo dominated to background alteration dominated is interpreted to represent a seafloor weathering overprint and suggests that the pillow lavas were exposed to open circulation of seawater for some period of time before becoming covered with sediment. The third zone (234–286 mbsf) is broadly associated with igneous Units 3 and 4 and is marked by the first appearance of orange-reddish yellow alteration within pillow lavas. This color likely represents the strongest alteration within Hole U1558D and

is generally associated with alteration fronts developing from the glassy margins of individual pillows. Macroscopically these orange-reddish yellow alteration fronts transition into the more ubiquitous brown halos seen throughout Hole U1558D. Some of the freshest volcanic glass is preserved where the groundmass alteration of the pillow lavas is strongest. The abundance of breccia and sediment at the top of this interval suggests that these rocks were also exposed to seawater for a significant duration before becoming covered by the overlying lava sequences. The fourth alteration zone is defined by the onset of mixed gray-brown background alteration that has a common but not unique association with variolitic textures. The orange-reddish yellow halos persist through this change in background alteration. Although there are some associations between the igneous units and the different alteration zones, the onset of the key alteration features defining the zones do not generally follow igneous unit boundaries.

Igneous Geochemistry

Representative samples were taken from the freshest portions of each volcanic subunit in Hole U1558D to obtain a downhole record of the primary magmatic conditions, along with one sample near the basalt/sediment contact. Additionally, four samples of breccia were taken to understand the basalt/sediment chemical exchanges that occurred as new lavas erupted and interacted with pelagic sediment. Twenty-nine 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 also characterized for elemental abundances via pXRF to complement the direct core measurements. The Hole U1558D basalts are weakly to strongly altered, with variable MgO and CaO concentrations, and elevated abundances of K_2O and Rb. Basaltic protolith compositions change downhole, with TiO_2 contents varying between 1 and 1.2 wt% from 160–290 mbsf, increasing to 1.3–1.5 wt% at >290 mbsf. In terms of basaltic rock type, the freshest samples classify as olivine tholeiites per the Yoder and Tilley (1962) normative classification scheme. K/Zr ratios, a broad measure of alteration extent, vary between 20 and 109 in Site U1558 basalts, averaging 44.5, much higher than fresh South Atlantic MORB (average = 7.4). Incompatible element concentrations are consistent with a similar, depleted Mid-Ocean Ridge Basalt (D-MORB) composition for lavas at Site U1558. The breccia fill materials, which are partly of sedimentary origin, vary widely in composition, from very Ca-rich to Ca-poor, with the most Ca-poor samples showing the highest K_2O abundances.

Paleomagnetism of Volcanic Rocks

Paleomagnetic measurements were conducted on basement cores of Hole U1558D using the SRM at a resolution of 2 cm. Remanent magnetization before and after progressive AF demagnetization at 5, 10, and 20 mT fields was measured on pieces that are longer than 9 cm. Since the recovery rate varied greatly throughout the hole (11% to 90%), there are clear differences in data resolution between cores. Rock magnetic experiments were performed on a total of 36 cube samples, targeting basalts of various degrees of alteration and one sample from the sedimentary breccia.

The SRM results mostly remove all viscous overprints and successfully reveal primary components at the 20 mT demagnetization step. These components mainly show a negative inclination which indicates a normal polarity, in agreement with the expected polarity for 49.2 Ma (Gradstein et al., 2020; Kardell et al., 2019) ocean crust, although positive inclinations were found in some layers in the lower parts of the hole. The distribution of inclination values is heavily clustered around −55°, about 6° steeper than the angle expected in the GAD (±49.1° at 30°S).

A subset of 32 discrete samples were subjected to stepwise AF demagnetization up to 130 mT to derive the ChRM. The remaining six samples were stepwise thermally demagnetized up to 580°C. Discrete sample measurements mostly reveal well-defined ChRM with MAD between 0.4° and 5.4°. IRM acquisition experiments were conducted on 24 selected samples, which reveal saturation levels around 150–300 mT, implying that low-coercivity minerals such as titanomagnetite and/or maghemite are the main magnetic carriers. Slight variations in remanence intensity and MS occurred depending on the alteration degree. AMS measurements reveal a well-defined prolate fabric characterized by subhorizontal magnetic foliation.

Physical Properties

Characterization of the basement physical properties at Site U1558 is primarily based on cores from Hole U1558D, supplemented by information from Holes U1558A and U1558F where the uppermost basement was also recovered. Whole-round, section-half, and discrete measurements were considered together to characterize the petrophysical signatures for the different lithologic units. All whole-round cores were imaged using an X-ray image logger. About 72% of the recovered material was scanned using the Deutsche Montan Technologie (DMT) core scanner.

NGR in Hole U1558D ranges from 0.1–11.6 counts/s with a mean of 4.0 counts/s. The highest NGR in this section is associated with an indurated calcareous sedimentary breccia (Volcanic Unit 3), although basalts in Units 4A and 4B also show elevated NGR. Discrete point contact MS measurements from section-halves range from 1–669 IU (mean 159 ± 88 IU, ±1σ). Units 1 and 2 have a higher mean MS than Units 4 and 5, with the lowest MS observed in the volcaniclastic sedimentary breccia Unit 3. A pronounced peak in MS is seen in Unit 5D (massive flow).

In order to integrate petrophysical measurements with the observations of other groups, all discrete moisture and density (MAD) samples were also used for paleomagnetic measurements, and, with the help of petrologists, all samples classified according to key attributes such as grainsize, alteration, or emplacement style. Discrete MAD measurements (bulk and grain densities and porosity) as well as *P*-wave velocity are affected by the alteration level in the 40 samples that were measured. Samples displaying higher levels of alteration, such as those with strongly developed brown alteration halos, mixed gray-brown variolitic textures, or orange-reddish yellow colors, generally have lower bulk and grain density, lower *P*-wave velocity, and higher porosity compared to less altered samples. There is no clear relationship between these physical properties and the igneous units. However, basalts emplaced as large pillow flows

appear to have higher density and *P*-wave velocity and lower porosity compared to mixed sheet and pillow flows, with smaller pillow flows occupying an intermediate range of values. The average thermal conductivity measured in basement samples is 1.54 ± 0.14 W/m·K (n = 39 measurements). Combined with an estimated vertical conductive heat flow in sediments of 28–30 mW/m^2, this suggests a temperature gradient of about 20°C/km in the shallow basement at Site U1558 if the thermal regime is mostly conductive.

Microbiology

Microbiology sampling in volcanic rocks occurred in Hole U1558D and was focused on exploring evidence for life in the basement, especially at the sediment/basement interface, using microscopy, culture-based, and culture-independent approaches. Twenty-one whole-round samples between 12 and 23 cm long were sampled to characterize the variety of volcanic formations in Hole U1558D. After the contaminated exteriors of whole-round pieces were removed, 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 above.

To determine the extent of contamination of microbiology samples, the perfluorocarbon tracer perfluoromethyldecalin (PFMD) was injected into the drilling fluids during coring in Hole U1558F. 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 18 ppb/g and a median concentration of 10 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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