IODP Expedition 395C: Reykjanes Mantle Convection and Climate: Crustal Objectives

Site U1562 Summary

Background and Objectives

International Ocean Discovery Program (IODP) Site U1562 (proposed Site REYK-3B) is located in the North Atlantic Ocean along the Reykjanes Ridge south of Iceland. Site U1562 is located on seismic line JC50-1 (CMP 39920), near the intersection with line JC50-C2 (CMP 685), both obtained in 2010 during RRS *James Cook* Cruise JC50.

Diachronous V-shaped features visible in bathymetry and gravity data, termed V-shaped ridges (VSR) and V-shaped troughs (VST), straddle the Reykjanes Ridge and may provide evidence of varying behavior of the Iceland mantle plume and its interaction with the Mid-Atlantic Ridge through time. Basalt samples from the VSRs and VSTs will test hypotheses relating to the formation of these crustal features. Site U1562 is located on VSR-3 with an estimated basement age of 13.9 Ma.

Cores and data from this site will address two of the primary science objectives: (1) crustal accretion and mantle behavior, and (2) time-dependent hydrothermal alteration of oceanic crust.

The operational objectives for this site were to core the sedimentary section using the advanced piston corer (APC), half-length APC (HLAPC), and extended core barrel (XCB) systems to the sediment/basement interface, use the rotary core barrel (RCB) system to core ~130 m into the basement, and use downhole wireline tools to log the borehole. All of the planned operations are in support of Expedition 395, which was postponed twice due to the COVID-19 pandemic.

Operations

Site U1562 consisted of two holes, U1562A and U1562B, ranging in depth from 429.8 to 561.5 m drilling depth below seafloor (DSF).

A total of 96 cores were recorded for Site U1562. These cores collected 484.12 m of sediment and basalt over a 583.2 m cored interval (83% recovery).

The APC system was used to collect 21 cores over a 192.0 m interval with 199.45 m of core recovered (104% core recovery). The HLAPC was deployed for 36 cores and recovered 173.8 m of sediment from a 169.2 m interval (103%). The XCB system was deployed over a 68.6 m interval. The 8 XCB cores recovered 37.79 m of sediment and basalt (55%). The RCB system was deployed for 31 cores over a 153.4 m interval with 73.08 m of core recovered (48%). Downhole wireline logging operations using four logging tool strings took place at Hole U1562B.

The total time spent at Site U1562 was 10.45 d.

Hole U1562A

The vessel began the 6.1 nmi transit from Hole U1554F to Site U1562 under dynamic positioning (DP) mode on 10 July 2021. The crew continued to pull up the drill pipe following the completion of operations at Hole U1554F during the transit. The end of the pipe cleared the rotary table at 1130 h. At 1306 h on 10 July, the vessel arrived at Site U1562 and the APC/XCB bottom-hole assembly (BHA) was made up. The drill pipe was run to 1996 m below sea level (mbsl) to take the first APC core.

Hole U1562A (60°06.3030′N, 26°30.1245′W), located 21 m west of the site coordinates, was spudded at 2115 h and Core U1562A-1H recovered the mudline and 2.08 m of core, establishing a seafloor depth of 2003 mbsl. APC Cores U1562A-2H to 21H advanced from 2.0 to 192.0 m DSF. Core 21H experienced significant overpull and was drilled over with the drill string to release the core barrel. HLAPC core barrels were made up and coring continued from Core 22F to 57F (192.0–361.2 m DSF) with 4.7 m long advances. HLAPC refusal was met at Core 57F, which also required the drill string to drill over the core barrel to release it from the sediment. The XCB core barrels were made up and coring continued with Cores 58X to 64X (361.2–429.1 m DSF). After coring Core 64X, the XCB cutting shoe was severely damaged and slightly melted, and the base of the core catcher contained basalt. Another core barrel was deployed and Core 65X was advanced to ensure that the bit had reached basement. The bit advanced 0.7 m over an hour and Core 65X contained 0.68 m of basalt, confirming a basement depth of 429.1 m DSF. The final depth of Hole U1562A was 429.8 m DSF. The drill string was pulled from the hole, with the bit reaching the seafloor at 1535 h on 13 July 2021. Hole U1562A ended when the bit reached the rotary table at 1935 h.

All of the full-length APC cores were oriented, and formation temperature measurements using the advanced piston corer temperature (APCT-3) tool were collected for Cores 4H, 7H, 10H, and 13H. Samples for interstitial water (IW), microbiology, micropaleontology, and gas analyses were routinely collected on the catwalk.

A total of 411.04 m of core was recovered over a 429.8 m interval (96%). The average recovery for piston cores was 104% with the APC system and 103% with the HLAPC system. The XCB system had an average recovery of 55%.

Hole U1562B

Following the end of Hole U1562A, an RCB BHA with a C-4 RCB bit was made up and the drill string lowered to the seafloor. The ship was offset 21 m east-southeast of Hole U1562A, near the site coordinates, and Hole U1562B (60°6.2993′N, 26°30.1026′W; water depth 2003 mbsl) was spudded at 0320 h on 14 July and advanced without coring to a depth of 408.1 m DSF. The center bit was recovered and an RCB core barrel was deployed. Cores U1562B-2R to 13R advanced from 408.1 to 474.2 m DSF, recovering 48.65 m of sediment and basalt (55%). The sediment/basement interface was recovered in Core 4R at a depth of 429.0 m DSF. Coring rates

sped up from ~2 m/h to over 7 m/h while drilling Core 14R. The driller noted that there was a ~3 m long interval that drilled extremely quickly. It was soon revealed that Core 14R recovered 0.6 m of chalk bracketed by basalt. Coring continued with Cores 15R to 19R advancing from 479.2 to 500.7 m DSF with 47% recovery. While coring Core 19R, the penetration rate dropped to 1 m/h and there was erratic torque on the bit. It was suspected that the drill bit was damaged and the rig floor crew began pulling the pipe out of the hole. A free-fall funnel was deployed at 0220 h on 17 July to allow for the reentry of Hole U1562B. The bit cleared the seafloor at 0312 h and the rotary table at 0708 h. The bit was indeed damaged, and a new C-7 RCB coring bit was made up to the BHA and the crew assembled the drill string. The subsea camera, along with the Conductivity-Temperature-Depth sonde, was deployed at 1130 h to observe the reentry of Hole U1562B, which occurred at 1450 h. The subsea camera was retrieved and the drill string advanced to 500.7 m DSF. After cleaning the hole with a high-viscosity mud sweep, Cores 20R to 28R advanced from 500.7 to 561.5 m DSF. Coring operations concluded at Hole U1562B after coring 132.5 m into the basement section. The final depth of Hole U1562B was 561.5 m DSF.

A total of 73.08 m of core was recovered over a 153.4 m cored interval at Hole U1562B (48% recovery). In all, 31 RCB cores were collected from this hole. The average rate of penetration while coring the basalt was 2.1 m/h.

Following coring, the rotary shifting tool was run to release the bit into the bottom of the hole. The drill string was pulled up and end of the pipe was set at a depth of 89 m DSF. The triple combo logging tool string was made up and deployed at 1755 h on 19 July. After completing two successful passes of the entire hole, the tools were retrieved and reached the rig floor at 2310 h. After the triple combo tool string was laid out, the Formation MicroScanner (FMS)-sonic was made up and deployed at 0100 h on 20 July. Following two passes that extended to the base of the hole, the FMS-sonic was pulled from the hole and reached the rig floor at 0645 h. The next logging run used the Versatile Seismic Imager (VSI) tool. The protected species observation protocols began at 0730 h and the JRSO technical staff ramped up the air guns starting at 0834 h. The VSI was lowered to the base of the hole and a total of four depth stations (420.5, 426, 459.9, and 556.6 m DSF) were completed, two within the basement section, one at the sediment/basement interface, and one in the lowermost sediment. The VSI could not be successfully run throughout the sedimentary section due to the wide diameter (>16 inch) of the borehole. Following the VSI run, the air guns were put away and the tool reached the rig floor at 1320 h. The final logging run, using the Ultrasonic Borehole Imager (UBI) tool, began at 1445 h. The UBI made two passes of the basement section, acquiring 360° borehole images. The UBI was recovered at the rig floor at 2130 h. The drill string was pulled out of the hole to a depth of ~1489 mbsl and the ship began the transit in DP mode to Hole U1554F at 2355 h on 20 July, ending Site U1562.

Principal Results

The JRSO technical staff processed all cores and samples in the laboratories, following the measurement and sampling plan constructed by the shore-based Expedition 395C Co-Chief Scientists and science party. Data interpretation, core description, and biostratigraphic analyses will take place postexpedition.

Sediment cores obtained from Holes U1562A (Cores U1562A-1H to 64X, 0–427.82 m cored depth below seafloor [m CSF-A]) were run through the whole-round (WR) physical properties tracks, which include magnetic susceptibility (MS), gamma ray attenuation bulk density, *P*-wave velocity, and natural gamma radiation measurements. The split section halves were imaged, measured for point magnetic susceptibility (MSP) and color reflectance, and scanned for magnetic remanence using the superconducting rock magnetometer (SRM). Thermal conductivity measurements and moisture and density samples were collected at a resolution of one per core.

Samples were collected on the catwalk and at the sample table for shipboard and shore-based IW, gas, microbiology, and micropaleontology analyses. Headspace gas samples for shipboard hydrocarbon safety analysis and postcruise research were collected with every core and the resolution increased to two samples per core ~30 m above the sediment/basement interface. Samples for postcruise biostratigraphy were collected from each core catcher. IW samples, 10 cm in length, were collected from each core and three per core were collected in the ~20 m above the sediment/basement interface. Microbiology samples were extracted using a sterile syringe, with 4 cm^3 of sediment frozen in the syringe and 1 cm^3 of sediment added to a glycol solution and flash frozen using liquid nitrogen. The microbiology samples were paired with the IW samples. X-ray diffraction and carbonate samples were subsampled from the IW squeeze cake sediment residues. Additional carbonate samples were collected beginning ~30 m above the sediment/basement interface.

RCB Cores from Hole U1562B were run through the WR tracks to collect the same measurements as Hole U1562A, with the exception of *P*-wave velocity, which was not recorded because the space between the liner and the core for RCB cores prevents meaningful measurements. The split section halves were imaged, measured for MSP and color reflectance, thermal conductivity, and *P*-wave velocity using the caliper, and scanned using the SRM. Section halves from Cores U1562B-3R to 4R were imaged using the X-Ray Imager. Each basalt core section was scanned using the portable X-ray fluorescence spectrometer. WR samples of basalt for postcruise microbiology studies were collected immediately after the core was received from the rig floor at a resolution of one sample per ~10 m. Samples for inductively coupled plasma–atomic emission spectroscopy and thin sections were selected by the shore-based petrologists using core photos, also at a resolution of ~10 m.

The sediments in the uppermost ~250 m (Cores U1562A-1H to 34F) are primarily composed of clay and silt with fine sand beds and dropstones interspersed throughout the section. The cores are mostly gray to dark gray, but contain brown and greenish gray intervals, as well. Within Core 35F (253.1–257.9 m CSF-A) is a transition from the overlying gray clay and silt to a lighter gray clay. This core contains notable soft sediment deformation. Cores 36F to 54F (257.8–347.2 m

CSF-A) range from light gray to dark gray clay with bioturbation and discrete intervals of soft sediment deformation. Core 55F (347.1–356.06 m CSF-A) captures a transition between the overlying clays and silts to a finer grained, carbonate-rich, greenish gray sediment with abundant bioturbation that continues to Core 64X. Cores 58X and 60X contain large (~5 cm) basalt clasts. The lithology in Core 64X (419.4–427.82 m CSF-A) transitions from the greenish gray, bioturbated, fine-grained sediment to a white carbonate ooze. Section 64X-CC and Core 65X (427.4–429.8 m CSF-A) are composed of dark gray, vesicular to avesicular basalt that contains white to green veins and infilled vesicles. The XCB cores are fractured and disturbed.

Core U1562B-2R through Section 4R-1 (408.1–428.57 m CSF-A) contain greenish gray, fine-grained, carbonate-rich, bioturbated sediment. Section 4R-2 through Core 32R (428.57–559.6 m CSF-A) are composed of dark gray to brown basalt. The basalt displays varying degrees of alteration with infilled vesicles, calcite veins, and staining. Glass rinds are observed on many of the core pieces. Section 14R-2 (475.54–476.2 m CSF-A) contains a 0.6 m long interval of nannofossil ooze bracketed by basalt flows, and intercalated carbonate beds are found in Cores 5R, 6R, and 15R to 19R.

The physical properties of the cores primarily reflect changes in lithology. Porosity of the sediments linearly decreases downhole from values ~80% at the top of the section to 63% above the sediment/basement interface (427 m CSF-A). MS and color reflectance values in the sediment align with color changes in the cores, potentially indicating changes in carbonate content. The MS values of the uppermost basalt cores (Cores U1562B-4R and 5R) are higher than the rest of the cored section at Site U1562. The average MS value of basalts in these two cores is ~400 instrument units (IU) with a maximum value of 1535 IU. The average MS value for Cores U1562B-6R to 32R is 124 IU. The average *P*-wave velocity of the basalts is 5400 m/s.

The downhole measurements program at Site U1562 consisted of downhole wireline logging and formation temperature measurements. All four downhole wireline logging tool runs were successful. The FMS-sonic and UBI tools recorded images of the borehole wall. Four formation temperature measurements from 30.5 to 116 m DSF show a linear increase with depth from 4.3° to 7.3°C.

Core sections were run through the SRM, which measured natural remanent magnetization before and after alternating field demagnetization. The APC and XCB cores were scanned at 2.5 cm resolution and demagnetized up to 25 mT. RCB cores were scanned at 2 cm resolution and demagnetized up to 20 mT. The magnetic inclination shows clear intervals of normal and reversed polarity, which will be used postcruise to establish the magnetostratigraphy for the site.

Chemistry measurements were made on gas, pore water, and sediment samples. Hydrocarbon gases in Hole U1562A are present in very low concentrations. Methane peaks at 2.61 ppmv at ~223 m CSF-A. The sediments of the uppermost 150 m of Hole U1562A contain little carbonate, with values ranging from 0.04 to 33 wt%. Within the interval of 150–300 m CSF-A, carbonate values range from 4 to 65 wt% and, below 300 m CSF-A, values are consistently elevated with a maximum of 78 wt%. Total organic carbon has an average value of 0.59 wt% with a maximum

concentration of 5.23 wt% at 413 m CSF-A. Pore water alkalinity increases downhole from ~2.5 mM at the top of the hole to a maximum value of 7.5 mM at 223 m CSF-A. Below 223 m CSF-A, alkalinity decreases to ~3.5 mM above the sediment/basement interface (~427 m CSF-A). Ammonium increases from 33 μM at the top of Hole U1562A to a maximum value of 635 μM at 100 m CSF-A and then decreases to 263 μM at the bottom of the hole. Sulfate decreases from 29 to 19 mM between 0–270 m CSF-A before increasing to the base of the hole. Boron decreases downhole, whereas Si and Sr increase with depth. Bromine, Ca, Mg all show an initial decrease with depth followed by an increase to the sediment/basement interface.