

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

Site U1563 Summary

Background and Objectives

International Ocean Discovery Program (IODP) Site U1563 (proposed Site REYK-11A) is located in the North Atlantic Ocean along the Reykjanes Ridge south of Iceland. Site U1563 is located on the intersection of seismic lines JC50-1 (CMP 53393) and JC50-C6 (CMP 888), both obtained in 2010 aboard 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 U1563 is located on VSR-2a with an estimated basement age of 5.2 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 U1563 consisted of two holes, U1563A and U1563B, ranging in depth from 327.6 to 456.6 m drilling depth below seafloor (DSF).

A total of 80 cores were recorded for Site U1563. These cores collected 397.36 m of sediment and basalt over a 482.8 m cored interval (79% recovery).

The APC system was used to collect 21 cores over a 197.4 m interval with 207.05 m of core recovered (105% recovery). The HLAPC was deployed for 26 cores and recovered 122.35 m of sediment from a 122.2 m interval (100%). The XCB system was deployed over an 8.0 m interval. The 2 XCB cores recovered 5.58 m of sediment and basalt (70%). The RCB system was deployed for 31 cores over a 155.2 m interval with 44.38 m of core recovered (29%). Downhole wireline logging operations using three logging tool strings took place at Hole U1563B.

The total time spent at Site U1563 was 8.51 d.

Hole U1563A

The vessel completed the 39 nmi transit from Site U1562 on 22 July 2021. The thrusters were lowered at 0212 h and the ship entered dynamic positioning mode at 0235 h, marking the start of Site U1563. The APC/XCB bottom-hole assembly (BHA) was made up and the drill string deployed to 1415.7 m below sea level (mbsl). Hole U1563A (60°11.9985'N, 28°00.0209'W) was spudded at 0800 h. Core U1563A-1H recovered 7.4 m of sediment, placing the seafloor at 1417.8 mbsl. Cores 2H to 16H advanced to 149.9 m DSF, with 105% core recovery. During the collection of Core 16H, the core barrel became detached from the sinker bars and GS overshot tool when the shear pin in the GS overshot tool evidently failed. The sinker bars and GS overshot tool were recovered, the GS overshot tool was replaced, and the core barrel was retrieved. However, the APC piston rods had twisted while the core barrel was in the BHA and the rods required replacement. Coring continued with Cores 17H to 21H advancing from 149.4 to 197.4 m DSF. APC refusal was reached with Core 21H when, after the core barrel became stuck in the sediment, it required 130,000 lb of overpull to release the barrel from the formation. The HLAPC was deployed for Cores 22F to 47F (197.4–319.6 m DSF) and was switched out for the XCB coring system as the bit neared the estimated depth of the basement. Core 48X (319.6–326.6 m DSF) recovered the sediment/basement interface and the basement was encountered at 326.4 m DSF. Core 49X was deployed to ensure that basement had in fact been reached. The core advanced 1 m, to a final hole depth of 327.6 m DSF, and recovered 0.42 m of basalt. Following Core 49X, the drill string was pulled out of the hole. The bit cleared the seafloor at 0400 h and the rotary table at 0715 h on 24 July, ending Hole U1563A.

A total of 334.98 m of core was recovered over a 327.6 m interval (102% core recovery).

Hole U1563B

The ship was offset 21 m east of Hole U1563A, ~3 m from the site coordinates, and the RCB BHA was made up with a C-7 RCB drill bit. The drill string was made up and deployed to 1403 mbsl. The center bit was lowered into the RCB bit and Hole U1563B (60°11.9946'N, 27°59.9996'W) was spudded at 1605 h on 24 July.

Hole U1563B was advanced without coring to a depth of 301.4 m DSF. The center bit was retrieved and Cores U1563B-2R to 5R advanced from 301.4 to 325.8 m DSF. The sediment/basement interface was encountered at ~315 m DSF, but was not preserved in Core 3R. While coring Core 5R, the wind had increased to sustained speeds of 35 kt, gusting up to 45 kt, which created hazardous conditions on the rig floor. The vessel began waiting on weather at 0800 h on 25 July. It was noted that there was an unusual noise emanating from a transformer for three of the thrusters. The vessel resumed operations at 1330 h once the wind speeds had died down. Core 5R was recovered and the drill string pulled up to 90 m DSF to work on the thrusters. The three affected thrusters were shut down and it was discovered that the insulation around a transformer cable was loose. Once this was repaired, the ship was able to resume operations at 1845 h on 25 July. The crew deployed a wash barrel into the BHA and lowered the

bit to 325.8 m DSF. After a high-viscosity mud sweep to clean the hole, the wash barrel was retrieved and a core barrel was deployed for Core 6R. Coring continued with Cores 6R to 32R advancing from 325.8 to 456.6 m DSF. Following Cores 25R to 32R, the crew cleaned the hole with high-viscosity mud due to deteriorating hole conditions. After Core 32R was recovered, the drill pipe became stuck in the hole and was unable to rotate, circulate fluid, or move. Coring operations were terminated, and after ~1.5 h the pipe was freed and the drill string was pulled up to a depth of 363.9 m DSF. The hole was prepared for downhole logging operations with another high-viscosity mud sweep. The rotary shifting tool was deployed to release the drill bit and allow logging tools to exit the drill pipe. The RCB drill bit was released in the hole at 2325 h on 28 July.

In total, 44.38 m of core was recovered over a 155.2 m cored interval (29%). Coring of the basalts advanced at an average rate of penetration of 3.6 m/h.

The drill pipe was pulled up to a depth of 87.6 m DSF in preparation for downhole logging operations. The triple combo tool string was assembled and deployed at 0410 h on 29 July. The tool string made two passes of the borehole, reaching a depth of 313.9 m DSF. At 0900 h, the triple combo reached the rig floor and was broken down. The second logging tool run was the Versatile Seismic Imager (VSI). At 1045 h, the VSI tool was deployed and the protected species observation protocols began. Whales were sighted in the area, delaying the start of operations. Once it was deemed safe to fire the air guns, the VSI was lowered to three stations: 283.9, 292.9, and 308.9 m DSF. Only the bottom two stations recorded successful measurements. At 1652 h, the protected species observation watch ended and the tool was pulled out of the hole, reaching the rig floor at 1810 h. After the VSI tool was broken down, the Formation MicroScanner (FMS)-sonic tool string was assembled and deployed at 1935 h. The FMS-sonic tool descended to 311.0 m DSF and recorded resistivity images of the borehole. The tools were pulled up to the rig floor at 2325 h and the day ended while breaking down the FMS-sonic tool string. The crew pulled the drill pipe up with the end of the pipe clearing the seafloor at 0105 h on 30 June and the rotary table at 0513 h. The rig floor was secured, thrusters raised, and the vessel began the 144 nmi sea passage to Site U1564 (proposed Site REYK-2A) at 0518 h on 30 July.

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 U1563A (Cores U1563A-1H to 48X, 0–324.7 m cored 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 (NGR) 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 interstitial water (IW), gas, microbiology, and micropaleontology analyses. Headspace gas samples for shipboard hydrocarbon safety analysis and postcruise research were collected 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 cm³ of sediment frozen in the syringe, and 1 cm³ 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 U1563B were run through the WR tracks to collect the same physical properties measurements as Hole U1563A, 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. 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 (ICP-AES) and thin sections were selected by the shore-based petrologists using core photos, also at a resolution of ~10 m.

The primary lithologies in Hole U1563A are clay and silt with occasional fine sand beds and dropstones. Core U1563A-1H alternates between brown and gray layers and Cores 2H to 44F (7.2–305.44 m CSF-A) show light gray to dark gray banding. Cores 13H, 17H, and 19H each contain a ~20 cm thick coarse sand bed. Core 40F and the tops of Cores 41F and 43F contain brown, unconsolidated fine sand. Within Core 45F (305.5–310.34 m CSF-A), the lithology transitions to a light gray silt and clay with gray and green mottling. This extends down to Core 47F (314.9–319.87 m CSF-A) where there is a sharp transition to yellow to white chalk. Core 47F contains three large (~3 cm diameter) basalt clasts. The calcareous ooze extends to the basalt basement, which is found in Section 48X-CC. Core 49X is dark gray basalt with intercalated carbonate beds.

Cores from Hole U1563B are primarily composed of basalt. Core U1563B-2R (301.4–301.94 m CSF-A) contains 0.54 m of carbonate ooze with basalt clasts. The sediment/basement interface in this hole was at ~315 m CSF-A, nearly 11 m shallower than at Hole U1563A. Cores 3R to 32R

(311.1–452.91 m CSF-A) are composed of dark gray basalt with vesicles and calcite veins. The basalts have some brown staining and contain infilled vesicles. Many of the basalt cores contain thin intercalated carbonate beds. Cores 15R and 17R contain carbonate pieces with brecciated clasts of basalt.

The physical properties of the cores reflect changes in their composition. The NGR values of the sediments range from 5 to 32 counts/s, from 0 to 212 m CSF-A, with the exception of a maximum peak of 46 counts/s at 136.7 m CSF-A. Below 212 m CSF-A, NGR values decline from ~10 to 5 counts/s at the base of the sedimentary section. The NGR values of the basalt cores from Hole U1563B are low, with an average of 2 counts/s. MS values of the sediments range between 15 and 541 instrument units (IU) in the uppermost 280 m of the section. Below 280 m CSF-A, values are consistently below 100 IU to the sediment/basement interface. The average MS value of the basalt cores is 177 IU. MS peaks occur in Cores U1563B-15R, 17R, and 24R. The *P*-wave velocity of the basalts is 5500 m/s on average. Sediment porosity decreases from 81% at the top of Hole U1563A to 69% at 323 m CSF-A.

The downhole measurements program at Site U1563 consisted of downhole wireline logging and formation temperature measurements. The triple combo, FMS-sonic, and VSI tool strings were all run successfully. Four formation temperature measurements, from 35.9 to 121.4 m DSF, show a linear increase with depth from 5.3° to 8.7°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. Methane values in Hole U1563A range from 0 to 2.15 ppmv. From 0 to 229 m CSF-A, calcium carbonate values range from 0.4 to 39 wt% (average of 12 wt%). Below 229 m CSF-A, concentrations show a stepped increase with values between 238–276 m CSF-A averaging 46 wt%, and between 285–324 m CSF-A averaging 80 wt%. The average total organic carbon concentration of the section is 0.35 wt%. Pore water was analyzed using titration, IC, ICP-AES, and spectrophotometry. Alkalinity increases from ~3 mM at the top of Hole U1563A to a maximum value of 5.8 mM at 210 m CSF-A, and then decreases to ~2 mM at the base of the sediment section. Ammonium broadly increases downhole from 7.3 to 565.9 μM at a depth of 200 m CSF-A. Below this depth, ammonium linearly decreases to 62.7 μM near the sediment/basement interface (324 m CSF-A). Sulfate linearly decreases from 0 to 105 m CSF-A, with values descending from 33 to 26 mM. Sulfate then fluctuates between 24.3 to 28.7 mM from 105 to 266 m CSF-A before increasing to 33 mM at the base of the section. Lithium increases downhole and Sr and Si initially increase downhole before decreasing to the sediment/basement interface. Magnesium and Ca display the opposite trend of decreasing downhole and then increasing to the sediment/basement interface.

Manganese decreases downhole, whereas B, Br, Na, and phosphate do not display any downhole trends.