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

Site U1555 Summary

Background and Objectives

International Ocean Discovery Program (IODP) Site U1555 (proposed Site REYK-13A) is located in the North Atlantic Ocean along the Reykjanes Ridge south of Iceland. Site U1555 is located at the intersection of seismic lines JC50-1 (CMP 57881) and JC50-60 (CMP 3720), 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 U1555 is located on VST-1 with an estimated basement age of 2.8 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/extended core barrel (APC/XCB) system to the sediment/basement interface, use the rotary core barrel (RCB) system to core ~200 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 at Site U1555 first occurred in August 2020 during IODP Expedition 384. Holes U1555A to U1555E were drilled through the sedimentary section and into the underlying basement to test different hard rock drill bits. Holes U1555F and U1555G were cored in support of Expedition 395 objectives and recovered 68.64 m of basalt basement. In addition to coring, Hole U1555G was logged with downhole tools.

Operations

Transit to Site U1555

The *JOIDES Resolution* departed Reykjavík, Iceland, on 11 June 2021. The pilot boarded the ship at 0852 h and, after some difficulties with the mooring lines, the ship left the dock with the last line away at 0948 h. At 1000 h the pilot departed and the ship began the 312 nmi transit to Site U1555. The ship averaged 11.6 kt and arrived at Site U1555 at 1225 h on 12 June. The thrusters were lowered and the vessel switched to dynamic positioning mode, beginning Hole U1555H at 1300 h.

Hole U1555H

Hole U1555H (60°13.6924′N, 28°30.0240′W) was positioned 12 m northwest of Hole U1555F. The crew began to assemble the drill collars until the weather deteriorated with winds blowing up to 40 kt. From 1645 to 2045 h on 12 June, the vessel waited on weather. After the wind subsided, the crew continued to assemble the drill collars and made up the drill bit. The drill string was advanced to 1518.6 m below sea level (mbsl) and positioned to fire the first APC core to establish the seafloor depth.

Coring in Hole U1555H was initiated at 0650 h on 13 June. Core U1555H-1H recovered a good mudline with 5 m of sediment, placing the seafloor depth at 1523.6 mbsl. Cores 1H–10H were cored to 90.5 m drilling depth below seafloor (DSF). Following Core 10H, 150 m of the core winch line was cut to remove a damaged section. Coring continued with Cores 11H to 15H to a depth of 138 m DSF. Coring was interrupted when the core winch line became stuck in the oil saver sub on the top drive. After removing, cutting, and reheading the line, coring continued with Cores 16H to 18H (138–166.5 m DSF). The XCB system was deployed for the remaining cores. Core 19X was only advanced 6 m to ensure that Core 20X would drill through the sediment/basement interface, which was encountered at 176.5 m DSF. The final depth of Hole U1555H was 177.5 m DSF. The crew began tripping pipe and the bit cleared the seafloor at 1525 h on 14 June. At 2000 h the bit cleared the rotary table, ending Hole U1555H.

All APC cores were collected using nonmagnetic core barrels and oriented using the Icefield MI-5 tool. Formation temperature measurements were collected on Cores 4H, 7H, 10H, and 13H using the third-generation advanced piston corer temperature (APCT-3) tool.

A total of 180.06 m of core was recovered from Hole U1555H, with 101% recovery. The APC system collected 18 cores over a 166.88 m interval with 166.58 m recovered (100%). Two cores were taken using the XCB system over a 12.67 m interval with 13.48 m recovered (106%).

Hole U1555I

The ship was offset 24 m east-southeast of Hole U1555H for operations at Hole U1555I. As the crew worked to assemble the drill string and RCB bottom-hole assembly, the weather deteriorated and at 0315 h on 15 June, operations paused while the vessel waited on weather. Winds picked up to over 30 kt with waves up to 5.5 m over the course of the day. After 30 h, operations resumed at 0900 h on 16 June.

Hole U1555I (60°13.6897′N, 28°29.9984′W) was spudded at 1000 h on 16 June and drilled without core recovery to 159.3 m DSF (drilled interval U1555I-1-1). The RCB system was used to cut all cores from Hole U1555I. Cores U1555I-2R and 3R were collected from 159.3 to 178.7 m DSF with 77% sediment recovery and the sediment/basement interface was encountered at 176.5 m DSF. Cores 4R–6R (178.7–207.8 m DSF) were cut using 9.7 m coring advances. Beginning with Core 7R, the drill string advances alternated between 5 and 4.7 m for each core, to prevent the core from jamming inside the barrel and improve core recovery. Mud sweeps were performed following Core 8R as hole conditions had deteriorated. Coring continued from Core

9R to 26R (227.2–304.8 m DSF). After cutting Core 26R, the drill bit reached 49 rotating hours and needed to be switched out.

At 0320 h on 20 June, a free-fall funnel (FFF) was installed to allow reentry into the hole. The subsea camera was deployed to observe the placement of the FFF and to ensure that the pipe did not move it out of position when the bit exited the hole. The Conductivity-Temperature-Depth sonde was run on the subsea camera frame to collect temperature, pressure, and conductivity measurements of the seawater. The bit cleared the seafloor and the FFF at 0450 h, the subsea camera was retrieved, and the bit cleared the rotary table at 0930 h. After changing the drill bit, the drill string was reassembled and the subsea camera deployed for the reentry of Hole U1555I. The FFF remained in position and the bit reentered Hole U1555I at 1605 h. After recovering the subsea camera, the center bit was dropped and the drill string advanced to 304.8 m DSF. Mud sweeps were used to clean the hole of debris.

Cores 27R to 41R were cut from 304.8 to 376.5 m DSF with 30.9 m of basalt recovered (43%). Core recovery significantly decreased in Cores 38R–40R (358.3–372.7 m DSF) with only 10% of the basalt section retrieved. After reaching a depth of 376.5 m DSF, or 200 m into the basement, coring concluded on 22 June.

A total of 40 RCB cores were recovered from Hole U1555I with 48% core recovery (77% sediment recovery and 45% basalt recovery). Cores were collected over a 217.2 m long interval with 104.19 m recovered.

Following coring operations, the borehole was prepared for downhole wireline logging operations. A high-viscosity mud sweep was used to clean the hole of debris. The drill bit was dropped at the bottom of the hole and the drill pipe brought up to 75.6 m DSF. The triple combo logging tool string was assembled and deployed at 1720 h on 22 June. The tool descended to the bottom of the hole and began making its first pass up the hole. At 1755 h the triple combo became stuck. After several attempts to pull the tools free using the Schlumberger logging line winch, the decision was made to lower the drill pipe over the tools to clear the obstruction. The drill pipe was lowered and the top of the triple combo was encountered at 183.5 m DSF, ~7 m below the sediment/basement interface. The obstruction in the hole was at 225.5 m DSF. The drill pipe was lowered until the obstruction was pushed past the base of the tool string. At 1015 h on 23 June, the tool string was free and the rig floor crew began pulling the tools up using the core winch line. At 1400 h, the tools were at the rig floor and were disassembled. The hole conditions prevented any other logging operation. The drill pipe was pulled from the hole. At 1700 h the pipe cleared the seafloor and at 2015 h it cleared the rotary table. The vessel was secured for transit to Site U1554 (proposed site REYK-6A) and the thrusters raised at 2036 h, ending Hole U1555I and Site U1555.

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 Hole U1555H (Cores 1H–19X; 0–179.17 m core depth below seafloor [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. WR core sections near the sediment/basement interface were imaged using the X-Ray Imager (XRI). 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 for shipboard and shore-based interstitial water (IW), gas, microbiology, and micropaleontology analyses. Headspace gas samples for shipboard hydrocarbon safety analysis as well as postcruise research were collected from every core and the resolution increased to two samples per core ~30 m above the sediment/basement interface. IW samples, 5–10 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 U1555I-2R to 41R (159.3–374.4 m CSF-A) were run through the WR tracks to collect the same physical properties measurements as Hole U1555H, 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, and scanned using the SRM. Section halves from Cores 2R to 4R (159.3–185.39 m CSF-A) were imaged using the XRI. Each basalt core section was scanned using the portable X-ray fluorescence spectrometer (pXRF). Sediment Cores 2R–4R were sampled for micropaleontology. WR samples of basalt were collected for postcruise microbiology studies 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 split core images of the basalt sections and pXRF data were sent to science party members on shore. Postcruise analysis of samples obtained from Expedition 384 Hole U1555G showed a downhole trend in the chemical composition of the basalts. The Expedition 395 shipboard pXRF data were compared to the shore-based inductively coupled plasma–mass spectrometry (ICP-

MS) data (1) to see if the trend could be reproduced on board, and (2) to determine if the basement coring depth needed to be extended past the 130 m initial plan. The pXRF data did show the same trends as the ICP-MS data and allowed the science party to determine what depth was required for coring.

The sediments at Site U1555 are clay to silt. Cores U1555H-1H to 2H (0–15 m CSF-A) alternate between brown and gray clay and silt and contain dropstones. From 15 to 176.5 m CSF-A, the sediment ranges from gray to dark gray in color. Sponge spicules and foraminifers are visible in the split core sections. Coring disturbance varies with some core tops heavily disturbed from the heave of the ship. The recovered basalts display varying degrees of alteration including calcite veins, infilled vesicles, and staining. Glass rinds are observed on some of the core pieces. The formation changes at the very base of the hole (~374 m CSF-A) to vesicular basalt.

The physical properties of the cores primarily reflect changes in the lithologic composition. The MS and NGR values differ greatly between the sedimentary and igneous rocks. The MS of the sedimentary section (0–178 m CSF-A) ranges from 8 to 485 instrument units (IU), with an average value of 237 IU. The basalt cores (178–375 m CSF-A) have much higher MS values, up to 2600 IU. The NGR values in the sediment average 12 counts/s, while the basalts have an average NGR value of 3 counts/s. The porosity of the sediments averages 75%, with values decreasing from 82% at the top of the hole to 75% near the base of the section. The deepest sample, obtained in Core U1555H-20X, has a porosity of 62%. Red, green, blue (RGB) color and color reflectance do not vary greatly as the cores are relatively homogeneous in color. *P*-wave velocity increases downhole to the sediment/basement interface. *P*-wave caliper measurements on basalts average 5300 m/s.

Downhole measurements at Site U1555 consisted of wireline logging and in situ temperature. Formation temperature measurements increase linearly from 8.3°C (33.5 m DSF) to 18.4°C (119 m DSF) in Hole U1555H. Despite the difficulties with the downhole logging, the triple combo collected data on the way downhole and over the lowermost ~180 m of the hole on its first and only pass uphole prior to becoming stuck.

Core sections were run through the SRM, which measured natural remanent magnetization before and after alternating field demagnetization. The sediment cores were demagnetized up to 35 mT and the basalt cores up to 30 mT. The magnetic inclination displays strong changes in polarity, which will be used to construct a magnetostratigraphy postcruise.

The Chemistry Laboratory measured hydrocarbon concentrations in gas samples and sediment and pore water geochemistry. Methane concentrations are low throughout the sedimentary section, with an average of 1.9 ppmv. Methane peaks at 3.14 ppmv at 103 m CSF-A. The average calcium carbonate and total organic carbon content of the sediments in Hole U1555H are 11.0 wt% and 0.3 wt%, respectively. Neither profile varies significantly downhole. Pore water alkalinity and calcium concentration slightly increase downhole. Ammonium and sulfate display opposing trends with ammonium initially increasing downhole before decreasing near the sediment/basement interface. Sulfate decreases downhole, but increases within ~20 m of the

basement. The concentrations of dissolved B, Mg, and K decrease downhole, whereas Li, Si, and Sr increase downhole.