IODP Expedition 396: Mid-Norwegian Continental Margin Magmatism

Week 8 Report (26 September–2 October 2021)

During Week 8 of the International Ocean Discovery Program (IODP) Expedition 396, Mid-Norwegian Continental Margin Magmatism, we completed coring operations in three holes at Site U1574 (proposed Site VMVM-80A) and began our transit to Reykjavík, Iceland, for the end of the expedition.

Operations

Week 8 of Expedition 396 began while coring using the rotary core barrel (RCB) with half-length advances in Hole U1574A from a depth of 176.3 m below seafloor (mbsf) (Core U1574A-21R). Coring continued through Core 32R to 225.8 mbsf. There were several shorter advances between 195.7 and 206.5 mbsf, where the core barrel was retrieved prematurely because of very slow penetration rates (<1 m/h). While coring Core 30R, we experienced a drilling break and the penetration rate increased to 29 m/h. These penetration rates continued from 216.2 to ~233 mbsf, where the formation firmed up again. Core recovery dropped throughout the softer formation interval. Coring continued to a final depth of 260 mbsf with Core 38R. There were two mud sweeps pumped while coring, each using 20 barrels. On 26 September 2021, we briefly paused coring operations because the ship's position had moved 30 m from Hole U1574A. This offset was quickly controlled and corrected, and the vessel resumed normal operations. As a precaution, an acoustic positioning beacon was launched at 1439 h on 26 September. The last core on deck from Hole U1574A was at 0100 h on 29 September. At the end of coring the hole was swept clean of cuttings with a 50-barrel sweep of high viscosity mud. After circulating the mud through the hole, the rotary shifting tool (RST) was run in on the coring line to release the RCB C-4 coring bit. The bit was released and the RST was run again to reposition the bit shifting sleeve back to the circulating position in the mechanical bit release (MBR). The RST was pulled back to the surface and the sinker bars were removed. The hole was displaced with 85 barrels of 10.5 ppg mud. The top drive was set back and the drill string was raised to 104.5 mbsf in preparation for wireline logging. After positioning the end of the pipe with knobbies through the guide horn, the rig floor was rigged up for logging. The rig floor personnel and the Schlumberger engineer held a meeting to review safety issues surrounding the upcoming logging operations.

At 0800 h on 29 September, we rigged up the triple combo tool string and deployed it to 213.0 mbsf. We encountered obstructions at 187 and 213 mbsf, and we were unable to pass the second obstruction even with repeated attempts. The hole was logged up for a full-length open hole calibration pass. The tool string was run back to bottom at 213 mbsf and the hole was logged up through the drill string to the seafloor. The caliper was closed prior to entering the drill string. The tools were at the surface at 1245 h and were rigged down by 1330 h on 29 September. We rigged up the Formation MicroScanner (FMS)-sonic tool string and deployed it into the hole at 1420 h. A downward log with the FMS calipers closed began at 2825 m below rig floor (mbrf)

to 3090 mbrf (256 mbsf). Natural gamma ray (NGR) was measured through the drill pipe to identify the seafloor to match the depth results on the first logging run. The FMS-sonic managed to avoid the obstructions experienced with the triple combo. At total depth, we started the first upward log and logged from 256 to 147 mbsf with the FMS calipers open. The tools were run back to bottom, reaching 255.5 mbsf. This time it was difficult to get the tool string back to the bottom. After numerous attempts, the tool string was worked down, the calipers were opened, and a second upward pass was conducted to the seafloor. The calipers were closed just prior to entering the drill pipe. Initially, there were problems reentering the pipe, but after several attempts at working the FMS arms open and closed, the entire tool string was pulled inside the drill pipe. A 2,000 lb overpull was experienced while trying to recover the tools. The tools were at the surface at 2010 h and rigged down by 2130 h on 29 September. While rigging down the FMS-sonic, one of the calipers and pads was found to be broken off the tool. The rig floor was cleared of logging equipment, and the drilling knobbies were removed from the top of the drill string and the drill string was retrieved to the surface. The bottom-hole assembly (BHA) reached the rig floor at 0520 h on 30 September after clearing the seafloor at 2230 h on 29 September. Two stands of drill collars were broken down and laid out to the drill collar racks on the main deck. The outer core barrel components were disassembled, inspected, and laid out.

While raising drill pipe, the vessel was relocated 20 m east of Hole U1574A to start a new hole. After recovering the drill string at 0520 h, we conducted required routine rig servicing, including lubrication of the traveling assembly and the drawworks. Following this, we made up the advanced piston corer/extended core barrel (APC/XCB) BHA and lowered the drill pipe to the seafloor. We prepared the core barrel and orientation tool and spaced out the bit to start Hole U1574B. After three attempts to fire the core barrel, the APC core barrel misfired. The mudline core was retrieved full (9.72 m or 102%). In an attempt to recover the sediment/water interface, we ended Hole U1574B and the ship was offset 20 m south to start Hole U1574C. The hole was spudded at 1650 h and Core U1574C-1H retrieved 9.91 m of sediment (104%). This time we decided to continue deepening the hole instead of attempting another mudline core. The calculated seafloor depth from the APC mudline core was 2819.6 m below sea level (mbsl). APC coring continued with core orientation from the seafloor through Core 19H, to a depth of 169.2 mbsf. Successful temperature measurements of the formation were recorded with the advanced piston corer temperature (APCT-3) tool on Cores 4H (38.0 mbsf), 7H (66.1 mbsf), 10H (94.6 mbsf), and 13H (118.7 mbsf). Cores 5H, 12H, 13H, 15H, 18H, and 19H were all recorded as partial strokes. Overpull reached a maximum of 40,000 lb during the coring process. A single hard layer was encountered at ~129 mbsf. After Core 19H was recovered, the XCB system was deployed, knowing from coring Hole U1574A that basement would be encountered on the next coring interval. The XCB core immediately contacted the basement at 169.2 mbsf. After cutting the core for 145 min, time expired for coring, and the core was retrieved on deck at 1655 h on 1 October. The 2.3 m advance returned a 1.47 m core. After laying out the last core, the coring systems were secured, the top drive was set back, and the bit was pulled clear of the seafloor at 1920 h. The pipe trip continued to the top of the APC/XCB BHA to 136.8 mbrf. The drill collars

were broken down and laid out to the main deck drill collar racks. The outer core barrel components were disassembled, inspected, and secured. The bridge was notified when the rig floor was secured for transit at 0231 h on 2 October, ending Hole U1574C. With the drill floor secured, the vessel switched from dynamic positioning (DP) to cruising mode. The thrusters were raised and secured, and we began our 877 nmi sea passage to Reykjavík, Iceland, at 0300 h at a speed of 10.0 kt.

Science Results

This week, the Expedition 396 scientists acquired and analyzed samples and data from Holes U1574A, U1574B, and U1574C. On Friday 1 October, the various laboratory teams presented their preliminary scientific results from Sites U1573 and U1574. On Saturday 2 October, the Co-Chief Scientists reviewed the operational and scientific achievements of the expedition, and the Staff Scientist provided guidance for completing the remaining tasks before the end of the expedition. All shipboard reports from Sites U1565–U1572 were completed, and we are conducting final measurements and analyses of samples from Site U1574 cores to finalize the remaining shipboard reports.

Lithostratigraphy

The core description team described and imaged the cores recovered from Holes U1574A and U1574C, completing all core measurements and descriptions for the expedition. The succession of recovered material from the two holes at Site U1574 consists of both sediments and basalts, and is divided into five lithostratigraphic units. Units I, II, III, and IV are sedimentary, and Unit V consists of basalt, hyaloclastite, and a small amount of interbasaltic sediments. Unit I consists of brown and brownish gray unconsolidated clay with intervals of rare pebbles and rare to common foraminifers. Unit II consists of pale yellow and grayish green consolidated clay. Unit III consists of very dark gray mudstone with rare beds of sandstone and ash; some intervals are finely laminated while others are moderately bioturbated. Unit IV consists of very dark gray to very dark grayish brown organic rich claystone with fine parallel laminations. Well preserved late early Eocene calcareous microfossils, including foraminifers, bivalves, and gastropods, are observed for the first time in the expedition. Unit V consists of aphyric to plagioclase phyric pillow basalt with localized hyaloclastite and rare interbedded claystone. Unit V has been divided into 2 subunits based on lithologic and geochemical variations.

Biostratigraphy

Samples from Holes U1574A and U1574C were processed for siliceous, calcareous, and organic microfossils. Both holes cored through ~170 m of sedimentary strata before igneous facies were reached. Most sedimentary core catcher samples from Hole U1574A, including two taken from between igneous facies, are assigned a late early Eocene age, based on marker dinocyst taxa and broader palynological assemblage characteristics, supported by calcareous microfossils and

pyritized diatoms in select intervals. In some of the lowermost samples, relatively abundant well-preserved calcareous microfossils and fish remains are found. These warrant further postcruise investigation.

Paleomagnetism

The archive sections of Site U1574 (Holes U1574A and U1574C) were measured on the superconducting rock magnetometer (SRM) at 2.5 cm intervals. The cores were subjected to a series of stepwise in-line alternating field (AF) demagnetization steps at 5, 10, 15, and 20 mT for sedimentary units, and 2, 4, 6, 8, 10, 15, and 20 mT for basalts.

Thirteen discrete samples from Hole U1574A, two from sedimentary units and eleven from basalts, were measured for natural remanent magnetization (NRM) in the JR-6 spinner magnetometer. For sediments, an AF demagnetization sequence of 5, 10, 15, 20, 30, 40, 50, and 60 mT, up to 70, 90, and 100 or 120 mT followed, and a similar sequence, but up to 150 mT was run for basalts, using the DTECH D-2000 AF demagnetizer. The demagnetization behavior for basalts is more stable than that observed for the sedimentary samples, and overall it was possible to achieve complete demagnetization for most of the basalts. The inclination values of the samples matched the ones in the core section run in the SRM at AF 20 mT. All the samples were measured for magnetic susceptibility (MS) on the KappaBridge KLY-4S.

From Hole U1574C, fifteen sedimentary samples were taken to confirm the measurements obtained for the cores, with almost one per core. The same demagnetization procedure for Hole U1574A was applied for these samples, including the measurement of their MS in the KappaBridge KLY-4S. The APC cored succession allowed a high resolution paleomagnetic record for this hole, that according to preliminary data from biostratigraphic analyses has an early Eocene age. The expanded stratigraphic section in this hole could eventually allow a detailed review of the early Eocene magnetostratigraphy for the area.

Geochemistry

Thirty-nine interstitial water (IW) samples were collected from Hole U1574C and nine were collected from Hole U1574A. At Hole U1574C, three samples were taken per core for the upper 50 mbsf and for the lowest 50 m above basement. Between these depths, one sample was taken per core. All samples were analyzed for the full suite of onboard measurements. As was the case at previous sites where sediments overlying basalt were sampled, the IW profiles are likely controlled by basaltic alteration and the formation of clay minerals and authigenic carbonates. Evidence for this at Site U1574 comes from the alkalinity, Mg, and K profiles, which all decrease downhole, due to clay and carbonate incorporation during authigenesis reactions. Ca and Sr increase downcore because of their release in the same reactions.

Corresponding squeeze cake samples were taken from all IW samples and have been freeze-dried, crushed, and analyzed for total carbon (TC), nitrogen, sulfur, and hydrogen by elemental analyzer, and total inorganic carbon analysis by coulometer. At Hole U1574C, organic carbon

gradually increases downcore, reaching values above 3 wt% below 120 mbsf. This trend is like those present in the sulfur and nitrogen data. Calcium carbonate concentrations are high in the uppermost 30 m of the hole and at the basalt/sediment interface. The first peak is related to biogenic carbonate, while the second is a combination of preserved nannofossils and authigenic carbonate precipitation.

Eighteen hard rock samples from Hole U1574A were digested and analyzed for their geochemical composition. These data indicate the rocks are andesitic to dacitic in composition, unlike anything we have observed at previous locations. This suggests the Eldhø volcano is different in composition from the outer and inner seaward dipping reflectors (SDRs).

Physical Properties and Downhole Measurements

The petrophysics team measured all the whole-round and split-half core sections recovered from the three holes cored at Site U1574 (only whole-round measurements were collected on the single core collected from Hole U1574B). The X-ray and multisensor logger tracks were run jointly with the JRSO technical staff. Discrete moisture and density (MAD) sampling and Gantry velocity measurements of the cores from Hole U1574A were completed. They consisted of 65 MAD samples, including 33 cubes, along with 363 Gantry *P*-wave measurements, including triaxial saturated and dry velocity measurements on cubes. Thermal conductivity measurements were taken on every core from Hole U1574C.

The raw wireline logging data from Hole U1574A were sent to the Lamont-Doherty Earth Observatory at Columbia University for processing and quality control. The processed data were received back on the ship on 2 October and are being reviewed by the petrophysics team.

Education and Outreach

Outreach activities during this week included updates to the IODP social media channels: Twitter, Facebook, and Instagram. Eight ship-to-shore educational and outreach events took place this week with universities, colleges, and schools in France, India, Ireland, Norway, and the United States.

Technical Support and HSE Activities

Laboratory Activities

- The JRSO technical staff helped process cores from Holes U1574A, U1574B, and U1574C and assisted the scientists in the laboratories.
- The glass panel of the Mettler balance in the Physical Properties Laboratory that broke last week was replaced with the one from a spare balance. A new glass panel is on order.

- A special insert for the Pycnometer was made from an aluminum rod by the ship's mechanic. This is to accommodate whole-round mini-core samples taken for a scientist. The standard method is used to calibrate and measure these long samples with acceptable results.
- In the Underway Geophysics Laboratory, the G-guns were cleaned and taken apart for storage.
- The JRSO technical staff are working on finishing analyses, packing up samples, and writing tech reports. The Assistant Laboratory Officer is preparing offgoing shipments.

IT Support Activities

- The main power surge protector (UPS) of the IODP data center fatally failed, causing the second complete crash of the IODP network, servers, internet, and all related systems. Power was restored without further issues, but all IT equipment is now directly connected to the ship's power supply.
- We held a Risk Assessment Spot Check with management on shore.
- We set up multiple users' devices for a series of Education and Outreach sessions on Zoom.
- The new Microsoft updates were applied to all general workstations and Windows servers.
- The latest Firefox update was pushed to macOS systems.
- We began the installation of macOS Big Sur 11.6 on multiple Big Sur 11.5 installations.

Developer Support Activities

- Work continued on the Sample and Data Request (SaDR) replacement application.
- We continued to work on a new version of LabVIEW LDAQ Library.
- We worked with scientists and technicians to resolve various data and uploading issues.
- Planning and designing the new SEM Uploader application continued.

Health and Safety Activities

- An abandon ship and fire drill was held at 1300 h on 3 October.
- The emergency shower and eye wash stations were tested.