IODP Expedition 396: Mid-Norwegian Continental Margin Magmatism

Week 6 Report (12–18 September 2021)

During Week 6 of the International Ocean Discovery Program (IODP) Expedition 396, Mid-Norwegian Continental Margin Magmatism, we completed coring and logging operations at Site U1572 (proposed Site VMVM-07A) and began coring operations at Site U1573 (proposed Site VMVM-09A).

Operations

Week 6 began while we were coring using the rotary core barrel (RCB) system in Hole U1572A from a depth of 38.5 m below seafloor (mbsf) (Core U1572A-5R). We continued RCB coring with full-length advances through Core 21R to 204 mbsf when we changed to half-length advances to improve core recovery, which averaged ~23% throughout the upper section. Cores 22R to 45R, from 204 to 320.7 mbsf, yielded 89 m of material, which translated into a coring recovery of 76%. The final core for Hole U1572A, 46R, was advanced at full-length to reach the final hole depth of 330.5 mbsf. Core U1572A-46R was on deck at 1240 h on 14 September 2021 (UTC + 0 h).

At the end of coring, we swept the hole clean of cuttings with a 50-barrel sweep of high viscosity mud and then lowered the rotary shifting tool (RST) and released the RCB C-4 coring bit at the bottom of the hole. The RST was pulled back to the surface and the sinker bars were removed. The hole then was displaced with 110 barrels of 10.5 ppg mud and the drill string was pulled back to 81.0 mbsf in preparation for wireline logging. The rig floor personnel and the Schlumberger engineer held a safety meeting as the drill floor was rigged up for logging. Only the triple combo logging tool string was deployed in Hole U1572A. The tools were assembled, tested, and deployed at 1900 h on 14 September. A downhole log was performed from just above seafloor to a maximum depth of 256 mbsf, where the tool encountered a blockage. The hole was logged up for a full-length open hole calibration pass, redeployed to 256 mbsf, and logged up one more time. The caliper was closed prior to entering the drill string. The tools were recovered, rigged down, and secured by 2400 h. No damage was found to the triple combo, but with solid evidence of hole deterioration, logging was terminated, and the drill pipe was pulled out of the hole, ending Hole U1572A. The total core recovery from Hole U1572A was 139.53 m (42%). The time spent in the hole was 86.25 h or 3.6 days.

After laying out the RCB outer core barrel components, we assembled the advanced piston corer/extended core barrel (APC/XCB) outer core barrel and bottom-hole assembly (BHA) and deployed the drill string to 1196.0 m below rig floor (mbrf). We picked up the top drive and drilling knobby and spaced out the bit to a core shot depth of 1215.0 mbrf based on an estimate combining the precision depth recorder (PDR) depth and the confirmed depth obtained from the logging run in Hole U1572A. Hole U1572B was spudded at 1015 h on 15 September. Based on

the 6.78 m of material returned in the mudline core, we calculated the water depth to be 1206.5 m below sea level (mbsl). We continued APC coring, advancing from the seafloor to 149.3 mbsf through Core U1572B-16H. Core 16H required 90,000 lb of overpull to retrieve the core from the formation, reaching APC refusal. We deployed the half-length advanced piston corer (HLAPC) system and continued coring from 149.3 mbsf to 209.6 mbsf, reaching HLAPC refusal with Core 29F. We then deployed the XCB system and coring continued with partial advances to a depth of 224.3 mbsf. The final core, 33X, was on deck at 1045 h on 16 September. We terminated the hole after reaching basement and having achieved our science objective of sampling the sediment/basement transition. 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 1235 h. We recovered the drill pipe, disassembled and inspected all the components, and secured the rig floor for transit to the next site. The total amount of core recovered in Hole U1572B was 218.37 (97%). The time spent on the hole was 36.25 h or 1.6 days.

The 99 nmi transit to Site U1573 (proposed Site VMVM-09A) was completed in 8.8 h at 0130 h on 17 September. After being cleared for operations at 0157 h, the rig crew assembled the RCB BHA and deployed it to the seafloor while filling the drill pipe with seawater every 20 stands. Based on the determined PDR depth of 3167.2 mbsl, Hole U1573A was spudded at 1140 h on 17 September. We drilled ahead with a center bit in place without core recovery to 300 mbsf, as was previously approved by the IODP Environmental Protection and Safety Panel (EPSP). After reaching 300 mbsf at 0330 h on 18 September, the center bit was retrieved by wireline, and a nonmagnetic RCB core barrel was dropped to begin coring in Hole U1573A. We RCB cored with full-length advances through Core U1573A-3R while poor weather conditions continued to build. At 0800 h, the decision was made to stop coring and to pull the bit up off bottom and wait on the weather to subside. The wind and vessel pitch made working conditions on the drill floor and in the derrick too dangerous for operations to continue. The forecast was favorable for later in the day and after evaluating the weather, operations resumed at 1200 h. RCB coring continued from Core 4R at 318.4 mbsf to Core 10R, reaching a depth of 386.5 mbsf at midnight on 18 September.

Science Results

This week, the Expedition 396 scientists acquired and analyzed samples and data from Holes U1571B, U1572A, and U1572B. The team continues to work on finalizing the Site U1569–U1570 reports and started to compile the preliminary versions of the Site U1571 and U1572 reports.

Lithostratigraphy

The core description team described cores from Holes U1571B, U1572A, and U1572B, and is in the process of defining the lithostratigraphic units for these two sites. In general, both sites yielded ~95–125 m of late Quaternary clay and Miocene biosiliceous ooze in the uppermost

interval. Below these sediments, ~20 m and ~75 m of early Eocene biosiliceous and ash-rich muds and mudstones were recovered at Sites U1571 and U1572, respectively. Overall, these sediments ranged in composition from diatom ooze to diamictite interbedded with sand-rich ash intervals. Radiolarian ooze, which likely corresponds to the upper Eocene, was recovered below the diatom-dominated interval. Below the radiolarian-rich sediments, ~125 m thick basaltic sequences with interbedded sediments were recovered at both sites. In Hole U1571A, the basement sequence is mostly composed of aphyric basalt with a variable degree of vesicularity. In Hole U1572B, the sequence starts with a slightly more differentiated fine-grained basaltic andesite. Interbasaltic sediments range in color from oxidized red, possibly due to subaerial deposition, to a reduced green, likely neritic marine. The team also began measuring and describing the first two cores from Hole U1573A at the end of the week.

Biostratigraphy

The biostratigraphy team continued to provide age control and paleoenvironmental reconstructions, this week on the recovered sediments from Sites U1571 and U1572. The processing of samples from Hole U1572B continued through Saturday 18 September, and micropaleontological and palynological analyses were conducted on samples from all the sites at the same time. All holes yield sediments overlying igneous facies, and representative sediment-containing core catchers were prepared for all major lithologies. In addition, a few sedimentary strata from between igneous flows in Hole U1572A were processed and analyzed.

All holes from Sites U1571 and U1572 comprise a biosiliceous-rich succession being Quaternary, (middle) Miocene, and late early Eocene to middle middle Eocene in age. The lowermost recovered sediments overlying the basalts contain various chronobiostratigraphic index species, constraining the onset of sediment accumulation to ~49 Ma (latest early Eocene). Further remarkable finds from the Eocene succession include fish remains, spectacular blooms of diatoms, remarkably well-preserved dinocysts, and massive remains of the freshwater fern *Azolla*.

Paleomagnetism

All the archive core sections of Holes U1572A and U1572B and the first four cores of Hole U1573A 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 sediment, and 2, 4, 6, 8, 10, 15, and 20 mT for rock (basalts). A track positioning test was performed on the SRM to confirm the offsets recorded by the instrument are accurate. Offsets were confirmed to be accurate to within 1 cm.

Twenty-one discrete samples were taken from Hole U1572A (three for sediment and 18 for basaltic flows), and 16 for Hole U1572B with a focus on the sedimentary units (15 out of 16 samples). Except for four samples taken from the lowermost section of Hole U1572B, all the samples were measured for magnetic susceptibility (MS) on the KappaBridge KLY-4S. Hole

U1573A is currently being sampled. In addition, all the discrete samples from Site U1572 were measured for natural remanent magnetization (NRM) in the JR-6 spinner magnetometer, followed by an AF demagnetization sequence of 5, 10, 15, 20, 30, 40, 50, 60, and up to 70, 90, and 100 mT for sedimentary samples and up to 200 mT for basalts, using the DTECH D-2000 AF demagnetizer. The demagnetization behavior of the basalt samples was more stable than the ones observed for sediment in general; however, all the samples matched the inclination measurements obtained by the SRM for both holes.

A preliminary assessment of the magnetostratigraphy for Hole U1572B suggests a good agreement with the biostratigraphy data, especially between core Sections U1572B-17H-3 to 29F-3 (~153–210 mbsf), where both indicate a middle Eocene age for that interval.

Geochemistry

Twenty-eight hard rock samples from Hole U1571A were collected and analysed for their elemental composition via inductively coupled plasma–atomic emission spectroscopy (ICP-AES). Twenty-four additional samples were collected from U1572A and are undergoing acid digestion before being analyzed in the coming days. The composition of the basement rocks recovered from Hole U1571A show basalt to basaltic andesite chemistries. Titanium concentrations in the basaltic lithologies are higher than in samples from Site U1566, suggesting a different provenance and/or timing of formation. The results are in good agreement with the portable X-ray fluorescence spectrometer (pXRF) analyses.

Forty-nine pore water interstitial water (IW) samples were collected from Holes U1572A (12 samples) and U1572B (37 samples). Three IW samples per core for the upper 50 m followed by one per core to the base of each hole were prepared. All samples from Holes U1572A and U1572B were analyzed for their alkalinity, pH, and the full standard range of elemental compositions. Alkalinity at Hole U1572B gradually increases downhole, reaching ~8 mM by 53 mbsf before gradually decreasing with depth. A similar trend is also noticed in the NH_4^+ profile, and in many of the elemental compositions (e.g., Mg, Sr, Ca). These profiles appear to show the influence of underlying basalt on the porewater. pH varies significantly in Holes U1572A and U1572B, with periodic increases at ~53, ~130, and ~210 mbsf.

Ninety-nine squeeze cake samples were subsampled, freeze-dried, crushed, and then analyzed for total carbon, nitrogen, sulfur, and hydrogen by elemental analyzer, and total inorganic carbon analysis by coulometer. Site U1571 shows gradual enrichments of total organic carbon (TOC), N, and S, and depletion of $CaCO_3$ with depth to ~95 mbsf. Below this interval is a sharp transition to trace amounts of all four measurements that continues to the base of the holes. Site U1572 is more exotic, with high peaks of TOC (up to 6.6 wt%) and N (up to 0.31 wt%) between 110–115 mbsf. There appear to be several fluctuations between terrestrially and marine-sourced organic matter across this interval. Site U1572 also shows a drop in TOC, $CaCO_3$, N, and S to trace concentrations like at Site U1571, but at a deeper interval at ~210 mbsf.

Physical Properties and Downhole Measurements

All cores from Sites U1571 and U1572 were measured for physical properties, including an extensive suite of hard rock *P*-wave velocity (V_P) Gantry and discrete moisture and density (MAD) analyses of the basaltic rock sequences at both sites. Combined MAD and paleomagnetic cube samples from the basaltic cores were measured for triaxial *x, y,* and *z* saturated *P*-wave velocities, followed by running MAD before finally repeating triaxial *P*-wave testing of the dried cubes. Automation workflows for utilizing the laser precision caliper measurements of the *P*-wave Gantry system on cubes for the MAD volume calculations were tested, resulting in improved efficiency for replicable results. The core tracks were run mostly by the JRSO technical staff with help from the physical properties team during busy coring times.

Detailed comparisons between ash layers and increased MS and *P*-wave velocity measurements were made for Sites U1569 and U1570, along with image log characterization of the igneous dacite units from Hole U1570D.

Formation temperature measurements were taken with the advanced piston corer temperature (APCT-3) tool in Hole U1572B at the seafloor, at 35.3 mbsf (Core 4H), at 73.3 mbsf (Core 8H), and at 111.3 mbsf (Core 12H). The raw downhole wireline logging data were sent to Columbia University for processing and quality control. Work is ongoing with the wireline logging data from Sites U1571 and U1572, both of which include full triple combo data for the volcanic sequence along with overlying sedimentary sequences.

Photogrammetry was undertaken on key samples for outreach and a mini-core and cube photographic archive was collected and archived for future data analyses. The first cores from Hole U1573A were measured though the whole-round tracks, and MAD sampling and V_P Gantry measurements are ongoing.

Education and Outreach

Outreach activities during this week focused on updates to the IODP social media channels: Twitter, Facebook, and Instagram.

Technical Support and HSE Activities

Laboratory Activities

- The JRSO technical staff helped process cores from Holes U1572A, U1572B, and U1573A, and assisted the scientists in the laboratories.
- *P*-wave velocities measured on the Whole-Round Multisensor Logger (WRMSL) stopped being saved during the measurement of Hole U1572B cores, including those with values within the filter range. After troubleshooting, it was determined that the gain was set too

high for the dense clay material recovered from the hole. The application was clipping the saturated signals and filtering the data. After adjusting the gain on the pulsar/receiver, the application started to measure and record the measurements properly. The operations manual was updated and now it includes this information.

- The CO_2 trap in the Chemistry Laboratory's source rock analyzer (SRA) was clogged. The trap was replaced, but it clogged again within hours. Troubleshooting this instrument continues.
- We began to test the new MFK-2 KappaBridge instrument in the Paleomagnetics Laboratory.

IT Support Activities

- We downloaded the latest security updates released by Apple and Microsoft.
- We started to conduct monthly maintenance and installed new updates and patches to spare laptops.
- We installed a newer version of PMAG Agico Safyr7 software upon a request from the Assistant Laboratory Officer. The new version required RS232 drivers from a second party vendor to get Safyr7 communicating with the Agico instrument.
- Tape Drive #1 of the HP MSL6480 data center was logging unrecoverable errors and was disabled. The other three drives are executing the backups correctly. IT opened a service/troubleshooting ticket with HP and is waiting for their response.
- We discovered that the Commvault backup process was not backing up a specific server. The cause was determined to be from the power outage suffered last week. Troubleshooting with Commvault allowed us to identify a method to restart the Commvault service on the downed server without rebooting the entire system.
- We noticed that the server *ship-srv* was out of disk space. The cause is believed to be Commvault writing logfiles to it. We cleared the logfiles and remediated the problem. We applied updates to server *ship-srv* from the Exchange patch updates from last week.
- We found 22 workstations with Identity Finder software installed. We developed a ZENworks script to remove the software and implemented it.

Developer Support Activities

- Work continued on the Sample and Data Request (SaDR) replacement application.
- We worked on a new version of LabVIEW LDAQ Library.
- Worked with scientists and technical staff to resolve various data and uploading issues.
- Worked with shore-based developers on planning and designing the new SEM Uploader application.

Health and Safety Activities

- An abandon ship and fire drill was held at 1300 h on 19 September.
- The emergency shower and eye wash stations were tested.