IODP Expedition 396: Mid-Norwegian Continental Margin Magmatism

Week 3 Report (22–28 August 2021)

During Week 3 of the International Ocean Discovery Program (IODP) Expedition 396, Mid-Norwegian Continental Margin Magmatism, we completed advanced piston corer/extended core barrel (APC/XCB) coring and logging operations at Sites U1567 (proposed site VMVM-31A) and U1568 (proposed Site VMVM-40B) and started coring using the rotary core barrel (RCB) at Site U1569 (proposed Site VMVM-55B).

Operations

Week 3 began at Site U1567 while APC coring from 33.9 to 52.9 meters below seafloor (mbsf) in Hole U1567A. Core U1567A-6H was recorded as a partial stroke despite a 10.02 m (105%) recovery. An overpull of 35,000 lbs was required to release the core from the formation. We deployed the half-length advanced piston corer (HLAPC) and despite the shorter barrel, the next core, 7F, also recorded a partial stroke. We determined we had reached APC refusal and switched to the XCB system. To maximize core recovery, we advanced the hole cutting half-length XCB cores to 69.4 mbsf (Core U1567A-10X). After cutting Core 10X, we continued with full advances through the final depth of the hole at 196 mbsf with Core 23X at 1655 h, 22 August 2021. Total core recovery for Hole U1567A was 181.55 m (92.7%).

After coring was completed, the hole was swept clean of cuttings with a 50-barrel sweep of high viscosity mud and displaced with 85 barrels of 10.5 ppg mud. The drill string was pulled back to 140.5 mbsf with the top drive installed. The top drive was set back, and the drill string was raised to bring the end of the pipe to 82.8 mbsf in preparation for downhole logging. The rig floor personnel and the Schlumberger engineer met to review safety issues surrounding the upcoming logging operations. Two downhole logging tool strings were run in Hole U1567A, the modified triple combo tool string with the magnetic susceptibility (MS) sonde and the Formation MicroScanner (FMS)-sonic tool string. The triple combo was assembled, tested, and deployed at 2105 h on 22 August. A downhole log was performed from just above seafloor to the full depth of the hole (~196 mbsf). The hole was logged up for a full-length open hole calibration pass and the tool string was deployed back to the bottom of the hole. Then we collected data over two successful upward runs. As the triple combo approached the bit, the drill string was raised 10 m to allow these additional meters of hole to be logged. The caliper was closed prior to entering the drill pipe. The tools were brought back to the surface and rigged down by 0100 h on 23 August. We then rigged up the FMS-sonic tool string and deployed it, collecting a downward log with the FMS calipers closed from just above the seafloor to 196 mbsf. We logged with the natural gamma radiation (NGR) tool through the drill pipe to identify the seafloor depth and match the results of the first logging run. Once we reached the bottom of the hole, we conducted two upward passes collecting data from 196 mbsf to ~125 mbsf with the FMS calipers open. The calipers were closed just prior to entering the drill pipe and the hole was logged to the seafloor.

The tool string was pulled back to the surface. At 0600 h on 21 August, all logging tools were rigged down, and the logging wireline was secured. No damage was found to any of the logging tools from either of the two tool strings. The drilling knobbies were removed from the drill string and the drill string was pulled to 1667 meters below rig floor (mbrf), clearing the seafloor at 0640 h on 23 August and ending Hole U1567A. The dynamic positioning (DP) operator was notified that operations at Hole U1567A were complete and began to move the ship to Hole U1567B. The time spent on Hole U1567A was 42.50 h or 1.8 days.

The vessel was offset 160 m to the south following the direction of the seismic line toward proposed Site VMVM-40B (Site U1568) to start Hole U1567B. The reason for coring a second hole at this site was to attempt to sample a critical interval between 50 and 70 mbsf that was not fully recovered in Hole U1567A. The top drive and drilling knobby were picked up and the bit spaced out in preparation to start the hole. The seafloor depth was established at 1704.3 meters below sea level (mbsl) using the offset depth from Hole U1567A with a small adjustment to account for the difference in seafloor depth using the precision depth recorder (PDR). An XCB wash barrel was dropped and Hole U1567B was spudded at 0820 h. We drilled without recovering any core down to 25.0 mbsf and the wash barrel was recovered by wireline. The APC coring system was deployed and we cut Cores U1567B-2H through Core 4H to a depth of 49.3 mbsf. Core 4H was recorded as a partial stroke with a 5.3 m advance (5.29 m core recovery). We switched to the XCB coring system and began cutting half-length cores to improve the chances of fully recovering the missing interval. We cored with the XCB system from 49.3 to 83.0 mbsf (Cores 5X to 11X) and recovered 30.45 m (90.4%). We then pulled the drill string out of the hole, ending Hole U1567B at 1900 h on 23 August. We set the end of the pipe at 1686.7 mbrf (1675.5 mbsl), secured the drill floor, and moved to the next site in DP mode. The time spent on Hole U1567B was 12.00 h or 0.5 days.

The 0.25 nmi move to Site U1568 (proposed Site VMVM-40B) was completed at 1936 h. With the thrusters already down, the move from Site U1567 to Site U1568 consumed only 45 min of vessel operations. The drill floor was cleared for operations at 1936 h, beginning Hole U1568A. With the top drive already in place, a PDR reading estimated the water depth at 1707.4 mbsl. Because most of the PDR depths had been shallow, the bit was spaced out to 1705.0 mbrf to spud Hole U1568A. An APC core barrel was fired but did not recover any core. The bit was lowered to 1710.0 mbrf and a second attempt recovered 3.89 m of core. The APC calculated water depth was 1715.6 mbrf (1704.4 mbsl). Hole U1568A was spudded at 2132 h. We continued APC coring through Core U1568A-7H to 51.7 mbsf. Core 6H was recorded as a partial stroke despite a 9.58 m recovery. An overpull of 20,000 lb was required to release the core barrel from the formation. The following attempt with the APC core barrel returned just a 0.3 m core, and we switched to the XCB coring system. In anticipation of a hard layer expected at ~60 mbsf and with the objective of improving core recovery through the interval, we deployed the XCB coring system with half-length advances for Cores 8X to 12X from 51.7 to 77.4 mbsf, collecting 25.05 m of core (97.5%). Then we switched to full XCB coring for Cores 13X to 21X from 77.4 to 165.3 mbsf. As core recovery dropped to ~40% in the last three cores, we switched

back to half-length XCB advances to reach the total approved depth for the site, 200 m, with Core U1568A-22X. The last core on deck was at 0050 h on 25 August. In total, we obtained 53.22 m of core (102.9%) with the APC system and 102.1 m (71.6%) with the XCB system from Hole U1568A.

After coring was completed at 0050 h, we conditioned the hole for downhole logging with a 50-barrel high viscosity mud sweep to clear the cuttings and then displaced the hole with 84 barrels of 10.5 ppg mud. We raised the end of the pipe to a logging depth of 82 mbsf, rigged up the triple combo tool string, and lowered it through the pipe, but it was unable to pass through the outer core barrel after several attempts. The tool string was brought back to the surface at 0830 h, rigged down, inspected, and all its components verified to be in good condition. We then picked up the top drive, dropped an XCB core barrel, and circulated to verify that the barrel was landed. As everything seemed to be in good order, we retrieved the core barrel by wireline, rigged up the triple combo once again, and lowered it inside the hole at 1200 h. This time, the tool string passed into the open hole without problems, reaching 188.7 mbsf on the first pass and 187.8 mbsf on the second pass. We conducted two successful passes upwards, collecting MS, resistivity, density (with caliper), neutron porosity, temperature, and NGR data. The triple combo was retrieved at 1505 h and was rigged down. Then we rigged up the FMS-sonic tool string and lowered it through the open hole. We conducted two upward passes from 185.7 mbsf. The FMS-sonic was retrieved at 1945 h and the rig floor cleared of all the logging equipment. We pulled up the pipe, clearing the seafloor, ending Hole U1568A at 2200 h on 25 August. After raising the pipe and setting the bit at 1677 mbrf (1665.8 mbsl), we moved 160 m north in DP mode to start Hole U1568B. We dropped an XCB wash barrel and dressed out the APC barrels in preparation for piston coring.

Hole U1568B was spudded at midnight on 25 August at a PDR depth of 1706.1 mbsl. An XCB wash barrel was dropped, and we drilled without recovery to 30.0 mbsf. At that point, the wash barrel was recovered by wireline and the APC coring system was deployed, advancing the hole to 49 mbsf with Cores U1568B-2H and 3H. Once the core was retrieved, we found that the liner had imploded inside the barrel, and we had to pump it out. We switched to the XCB coring system and cored from 49 mbsf to a final depth of 124.6 mbsf (Cores 4X to 17X). We then raised the drill string out of the hole, clearing the seafloor at 1900 h, ending Hole U1568B. Total core recovery for the hole was 63.95 m (84.6%). The time spent on Hole U1568B was 21.00 h or 0.9 days.

After completing coring operations at Site U1568, we set the end of the pipe at 1666 mbrf and returned to Site U1567 in DP mode to core an additional hole between the positions of Holes U1567A and U1567B with the objective of improving the sampling across the Paleocene/Eocene boundary at this site. Once over the new hole coordinates, we spudded Hole U1567C at 2040 h on 26 August. The PDR seafloor depth was 1706.1 mbsl. We drilled down to 30 mbsf without recovery and then APC/XCB cored to 106.0 mbsf (Cores U1567C-1H to 14X). Total core recovered in Hole U1567C was 66.48 m (87.5%).

The APC/XCB coring equipment was secured, the top drive was set back, and the drill string was pulled back to the surface and disassembled. All parts were inspected, stored away, and secured, and the bridge was notified at 1340 h that all operations at Site U1567 were complete. The time spent on Hole U1567C was 17.75 h or 0.7 days.

The thrusters were raised and the 38 nmi sea passage to Site U1569 began at 1400 h on 27 August. On arrival, the thrusters were lowered, and the vessel positioned on the coordinates of Hole U1569A at 1759 h. The rig crew made up the RCB bottom-hole assembly (BHA), and by 2015 h, a 172.1 m long BHA was assembled with the C-4 RCB and a mechanical bit release (MBR) above the bit. A PDR for the site estimated a water depth of 2171.2 mbsl. The rig crew assembled the drill pipe to 2163.0 mbrf, filling it with seawater every 20 stands. Before beginning coring operations, the drilling equipment was serviced. The top drive was picked up and spaced out to spud Hole U1569A. A dressed nonmagnetic RCB core barrel was dropped and pumped down to land in the outer core barrel. Hole U1569A was spudded at 0245 h on 28 August. The PDR water depth appeared to match the driller's tag depth and was used for the official water depth for Hole U1569A. Coring continued throughout the day, and at the end of the week we were RCB coring at a depth of 234.3 mbsf in Hole U1569A.

Science Results

Scientists acquired and analyzed data from Holes U1567A, U1567B, U1567C, U1568A, U1568B, and U1569A, and continued to summarize their results in the shipboard reports. The 2-week COVID mitigation period ended on 25 August at 1326 h, and on 26 August we held the first in-person meeting with the entire science party to present and discuss the results from Sites U1565 and U1566. The next day, the Co-Chief Scientists presented the scientific and operational objectives for Sites U1569.

Lithostratigraphy

The remaining cores from Hole U1566A and all cores from Hole U1567A, U1567B, U1567C, U1568A, and U1568B were described. Sites U1567 and U1568 were combined into one 500 m transect of five holes consisting of six lithostratigraphic units. Unit boundaries were located at each hole through lithologic observations, supported by biostratigraphic constraints and physical properties data. The overall recovery for all holes is high. Therefore, the precise depth of most boundaries between the lithostratigraphic units and subunits can be determined. Occasionally, boundaries are placed at the top of the underlying unit or subunit, where recovery is low. Unit I is gray clay with occasional dropstones. Unit II consists of a dark brownish-gray mixture of clay- to pebble-sized grains rich in manganese and iron in the uppermost interval, and light yellowish-brown sand-rich clay throughout. Unit III is light yellowish-brown to pale yellow to very dark greenish-gray clay with silt, with clasts of clay and siltstone. Unit IV is dark greenish-gray to very dark gray claystone or siltstone, with occasional black sand beds, some of which are rich in

volcanic glass. Unit V is very dark gray to black laminated claystone, without bioturbation. Unit V in Hole U1567C contains occasional glendonite. Unit VI is very dark greenish-gray claystone or siltstone with common bioturbation, often in the form of burrows.

Biostratigraphy

All core catcher samples and a few selected samples from split core sections from Holes U1567A, U1567B, U1567C (only smear slides), U1568A, and U1568B (only smear slides) were examined for calcareous, siliceous, and organic-walled microfossils. Siliceous and organic-walled microfossils are abundant, whereas only very few calcareous microfossils were observed in all holes. Several laminated intervals corresponding to the upper part of the Paleocene/Eocene Thermal Maximum (PETM) successions contain unprecedented concentrations of finely preserved diatoms. We were able to construct a first chronostratigraphic framework for these holes, allowing tentative correlations. Quaternary overburden sediments overlie mid-lower Eocene sediments, with an expanded PETM interval below.

Paleomagnetism

All archive sections from Sites U1567 (Holes U1567A, U1567B, and U1567C) and U1568 (Holes U1568A and U1568B) were measured in the superconducting rock magnetometer (SRM). After measuring the natural remnant magnetization (NRM) the alternating field (AF) sequence steps used to demagnetize these sedimentary sections were 5 mT, 10 mT, 15 mT, and 20 mT. In general, XCB coring generated noisier paleomagnetic data, mostly due to the fragmentation of the hardened sediment among other drilling disturbances.

The Icefield MI-5 core orientation tool was run on Cores U1567A-3H through 6H and Cores U1568A-2H through 6H. The reoriented cores can then be compared to the inclination polarity record. Cores U1567A-3H, 4H, and 6H showed general agreement with the inclination polarity record. Core U1567-5H was approximately 180° from the expected declination. Cores U1568A-2H, 3H, 5H, and 6H were in general agreement with the inclination polarity record. The SRM declination data for Core 4H was noisy and no clear conclusions could be made.

Fifteen discrete sediment samples were measured for Site U1567 (twelve for Hole U1567A and three for Hole U1567B). Because Sites U1568 and U1567 were close to one another and have similar lithological facies, discrete sampling was reduced for the rest of the cores, and just two more samples were obtained from Hole U1568B. For Site U1567, most of the samples showed irregular demagnetization curves, possibly from a drilling overprint.

The downhole variation for whole-round magnetic susceptibility (WRMS) for both sites showed a pattern of very low relative values from the surface down, increasing around ~36 mbsf, with a peak at ~52 mbsf, followed by a sharp decline toward lower values through the base of the hole. This coincides with the change in the lithological units from the yellowish mud of the upper units, followed by the dark grey clays and silt from 36 to 52 mbsf, to the black siltstone units and laminated black and green beds below 52 mbsf.

Geochemistry

Forty-six samples were taken from Site U1565 and U1566 cores to measure their elemental composition by inductively coupled plasma–atomic emission spectroscopy (ICP-AES) analyses. From Hole U1565A, two samples of basement granite were analysed, and the compositions indicate A-type granite. Twenty-one basalt samples taken from Core U1566A-4R to 12R were analysed. Basalts are mostly mid-ocean-ridge basalt (MORB) in composition with low-Ti concentration. They are in good agreement with the portable X-ray fluorescence spectrometer (pXRF) analyses, validating both approaches. Furthermore, 22 samples are in the process of being digested.

Thirty-nine interstitial water (IW) samples were collected from the three holes at Site U1567, 37 from Site U1568, and 15 from Site U1569. The IW samples from Sites U1567 and U1568 will allow us to examine pore water flow along a transect associated with a hydrothermal vent structure. Alkalinity in the IW samples from Hole U1567A does not vary significantly downhole, with an almost linear increase. In contrast, at Hole U1568A alkalinity decreases after 25 mbsf, reaching 2 mM at 51 mbsf. A similar trend is also noticed in the NH_4^+ and PO_4^{3-} profiles. Carbonate analyses have been completed on 110 sediment and hard rock samples.

Physical Properties and Downhole Measurements

The physical properties team have conducted a suite of geophysical and petrophysical analyses of core samples from Sites U1567 and U1568. All whole-round cores of sufficient length were run through the Whole-Round Multisensor Logger (WRMSL), X-ray imager, and NGR tracks with the help of the JRSO technicians. These data were quality assessed through discrete moisture and density (MAD) analyses and half-round Gantry *P*-wave measurements. The petrophysical data revealed key lithological units and aided in the constraint of important stratigraphic transitions within the recovered cores.

Downhole logging was conducted in Holes U1567A and U1568A. The raw logging data were sent to the Lamont-Doherty Earth Observatory for processing and quality control. The petrophysics and downhole measurements team is reviewing the processed data once they are returned to the ship after processing.

Education and Outreach

Outreach activities during this week focused on updates to IODP social media channels: a blog post on joidesresolution.org, Twitter, Facebook and Instagram.

Technical Support and HSE Activities

Laboratory Activities

- JRSO staff processed cores from Holes U1567A, U1567B, U1567C, U1568A, U1568B, and U1569A, and assisted scientists in the laboratories.
- The LIMS database experienced two failures between Sites U1568 and U1569. The scientists were unable to process core on the tracks or enter descriptions. The Applications Developer and the Marine Computer Specialists solved the issue prior to the start of coring at Site U1569.
- The burned capacitor of the source rock analyzer (SRA) was replaced by a Siem Offshore Electronics Technician. The SRA power light now turns on and the instrument is communicating to the software. Testing is ongoing to determine if the SRA is fully functional. The glow-plug is not lighting automatically, but can be ignited using a manual lighter and will stay lit.
- The touch screen monitor on the Section Half Imaging Logger (SHIL) was replaced with a non-touch screen after scientists were experiencing issues viewing the images. The non-touch screen monitor seems much better suited for viewing SHIL images.
- Issues occurred with the SHIL losing focus during measurements, resulting in the need to reimage sections after the issue was discovered.
- The splitting room flooded while using the Supersaw. Water was coming up from the deck sediment trap (aft, by the NGR door). Siem Offshore engineers tracked down a blockage down the drain line. The drain goes all the way to a "mud pit" in the chiller room. After several attempts to unblock the drain using the mechanical snake and ship air, the blockage was cleared.
- A plumbing leak was reported from the Thin Section Laboratory aft sink. A straight union joint of the chemical drain line was replaced. Another suspected blockage down the drain line was cleared by Siem Offshore engineers. This drain line also goes down to the "mud pit" in the chiller room.

IT Support Activities

- The Tomcat server load balancer hung on Mattlehorn and Elcapitan. We rebooted the servers but the IODP applications LORE and LIVE returned 404 browser screen errors. Further investigation found that permissions were altered on various Tomcat directories. The permission issues were corrected and functionality was restored. The cause of the failure is still being investigated.
- Net 3.5 was removed from XRD PC, causing the Brucker FileExchange software to not function. The installation of Net 3.5 resolved the matter.
- Held a Spot Check on various systems as part of Risk Assessment with shore management.
- Installed Strater version 5.7 on multiple workstations as requested by Publications.

- Updated the Publications Office MAC53988 to the latest version of macOS Big Sur.
- Pushed the latest Firefox browser out to all shipboard Macs.
- The Applications Developer was able to install docking station drivers successfully and resolve blanking screen issue.

Developer Support Activities

- The developer continued work on the SADR replacement project.
- A new version of LIVE was deployed in which:
    - DESClogik data is presented without classifications.
    - When the DESClogik template has multiple columns that reference the same component (e.g. "principal_lithology"), but different domains, domain types, constituents, etc., values in those columns are presented on separate lines, rather than being drawn on top of each other.
- A new version of the VirtualPhotoTable (VPT) program that creates the composite core images was deployed. This version greatly reduces the amount of data the program retrieves with each scan of the database. The load on the servers produced by the VPT program might have contributed to the server failures.
- A new version of Catwalk was deployed with a minor change: the message box that pops up when labels are printed now appears always centered over the main Catwalk window and can be dismissed by clicking anywhere on the screen.
- Manually added the comment "Dry" to ~50 PWC tests because a scientist forgot to enter this at the time of test entry.
- Assisted the Core Description technician in correcting some problems with the 396_macroscopic template in DESCLogik, which had several columns misdefined and the data uploaded in them did not appear in the proper columns when downloaded. This also involved the manual correction of many database records from prior uploads.
- Assisted the technicians and scientists with several sample processing issues: mislabeling and misparenting of samples, etc.
- Assisted with the diagnosis of ongoing issues with one of the microscope work stations.
- Participated in shore-based developer meetings via Zoom.

Health and Safety Activities

- An abandon ship and fire drill was held at 1030 h on 29 August.
- The emergency shower and eye wash stations were tested.
- The COVID mitigation period was completed successfully.