IODP Expedition 402: Tyrrhenian Continent–Ocean Transition

Week 4 Report (3–9 March 2024)

Week 4 of the International Ocean Discovery Program (IODP) Expedition 402, Tyrrhenian Continent–Ocean Transition was spent at Sites U1614 and U1615 within the Vavilov Basin, using the rotary core barrel (RCB) system to drill basement in Hole U1614C, and then using the advanced piston corer/extended core barrel (APC/XCB) system to core sediment in Hole U1615A. In Hole U1614C, the depth objective in basement was met (140 m penetration) but the decision was made to continue deepening the hole by an additional ~40 m. Shortly thereafter, the pipe became stuck and we were required to sever, ending operations at Site U1614. At the next two sites, Site U1615 and upcoming Site U1616, we plan to APC/XCB core to the basement contact and then choose one of the sites for a casing installation to allow RCB drilling in basement. However, Site U1615 was ended prior to reaching basement due to poor core recovery and to the basement contact being substantially deeper than expected.

Operations

During Week 4, we installed a reentry system and two casing strings in Hole U1614C, extending to a depth of 227.3 meters below seafloor (mbsf) and with a ~20 m rathole drilled ahead. The third reentry into Hole U1614C to begin RCB drilling occurred at 0135 h on 3 March 2024, guided by the vibration isolated television (VIT) camera system. We then picked up the top drive, recovered the VIT, and dropped a core barrel with the bit at a depth of 229.7 mbsf. The core barrel was washed down to the bottom of the previous drilled interval (250.0 mbsf) before we began coring.

Cores U1614C-2R through 28R advanced 160.6 m to a total hole depth of 410.6 mbsf with a 71.58 m recovery (45%). Recovery varied from 6%–99%. Cores from 8R–28R were taken as half advances to improve recovery. After drilling Core 11R, we experienced high overpull and loss of rotation, but we were able to work the pipe free. Recovery was relatively high (61%) in Cores 5R–19R, as well as Cores 22R–28R (49% recovery), and was very low in Cores 20R (9%) and 21R (21%), likely due to the differences in lithology recovered.

Following recovery of Core U1614C-28R, we lost pipe rotation and became stuck. Working the pipe allowed us to regain rotation and lay out two single pieces of pipe from the drill string. The drill string became stuck again, with no rotation or vertical movement. Good circulation suggested that we were losing circulating fluids into the formation. From 1430 to 1700 h on 6 March, we worked the pipe without regaining

movement. The vessel was offset to retrieve the core barrel and to release the bit as a last attempt to free ourselves. When this effort failed, we made the decision to deploy a severing charge and sever the pipe just below the casing. A severing charge was lowered to a depth of 234.7 mbsf, just below the depth of the casing string. The charges were detonated with a 20,000 lb overpull on the pipe; an immediate drop in string weight indicated that the drill pipe was free. The Schlumberger wireline was recovered and we began pulling out of the hole. Once the end of the pipe cleared the seafloor at 0500 h on 7 March, the vessel started to move in dynamic positioning (DP) mode at 0.5 kt toward proposed Site TYR-16A (Site U1615). The end of the pipe reached the rig floor at 1000 h, ending Hole U1614C, and an APC/XCB bottom-hole assembly (BHA) was made up to begin operations at Site U1615.

The 5.1 nmi transit was completed at 1608 h on 7 March. Tripping pipe toward the seafloor began while the ship was still in transit. Hole U1615A was spudded at 2230 h with the bit positioned 5 m above the precision depth recorder water depth of 3571.4 m. Core U1615A-1H recovered the mudline and 7.49 m of material from a 7.3 m advance (103%), confirming the water depth as 3568.6 m. Coring in Hole U1615A continued through Core 34X, achieving a depth of 300.0 mbsf and recovering 107.57 m of sediment (38%). Recovery was high in the first five cores (97%) but low throughout much of the rest of the hole, including six cores with no recovery. Formation temperature measurements using the third-generation advanced piston corer temperature (APCT-3) tool were taken during Cores 4H, 7H, and 10H. Cores 8H and 10H experienced partial strokes; as such, Cores 11F–13F were taken as half-length APC (HLAPC) cores before transitioning to XCB for the remainder of the hole. Nonmagnetic core barrels were used for all APC and HLAPC cores, and all full-length APC cores were oriented.

Because of the poor core recovery in sediment, and because the basement contact appears to be deeper than predicted at this site, we determined it would not be a suitable location for the next casing installation and we ended operations at Site U1615 at 1500 h after Core 34X. Pipe was tripped to a depth of 83 m above seafloor and a cut and slip of the drill line and core winch line was performed. At midnight, the vessel was in transit the 4.8 nmi distance to proposed Site TYR-15A (Site U1616) in DP mode at a speed of 0.5 kt.

Science Results

Lithostratigraphy

Drilling operations in Hole U1615A were completed after reaching 300 m penetration into sediment in Cores U1615A-1H through 34X. Cores 1H–4H are a mixture of dark gray to light olive brown nannofossil ooze and volcaniclastic rich silty sand. Some horizons in Core 1H have shell fragments. Wood, pumice granules, and ash layers are also noted. Cores 5H and 6H contain a gray volcaniclastic rich gravel with mud with a slight fining upward sequence. Cores 7H–13F contain volcaniclastic rich mud, sand, or gravel with sharp boundaries where the boundary was recovered. Core 14X had no recovery; Cores 15X–20X contain gray nannofossil chalk with variable amounts of silt or mud. Core 21X has a layer of tuff that transitions back to nannofossil chalk in Cores 22X and 23X. Sapropel layers and foraminifera rich layers are noted. Description of Cores 24X–34X was not completed by the end of the week.

Biostratigraphy

Micropaleontologists analyzed samples obtained from the few meters above the basement contact captured in Hole U1614C. Sediments from three of the four samples are volcanogenic in nature and are completely devoid of any planktic foraminifera. Based on the calcareous nannofossil assemblages observed, Sample U1614C-3R-CC (the bottommost core above the basement) is <2 Ma in age. During basement coring in Hole U1614C, the micropaleontologists prepared scanning electron microscope (SEM) stubs to image planktic foraminifera marker species from Holes U1612A, U1614A, and U1614C.

Core catcher samples from Hole U1615A are being processed for analysis.

Paleomagnetism

Paleomagnetic measurements were performed on archive half sections and discrete samples in Holes U1614C and U1615A. Hole U1614C consists of highly magnetic serpentinized peridotites. Initial natural remanent magnetization of the basement rocks is strong with a normal polarity; however, the intensity drops quickly at low demagnetization levels. Once the overprint is removed, most rock segments exhibit a reversed polarity. Different magnetic minerals, including magnetite, hematite, and possibly iron sulfide, were found through experiments on the discrete samples. For Hole U1615A, 34 cores of sediments were recovered down to 300 m below seafloor. Like previous sites, demagnetization of archive half sections and discrete samples show only normal polarity, even though several intervals of reversed polarity are expected given the age of the sedimentary column.

Igneous and Metamorphic Petrology

The igneous and metamorphic petrology team worked on the description of the recovered basement rocks from Hole U1614C. The team observed the cores macroscopically and studied several thin sections of the rocks. Basement cores from Site U1614 consist of very heterogeneous mantle lithologies including serpentinized lherzolites, harzburgite, dunite, and pyroxenite, with a short interval of brecciated ophicarbonate. The mantle section is crosscut by mafic intrusions. The recovered cores of the basement show variable degrees in the style of deformation and alteration. The degree of alteration is moderate to high. Alteration minerals include serpentine, magnetite, clays, and carbonate with instances of tremolite and amphibole replacing the clinopyroxene. The primary mineralogy and alteration features were also confirmed by thin section observations.

Five lithological units were defined in basement based on primary igneous and alteration features. Units I–III are sediment lithological units. Unit IV includes the sediment/basement interface and contains a mélange of mud and serpentinized peridotite. Unit V consists of variable mantle lithologies with gabbroic intrusions; Unit VA is lherzolite-dominated, transitioning to dunite- and harzburgite-dominated in Unit VB. Unit VI is defined by plagioclase- and clinopyroxene-bearing peridotites with dense mafic veins increasing in concentration with depth. Unit VII contains reddish serpentinized peridotites with mafic intrusions and dense veins. The lithology in Unit VIII returns to plagioclase- and clinopyroxene-bearing peridotites and is relatively homogeneous compared to overlying units.

Structural Geology

The structural geology group described and measured the orientation of ~770 deformation structures in the 150 m of mantle peridotites recovered from Hole U1614C. They include crystal-plastic and brittle fabrics, magmatic impregnations, gabbroic intrusions, and metamorphic veins (serpentine and carbonate). Orientations of sediment structures in Hole U1615A were also measured.

Sediment and Pore Water Geochemistry

Sample preparation and analyses for cores newly collected from Hole U1615A are in progress. The interstitial water samples were squeezed from 25 sediment whole rounds, and measured for chemistry (alkalinity, pH, and salinity), as well as major and minor elements. Alkalinity is high in Cores U1615A-1H through 5H and then decreases across Cores 6H–9H, remaining below 2 mM in the rest of the hole. Ca^{2+} shows an inverse trend to alkalinity, increasing in concentration across the interval that alkalinity decreases. Twenty-five headspace samples were collected and the concentration of

various hydrocarbon gases was measured. Methane concentration peaks at 5.16 ppmv in Section U1615A-24X-5; no other hydrocarbon gases are present.

Igneous Geochemistry

Powdered sediment samples collected from Hole U1612A were reignited at higher temperature (950°C) to better evaluate loss on ignition, and then rerun via inductively coupled plasma–atomic emission spectrometry (ICP-AES). This reanalysis yielded much better values than previous attempts, which allowed us to finalize the data. Glass beads of sediment samples from Site U1613 were available this week, which allowed us to analyze them by ICP-AES.

At Hole U1614C, we used the portable X-ray fluorescence spectrometer (pXRF) to scan 85 intervals of igneous rock, assisting petrologists with core descriptions and providing preliminary geochemical data. We selected 26 intervals of basement material for ICP-AES analysis from Hole U1614C, which will be analyzed once the glass beads are processed. Preliminary geochemical data provided by pXRF confirm the wide range of lithologies recovered in Hole U1614C, including various types of peroditite, websterite, and granitic rocks. Peridotites are generally high in Cr, as expected for mantle lithologies. Seemingly sporadic increases in TiO_2 occur in some dunites and gabbros, which will be investigated in greater detail with ICP-AES analyses.

Physical Properties

During Week 4, the physical properties of the rocks and sediment recovered in the Vavilov Basin from Holes U1614C and U1615A were measured. Measurements include standard physical properties such as gamma ray attenuation bulk density, magnetic susceptibility (MS), *P*-wave velocity (V_P), natural gamma radiation (NGR), and X-ray imaging of all cores. Discrete moisture and density measurements were made on 55 samples from Hole U1614C. 644 V_P measurements were made using the Gantry system on section halves from Hole U1614C as the hard rocks did not fill the core liner, eliminating use of the Whole-Round Multisensor Logger as an option for measurements of V_P.

The basement rocks (serpentinized peridotites) from Hole U1614C have densities ranging from 2.34 (granitoid) to 2.79 g/cm^3 (gabbro), while serpentinized peridotites average ~2.5 g/cm^3. Porosity ranges from 2% (gabbro) to 19% (granitoid) and average ~9% for serpentinized peridotites. Seismic velocities range from ~2400 (granitoid) to 6000 m/s (gabbro) with an average value of ~4000 m/s for the serpentinized peridotites. Finally, thermal conductivity varies from 0.98 up to 3.55 W/(m·K) within calcareous veins.

During Week 4, we also performed physical properties measurements and X-ray scanning for the sediments recovered at Site U1615A in the Vavilov Basin, as well as collected discrete samples for further analysis. NGR increases gradually with depth and is particularly elevated in Core U1615A-25X and below. MS appears elevated in the volcaniclastic gravel layers. These measurements are still in progress.

Downhole Measurements

The APCT-3 downhole instrument was deployed three times in the upper part of Hole U1615A to measure in situ sediment temperatures. All measurements were successful and reveal a thermal gradient of 11.8°C/100 m, hence a heat flow in the range of 106 mW/m^2 using an average 0.9 W/(m·K) for thermal conductivity. This is the lowest heat flow value measured by ocean drilling in the center of the Vavilov Basin thus far.

Microbiology

During coring of Hole U1614A, the microbial contamination tracer perfluorodecalin (PFD) was pumped in the drill fluid to assess possible intrusion of drill fluid into the core interior. Data documenting instances of contamination were finalized, revealing drill fluid intrusion and subsequent sample contamination in 2 out of 10 samples (U1614A-1H-4 and 17H-2). Most of the microbiological samples are suitable for analysis and are unlikely to be affected by drilling fluid contamination.

Oxygen measurements were conducted on whole-round core sections from Hole U1615A immediately after core recovery and before temperature equilibration by drilling two small holes in the core liner and inserting oxygen and temperature probes into the undisturbed core center. In Section U1615A-1H-1, oxygen was measured at intervals of 5 cm from 0 to 30 cm, where oxygen was detected in the first 20 cm with a minimum value of 0.76 µM; thereafter, oxygen was undetectable. However, measurements were continued for subsequent cores through Section 15X-3, although they were very sandy and soupy, yielding erroneous results. It was not feasible to proceed with oxygen measurements below this section.

In Hole U1615A, whole-round samples and syringe plugs of the core were collected on the catwalk for metagenomics, 16S rRNA, microbial experiments, and viral counts. Metagenomic and 16S rRNA samples were promptly frozen at –86°C after collection. Samples for viral counts were fixed in a phosphate-buffered saline formaldehyde solution. Microbial experiments were initiated under anaerobic conditions, including enrichment cultures, viral incubations, and one prophage induction experiment. Additional samples were taken for contamination analysis using the PFD tracer. These samples were collected each time microbiology samples were taken. Three samples, including drilling fluid, outer core, and inner core, were extracted using cutoff syringes

and placed in glass vials. They were then transported to the laboratory for analysis; results are pending.

Outreach

The following outreach activities took place during Week 4.

- The Science Art Gallery was posted as a blog on the *JOIDES Resolution* website, with links to thin section and X-ray images.
- Completed 14 ship-to-shore broadcasts for ~3,225 people.
- A third blog post was published for the Reach the World partnership, documenting life on the ship.
- Facebook: 24 posts with a reach of 41,906 and 33 new followers.
- Twitter: 16 new tweets posted with 720 engagements.
- Instagram: 25 new posts with 423 engagements; gained 25 new followers.
- Threads: 2 new posts; engagements are not tracked.

Technical Support and HSE Activities

The following technical support activities took place during Week 4.

Laboratory Activities

- Technical staff assisted with core processing, sampling, and science support at Holes U1614C and U1615A.
- Technical staff processed samples from Expedition 399 for shipboard analysis.
- Technical staff made some spare parts for the SEM and an adaptor for sample stubs so they are compatible with both SEMs.

Developer Activities

- Updated the test comments for a few hundred superconducting rock magnetometer tests as requested by the technician.
- Continued to troubleshoot and resolve issues related to uploading pXRF data.
- Worked on bug fixes for the ThermCon application.

IT Support Activities

- Deployed video distribution streaming files to selected PC and Mac workstations and personal mobile devices for testing using the VLC video player. Desktop users can view multiple video streams and mobile users can view their favorite channel from anywhere while on the ship's network.
- Updated the virtual management vCenter Server (Fuji) to version 8.0.2.0020 and ESXI to 8.0 U2sb – 23305545 on all ESXI hosts.
- Tested the newly created DriveMapper for Windows GUI version.

HSE Activities

- Emergency shower and eyewash stations were tested.