IODP Expedition 402: Tyrrhenian Continent–Ocean Transition

Week 3 Report (28 February–2 March 2024)

Week 3 of the International Ocean Discovery Program (IODP) Expedition 402, Tyrrhenian Continent–Ocean Transition was spent coring and casing at Site U1614. We used the advanced piston corer/extended core barrel (APC/XCB) system to recover the complete sediment succession and to capture the sediment/basement interface in Hole U1614A. Improved core recovery at this site compared to Site U1612 allowed us to identify two distinct sedimentary layers—a volcaniclastic-rich gravel and a volcanic tuff—that may cause hole instability. The rest of the week was spent installing a reentry system and two casing strings in Hole U1614C to improve hole stability while rotary core barrel (RCB) drilling in basement.

Operations

At the beginning of Week 3, we were APC/XCB coring in Hole U1614A at a depth of 89.3 meters below seafloor (mbsf). We collected two half-length APC cores (HLAPC; Cores U1614A-13F and 14F) with 81% recovery and then transitioned to XCB coring. Cores U1614A-15X through 34X advanced 186.4 m to a total depth of 280.1 mbsf and recovered 90.41 m of core material (49%). Recovery across this interval ranged from 0% to 103%. The basement contact was encountered in Core 33X. Core 34X penetrated another 9.8 m but only recovered 0.76 m (8%). We attempted to XCB drill an additional core, but we experienced high torque after deploying the core barrel. We recovered a ghost core, Core 35G, which contained 2.16 m of fill from an undetermined depth, and then we ended the hole. A standard cut and slip of drill line occurred with the drill pipe positioned above the seafloor. Pipe was tripped back to the surface and the drill collars were racked. We then laid out the upper guide horn to prepare for a jet-in test for the planned casing installation at this site. In total, the 35 cores collected in Hole U1614A recovered 179.36 m of material, or 64%, and took 3.2 d.

The planned casing installation consisted of a 13⅜ inch casing string to ~60 mbsf and a second 10¾ inch casing string extending to ~40 m above the basement interface. A jet-in test in Hole U1614B was necessary to determine if the full 60 m length of the 13⅜ inch casing string could be installed. We made up the bottom-hole assembly (BHA) with a 14¾ inch tricone bit, tripped pipe to the seafloor, and spudded Hole U1614B at 0900 h on 27 February 2024. The jet-in test was successful, penetrating 65.2 mbsf. We then pulled out of the hole and tripped back to the surface, with the bit clearing the rig floor at 1900 h, ending Hole U1614B.

The reentry cone was then positioned in the moonpool and the five joints of 13⅜ inch casing, as well as a shoe joint, were hung in the guide base, using a 16 inch casing hanger and a 16 to 13⅜ inch crossover. The stinger with the running tool and BHA were made up and latched into the casing and reentry cone, which was deployed through the moonpool at 0515 h on 28 February. Pipe was tripped toward the seafloor, and the vibration isolated television (VIT) camera system was deployed after 60 stands of pipe, to follow the reentry cone. At 1400 h, we installed the top drive and spudded Hole U1614C, jetting in casing to a depth of 66.0 mbsf. We detached the running tool from the casing at 1550 h by rotating the drill string 3½ times to the right, began pulling out of the hole, and recovered the VIT. We then tripped pipe back toward the surface.

To aid installation of the 10¾ inch casing string, we conducted a drill ahead to a depth ~20 m above the expected basement contact. The drilling BHA with a 12¼ inch bit was made up and deployed, reentering Hole U1614C at 1100 h on 29 February using the VIT camera system to guide reentry. After retrieving the VIT, the drill ahead successfully penetrated to a depth of 250.0 mbsf, after which the hole was displaced with 100 bbl of heavy mud, and pipe was tripped back to the surface.

The final casing step involved the installation of the 10¾ inch casing string. The running tool and drill collars were made up and a standard cut and slip of drill line was performed prior to running the 20 joints of casing. With the casing hanging off the moonpool doors, we made up the BHA and latched into the casing hanger, and then began tripping toward the seafloor. The VIT camera system was launched and lowered to guide reentry. The second reentry into Hole U1614C occurred at 0030 h on 2 March. We then washed in the casing to a depth of 227.3 mbsf, working through an obstruction at 172.7 mbsf by picking up the top drive and using the rig pumps. The casing was latched and released at 0345 h. We recovered the VIT camera system and tripped pipe back to the surface, with the bit clearing the rig floor at 1300 h. After racking the drill collars in the derrick and reinstalling the upper guide horn, we prepped the RCB core barrels and made up the BHA with a C7 RCB drill bit. At the end of Week 3, we were tripping pipe toward the seafloor to begin coring in the basement of Hole U1614C, and we had launched the VIT to guide reentry. We expect to recover a second copy of the sediment/basement interface as well as 140 m of basement.

The Conductivity-Temperature-Depth (CTD) sensor and the Niskin bottle water sampler were attached to the VIT camera system frame and deployed during the first two runs of the VIT, generating temperature and conductivity profiles of the water column and collecting bottom seawater samples for chemistry and microbiology.

Science Results

Lithostratigraphy

During Week 3, all sediment cores from Hole U1614A were described both macroscopically and microscopically (via smear slide). The upper part of the hole is characterized by light gray nannofossil-rich silt with sand (Cores U1614A-1H to 3H), underlain by nannofossil ooze at the top of Core 4H. Sharp, erosive boundaries are observed between layers. Volcaniclastic-rich sand and gravels, possibly an unconsolidated breccia, are observed from Cores 4H to 7H. Bioturbation is absent. Cores 8H–15X contain some proportion of volcaniclastic-rich unconsolidated breccia at the top of each core, interpreted as fall-in. The remainder of the cored material in this interval is silt-rich sand, sometimes with volcaniclastics. Cores 17X and 18X contain an olive gray tuff. Cores 20X–26X consist of nannofossil ooze, with foraminifera-rich layers intercalated with tuff or volcaniclastics, becoming chalk toward the lower part of this interval. The oozes include fine laminations and cross-laminations, as well as occasional pyrite precipitates and sapropel layers. Core 32X recovered lapilli and ash. Nannofossil chalk and dolomite are documented at the boundary with the serpentinite basement.

Biostratigraphy

Micropaleontologists obtained and analyzed 32 core catcher (CC) samples from Hole U1614A for biostratigraphic analysis (Section U1614A-13F-CC was not sampled for paleontology).

Most CC samples are volcanoclastic in nature and are barren of any planktic foraminifera. When present, planktic foraminifera from the middle (between Samples U1614A-9H-CC and 23X-CC) and the bottommost (Samples 29X-CC to 33X-CC) volcanoclastic-dominant layers are reworked, making biozonal and age assignments difficult. The topmost Holocene sedimentary layers (Samples 1H-CC to 3H-CC) have well-preserved planktic foraminifera species. Additional samples were taken from nannofossil ooze intervals to refine the biozone assignments through successive sedimentary layers. Based on the planktic foraminifera assemblage observed, Sample U1614A-29X-2, 52–54 cm, was concluded to be Lower Pleistocene (Late Gelasian; <2 Ma) in age.

Smear slide samples for nannofossil analysis were prepared from CC samples, but most were not suitable due to the predominance of coarse-grained volcanic material. Samples from Cores U1614A-1H through 9H yield abundant and well-preserved nannofossil assemblages. These are assigned to the interval between biozone MNQ21 and subzone MNNQ19d of Middle Pleistocene–Holocene age (<0.96 Ma). In the intermediate part of the succession, only Sample U1614A-12F-CC provided a reliable datum, and it is assigned to the Lower Pleistocene (Calabrian) subzone MNN19b (0.96–1.61 Ma). Samples from Cores 14X–18X are barren or the nannofossil assemblage is too sparse to provide reliable information. Samples U1614A-19X-CC to 28X-CC are assigned to the Lower Pleistocene (Calabrian) subzone MNN19a (1.61–1.71Ma). The oldest sample (Core 33X-1, 24 cm) is assigned to the MNN19a subzone, thus still younger than 1.71 Ma in age.

Paleomagnetism

APC/XCB cores from Hole U1614A had improved recovery relative to the succession drilled through similar lithologies via RCB at Site U1612. Demagnetization of natural remanent magnetization (NRM) of discrete samples suggests the quality of NRM is much better compared to the results of the previous two sites. However, the paleomagnetic records of the ~280 m thick sedimentary column are all normal polarity, even though the biostratigraphy suggests the bottom of Hole U1614A is older than the Brunhes Chron. We note that previous Ocean Drilling Program (ODP) Site 651 of Leg 107, which is close to Site U1614, was also documented to have a thick sedimentary sequence (~320 m) in the Brunhes Chron, although their magnetostratigraphy is very crude due to poor core recovery.

Igneous and Metamorphic Petrology

During Week 3, the igneous and metamorphic petrology group described thin sections from the basement of Site U1613 and defined the lithological units.

The basement material recovered in Cores U1614A-33X and 34X was also described, and it consists of variably serpentinized and highly fractured mantle peridotites, with the primary mineralogy and alteration features confirmed via thin section. The sediment/basement interface is denoted by brown dolomite overlying a thin layer of greenish gray nannofossil chalk that directly contacts the serpentinite.

Structural Geology

Sediment in Hole U1614A has subparallel bedding throughout the succession. Observed features include laminations, graded bedding in a turbidite layer in Core U1614A-26X, and normal faulting with 2 mm thick boudinage in Section 26X-6.

Sediment and Pore Water Geochemistry

During this week, all analyses were completed for the interstitial water (IW) and sediment samples from Hole U1614A. The significant feature observed for IW is the constant decline of Mg^{2+} concentration with depth in the upper ~200 mbsf. Alkalinity decreases continuously from the seafloor until 78.18 mbsf and is then constant with depth, whereas Ca^{2+} content becomes elevated below approximately the same depth. Taken together, these data suggest the formation of dolomite, which is coupled with dissolution of calcite below 78.18 mbsf to keep alkalinity at a constant level. The sulfate concentration also shows a decreasing trend for almost the whole depth. The concentration of minor elements (Li, B, and Sr) increases gradually below 78.18 mbsf. In particular, the ratio of B/Cl at the base of the hole is 5× the normal seawater value, suggesting the availability of organic matter is contributing to the concentration of B.

The percentage of calcium carbonates ($CaCO_3$) varies between 0.4 and 77.8 wt%. Total carbonate ranges from 5.7 to 77.9 wt% and is always higher than the percentage of $CaCO_3$, revealing the occurrence of other carbonates in the sedimentary column. A positive correlation is observed between the percentages of $CaCO_3$ and the total carbonate contents. The percentage of sedimentary organic matter varies between 3.1 and 17.3 wt%, as determined by loss on ignition (LOI). This percentage is higher than 14.7 wt% at 23.2, 85.8, 140.6, and 228.1 mbsf. At 222.6 mbsf, sediments exhibit the highest values of total organic carbon (TOC), total nitrogen (TN), and total sulfur (TS) contents. Low atomic TOC/TN values (from 0.1 to 8.8) are found in sediments from Hole U1614A, except at two depths (29.1 mbsf, 12.4; 222.6 mbsf, 13.9). This trend indicates that these two samples have a continental source of organic matter rather than a marine source. TS and TOC are not correlated at this site and show an excess of TS compared to most fine-grained normal marine siliciclastic sediments at depths of 78.9 and 151.9 mbsf.

Headspace samples were taken from each core to monitor C_1–C_6 hydrocarbons, according to the standard safety protocol during drilling. At Hole U1614A, 32 headspaces were analyzed. Only methane (CH_4) is identified with concentrations ranging from 0.1 to 49.6 ppmv.

Igneous Geochemistry

The igneous geochemistry group spent the week analyzing inductively coupled plasma–atomic emission spectroscopy (ICP-AES) data from Hole U1612A. These analyses confirmed the compositions of the igneous rocks, as determined by the igneous petrology group. The high alkali content of the basalt sample classifies it as basalt to trachybasalt, while the felsic samples are granite in composition.

Sediment samples from Hole U1612A were also analyzed via ICP-AES, however the results of these analyses yielded anomalously low totals. We believe there is an issue with the sample preparation process that stems from the difference of temperature between the powder ignition and the bead-making furnace. Powder ignition was done at 500°C, while temperatures of 1050°C are reached during the bead-making process. The higher temperature of the bead furnace could cause the degradation of carbonates, yielding low analytical totals during ICP-AES analysis. Powders will be reignited at 950°C before being made into beads, hopefully to fix this issue.

We conducted portable X-ray fluorescence spectrometry (pXRF) analyses on IW squeeze cakes and section halves adjacent to IW samples for all sediment cores recovered from Hole U1614A. pXRF analyses were undertaken on basement samples, indicating the recovery of altered dunnite and harzburgite.

Physical Properties

During Week 3 of Expedition 402, the physical properties team finalized measurements obtained for the cores recovered at Hole U1613A, drilled in the Cornaglia Terrace. We also performed regular measurements of the physical properties of the rocks recovered at Site U1614 in the Vavilov Basin. In total, we have run 142 whole-round core sections through multiple instruments to collect the natural gamma radiation, *P*-wave velocity, gamma ray attenuation bulk density, and magnetic susceptibility (MS) measurements. We obtained X-ray images on all section halves after the cores were split. We then collected and processed 52 moisture and density samples to measure the bulk density and porosity of the retrieved sediment. We also performed 55 discrete velocity measurements with the Gantry system and 30 thermal conductivity discrete measurements to study their acoustic and thermal characteristics. Changes in the physical properties revealed some heterogeneities and lithological changes throughout the sedimentary layer. At the sediment/basement transition, the physical properties, such as density, porosity, and seismic velocities, change drastically.

Downhole Measurements

In Hole U1614A, the advanced piston corer temperature (APCT-3) tool was deployed at 34.2 and 62.7 mbsf (Cores U1614A-4H and 7H) and collected readings of 20.43° and 27.42°C, respectively. When combined with the seafloor temperature of 13.65°C recorded after the second APCT-3 run, it yields a thermal gradient of 17.9°C/100 m and a heat flow of 161 mW/m^2 using a thermal conductivity of 0.9 W/(m·K).

Corrected logging profiles from Site U1613 were analyzed for data quality and downhole trends. All downhole measurements were affected by the large borehole size. Spectral gamma ray values are relatively low throughout Lithologic Unit II, but they increase in the nannofossil ooze/chalk intervals. The density and MS profiles are in good agreement with core data when not affected by the hole size.

Microbiology

In Hole U1614A, whole-round samples and syringe plugs of core were collected on the catwalk for metagenomics, 16S rRNA, microbial experiments, and viral counts. Metagenomic and 16S rRNA samples were frozen at –86°C immediately after collection. Samples for viral counts were fixed in a phosphate-buffered saline formaldehyde solution. Microbial experiments were initiated in anaerobic conditions, including enrichment cultures, viral incubations, and prophage induction experiments for Sample U1614A-2H-5, 137–142 cm.

Pore water dissolved oxygen measurements were made on whole-round core sections from Hole U1614A, immediately after core recovery and prior to temperature equilibration, by drilling two small holes in the core liner and inserting the oxygen and temperature probes into the undisturbed core center. In Core U1614A-1H, oxygen is detected in the upper 20 cm of Section 1H-1, with a maximum peak of 109.5 µM/L, and decreasing with depth. Measurements continued through the base of Section 3H-5. Measurements were attempted on Cores 4H through 8H; however, as these cores are very sandy and a good contact with the probe tip could not be achieved, the measurements were of poor quality. As sand can also damage the fiberoptic probes, it was not feasible to proceed with oxygen measurements below Core 8H. A marginal increase in oxygen in Core 8H was observed, but it was associated with a possible void space in the section.

During APC/XCB coring, the microbial contamination tracer perfluorodecalin was pumped with drilling fluid. Samples to evaluate the extent of core contamination were taken each time a microbiology sample was collected. Three samples, including drilling fluid, core exterior, and core interior, were extracted using syringes and placed in glass vials. They were then taken to the laboratory and analyzed on the gas chromatograph (GC). The results were compared between the drilling fluid and the core samples (inner and outer). Most of them were unaffected by drilling fluid intrusion, as the GC detected minute amounts that could be interpreted as clean samples. However, two of the samples showed high tracer peaks, indicating drilling fluid intrusion (samples from Sections 1H-4 and 17X-4).

The Niskin bottle water sampler deployed on the VIT camera system frame collected 1 L of water from a depth of ~3.5 km. This sample was processed in the laboratory, with 5 mL distributed in 1 mL cryotubes and fixed with 4% formaldehyde for cell counts. The remaining water was filtered using a 0.2 µm membrane filter. The entire filter was wrapped in an aluminum envelope and frozen at –86°C.

Outreach

The following outreach activities took place during Week 3.

- A blog was posted on the *JOIDES Resolution* website: A rock is rock is it not?
- Completed 14 ship-to-shore broadcasts for ~463 people.
- Planning a live broadcast with the Time Scavengers organization.
- Planning two "art gallery" live broadcasts where a petrologist will give a walk-through of interpreting thin sections while also drawing them.
- Planning social media live streams focusing on ship life.
- Facebook: 24 posts with a reach of 76,624 and 61 new followers.
- Twitter: 23 new tweets posted with 1,208 engagements.
- Instagram: 23 new posts with 445 engagements; gained 43 new followers.
- Threads: Two new posts; engagements are not tracked.

Technical Support and HSE Activities

The following technical support activities took place during Week 3.

Laboratory Activities

- Technical staff assisted with core processing, sampling, and science support at Hole U1614A.
- Technical staff began processing samples from Expedition 399 for shipboard analysis.
- The CTD and water sampler were run on two of the VIT deployments. Styrofoam cups were attached on all four deployments.

Developer Activities

- Completed bug fixes and deployed GEODESC Catalog Manager v1.0.3 to shore.
- Changed passwords for the ship password safes.
- Continued to troubleshoot issues related to uploading pXRF data.
- Worked on bug fixes for the ThermCon application.

IT Support Activities

- Developed a workflow that allows the video distribution broadcasts (e.g., drill floor, RigWatch) to be streamed to a desktop (Mac or PC) without disrupting the entire video distribution system. The workflow is ready for testing by general users.

- Finished creating a DriveMapper for the Windows GUI version that is ready for user testing.

HSE Activities

- Emergency shower and eyewash stations were tested.
- A lifeboat and fire drill was held on 25 February at 1300 h.