IODP Expedition 402: Tyrrhenian Continent–Ocean Transition

Week 5 Report (10–16 March 2024)

Week 5 of the International Ocean Discovery Program (IODP) Expedition 402, Tyrrhenian Continent–Ocean Transition was spent at Sites U1616 and U1617. At Site U1616, in the Vavilov Basin, we used the advanced piston corer/extended core barrel (APC/XCB) system to capture the complete sediment column and tag a hard layer of breccia, assumed to be at or near the basement contact. We cored the sediment at both Sites U1615 and U1616 with the intention of choosing to return to one of the two sites and to install casing and a reentry system to facilitate drilling in basement with the rotary core barrel (RCB) system. Based on the sediment stratigraphy and the lithology of the breccia, Site U1616 was selected for the casing installation. Site U1617 is on the Campania Terrace and was expected to have oceanic crustal basement possibly related to magmatism during the development of the continent–ocean transition. Coring in Hole U1617A reached a depth of 339.9 meters below seafloor (mbsf), within evaporite deposits likely dating to the Messinian, before the hole was ended. Downhole logging in Hole U1617A was limited by relatively shallow obstructions within the sediment column.

Operations

At the beginning of the week, the vessel was in transit in dynamic positioning (DP) mode with the drill pipe positioned 50 m above seafloor between Sites U1615 and U1616 at a speed of 0.5 kt. This 5 nmi transit was completed at 0315 h on 10 March 2024. The top drive was picked up and the drill pipe spaced out to spud, filling the drill string with the microbial contamination tracer prior to coring. APC/XCB Hole U1616A was spudded at 0530 h, recovering the mudline and penetrating 2.7 m into the formation (101% recovery), placing water depth as 3567.0 m. APC coring continued through Core U1616A-6H, reaching a depth of 50.2 mbsf and recovering 47.72 m of sediment (95%) overall. A formation temperature measurement was made with the third-generation advanced piston corer temperature (APCT-3) tool during Core 4H. Ship heave intensified throughout the morning and, after recovery of Core 6H, the decision was made to pull out of the hole and wait on weather (WOW), thereby ending Hole U1616A.

Hole U1616B was spudded at 1500 h on 10 March, after 2 h of WOW. This hole began with a drilled interval (U1616B-1-1) to a depth of 31.2 mbsf, where APC/XCB coring resumed with Core U1616B-2H. Cores 2H–6H advanced 47.5 m and recovered

34.25 m of sediment (72%). An APCT-3 measurement was made during the collection of Core 4H. After Core 6H, a half-length APC (HLAPC) attempt misfired and resulted in a dropped core barrel. Two wireline runs were required to retrieve the empty barrel. Cores U1616B-7X through 29X, taken with the XCB system, advanced to a final hole depth of 302.6 mbsf. Recovery was poor in Cores 7X–10X (3%, including Core 8X which had no recovery) but improved in Cores 11X–27X (72%). A hard contact was reached during XCB coring of Core 28X and rate of penetration (ROP) slowed. The core advanced 8.3 m after an hour of drilling and was retrieved with only 6% recovery, but it contained clasts identified as basement material. A final core, Core 29X, was collected to verify the basement contact. We then began tripping pipe back to the surface. We plan to return to Site U1616 to install a casing string and RCB drill 70 m into basement after completion of operations at proposed Site TYR-02A (Site U1617). The bit cleared the rig floor at 1700 h on 12 March, ending Hole U1616B. Overall, Hole U1616B advanced 271.4 m past the drilled interval and recovered 156.58 m of core (58%). Nonmagnetic core barrels were used for all APC cores, and all full-length APC cores were oriented. The perfluorocarbon microbial contamination tracer was pumped with the drill fluid throughout coring.

The ship transitioned into cruise mode and transited the 40.1 nmi distance to Site U1617 at an average speed of 10.4 kt, arriving at 2150 h on 12 March. The precision depth recorder (PDR) gave a water depth reading of 2822.3 m. After tripping pipe to the seafloor, we spaced out and spudded Hole U1617A at 0715 h on 13 March, confirming a water depth of 2822.3 m. The mudline Core U1617A-1H advanced 4.5 m with 100% recovery. Coring continued smoothly up until Cores 15H, 16H, 20H, and 21H, which were partial strokes, and the drill bit was advanced by recovery. Cores 22F–27F were subsequently collected by HLAPC. Cores 18H–27F all experienced overpull, ranging from 12,000 to 40,000 lb. As such, the XCB system was used starting with Core 28X. Recovery in Cores 28X and 30X–35X was over 100%, but Cores 29X, 36X, and 37X had low recovery. ROP slowed considerably starting in Core 36X and a lithological change into evaporite deposits was noted. All cores after Core 36X were taken as half advances to improve recovery and because of slow ROP. Coring continued through Core 47X, reaching a final hole depth of 339.9 mbsf. While we did not achieve the objective of tagging basement, the hole was ended to conserve time and because the thickness of the evaporite deposits is not clear from the seismic data.

Overall, Hole U1617A recovered 304.16 m of sediment (89%). APC and HLAPC cores recovered 217.74 m of sediment (104%) while XCB recovered 86.42 (66%). APCT-3 temperature measurements were made during Cores U1617A-4H, 7H, and 10H. As with Hole U1616B, nonmagnetic core barrels were used for all APC cores, and all full-length APC cores were oriented. The perfluorocarbon microbial contamination tracer was pumped with the drill fluid throughout.

Following completion of coring in Hole U1617A, the hole was conditioned for downhole logging via pumping a sweep of high-viscosity mud. The drill pipe was tripped up with the bit at a depth of 74.6 mbsf, and the triple combo tool string was deployed to log the open hole. At 0500 h on 16 March, with the triple combo tool string at a depth of 135.4 mbsf, the tool encountered an obstruction and this first logging attempt was ended. The tools were recovered and three stands of drill pipe were added to the drill string, bringing the bit depth to 151.7 mbsf, past the initial obstruction. At 0845 h, the triple combo tool string was deployed a second time; however, the tool string was unable to pass out of the drill pipe into the hole. The decision was made to end logging attempts and to pull out of the hole. The rest of the day was spent tripping pipe back to the surface. At 2100 h, the rig floor was secured, the thrusters were raised, and we began the transit back to Site U1616 where we plan to install a reentry system and casing for RCB drilling in basement. By midnight the vessel had completed 33.1 nmi of the 40.1 nmi transit at a speed of 11.8 kt.

Science Results

Lithostratigraphy

Operations at Site U1616 involved APC/XCB coring in Holes U1616A and U1616B. In Hole U1616A, we observe nannofossil ooze intercalated with silty sand with volcaniclastics in the upper part of the hole. Underlying these lithologies is mud with calcareous nannofossils and, progressively toward the bottom of the hole, volcaniclastic-rich sandy silt, volcaniclastic-rich silty sand, and volcaniclastic-rich gravel.

Hole U1616B began with a drilled interval to 31.2 mbsf. In the upper part of the cored hole, we observe volcaniclastic-rich gravel, intercalated with nannofossil ooze with volcaniclastics, ash layers, and sandy silt. Below, cores contain silt with volcaniclastics, nannofossil ooze, diatom-radiolarian-rich sandy silt with volcaniclastics, and foraminifer-rich silt with volcaniclastics. From Core U1616B-18X toward the bottom of the hole, the sediment is more lithified but is still classified as a nannofossil ooze, with occasional foraminifer-rich intervals. Sapropel layers are present. Core 19X is predominantly a tuff. Below, volcaniclastic-rich coarse sand with mud is intercalated with nannofossil chalk, which is occasionally rich in glauconite. From Core 22X downhole, we observe foraminifer-rich clast supported, polymictic conglomerate and foraminifer-rich matrix supported, and polymictic nannofossil chalk underlined by nannofossil ooze with foraminifers, becoming dolomitic-rich from Core 26X. The bottom part of the hole is characterized by muddy consolidated breccia.

Site U1617 on the Campania Terrace was cored to a depth of 339.9 mbsf with overall high recovery. The upper part of the hole is characterized by gray nannofossil ooze, sometimes either foraminifer-rich or glauconite-rich, intercalated with tephra, ash, volcaniclastic-rich silt, and sapropel layers. From Core U1617A-33X downhole, the predominant lithologies are oxide-rich nannofossil ooze, followed by oxide-rich mud with foraminifers, gypsum-rich clay, and a ~10 m interval of organic-rich silt with calcareous nannofossils. The latter lithology overlies additional oxide-rich mud intercalated with gypsum-rich clay, nannofossil ooze intercalated with gypsum, and nannofossil ooze intercalated with black shale and gypsum. Gypsum-rich mud and gypsum with mud are present until Core 44X. From Core 44X, we observe mud with intervals of sandy material, and with intercalation of gypsum and anhydrite layers increasing in frequency and thickness toward the bottom of the hole.

Biostratigraphy

Micropaleontologists spent Week 5 analyzing the microfossils from Sites U1616 and U1617. Two holes were drilled at Site U1616, and core catcher (CC) samples were analyzed from both for planktic foraminifera and calcareous nannofossil marker species. Holocene–Upper Pleistocene sediments were recovered from Hole U1616A before we had to end the hole due to weather and to core Hole U1616B. Site U1616 contains thick successions of volcanogenic sediments, which are barren of planktic foraminifera. However, the nannofossil ooze sedimentary intervals in the bottom half of the succession contain well-preserved planktic foraminifera marker species, and the basal sediment above the basement rocks are ~3.6 Ma in age.

Sediment recovery (~89%) in Hole U1617A was the best of all the sites on the expedition and the nannofossil ooze lithology is rich in planktic foraminifera species. Limited volcanigenic sediments are observed at this site. Holocene–upper Zanclean (~4.1 Ma) sedimentary successions are recognized, deposited above the gypsum-containing evaporite deposits assumed to be Messinian in age. One hiatus ~0.6 Ma long (between 1.7 and 2.3 Ma) is observed. Two CC samples, U1617A-34X-CC and 35X-CC, were taken to date the sediments above the Messinian deposits. However, these sediments contain entirely organic silt and oxide rich mud, which are barren of planktic foraminifera marker species. Further age refinement within the Messinian deposits using microfossils and calcareous nannofossils will be undertaken in Week 6.

Paleomagnetism

Archive halves of sediment cores from Sites U1616 and U1617 were measured on the superconducting rock magnetometer (SRM). Sections from Holes U1616A and U1616B showed normal polarity for all 47.72 and 156.58 m of recovered core, respectively. Variations in inclination are attributed to drilling disturbance or lithology changes. Site

U1617, unlike previous sites, shows continuous reversals and can likely be tied to specific polarity-chrons with biostratigraphic constraints. Alternating field (AF) demagnetization for Site U1616 discrete samples are complete and agree with archive-half data, while analyses on discrete cube samples from Site U1617 are still in progress.

Igneous and Metamorphic Petrology

The igneous and metamorphic petrology team delved into exploring the texture and composition of the minerals in several thin sections of the mantle peridotites and associated veins recovered from Expedition 402 cores using the scanning electron microscope–energy dispersive spectrometry. Several generations of veins and host peridotites were defined and will be the subject of further analyses.

Structural Geology

Structural features were described and measured in all cores from Holes U1616A (48 structures), U1616B (148 structures), and U1617A (267 structures). The high recovery and quality of the data from Hole U1617A will allow inference of the geometrical relationships between sediments of different ages. In Hole U1616A, the predominant features are laminations and oriented fractures with apparent dip directions of typically 90° and variable apparent dip angles. Hole U1616B, which recovered the rest of the sedimentary succession through the basement contact, contains predominantly laminations with either 90° or 270° apparent dip directions. A series of centimeter-scale faults are noted in Core U1616B-18X, and Core 22X contains slumped material. Tilted or subhorizontal laminations are noted near the hole bottom.

Sediment features observed in Hole U1617A are predominantly laminations and occasional convolute laminations. Intervals within Cores U1617A-2H through 16H contain slumps, slump-tilted bedding, or turbidite bases. Tephra layers and sapropels are also noted. Observed faulting may be due to drilling disturbance, which increases in prevalence and intensity downhole, particularly in the XCB cores.

Sediment and Pore water Geochemistry

In the fifth week of Expedition 402, all samples collected from Hole U1615A and at Site U1616 (Holes U1616A and U1616B) were processed for analysis, including 56 headspace, 41 interstitial water (IW), and 69 bulk sediment samples. The significant feature observed in the IW dataset from Sites U1615 and U1616 is the inversely correlated depth profiles of Mg^{2+} and Ca^{2+}. Mg^{2+} concentration decreases with depth from about 60 mM near to the seafloor to a minimum value around 15 to 20 mM between ~150 and 190 mbsf, then increases again downhole. Ca^{2+} concentration increases from 12 to ~38 mM with its concentration peak coincident with the minimum in Mg^{2+}. Ca^{2+} concentrations decrease again with depth. The percentage of calcium

carbonate in sediment samples ranges from 1.4 to 47.2 wt% for Hole U1615A and from 1.7 to 84.5 wt% at Site U1616. Total organic carbon (TOC) contents in sediments are generally low with a mean value of 0.21 ± 0.24 wt% for Hole U1615A and 0.63 ± 0.92 wt% for Site U1616. However, TOC values greater than 1 wt% occur at 198.8 mbsf in Hole U1615A and at seven different depths (179.2, 213.5, 218.4, 237.7, 243.2, 258.5, and 277.8 mbsf) at Site U1616. For these two sites, total nitrogen (TN) content varies between undetectable and 0.30 wt%. Atomic TOC/TN ratios are mostly less than 12, indicating that sedimentary organic matter predominantly originated from a marine source. The occurrence of inorganic nitrogen could result in an overestimation of the relative contribution of the marine source. Total sulfur generally varies between undetectable and 3.38 wt% for these two sites.

Most of the samples (40 headspace, 34 IW, and 42 sediment) collected from Hole U1617A have also been analyzed; the results are being processed.

Igneous Geochemistry

The igneous geochemistry group completed portable X-ray fluorescence spectrometry (pXRF) analysis of the sediment IW squeeze cakes and intervals along the corresponding section halves from Sites U1615 (18 sections), U1616 (17 sections), and U1617 (32 sections).

Analysis of bulk rock geochemistry via inductively coupled plasma–atomic emission spectrometry (ICP-AES) has been conducted for about half of the samples taken from Hole U1614C. Some samples have low values for the sum of major elements (e.g., do not add up to 100%) and will likely be reanalyzed.

Physical Properties

During Week 5, the physical properties group analyzed cores recovered in the Vavilov Basin at Site U1616 and at Hole U1617A on the Campania Terrace. In total, we measured more than 600 m of sediment and the short interval of basement recovered in Hole U1616B. We acquired standard physical properties measurements on 78 recovered cores, including natural gamma radiation (NGR), *P*-wave velocity (V_P), gamma ray attenuation (GRA) bulk density, and magnetic susceptibility (MS) data. We also collected X-ray images of all section halves after the cores were split. In addition, we collected at least one thermal conductivity and discrete V_P measurement per core using the Gantry system and over 86 discrete samples for moisture and density (MAD) analysis. The physical properties data from Holes U1616A and U1616B will be merged to analyze physical property trends for the collective sedimentary sequence recovered at the site. The excellent recovery at Site U1617 will enable a high-quality stratigraphic analysis of the sediments on the Campania Terrace.

In Hole U1616B, GRA bulk density is variable in Cores U1616B-2H through 6H, then gradually increases with depth from Core 10X. MS values are high in the uppermost cores where the concentration of volcaniclastic material is relatively high, then shows spikes in MS downhole, likely corresponding to volcaniclastic layers. NGR has intermediate values through most of the hole, peaking in Cores 19X and 20X around the occurrence of the tuff. NGR is low through the rest of the hole. Thermal conductivity shows a clear increasing trend with depth. Data from Hole U1617A reflect the continuous sediment record recovered, with GRA bulk density and V_P increasing smoothly downhole. MS and NGR values are overall low with occasional spikes. NGR decreases with depth overall until Core 36X and the lithological change to the evaporite deposits. V_P increases gradually downhole, with an apparent inflection point and a sharper increase starting just above the evaporite deposits.

Downhole Measurements

The APCT-3 tool was deployed at Site U1616 during coring of Cores U1616A-4H and U1616B-4H. Combined with measurements of seafloor water temperature, these two formation measurements give a thermal gradient of 8.8°C/100 m, hence a heat flow estimate of 79 mW/m^2, an even lower heat flow value than that measured at Site U1615. In Hole U1617A, APCT-3 measurements were successfully made during coring of Cores U1617A-4H, 7H, and 10H. These data give a thermal gradient of 12.8°C/100 m, hence a heat flow estimate of 115 mW/m^2 for the Campania Terrace, a value close to that measured earlier during Expedition 402 on the Cornaglia Terrace at Site U1613 with 120 mW/m^2.

The triple combo logging tool string, including tools for measuring MS, electrical resistivity, bulk density, and NGR, was deployed twice in Hole U1617A. On the first run, the drill bit was positioned at 74.6 mbsf and the tool string encountered an obstruction at 135.4 mbsf that could not be worked through. For the second run, the drill bit was lowered to 151.7 mbsf, past the initial obstruction, but the logging tool could not fully pass out of the drill pipe. The bottommost tool on the string, measuring MS, recorded data to 171.5 mbsf. For both runs, the NGR tool recorded data through the open hole and through the pipe up to the mudline.

Microbiology

In Holes U1616A, U1616B, and U1617A, whole-round samples and syringe plugs of sediment cores 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 for samples collected from Sections U1616B-11H-2, U1617A-9H-

5, and U1617A-12H-4. In addition, viral incubations and prophage induction were initiated for samples from Sections U1617A-3H-5 and 7H-4.

Oxygen measurements were conducted on whole-round core sections from Hole U1616A, U1616B, and U1617A 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 U1616A-1H-1, oxygen was measured at intervals of 3 cm over the top ~40 cm of core, where it was detected in the first 20 cm with a minimum value of 0.66 µM. Subsequent measurements were made in each section of Core 1H, and then at a frequency of one per core downhole. Measurements continued in Hole U1616B, though oxygen concentration is below the detection limit until approximately 135 mbsf, where it began to increase slightly. In Hole U1617A, oxygen was detected in the first 9 mbsf with a minimum concentration of 0.01 µM; thereafter, readings remain very low until approximately 33 mbsf where they began to increase slightly. They then decrease and remain low until about 90 mbsf, where no further measurements could be taken because it was not possible to continue inserting probes.

Samples were taken to test whether drill fluid had intruded into the core interior using the perfluorodecalin (PFD) tracer, which is pumped along with drill fluid during the coring process. These samples were collected each time microbiology samples were taken. Three samples, including drilling fluid from the top of the core, core exterior, and core interior, were extracted using syringes and placed in glass vials. They were then transported to the laboratory for analysis on the gas chromatograph.

Outreach

The following outreach activities took place during Week 5.

- Blog was posted on the *JOIDES Resolution* website: “What do soda cans, resistivity, and drilling have to do with each other?”
- Completed 15 ship-to-shore broadcasts for ~521 people.
- Fifth blog post was published for the Reach the World partnership, with a spotlight on scientist Walter Menapace.
- Facebook: 24 posts with a reach of 25,286 and 52 new followers.
- X (Twitter): 20 new posts with 873 engagements.
- Instagram: 25 new posts with 448 engagements; gained 45 new followers.
- Threads: 2 new posts; engagements are not tracked.

Technical Support and HSE Activities

The following technical support activities took place during Week 5.

Laboratory Activities

- Technical staff processed core and provided sampling and science support during coring in Holes U1616A, U1616B, and U1617A.
- Technical staff facilitated and cut samples for the first half of the Hole U1614C hard rock sample party.
- It was observed that oxygen was contaminating the COY polymer anaerobic chamber. The rubber relief valves were not sealing well, likely due to age and the cold environment. A small heater was built and installed around the valve set to bring the temperature up to approximately 20°C to soften the rubber and help it seal. This temporary solution seems to be working, though replacement purge valves have also been ordered from the manufacturer.

Developer Activities

- It was reported by the technical staff on 13 March that no data could be uploaded to the database by the MegaUploaderTron (MUT) system. The issue was identified as being with the web service that creates a new LIMS result.
    - The result number became larger than what Java could represent as an integer.
    - A script written with the help of shore personnel was run to reset the sequence so that the result number will be low enough for our web services to work.
    - The issue is resolved for the current expedition; it will require work when moving the data into shore LIMS.
- Routine support and maintenance of the database and science applications.
- Fixed an issue with the Drill Report.
- Continued to troubleshoot issues related to uploading pXRF data to the database.
- Completed work on the ThermCon application, now ready to be deployed.

IT Support Activities

- Applied Windows updates on all Windows Servers.
- Checked patch status of all Linux Servers and all are up to date.
- Deployed March Windows updates to all Windows workstations and instrument hosts; workstations need a reboot to be applied.
- Identified a defective cable with GTAC in the Core Deck Network rack.

- Starlink outage for 4 h on 16 March due to license expiration on Siem Offshore/Marlink Fortinet appliance.

HSE Activities

- Emergency shower and eyewash stations were tested.