IODP Expedition 402: Tyrrhenian Continent–Ocean Transition

Week 7 Report (24–30 March 2024)

Week 7 of the International Ocean Discovery Program (IODP) Expedition 402, Tyrrhenian Continent–Ocean Transition was spent operating at two sites, U1616 and U1617. During Week 6, a reentry system and casing were installed in Hole U1616E to facilitate coring of basement at the site with the rotary core barrel (RCB) system. Reentry and initiation of coring in Hole U1616E occurred at the very end of Week 6, with Core U1616E-2R being drilled from a depth of 250 meters below seafloor (mbsf). Coring progressed during Week 7 across an interface between sediment and breccia and then into basement, penetrating ~67 m into mantle peridotites. Drilling in Hole U1616E ended when we encountered a layer that caused high torque and overpull during drilling; a logging attempt was limited by an obstruction at the breccia/basement interface.

At Site U1617, we drilled ahead to a depth of 250 mbsf in Hole U1617B, then began coring with the RCB system with the intention of recovering a complete Messinian section and then sampling the underlying sediment and basement. Coring was halted at a final depth of 370.4 mbsf when an anomalously low ratio of methane/ethane gas was measured in Core U1617B-23R, indicating that it was unsafe to advance further. Logging of Hole U1617B was in progress at the end of the week.

Operations

At the beginning of Week 7, we were recovering Core U1616E-2R, the first core in Hole U1616E following the drilled interval for the casing installation. Coring continued in the hole through Core 23R, reaching a total depth of 371.0 mbsf. Cores 2R and 3R recovered 5.08 m of sediment from a 19.6 m advance (26%). A hard contact was encountered in Core 4R between sediment and a peridotite breccia, and recovery in Cores 4R–9R was very low (10%). All cores after Core 4R were taken as half advances to try to improve recovery. Drilling parameters and formation lithology became more consistent starting from Core 10R (303.5 mbsf), which was designated as the top of basement and which marks a transition from breccia into peridotite. Cores 10R–23R advanced 67.5 m into basement and recovered 17.5 m of hard rocks (26%).

During the drilling of Core U1616E-23R, the drill string experienced high torque and overpull at the bottom of the hole. Attempts to clean the hole bottom of any debris were unsuccessful and coring was terminated in favor of logging after about 3 h of effort. Core 23R ultimately recovered 0.15 m of rock out of a 2.8 m advance (5%). Overall,

Hole U1616E cored a 121.0 m interval and recovered 25.87 m (21%). All cores were taken with nonmagnetic core barrels.

To condition the hole for logging, a 40 bbl sweep of sepiolite mud was pumped prior to backreaming up to 212.7 mbsf. We then deployed the center bit and reamed back down to the hole bottom to further flush cuttings or debris from the hole. We recovered the center bit and pulled most of the way out of the hole before launching the vibration isolated television (VIT) camera system to observe dropping the RCB bit on the seafloor. Once the VIT had been lowered, we pulled the drill string out of the hole, clearing the seafloor at 0545 h on 26 March 2024. The vessel was offset away from the reentry cone and the bit was released using the shifting tool on the wireline. Once this operation was successfully completed, we recovered the shifting tool, reentered Hole U1616E at 0815 h, and recovered the VIT.

The triple combo logging tool string was rigged up and deployed at 1230 h on 26 March with the drill pipe set at 266.6 mbsf, ~10 m above the contact between sediment and breccia. The tool encountered an obstruction at 306.7 mbsf, directly below the breccia/basement contact at 303.5 mbsf. We made the decision to recover the triple combo tool string, lower the drill pipe past this interface to a depth of 309.8 mbsf, and attempt a second logging run. The tool string was deployed for this second logging run at 1900 h, reaching a depth of 251.8 mbsf where it encountered an obstruction inside of the drill pipe. Attempts to clear the obstruction via circulation were not successful, with the pipe holding ~500 psi of pressure. Consequently, we ended logging operations and began pulling the Schlumberger tools out of the hole. After recovery of the triple combo tool string, the circulating head was rigged up and 1000 psi was applied to the drill pipe to clear the obstruction. The drill pipe was then recovered with the end of the pipe clearing the seafloor at 0245 h on 27 March. The end of the pipe cleared the rotary, and the rig floor was secured for transit at 0925 h, ending Hole U1616E.

The transit to Site U1617 included bathymetric surveying with the 3.5 and 12.0 kHz sonar systems, crossing perpendicular to a series of ridges that may have formed during detachment faulting. In all, the transit was 57.7 nmi and took 5.3 h at a speed of 10.9 kt. After the vessel arrived on site, we lowered the ship’s thrusters and transitioned to dynamic positioning mode. By 1600 h, we were positioned over the coordinates for Hole U1617B. After making up the bottom-hole assembly with an RCB bit, we began tripping pipe toward the seafloor. Hole U1617B was spudded at 2330 h on 27 March and drilled ahead to a depth of 250 mbsf prior to coring, with the goal of recovering a complete Messinian sequence and sampling the underlying sediment and basement.

Drilled interval U1617B-11 in Hole U1617B penetrated to a depth of 250.0 mbsf and was completed at 1030 h on 28 March. RCB drilling progressed from 250.0 to 370.4 mbsf with Cores U1617B-2R through 22R. Recovery was high in Cores 2R–5R

(ranging from 89%–126%), but only 10% in Core 6R. Cores were drilled as half advances starting from Core 7R to improve recovery. The low recovery is attributable to the evaporite and halite lithologies. The final core, Core 22R, crossed a lithological boundary from halite into a black shale that was observed on the catwalk to have a strong petroleum smell. Coring operations were paused while the headspace gas safety measurement for hydrocarbon content and composition was completed. The sample was found to have an anomalously low ratio of methane/ethane, indicating a thermogenic origin, halting further drilling in Hole U1617B. Overall, coring in Hole U1617B advanced 120.4 m and recovered 68.6 m of sediment, evaporites, and shale (57%).

Preparations then began for logging of Hole U1617B using the triple combo and Formation MicroScanner (FMS)-sonic tool strings. Drill fluid was circulated through the hole, and the core barrel that was deployed prior to stopping coring operations was retrieved. Pipe was tripped up to a depth of 311.6 mbsf and a 40 bbl sweep of sepiolite mud was pumped. Pipe was then tripped back down to 370.4 mbsf and the rotary shifting tool was deployed to release the RCB bit at the hole bottom. Finally, the pipe was set at 279.9 mbsf and the triple combo tool string was deployed at 1700 h. The tool string encountered an obstruction at 328.4 mbsf that could not be worked through. The triple combo tool string was recovered. Because we did not reach a great enough depth to open the caliper on the triple combo and measure the hole diameter, we could not run the FMS tool, so instead we ran the sonic tool without the FMS. The tool was deployed at 2300 h on 30 March.

Science Results

Lithostratigraphy

The sedimentology group described cores recovered from Holes U1616E and U1617B. Sediment in Cores U1616E-2R and 3R consists of foraminifera-rich nannofossil ooze, with sapropel layers and an interval of volcaniclastic-rich siltstone. The top sections of Core 4R contain dolomite, which then transitions into the matrix-supported consolidated breccia observed in Cores 4R–9R. These lithologies can be correlated with those recovered in Hole U1616B.

In Hole U1617B, we observe predominantly nannofossil ooze in Cores U1617B-2R and 3R. Core 2R contains nannofossil ooze with foraminifera, while intervals in Core 3R are glauconite-rich and are disturbed by biscuiting. From ~270 mbsf downhole, we observe organic-rich muds and silts with calcareous nannofossils, marking the transition to Messinian-age deposits. This transition is consistent with Hole U1617A. From the

bottom of Core 4R through Core 9R, the cores contain alternating layers of gypsum, gypsum-rich muds and silts, and unconsolidated gypsum breccia. Core 10R contains clay and occasionally gypsum-rich mud. In Core 11R, oxide-rich gypsum and gypsum are at the top, while mudstone, anhydrite, and dolomite comprise the bottom. Core 12R contains claystone, fine sandstone, and siltstone at the top, and then contains a boundary where the lithology transitions to intercalated clay with dolomite and clay with gypsum. From Core 13R to 16R, we observe anhydrite with mud followed by gypsum and anhydrite intercalated by mudstone. In Cores 17R and 18R we observe mudstone, gypsum with mud, and anhydrite with mud. At the bottom of Core 18R, continuing through Core 22R, we find halite intercalated by mudstone. The lowermost interval of Core 22R contains a black shale.

Biostratigraphy

Micropaleontologists spent Week 7 analyzing the sedimentary successions retrieved from Holes U1616E and U1617B. Hole U1616E was RCB cored with a primary objective to drill and retrieve the basement rocks. As a part of this, sedimentary layers just above the basement were retrieved and dated. Planktic foraminiferal species events associated with the MPl5a biosubzone and calcareous nannofossils indicative of MNN16 were observed in Cores U1616E-2R-CC and 3R-CC and were found to be Piacenzian (<2.82 Ma) in age.

Hole U1617B was drilled to retrieve Messinian-age sediments at the site. No core catcher (CC) samples were collected from the Messinian evaporite sedimentary sequences. The CC samples collected above (Samples U1617B-2R-CC to 5R-CC) are stratigraphically concurrent to the sedimentary succession observed in Samples U1617A-32R-CC to 35R-CC. Samples U1617B-2R-CC to 5R-CC are Zanclean age (<5.332 Ma), based on the identification of planktic foraminifer Zones MPl2 and MPl1 and calcareous nannofossil Zone MN12.

Paleomagnetism

Paleomagnetists measured the archive halves of basement material cored in Hole U1616E as well as representative discrete samples. We found a highly magnetic rock sample of which the isothermal remanent magnetization is over the measurement range of the spinner magnetometer.

Measurements of archive-half sections from Hole U1617B were completed. The sediment recovered consists mostly of Messinian sediments such as gypsum mud and anhydrites, most of which are magnetically weak. Measurements of discrete cube samples are still in progress.

Igneous and Metamorphic Petrology

During Week 7, the igneous and metamorphic petrology group described rocks and thin sections from Hole U1616E. Coring in the hole recovered a preserved contact between sediments and serpentinized breccia in a carbonaceous cement, as well as ~65 m of variably serpentinized and highly veined mantle peridotites. Lithologies include harzburgites, lherzolites, and gabbroid/dioritic intrusions. Overall, the site is more lithologically homogeneous than Site U1614. Alteration in this site is more static than in Site U1614, with pervasive serpentine and carbonate veins. Five basement stratigraphic units are defined, which are distinguished based on alteration features and lithology.

Structural Geology

Week 7 involved drilling of sediment, breccia, and basement in Hole U1616E as well as Messinian-age deposits in Hole U1617B. Deformation structures from both holes were described and their orientations were measured. In the breccia and basement of Hole U1616E, 297 features were noted, primarily metamorphic veins with highly variable dip angles. The overall plastic deformation of rocks in Hole U1616E is lower than that observed at Site U1614.

Coring in Hole U1617B recovered Messinian-age deposits and evaporitic facies, with the most prevalent features being subhorizontal laminations. Higher dip angles are noted in faulted intervals. Gypsum layers display chicken wire structures.

Sediment and Pore Water Geochemistry

During Week 7, whole-round core sections from Hole U1617B were collected on the catwalk for extraction of interstitial water (IW) and sediment analyses. No IW samples were collected in Hole U1616E. The salinity of IW samples in Hole U1617B shows elevated values, with a maximum of 73.5 at 308.13 mbsf (Section U1617B-10R-1) due to the dissolution of deeper evaporite deposits. Other geochemical analyses for Hole U1617B are currently in progress.

Twenty-one headspace samples were collected from Hole U1617B and the concentration of various C_1–C_6 hydrocarbon gases were measured. From 252.7 mbsf to 356.7 mbsf, only methane occurs in headspace samples and its concentration is low, ranging from 0.6 to 4.7 ppmv. Methane concentrations increase sharply in samples from Cores U1617B-21R and 22R, to 155.1 ppmv at 367.4 mbsf. The sample from Core 22R additionally contained ethane (14.0 ppmv) and propane (7.6 ppmv), producing a C_1/C_2 ratio that is anomalously low for the calculated formation temperature of ~60°C. This observation resulted in the termination of coring in Hole U1617B.

Igneous Geochemistry

The igneous geochemistry group, in conjunction with the sediment geochemists, measured total inorganic carbon (TIC), total carbon (TC), total nitrogen (TN), and total sulfur (TS) of hard rock samples from Site U1614 that inductively coupled plasma–atomic emission spectrometry (ICP-AES) analyses identified as having high CaO values. Through these analyses, we found a direct correlation between CaO and calcium carbonate, indicating that the high CaO values stemmed from the presence of carbonate veins.

At Hole U1616E, we performed portable X-ray fluorescence spectrometry (pXRF) analyses on archive half sections to help in petrological interpretations. Samples were also selected from the working half section for analysis by ICP-AES. The presence of carbonate veins prompted the analysis of TIC, TC, and TS in these samples. ICP-AES analyses for all selected samples are complete, and TIC, TC, and TS analyses will be done soon. Data processing is in progress.

At Hole U1617B, we analyzed IW squeeze cakes and their corresponding section halves via pXRF to assist sediment geochemists.

Physical Properties

The physical properties group acquired the standard set of physical properties measurements for sediment and hard rocks from Hole U1616E in the Vavilov Basin and the sediment and evaporitic facies encountered in Hole U1617B on the Campania Terrace. Our measurements included gamma ray attenuation (GRA) bulk density, *P*-wave velocity (V_P), and magnetic susceptibility (MS) on the Whole-Round Multisensor Logger, thermal conductivity, and natural gamma radiation (NGR). We also collected X-ray images of all section halves after the cores were split. For Hole U1616E, 31 discrete samples were processed for moisture and density analysis, while over 200 discrete V_P measurements were made with the Gantry system.

The peridotites recovered at Site U1616E are highly heterogeneous in terms of their physical properties, but they have an average seismic velocity of ~3.5 km/s, density of ~2.6 g/cm^3, and porosity of ~9%. Thermal conductivity ranges from 2 W/(m·K) to 3.79 W/(m·K). We performed a set of 18 seismic velocity measurements with the Gantry system over the same interval of peridotites from Site U1616E that revealed the precision of our velocity measurements within a few percent.

Data generated from Hole U1617B cores are still being processed. NGR values are low in the nannofossil oozes overlying the Messinian contact, and they increase in the evaporite deposits. NGR values in the halite intervals are near zero. MS is also low throughout the hole. Thermal conductivity is elevated in Cores U1617B-13R through

17R. GRA bulk density measurements are noisy but stable through the evaporites, then low in the halite.

Downhole Measurements

Two logging attempts were made in Hole U1616E with the triple combo tool string, including MS, electrical resistivity, bulk density, and NGR tools. During the first logging attempt, an obstruction was encountered just below the breccia/basement contact, at 306.7 mbsf. The MS sonde and the bottom of the tool string recorded data down to this depth, going through the brecciated basement top and 1 m into peridotites. Electrical resistivity, bulk density, and NGR data were also recorded over a shorter distance. On the second run, the tool string became stuck inside of the pipe and logging operations were ended to clear the obstruction. For both runs, the NGR tool recorded data through the pipe up to the mudline. The seafloor temperature was measured as 13.40°C. In all, 42 m of petrophysical data were recorded in the open hole at Hole U1616E.

Logging in Hole U1617B was in progress at the end of Week 7, after coring operations were terminated due to the anomalously low methane/ethane ratios. The first run occurred with the triple combo tool string and the drill pipe set at 279.9 mbsf. The tool string recorded MS data down to 328 mbsf, going through the gypsum-rich layers and some anhydrite near the base of the section before encountering an obstruction. Electrical resistivity and NGR data were also recorded over a shorter distance. On the second run, the Dipole Sonic Imager tool and the Hostile Environment Natural Gamma Ray Sonde recorded data down to the same depth as in the first run. The FMS tool was not run, as the caliper was not opened during the triple combo run and the hole diameter was unknown.

At the beginning of Week 8, the hole had been cleaned and the pipe was moved down past the obstruction for a final logging attempt. MS, electrical resistivity, and NGR data were recorded through the halite deposits and down to ~365 mbsf, only a few meters off hole bottom (370.4 mbsf). Because we expect the halite interval to be washed out, the sonic tool was not deployed.

Microbiology

Microbiological sampling for the expedition is now complete. All samples were stored according to their respective requirements (room temperature or frozen at –86°C). Overall, the perfluorodecalin microbial contamination tracer revealed limited intrusion of drilling fluids into samples and therefore minimal contamination. Site U1617 samples were the best quality. Oxygen concentration data has been processed; at all sites, oxygen is rapidly depleted in the first meters below seafloor.

Outreach

The following outreach activities took place during Week 7.

- Completed 23 ship-to-shore broadcasts for ~624 people.
- A blog released for the Reach the World partnership, interviewing Alejandro Avila Santis, the Physical Properties Laboratory Specialist.
- A blog was posted on the *JOIDES Resolution* website regarding "Time" at sea and geological time.
- Facebook: 24 posts with a reach of 2,169,518* and 513 new followers.
- X (Twitter): 24 new posts with 1,195 engagements.
- Instagram: 28 new posts with 721 engagements; gained 57 new followers.
- Threads: 2 new posts; engagements are not tracked.

*This is an anomalously high value for reach and we are determining whether it is real.

Technical Support and HSE Activities

The following technical support activities took place during Week 7.

Laboratory Activities

- Processed core and provided sampling and science support for Holes U1616E and U1617B.
- Facilitated and cut samples for the Hole U1616E hard rock and U1617B sample parties.
- Conducted a sonar survey between Sites U1616 and U1617 to cross seafloor features of tectonic interest.
- Installed an inline water trap in the carbon-hydrogen-nitrogen-sulfur analyzer to absorb moisture evolved from serpentinite samples.
- Repaired a faulty cable connector on the Velocity Gantry system that was causing intermittent loss of communication to the instruments.
- Completed expedition logo contest and T-shirt pressing.

Developer Activities

- Deployed multiple versions of the ThermCon application and tested the application with the staff.
- Fixed an issue with GEODESC showing offset errors in Data Capture by changing one of the sample's values from null to zero.

- Performed routine support and maintenance of the database and science applications.

IT Support Activities

- Updated macOS daily-use applications such as internet browsers, Adobe Creative Cloud applications, and Windows Office Suite.
- Finalized testing of the new GUI DriveMapper application for Microsoft Windows.
- Prepared for end-of-expedition activities and data backups.

HSE Activities

- Emergency shower and eyewash stations were tested.
- An abandon ship drill was held on 24 March at 1030 h.