IODP Expedition 402: Tyrrhenian Continent–Ocean Transition

Week 2 Report (18–24 February 2024)

Week 2 of the International Ocean Discovery Program (IODP) Expedition 402, Tyrrhenian Continent–Ocean Transition, involved operations at three sites, Site U1612, U1613, and U1614. At Site U1612, the basement target was reached but we became stuck in the hole and we were required to sever the drill pipe twice, ending operations at that location. At Site U1613, we drilled to the basement with the rotary core barrel (RCB) system but did not encounter the targeted lithology (basalt). Operations are ongoing at Site U1614 in the Vavilov Basin of the Tyrrhenian Sea, where we plan to first core the sediment succession and tag the basement with the advanced piston core/extended core barrel (APC/XCB) system prior to drilling 140 m of basement material via RCB in an additional hole.

Operations

Week 2 began with RCB drilling in the basement of Hole U1612A. Core U1612A-39R was cored with a 1.5 m/h rate of penetration (ROP), advancing 5 m to a depth of 348.7 meters below seafloor (mbsf) with 1 m recovery (20%). At 0400 h on 18 February 2024, after adding a joint of pipe to begin drilling Core 40R, the driller observed significant overpull and attempted to remediate the hole. Several mud sweeps were pumped, but both rotation and vertical movement were lost. The timing of these events, combined with the rubbly material recovered from basement in previous cores, led us to believe that the pipe was stuck somewhere along the bottom-hole assembly (BHA). After several hours of trying to free the pipe, the decision was made to sever the pipe near the top of the BHA, in the middle of the lower joints of 5½ inch drill pipe. A severing charge was lowered into the hole to 3792 meters below rig floor (mbrf) and detonated at 1905 h, with 20,000 lb of tension on the drill string. A decrease in tension was not observed, indicating that the pipe was stuck further up in the sediment column.

A second severing charge was delivered to 3589.5 mbrf, or 4.5 m below the sediment/water interface, and detonated at 0230 h on 19 February, again with 20,000 lb of tension applied to the drill string. An immediate drop in string weight indicated the pipe was successfully severed and was free. The decision was made to discontinue operations at Site U1612 and instead move to proposed Site TYR-07A (Site U1613). The severing equipment was recovered, the remaining pipe was tripped back to the surface, and the rig floor was secured. The vessel transitioned to cruise mode at 1300 h, ending Hole U1612A.

The ship completed the 76.4 nmi transit to Site U1613 at an average speed of 11.75 kt, arriving at 1930 h on 19 February. A new BHA with a C7 RCB bit was made up to better recover hard formations such as the basalt basement lithology anticipated at Site U1613. Pipe was tripped to the seafloor and Hole U1613A was spudded at 0830 h on 20 February, with a seafloor depth of 2706.8 meters below sea level (mbsl). Coring reached a total depth of 223.6 mbsf, recovering 99.6 m of material (45%). Core 2R had 0 m of recovery, later attributed to a malfunctioning core catcher (CC), which was removed and repaired. A hard layer identified as sandstone was encountered in the CC of Core 16R. The ROP decreased substantially below that depth, varying between 14.7 m/h in Core 17R to 1.2 m/h in Core 22R, relative to the average 80.2 m/h in Cores 1R–16R. The sandstone in Section U1613A-16R-CC was preliminarily determined to be continental basement, suggesting that the targeted basalt layer was not present at this site, and the decision was made to stop coring after Core 24R.

Temperature measurements using the Sediment Temperature 2 (SET2) tool were made at depths of 67.1, 95.6, and 125.9 mbsf, following Cores U1613A-7R, 10R, and 13R. The advanced piston corer temperature (APCT-3) tool was also run to seafloor depth to verify the calibration of the SET2. Nonmagnetic core barrels were used on all cores in Hole U1613A.

Logging was planned in Hole U1613A to better characterize intervals of low recovery and borehole physical properties. To prepare for logging, we swept the hole with 60 bbl of high-viscosity sepiolite. We then ran the rotary shifting tool to drop the RCB bit at the bottom of the hole. The knobbies were laid out and the top drive set back, and pipe tripped up to 74 mbsf. A first logging run was made with the triple combo tool string starting at 1430 h on 22 February. The tool string encountered a bridge at 127 mbsf but was able to work through it. A second bridge at 197 mbsf could not be worked through. Given the poor hole conditions, only a single pass was made with the triple combo. Also as a consequence of the hole conditions, the Formation MicroScanner (FMS) was removed from the standard FMS-sonic tool string and a single pass was made with just the Dipole Sonic Imager (DSI) tool. This modified tool string was deployed at 2100 h and reached a depth of 182 mbsf. The tool string was recovered by 0100 h on 23 February and the pipe tripped back to the surface. Hole U1613A and Site U1613 ended at 0935 h on 23 February, as the vessel transitioned into cruise mode and began the transit to proposed Site TYR-11A (Site U1614).

The 80.4 nmi transit to Site U1614 took 7.6 h at an average speed of 10.6 kt. We arrived on site and transitioned to dynamic positioning (DP) mode at 1755 h on 23 February. The precision depth recorder (PDR) estimated the seafloor as 3580.1 mbsl. An APC/XCB BHA with a 9⅞ inch polycrystalline diamond compact (PDC) bit was assembled and deployed to 5 m above seafloor. Prior to spudding, we pumped enough

microbial contamination tracer with circulating drilling fluid to fill the drill string. Hole U1614A was spudded at 0645 h on 24 February, with the first core recovering 5.7 m of sediment as well as the mudline. Based on this recovery, the seafloor is calculated at 3579.0 mbsl. Cores U1614A-2H through 12F advanced to 89.3 mbsf and recovered 85.36 m of sediment (96%). Measurements with the APCT-3 tool were made during Cores U1614A-4H and 7H, and all full-length APC cores were oriented. Cores 7H and 9H were partial strokes, where Core 9H experienced 30,000 lb of overpull. As a result, Cores 10F–12F were taken as half-length APC (HLAPC) cores. Gravel recovered in the tops of multiple cores is interpreted as fall-in. Coring of Core 13F was in progress at the end of Week 2.

Science Results

Lithostratigraphy

Cores U1612A-1R to 35R (0–324.4 mbsf) were described both macroscopically and microscopically (via smear slides) during Week 2. Three lithological units are proposed. Subunits IA and IB extend through Core U1612A-26R. The unit is composed of gray nannofossil ooze with a variable content of volcaniclastic material. Contacts between lithologies are gradational and marked by subtle color changes. Bioturbation is sparse to moderate. Unit II (Cores 26R–34R) contains foraminifera-rich nannofossil chalk that interrupts deposition of calcareous chalks. Bioturbation is moderate and occasionally abundant. There are a few shell fragments and pyrite precipitates, as well as black organic matter patches. Several sapropel and tephra layers were noted, including a faulted sapropel. Unit III extends to the basement contact and is composed of dolomite-rich mud with abundant bioturbation. Much of the cored material was slightly to severely disturbed, including biscuiting and cracking.

Four lithological units were preliminarily defined for sediments from Hole U1613A. The first two units transition from soupy, nannofossil-rich very fine sand to ooze with mud, with a layer of foraminifera-rich material in Unit II. Contacts are either sharp erosive or defined by a color change. Bioturbation is absent to sparse. Unit III (Cores U1613A-14R to 19R) encompasses the Messinian gypsum-rich silt facies followed by deeper oxide-rich sand, matrix-supported polymict sand, and sandy mudstone. Unit IV, at the bottom, contains sandy mudstone and silty rich black shale.

Cores U1614A-1H through 3H contain turbiditic facies, transitioning to volcaniclastic-rich gravel and coarse sand.

Biostratigraphy

At Hole U1612A, age determination is based on foraminifera and nannofossil content of CC samples. Down to Section U1612A-26R-CC, the data indicate a Late Pleistocene–late Gelasian succession characterized by a high sedimentation rate (~14 m/100 ky) with two small hiatuses, each about 0.5 My long. The lower part of Hole U1612A contains an Upper Pliocene (Piacenzian)–Lower Pleistocene (Gelasian) succession, characterized by a much lower sedimentation rate (~4 m/100 ky).

Week 2 was mainly devoted to analysis of samples recovered at Hole U1613A. Fourteen out of the 22 CC samples (U1613A-1R-CC to 15R-CC) were used for biostratigraphic analyses. According to planktic foraminifera data, 9 biosubzones from Holocene to Lower Pliocene (Zanclean) were identified. According to nannofossil data, the upper part of the recovered succession (down to Section 11R-CC) is Middle Pleistocene–Gelasian in age and is characterized by a sedimentation of ~48 m/My. Both foraminifera and nannofossil data indicate a temporal hiatus ~1.5 My long and latest Zanclean/basal Gelasian in age. Samples from Sections 12R-CC to 14R-CC are of Zanclean age (Early Pliocene). In Sample U1613A-15R-2, an 8 cm horizon comparable to one of the late Messinian salinity crisis onset events was identified ranging in age from 5.97 to 5.85 Ma. Sediments and sedimentary rocks below Core U1613A-16R were correlated to units outcropping on Sardinia and correspond to continental basement.

Paleomagnetism

Inclinations measured in archive half sections of Cores U1612A-1R to 31R (~294 mbsf) on the superconducting rock magnetometer (SRM) all show normal polarity, although several geomagnetic reversals were expected. However, recovery in Hole U1612A was very low, which may account for the fact that no reversals were captured. Following a more in-depth discrete sample demagnetization analysis, we identify a possible reversal in Section U1612A-31R-1, which correlates strongly with Mediterranean biostratigraphy.

Core recovery in Hole U1613A was higher, resulting in a more continuous paleomagnetic profile. Cores U1613A-1H through 5H were measured on the SRM, but the material is reworked, and the observed irregular polarity changes are not reliable for magnetostratigraphy. Despite the unreliable reversals in the top of the hole, a deeper normal-reversal sequence suggests an age of ~5 Ma at 125 mbsf.

Igneous and Metamorphic Petrology

The main finding of this week was the potential Triassic to Paleozoic succession in Hole U1613A, which is assigned as the basement at this site. Based on analogies with similar formations in Sardinia, three main basement units were identified and described: conglomerates (Unit I), green/red shales (Unit II), and black shales (Unit III). The

probable difference in depositional ages of the different units indicates the occurrence of unconformities in the basement. The black shales are preliminarily identified as analogs of those formed in the Silurian during a well-documented period of widespread anoxia. If confirmed, the black shale may represent the most ancient lithology ever recovered by the *JOIDES Resolution*.

Structural Geology

During this week, the structural geology group described and measured the orientation of all the deformation structures encountered in Hole U1613A. We also assisted the sedimentology group in taking core images and collecting magnetic susceptibility (MS) and color reflectance data on the sediments.

The main results of the week are the discovery of a Messinian unit in the sediment and a thick incohesive cataclastic zone in the assigned basement below, between volcanoclastic deposits and black shales. We interpret this cataclastic zone as a fault gouge, either related to normal faulting or a reactivation of a normal fault in reverse shearing. Reverse shearing can be explained by compressive strength on the ridge flanks due to the spreading ridge. Interestingly, the dip of the structures increases with depth, shifting from 1° to 20° in the sediments to 21° to 70° in the basement. The number of fractures and reverse faulting also increases with depth.

Sediment and Pore Water Geochemistry

During Week 2, the sediment and pore water geochemistry team finished the shipboard analyses of samples from Holes U1612A and U1613A and started processing samples from Hole U1614A. These samples include 38 interstitial water (IW) samples (18 from Hole U1613A and 20 from Hole U1614A) and ~59 sediment samples (39 from Site Hole U1613A and ~20 from Hole U1614A). The IW analyses included basic chemistry (alkalinity, pH, and salinity), major cations (Na^+, Ca^{2+}, Mg^{2+}, and K^+) and anions (Cl^-, SO_4^{2-}, and Br^-) by ion chromatography (IC), major and minor elements (Si, Ba, B, Li, Fe, Mn, Sr, and S) by inductively coupled plasma–atomic emission spectrometry (ICP-AES), and ammonium (NH_4^+), phosphate (PO_4^{3-}), and total sulfide concentrations by spectrophotometry. The sediment samples were analyzed for total inorganic carbon content, total carbonate content, total carbon, nitrogen (TN), and sulfur (TS) content, and total organic carbon (TOC) and matter content.

In Hole U1613A, IW salinity shows an increasing trend with depth and is higher than 45.0 below 100 mbsf. A maximum salinity value of 50.5 is reached at 166.22 mbsf (Section 18R-1). The Ca^{2+} concentration exhibits a similar trend, which may suggest the formation of evaporites. The percentage of sediment calcium carbonate varies from 0.6 wt% (Section U1613A-19R-1, 176.4 mbsf) to 69.3 wt% (Section U1613A-12R-3,

170.6 mbsf). Low TOC (0.07–0.39 wt%), TN (0.00–0.05 wt%) and TS (0.0–0.2 wt%) contents were measured in sediments collected from this site. Higher atomic TOC/TN ratios (15.0–37.0) occurred at 61.6, 77.9, 119.1, and 130.3 mbsf, indicating higher inputs of terrestrial organic matter and/or diagenetic processing of organic matter.

Igneous Geochemistry

The igneous geochemistry group assisted the sedimentology and sediment geochemistry groups with collecting portable X-ray fluorescence (pXRF) data from IW squeeze cakes and archive section half intervals adjacent to the squeeze cakes for 18 cores recovered from Hole U1613A. pXRF analyses allow for preliminary interpretation of elemental concentration with depth, and show inverse relationships between Rb and Sr as well as K_2O and CaO in the sediment cores, with the concentrations of both Rb and K_2O increasing with depth. Additionally, we analyzed four spots on the last core (U1613A-24R-1, 35 cm, 68 cm, 87 cm, 112 cm), which has been preliminarily interpreted to represent a Silurian black shale. Data reveal that this section has higher CaO and lower Rb concentrations, without the corresponding changes in Sr and K_2O that were observed in the sediment cores from this site.

Physical Properties

During Week 2, the physical properties team finalized measurements for the Hole U1612A cores recovered in the Vavilov Basin. We also measured cores recovered from Hole U1613A on the Cornaglia Terrace for density, MS, and *P*-wave velocity (V_P) on the Whole-Round Multisensor Logger (WRMSL), X-ray imaging, and natural gamma radiation (NGR). Discrete samples were taken for moisture and density (MAD) analysis, in addition to discrete measurements of thermal conductivity and V_P made on the Gantry system. Our measurements highlight the changes in physical properties between the sedimentary cover and the pre-Messinian basement and allows us to identify various heterogeneities within the sediments, such as coarse-grained layers or changes in the organic content. For example, a thin gypsum layer just above basement is evident from changes in all measured parameters. Measured physical properties within the basement show trends consistent with the presence of alternating layers of sandy mudstone and conglomerate.

Downhole Measurements

Downhole measurements conducted during Week 2 in Hole U1613A included three runs of the SET2 tool and downhole logging runs with two tool strings.

In situ formation temperature measurements were taken with the SET2 following Cores U1613A-7R, 10R, and 13R. Two of the three SET2 runs were successful, recording temperatures of 24.06 and 29.65°C at depths of 67.1 and 125.9 mbsf, respectively.

These temperatures are coherent with an equilibrium seafloor temperature of 13.58°C recorded before and after the second SET2 run, yielding a thermal gradient of 12.7°C/100 m and a heat flow in the range of 127 mW/m^2 using an average value of 1.0 W/(m·K) for the thermal conductivity measured from the cores. The APCT-3 tool was also run to seafloor depth to verify the calibration of the SET2.

In Hole U1614A, the APCT-3 tool was deployed twice to measure sediment temperature. Measurements from 34.2 and 62.7 mbsf (Cores U1614A-4H and 7H) gave readings of 20.26 and 27.05°C respectively. When combined with the seafloor temperature of 13.68°C recorded after the second APCT-3 run, it yields a thermal gradient of 21.3°C/100 m and a heat flow of 213 mW/m^2.

The first logging tool string deployed in Hole U1614A was the triple combo, including the logging equipment head for borehole fluid temperature, the Hostile Environment Natural Gamma Ray Sonde tool, the Hostile Environment Litho-Density Sonde for bulk density, photoelectric factor, and a one-arm caliper, the High-Resolution Laterolog Array electrical resistivity tool, and the Magnetic Susceptibility Sonde. Because of poor hole conditions, we made a single pass with this string. The second tool string included just the DSI tool.

Microbiology

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 formaldehyde. Microbial experiments were initiated in anaerobic conditions, including enrichment cultures in Section U1613A-5R-5 and viral incubations and prophage induction experiments in Sections 1R-2 and 11R-2.

Oxygen measurements were made on whole-round cores from Hole U1613A immediately after core recovery, 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. Core U1613A-1R exhibited significant disturbance, particularly in Sections 1R-1 and 1R-3, which hindered the generation of reliable data. From Core 3R onward, the oxygen profile exhibited a consistent decline, maintaining low or zero concentration levels. In Cores 11R and 13R, oxygen levels increased marginally. The measurement was repeated in at least one additional section, yielding similar values, which were associated with the presence of a void space in the core liner.

Oxygen measurements were also conducted for Cores 1H, 2H, 3H, and 8H from Hole U1614A. In Core 1H, oxygen was detected in the first 15 cm of Section 1H-1 with a maximum peak of 109.5 µM/L, but then decreased. As these cores are very sandy and

sand can damage the fiberoptic probes, it was not feasible to proceed with oxygen measurements below Core 8H.

Outreach

The following outreach activities took place during Week 2.

- First blog on the *JOIDES Resolution* website: Pet Wall of Expedition 402.
- Second blog post published in partnership with "Reach the World," covering Tessa and Larkin's travel to the ship.
- Completed eight ship-to-shore broadcasts for ~200 people.
- Planning a live broadcast with the Time Scavengers organization.
- Coordinating with a research group in Germany working on how people experience deep sea environments and cores using their senses.
- Facebook: 24 posts with a reach of 47,862 and 39 new followers.
- Twitter: 23 new tweets posted with 1156 engagements.
- Instagram: 29 new posts with 664 engagements; gained 75 new followers.
- Threads: three new posts; engagements are not tracked.

Technical Support and HSE Activities

The following technical support activities took place during Week 2.

Laboratory Activities

- Technical staff assisted with core processing and science support at Holes U1612A, U1613A, and U1614A.
- Downhole logging was conducted in Hole U1613A.
- Technical staff finished constructing enclosures for all rock cutting saws in the splitting room for asbestos mineral handling procedures.
- The sample holders on the AGICO JR-6A spinner magnetometers were becoming magnetized on both instruments. The problem was resolved by changing the power supply and cables.

Application Support Activities

- Performed bug fixes for the GEODESC Catalog Manager.
- Troubleshooting the MUT uploader for pXRF data, which is not uploading data and files consistently. When an error occurs, no error messages are reported by

the application, thus making troubleshooting more challenging. Data and files are being thoroughly checked, ensuring they are properly reported in the database.
- Started work on small changes to the Thermcon application, based on bugs reported by the Assistant Laboratory Officer.
- Encountered another instance of a corrupt “ProgramData/” application directory folder causing failure of the Image Capture application to launch. The solution was to uninstall the application, reboot, delete the directory, then reinstall the application.

IT Support Activities

- Two unsuccessful attempts were made with Marlink to reroute network traffic back to campus. The maintenance attempts resulted in the Internet being unavailable on VSAT and Marlink for a few hours.
- Resolved general help desk issues from customers.

HSE Activities

- Emergency shower and eyewash stations were tested.
- Postdeparture COVID-19 test was conducted on February 18.
- A lifeboat and fire drill was held on 18 February at 1030 h.