IODP Expedition 401: Mediterranean–Atlantic Gateway Exchange

Week 5 Report (7–13 January 2024)

This week we completed coring Hole U1610A from 953.9 to 1438.7 meters below sea floor (mbsf), and logged from 517.6 to 725.9 mbsf, where an obstruction in the hole prevented deeper logging. On 12 January we made the 0.5 d transit to Site U1385, and at the end of the week we had just started coring in Hole U1385K.

Operations

Week 5 of the expedition began on 7 January 2024 with Core U1610A-50R from 953.9 mbsf in Hole U1610A (proposed Site GUB-02A). Coring continued with very good recovery until Core 95R, which recovered just 15 cm of hard dolostone rock pieces. Core 96R was empty, so we ran the bit deplugger to remove any potential obstructing rock lodged in the bit. Although the drilling rate indicated that we were drilling recoverable sediments and had passed below the hard lithified sediments that had been partly recovered in Core 95R, no sediments were recovered, so we stopped coring at 0515 h on 11 January with Core 100R. Cores 50R to 100R penetrated from 953.9 to 1438.7 mbsf and recovered 484.8 m (75%). Throughout the week, the driller pumped sepiolite mud sweeps to help keep the hole in good condition, with sweeps increasing in frequency as the depth increased.

We prepared for downhole logging by releasing the bit at the bottom of the hole, filling the hole with 354.3 bbl of heavy (10.5 lb/gal) barite mud, and raising the pipe. When the end of the pipe reached 779.4 mbsf, the drill pipe became stuck. After an overpull of 60,000 lb would not free the pipe, the circulating head was attached so that fluid could be pumped, and the top drive was picked up so that the pipe could be rotated. After several attempts, the pipe came free at 1215 h with 90,000 lb overpull and a pump pressure of 600 psi. The end of pipe was set at 516.6 mbsf for logging, 14.7 m below the casing shoe.

At 1415 h, we started to assemble the quad combo tool string, including natural gamma radiation (NGR), density, resistivity, and sonic velocity tools. The tool string was lowered down the hole, passing out of the casing into the open hole at 1640 h. At ~726 mbsf, the tool string encountered an obstruction and, after eight attempts, could not pass any further down the hole. This depth interval is the same one that closed in on the drill pipe earlier in the day. However, useful log data were acquired from the ~208 m open hole logged interval.

Notably, the inclinometer in the cable head of the quad combo logging tool string showed that Hole U1610A was inclined between 13° and 15° from vertical in the logged interval. The hole had been suspected not to be vertical from the observation of inclined beds in the cores. If the beds were originally horizontal, then inclination of the borehole reaches ~25° at some depths.

The downhole logging equipment was rigged down by 0045 h on 12 January and the pipe was raised, clearing the seafloor at 0130 h and the rig floor at 0300 h. The rig floor was secured for transit, we raised the thrusters at 0336 h, and we started the sea passage to Site U1385 at 0348 h, ending Site U1610.

The 154 nmi voyage to Site U1385 took 12.8 h at a speed of 12 kt. We lowered the thrusters at 1622 h and switched to dynamic positioning (DP) mode at 1652 h. Site U1385 was cored to 151 mbsf on Expedition 339 in 2011 and to 400 mbsf on Expedition 397 in 2022. Our plan is to extend the Site U1385 record deeper than 400 mbsf and recover late Miocene sediments. The advanced piston corer/extended core barrel (APC/XCB) bottom-hole assembly (BHA) was assembled with a polycrystalline diamond compact (PDC) bit and was lowered toward the seafloor, and a pipe-cleaning “pig” was pumped down to clean the inside of the drill pipe. The ship was positioned 20 m east of Hole U1385J, ready to start the new hole at this preexisting site. Hole U1385K was started at 0035 h on 13 January and was drilled ahead, reaching 385.0 mbsf at 1615 h. The center bit was retrieved and we started coring. Cores U1385K-2X to 4X penetrated from 385.0 to 402.4 mbsf and recovered 0.9 m (5%).

Science Results

Lithostratigraphy

Cores U1610A-46R to 95R (915.1–1390.6 mbsf) were described and the following lithostratigraphic units were defined.

Unit III extends from 837.5 to 934.5 mbsf (Cores U1610A-38R to 47R) and is characterized by calcareous mud, clayey calcareous ooze, and minor sandy silt intervals. The unit names have been revised since last week’s report; this unit was previously designated as Unit V and was described in more detail there.

Unit IV extends from 934.5 to 1388.8 m mbsf (Cores U1610A-48R to 94R), and consists of calcareous mud, calcareous silty mud, calcareous (silty) sand(stone), calcareous (sandy) silt(stone) and clayey calcareous ooze to calcareous clay. Cores 66R to 70R are much coarser, and include conglomerates, calcareous medium sand, and sandstones ranging in grain size from very fine to medium sand. Most lithologies of this

unit are dark greenish gray in color (GLEY1 4/10Y) except for the clayey calcareous ooze that is a lighter greenish gray (GLEY1 5/10Y). Coarser lithologies range in color from gray (GLEY1 6/N) to dark gray (GLEY1 4/N). Contacts between lithologies are predominantly gradual and correspond to a change in color; however, sometimes the boundaries are sharp grain-sized contacts. Subtle lamination is common and is characterized by slight changes in color and grain size. There are shell fragments, pyrite, plant debris/fragments, and foraminifera disseminated throughout the unit. Bioturbation is absent to abundant, with the clayey calcareous ooze lithology exhibiting a noticeable increase in bioturbation compared to the calcareous mud intervals. Trace fossils include *Chondrites*, *Planolites*, *Thalassinoides*, *Zoophycos*, *Palaeophycos*, and *Macaronichnus*.

Unit V extends from 1388.8 to 1390.6 m CSF-A (Core U1610A-95R) and is composed of dolostone. The dolostone is greenish gray in color (GLEY1 6/10Y), and the maximum grain size is silt.

Biostratigraphy

Micropaleontologists sampled, processed, and observed 64 core catcher (CC) samples from Hole U1610A. All microfossil abundances range from moderate to very abundant, with very poor to good preservation. The biostratigraphers recorded the disappearance of *Ceratolithus acutus* between Section U1610A-30X-CC and 31X-CC giving an age of 5.36 Ma. Between Section 47R-CC and 48R-CC, the highest common occurrence (HCO) of *Neogloboquadrina incompta* (sinistral) gives an age of 5.78 Ma. Between Section 51R-CC and 52R-CC, the HCO of *Globorotalia scitula* (dextral) gives an age of 5.9 Ma. Between Section 56R-CC and Sample 57R-2, 145–147 cm, the highest occurrence (HO) of *Reticulofenestra rotaria* gives an age of 5.94 Ma. Between Section 55R-CC and 56R-CC, the lowest regular occurrence (LRO) of *Globorotalia margaritae* was recorded, giving an age of 5.98 Ma. We note that the slight discrepancy in the order of the bioevents, HO of *R. rotaria* and LRO of *G. margaritae*, could be a result of the coarse sample spacing of CC samples, spaced ~9.7 m apart. Between Samples 66R-2, 23–25 cm, and 66R-3, 130–132 cm, the HCO of *Globorotalia miotumida* gives an age of 6.32 Ma. Finally, between Sample 66R-5W, 102–104 cm, and Section 66R-CC, the sinistral-to-dextral change of coiling in *Neogloboqradrina incompta* gives an age of 6.38 Ma. No further bioevents were recorded, partly due to the likely high sedimentation rate of Unit IV, and partly because microfossil preservation decreases toward the bottom of the hole.

Thirty CC samples from Hole U1610A were analyzed for benthic foraminifer assemblages. Variation of the abundance of certain benthic foraminifer species, like the uvigerinids, was noted with lithologic changes. Influx of shallow water benthic assemblages, echinoderm plates and spines, and the presence of many detrital

aggregates, pyrite, quartz, and glauconite grains were noted in most samples, which indicates that they are reworked sediments.

The first sample from Hole U1385K was analyzed at the end of the week. Section U1385K-2X-CC (385.9 mbsf) was found to be Early Pliocene in age.

Paleomagnetism

The paleomagnetists finished measuring the natural remanent magnetization (NRM) of all the archive half-core sections from Hole U1610A on the superconducting rock magnetometer (SRM). Alternating field (AF) demagnetization was performed at 5, 10, 15, and 20 mT, with measurement of the remaining NRM being taken at 2 cm resolution after each step. A drilling overprint was mostly removed by 10 mT demagnetization.

In addition, we measured the NRM of 134 cube samples on the JR-6A AGICO spinner magnetometer, then the samples were AF demagnetized. The NRM of discrete samples is significantly stronger than at Site U1609, with an average of 10×10^{-4} A/m. In general, steps of 5, 10, 15, 20, 30, 40, 50, and 60 mT, and in some cases up to 100 mT, were added to fully demagnetize the characteristic magnetic component.

Results from 501 to 540 mbsf clearly show normal inclinations in both SRM and JR-6A records. Between 540 and 1010 mbsf, reversed directions are dominant and many SRM inclination values approach the expected antipodal geocentric axial dipole (GAD) inclination at the site (57°). Some short (<20 m) normal polarity depth intervals are present, but they are not clear, and only few show successive inclinations with the expected GAD value. Normal polarities dominate from 1010 to 1390 mbsf.

We measured the anisotropy of magnetic susceptibility (AMS) and bulk magnetic susceptibility (MS) of all the discrete samples using the MFK2 KappaBridge instrument. Results show that all the κ_{min} axes have a tilt of ~15°–17° deviating from the vertical. Because κ_{min} is generally perpendicular to the sedimentary bedding plane, this value indicates that drilling has not been vertical, but must have occurred with an angle of 15°–17°, and is consistent with the observation of inclined beds in the visual core descriptions and the logging data. In principle, we think it should be possible to reconstruct the strike of the dipping borehole, provided the paleomagnetic signal is robust enough, which will allow AMS results to be interpreted in terms of current flow direction.

Geochemistry

At Hole U1610A, the organic geochemistry team continued routine monitoring of headspace gas for safety to the base of core recovery (Core 94R). Low measured concentrations of hydrocarbons were within safety thresholds.

The inorganic geochemistry team sampled interstitial water (IW) samples from Hole U1610A until water yields decreased below ~1 mL at Core 61R. The team also obtained an additional IW sample from Core 72R with insufficient yield for most measurements. The team continued measurements of salinity, pH, and alkalinity. Major and trace elements in the IW samples were measured by ion chromatography (IC) and inductively coupled plasma–atomic emission spectroscopy (ICP-AES). Salinity and pH increased to 59 and >7.8 at the lowermost samples, respectively, whereas alkalinity was low (<1.5).

Sediment samples were obtained from the squeeze cake residues where IWs were taken, or from one sample per core if there was no IW sample, to understand geochemical variations. Sediment samples were dried, ground, and weighed to measure C, N, and $CaCO_3$. The carbonate fraction was additionally dissolved to study its chemical composition.

At the end of the week, the geochemistry team collected headspace gas samples in the first core recovered at Hole U1385K from 385.0 mbsf. Gas content in Core U1385K-2X was within the safety range.

Physical Properties and Downhole Measurements

Physical property measurements for Hole U1610A were completed. Five physical property units were informally defined.

Physical Properties Unit I (510–685 mbsf) consists of ~2 m cycles evident in the MS and NGR data. Physical Properties Unit II (685–975 mbsf) corresponds to higher amplitude cycles in NGR and MS than in the overlying unit. Physical Properties Unit III (975–1130 mbsf) is characterized by an increase in MS values by two orders of magnitude compared to the overlying unit, as well as a decrease in NGR values. Physical Properties Unit IV (1130–1295 mbsf) corresponds to lower values and lower amplitude variations than Unit III, with longer wavelength changes in the MS and NGR datasets than in Units I and II. Physical Properties Unit V (1295 mbsf to the base of measurements) corresponds to a return to higher frequency variability in the MS and NGR datasets.

Downhole logging unfortunately did not reach deeper than 726 mbsf. Caliper logs show that the hole was alternately washed out to greater than 15 inch and closed in to narrower than the bit diameter. However, the natural gamma logs show cyclic variation that can be used to cover stratigraphic gaps in lithostratigraphic Unit I. The density log is strongly affected by borehole conditions, but in narrower borehole intervals, the readings are valid and reach a maximum of 2.0 g/cm^3. Perhaps the most important logging result is quantifying that the hole is inclined from vertical by 13°–15° in the logged interval. Hole inclination will have to be taken into account in calculating bed

thicknesses and depths to seismic reflectors, because coring depth along the borehole will overestimate true vertical depth.

Outreach

Ship-to-shore tours this past week reached nearly 500 students in six countries: Greece, Australia, United Kingdom, United States, Spain, and India. A scale model of a drill bit was 3-D printed for ship-to-shore tours, allowing for better visual explanations of coring techniques.

A blog post published on the *JOIDES Resolution* website highlighted the decisions faced by the science team this past week. Two pieces of artwork created by an Outreach Officer on board were shared, highlighting a member of the geochemistry team and the drilling crew.

The top posts of the week on social media were:

- Facebook: Photos of the food supplies on board the ship.
- Instagram: A video highlighting sleeping schedules on the *JOIDES Resolution*.
- X: A video featuring Co-Chief Scientist Rachel Flecker, highlighting accomplishments from the first half of the expedition.
- Threads: A timelapse of the ship's thrusters announcing our arrival at our third site.

The Threads post did exceptionally well, resulting in hundreds of new followers for the *JOIDES Resolution* Threads account.

Technical Support and HSE Activities

Laboratory Activities

- Staff processed cores and samples from Holes U1610A and U1385K. The total recovery for the expedition so far is 1832.91 m.
- Staff conducted measurements in the NGR instrument using a standard to profile the detector response and found that the detector position in the control software settings was different from the actual detector position. The setting was updated and the NGR instrument was calibrated. Former position setting: 43.21 to 183.21 cm; new position: 42.12 to 182.12 cm.

- The Supersaw motor started making a grinding noise. After troubleshooting, we replaced the motor and it is now operating smoothly. The replaced motor will be serviced at the next tie-up.
- The Whole-Round Multisensor Logger (WRMSL) *P*-wave unit was skipping signals. The issue was traced to a failed BNC connector.
- The Chemistry Laboratory encountered an issue with the ICP-AES uploader. The uploader uses a macro to combine raw data from the instrument with downloaded Sample Report information (such as text ID and depth) and to create the final spreadsheet to upload into LIMS. The recent changes made in Sample Report (adding “top and bottom offset in parent”) created two extra columns, causing the macro to read from the wrong columns. The ICP-AES uploader macro was updated to read the correct columns in Sample Report.

IT Support Activities

- Continued working with WifiGem to troubleshoot connection issues.
- Working on Windows, Mac, and server updates.
- Troubleshooting issues with replacement switch connection to Marlink.

Developer Activities

- Helped a technician and scientist upload the IW Sample Report.
- Worked on Sample Report and Expanded Sample Report changes.
- Redeployed GEODESC DataCapture that includes a new Sample Type requested by the scientist on the ship.
- Worked on the Hyperscan shore-based project.
- Worked on debugging IMS changes for the X-Ray Linescan Logger (XSCAN).

HSE Activities

- Emergency shower and eye wash stations were tested.
- A boat drill was held on Sunday, 7 January.