IODP Expedition 401: Mediterranean–Atlantic Gateway Exchange

Week 3 Report (24–30 December 2023)

During Week 3, Hole U1609B was cored from 72.6 to 508.7 meters below seafloor (mbsf). Then we made the transit to Site U1610 (proposed Site GUB-02A) and drilled in casing and a reentry system to 503 mbsf in preparation for coring.

Operations

Week 3 began having just completed downhole logging in Hole U1609A. From midnight to 0215 h on 24 December, the crew serviced the drilling line and rig equipment. The ship was offset 20 m to the south of Hole U1609A along the slope, and at 0305 h we started Hole U1609B by drilling down without recovery. The plan was to drill down without coring in order to spend more time coring the early Pliocene to late Miocene target interval; however, in these clay-rich sediments, drilling was not any faster than taking cores. At 0930 h, we retrieved the center bit and started taking advanced piston corer (APC) cores at a depth of 72.6 mbsf. Cores U1609B-2H to 4H penetrated from 72.6 to 101.4 mbsf and recovered 28.5 m (95%). After Core U1609B-4H had partial recovery and required 20,000 lb overpull to retrieve, we switched to coring with the half-length APC (HLAPC) at 101.1 mbsf. HLAPC coring proceeded without incident, and after the last one, Core 32F at 234.1 mbsf, we ran the Sediment Temperature 2 (SET2) tool to measure formation temperature deeper than had been possible with the advanced piston corer temperature (APCT-3) tool in Hole U1609A. Cores U1609B-5F to 32F penetrated from 101.4 to 234.1 mbsf and recovered 133.0 m (101%).

At 1630 h on 25 December, we switched to the extended core barre (XCB) coring system. At 1600 h on 26 December, after taking Core 48X at 389.3 mbsf, we ran the SET2 tool a second time to measure formation temperature. At 2230 h on 26 December, we decided that the next core, 52X, would advance 3 m rather than the usual 9.7 m to realign the cores in Hole U1609B to cover stratigraphic gaps in Hole U1609A. XCB coring proceeded until strata reached the age of 8.4 Ma, old enough to cover the main events in the history of the Mediterranean–Atlantic gateways. Cores U1609B-33X to 61X penetrated from 234.1 to 508.7 mbsf and recovered 264.9 m (91%). At 1700 h on 27 December, we set back the top drive and started to pull up the drill pipe. The bit cleared the seafloor at 1905 h, and the bottom-hole assembly (BHA) was on deck by 2345 h. The thrusters were raised and we started the transit to proposed Site GUB-02A (Site U1610) at 2354 h, ending Site U1609. Overall, we spent 10.2 d at Site U1609, about two days shorter than in the original operations plan,

because the age targets were shallower than had been anticipated. For this reason, we were also able to recover two cored records of the target interval rather than the single core record that originally had been planned in the expedition *Scientific Prospectus.*

The ship completed the 122 nmi voyage to Site U1610 (proposed Site GUB-02A) at a speed of 11.5 kt, arriving at 1010 h on 28 December. The 3.5 kHz echosounder precision depth recorder (PDR) seafloor depth of 556.5 meters below sea level (mbsl) is slightly deeper than the expected seafloor depth of 547 mbsl.

Site U1610 has a target depth of 1464 mbsf, which will be among the deeper holes that the *JOIDES Resolution* has cored. The upper 501 m of the hole will be cased to prevent caving and to make it easier to flush cuttings out of the borehole, with the aim of increasing the chances of coring and logging successfully to the target depth. The Pleistocene and late Pliocene stratigraphy, which will not be recovered in the top 501 m at Site U1610, is already known from nearby Expedition 339 Site U1387, located ~27 km to the northwest.

The thrusters were lowered and the vessel switched to dynamic positioning (DP) mode, beginning operations at Site U1610 at 1037 h. At 1030 h the rig floor team prepared the rig floor and moonpool area, and at 1200 h they started to assemble the hydraulic release tool (HRT) assembly, the HRT base, and 498 m of 10.75 inch casing. On 29 December, the top of the 10.75 inch casing string was landed on the HRT base and hung beneath the ship. The base will sit on the seafloor after the casing is installed to provide a firm platform and to stop the reentry funnel from subsiding. The rig team then made up the BHA, including the bit, underreamer bit, and mud motor. The underreamer and mud motor were tested and found to operate well at a pressure of 300 psi. The BHA and drill pipe were lowered down through the casing until the bit and underreamer extended below the casing by 3 m. The HRT running tool was attached to the casing and the funnel was welded on; then the whole casing system was lowered down through the moonpool and the ship was positioned over the hole coordinates.

Hole U1610A started at 1200 h when the seafloor was tagged at 561.7 mbsl. We continued to drill in the casing, pumping five 30 bbl sepiolite mud sweeps to flush out sediment and keep the hole clear. The casing system was drilled in until it reached 480 mbsf at 1700 h on 30 December, when the subsea camera was deployed to observe the funnel’s approach to the seafloor. The base landed on the seafloor with the bit at a depth of ~506 mbsf. The HRT go-devil was dropped down the pipe to release the pipe and BHA from the casing system. After the release had been verified, the subsea camera was raised back to the ship. The bit was raised, clearing the seafloor at 2215 h and continuing to raise for the rest of the day.

COVID-19

One person remained in COVID-19 quarantine at the start of the week and ended their quarantine on 24 December. Those who had previously tested positive continued to wear masks for a further five days after testing negative, per the COVID Mitigation Protocols Established for Safe JR Operations (COPE) protocol. No further cases have appeared in the last week and it is likely that the ship is now free of COVID-19.

Science Results

Lithostratigraphy

Cores U1609A-66X to 73X (522.7–609.3 mbsf) and Cores U1609B-2H to 61X (72.6–507.8 mbsf) were described and the following lithological units and transitional contacts between them were defined.

Unit 1 extends from 0 to 344 mbsf and is composed of calcareous mud and calcareous silty mud, with dominant sediment colors of grayish olive (10Y 5/2) and grayish green (5GY 5/2). Lithological contacts are gradational and diffuse and are associated with subtle color changes. Calcareous nannofossils are abundant and there are occasional shell fragments and pyrite nodules. Subtle color mottling is present throughout. Sediments are initially interpreted as deepwater hemipelagic and fine-grained contourite deposits. Bioturbation is sparse to moderate, occasionally abundant, and trace fossils include *Chondrites*, *Planolites*, *Thalassinoides*, and *Zoophycos*. Where the calcareous mud was uniform over several tens of cm, bioturbation intensity can be hard to distinguish. Sometimes burrows are filled with silt and very fine sand.

Unit 2 extends from 344 to 457.7 mbsf and is composed of calcareous muds similar to Unit 1 (grayish olive; 10Y 5/2), but with a slightly coarser texture and clayey calcareous ooze (greenish gray; GLEY1 6/1). These sediments are initially interpreted as deepwater hemipelagic deposits, with occasional layers of fine-grained silty sand turbidites (dark greenish gray; GLEY1 4/1) with varying proportions of quartz, feldspar, glauconite, and calcareous and siliceous biogenic particles. Pyrite is disseminated throughout the unit. Some thinly bedded cross-laminations occur in places throughout the unit and are inferred to be fine-grained contourites. Contacts between lithologies are mostly gradational and diffuse and are marked by subtle color changes, except for the silty sand turbiditic layers, which have a sharp erosional base. Bioturbation varies from sparse to abundant. Trace fossils include *Chondrites*, *Planolites, Zoophycos*, *Thalassinoides*, and rare *Phycosiphon* and *Palaeophycos*.

Unit 3 extends from 457.7 to 531.5 mbsf and is composed of clayey calcareous ooze (pale green; GLEY1 6/1) with two distinct calcareous mud lithologies (olive gray; 5Y 5/2 and grayish green; GLEY1 5/2). The darker grayish green, homogeneous calcareous mud lithologies dominate Unit 3. Deposits are initially interpreted as deepwater hemipelagic, but there are also occasional layers of silty sand (dark greenish gray; GLEY1 4/1) interpreted to be fine-grained turbidites with varying proportions of quartz, feldspar, glauconite, and calcareous and siliceous biogenic particles. Pyrite is disseminated throughout the unit. Contacts between lithologies are mostly gradational and are marked by subtle color changes, except for the silty sand turbiditic layers, which have a sharp erosional base. Bioturbation varies from sparse to abundant and trace fossils include *Chondrites*, *Planolites, Zoophycos*, and *Thalassinoides*.

Unit 4 extends from 531.5 to 609.2 mbsf and is composed of the same three lithologies as Unit 3 (clayey calcareous ooze and two distinct calcareous muds); however, the three-part cycles are more closely spaced, repeating about every ~1 m. Also, the olive gray calcareous mud (5Y 5/2) is more dominant than the darker grayish green calcareous mud (GLEY1 5/2). The silty sand layers (dark greenish gray; GLEY1 4/1) are less common compared to Units 2 and 3. These sediments are initially interpreted as deepwater hemipelagic, with few fine-grained turbidites. Except for the silty sand layers, which have sharp erosional basal contacts, the boundaries between lithologies are mostly gradational, but are less diffuse than in higher units and are marked by more obvious color changes. Trace fossils include *Chondrites*, *Planolites, Zoophycos*, and *Thalassinoides*.

Biostratigraphy

Micropaleontologists sampled, processed, and observed 53 samples from Hole U1609B. A subset of sections and core catchers was sampled to fill in age gaps in Hole U1609A and to refine the dating for the site. This indicated that Hole U1609A spans 1.2–1.6 Ma at the seafloor to ~11 Ma at the bottom. Samples from Cores U1609B-25F to 29F, 37X, and 45X to 61X were analyzed for both calcareous nannofossils and planktonic foraminifera. All calcareous microfossils are typically abundant, with consistently very good preservation. The age of the bottom of Hole U1609B is estimated to be >8.8 Ma.

Benthic foraminifera assemblages were analyzed for a total of 18 samples to deduce paleoenvironmental conditions, including paleodepth, which is estimated to be >1200 mbsl. The assemblages are characteristic of a low-energy setting at the seafloor. Selected benthic foraminifera species were picked from 57 samples and a subset was cleaned by ultrasonification for postexpedition oxygen isotope analyses. The efficacy of the cleaning was checked by scanning electron microscope (SEM) imaging of individual

benthic foraminifera specimens before and after ultrasonic treatment to ensure the removal of adherent coccoliths and other debris.

Paleomagnetism

The natural remanent magnetism (NRM) intensity in Holes U1609A and U1609B is very weak, ranging from 1.5×10^{-5} to 5×10^{-3} A/m, and NRM removed by 10 mT alternating field (AF) demagnetization is likely related to overprint caused by core drilling. We measured the NRM of all the archive half core sections from Hole U1609B on the superconducting rock magnetometer (SRM). AF demagnetization was performed at 5, 10, 15, and 20 mT, with measurement of the remaining NRM being taken at 5 cm resolution in Hole U1609A and 2 cm for Hole U1609B after each demagnetization step. Inclination values from the NRM remaining after 20 mT demagnetization were used to identify magnetic reversals and to generate an integrated polarity pattern. To suppress the influence of the many scattered data points, we ran a smoothing window of 1 m for the inclination values and, based on the smoothed inclinations, multiple normal and reversed polarity intervals can be recognized. The magnetic directions appear to be more consistent in Hole U1609B than Hole U1609A. In Hole U1609B, all magnetic subchrons of the time interval between 3.5 and 9 Ma can be preliminarily identified. These results appear to be in general agreement with the biostratigraphic ages of the cores. Comparison of the inclination results of Hole U1609B with Hole U1609A shows that in the upper 400 m most reversals are replicable. Below 400 mbsf, polarity interpretation of the directional data from both holes is speculative and additional comparison with biostratigraphy and stratigraphic correlation between holes is required.

Geochemistry

The geochemistry team completed the standard shipboard geochemistry for samples from Hole U1609A. In the Chemistry Laboratory, new methodologies were developed for the shipboard analysis of the carbonate fraction of the squeeze cake samples to complement the data on the bulk sediments, and for microfossil cleaning for future shore-based geochemistry. The inorganic geochemistry team, assisted by the Chemistry Laboratory technicians, dissolved the carbonate fraction of the sediments and measured the elemental composition of the dissolved carbonates by inductively coupled plasma–atomic emission spectroscopy (ICP-AES) for 66 squeeze cake samples from Hole U1609A. Comparison of the natural gamma radiation (NGR) data with the discrete carbonate concentration data was found to yield a strong inverse relationship suggesting that carbonate cyclicity in the core can likely be predicted by the physical properties data to provide quantitative constraints on the changing lithologies of the core.

Physical Properties and Downhole Measurements

The physical properties data in Hole U1609A matches well with Hole U1609B, allowing the two successions to be correlated. Based on the long-term trends in the physical properties records, four units can be identified that are broadly consistent with the lithological units: Unit I (0–350 mbsf), Unit II (350–460 mbsf), Unit III (460–530 mbsf), and Unit IV (530–610 mbsf).

Physical properties at Site U1609 show obvious cycles across much of the succession. The thickness of these cycles varies downcore, broadly paralleling the change in sedimentation rate. In addition, several of the higher-resolution (2–10 cm) physical properties records, such as NGR, magnetic susceptibility, bulk density, and color reflectance, indicate the thin turbidite layers.

Logging data from the downhole logging operations in Hole U1609A were processed at Lamont-Doherty Earth Observatory and were sent back to the ship. The sonic velocity logs and check shot interval velocity values reached 2.25 km/s at the base of the logging interval, 578 mbsf. These in situ velocity data enabled the Hole U1609A stratigraphy to be more accurately tied to the seismic stratigraphy.

Outreach

Ship to Shore

We completed seven tours in total this week, including two for the families and friends of the science party and technical crew. Those two tours were recorded and are saved on the Zoom cloud. We are currently working to post these online, potentially on YouTube, but need to speak to the Marine Computer Specialists (MCS) about the best/fastest way to achieve this.

The seven tours this week were in three languages (Spanish, French, and English) and reached Morocco, Spain, and the United States (Florida and Washington). The family tours also allowed people from all over the world to join, including, but not limited to, Japan, Lebanon, Australia, and the United Kingdom. One tour was held in French for a Moroccan elementary school; the teacher sent us footage of the students watching the tour that was posted on our Instagram/Facebook story.

Social Media

- Currently, our top post for this week on Instagram is Erin's video about the science of Expedition 401.
- Our most-viewed post of the week on Facebook was our Christmas photo collection. Our second-most-viewed post on Facebook was also about Christmas.
- On Twitter, the video about palynology was the most viewed, reaching more than 3900 people. Our posts reach about 1000 to 3000 people on a regular day.
- Two Outreach Officer illustrations went online this week. One of these was presented as a video with a voice-over by one of the scientists, where she spoke about her background. Four additional videos were posted to the *JOIDES Resolution* account.

Other highlights

- We posted a blog on social media about how to weigh things on a ship, presented as a captioned set of photos. We hope to continue to do this kind of blog posting in the future. Turning our blogs into social media posts will hopefully draw more people to our website and keep people up to date with the science party's research.
- More scientists have volunteered for the "Science in 60 Seconds" series. The video starring the Operations Superintendent was completed and will be posted next week.
- Both Outreach Officers are posting on their personal accounts and sharing those posts to the *JOIDES Resolution* story. We are encouraging other scientists to do the same and have noticed an increase in the *JOIDES Resolution* accounts being tagged. Outreach will continue to do its best to share any posts the *JOIDES Resolution* is tagged in to further its audience.

Technical Support and HSE Activities

Laboratory Activities

- Staff processed cores and samples from Holes U1609A and U1609B. A total of 982.89 m of core was recovered from Site U1609.
- Siem Offshore crew performed maintenance on the H_2S sensor/bracket on the catwalk.
- The underway hydrophone produced a noisy signal during the Versatile Seismic Imager (VSI) deployment. On testing, a loose cable and the proper setting in the

new Schlumberger software were found. The signal was restored to 100% after both issues were corrected.
- The Haskris cooler for the X-ray diffraction (XRD) instrument was found to be losing flow. The heat exchange was removed and cleaned, and after several flushes, the flow rate was restored.
- Two Conductivity-Temperature-Depth (CTD) runs were performed during subsea camera deployment for the Hole U1610A casing system release and reentry. Both Niskin bottles were used to collect bottom seawater for paleontologist and chemists.

IT Activities

- Working with WifiGem to fix a false reporting issue that shows a user is logged on as a different user.
- Fixed a communications issue with the X-Ray Linescan Logger (XSCAN) serial connection.
- Configured a replacement solid-state drive (SSD) for the rig instrumentation display laptop and installed it in the unit to replace the faulty hard drive.
- Downloaded new software patches via ZENworks and prepared for deployment.
- Assisted SLB (Schlumberger) engineer with reinstalling a repaired SLB heave compensator control computer and establishing communications with the wireline heave compensator (WHC).
- Assisted XRD technician with installing database structures in TOPAS on Core Laboratory workstations.

Developer Activities

- Made a utility tool that can download core images with top and bottom depths attached to the filenames for import into Techlog software.
- Working with a staff scientist on shore to make an offset correction for the sample report.
- Worked on the hyperspectral imaging (Hyperscan) project.
- Deployed some minor IMS changes on the Section Half Imaging Logger (SHIL) (e.g., to ensure SCAN field has focus after VCD prints, etc.).

HSE

- Emergency shower and eye wash stations were tested.