IODP Expedition 399: Building Blocks of Life, Atlantis Massif

Week 1 Report (12–22 April 2023)

Introduction

International Ocean Discovery Program (IODP) Expedition 399, Building Blocks of Life, Atlantis Massif, is operating at the Atlantis Massif, an oceanic core complex at 30°N on the Mid-Atlantic Ridge. The core complex is capped by a corrugated fault zone and is composed of a large gabbro intrusion into hydrothermally altered (i.e., serpentinized) mantle rocks to the south. These altered mantle rocks host the Lost City hydrothermal field, which is famous for its carbonate-brucite chimneys the height of a 10-story building, venting alkaline fluids rich in hydrogen and methane. The hydrogen is formed by the reaction between seawater and the mantle rocks and is a powerful reducing agent that may have fueled the formation of the first building blocks of life on Earth. Before life could begin, small organic molecules must have formed abiotically, and because the hydrothermal alteration of mantle has been taking place throughout most of Earth's history, it may have been a key process in the formation of organic molecules. To look at active exchange of chemical components between fluid and rock and production of hydrogen and methane, we will sample fluids in the 1415 m deep Hole U1309D, before deepening it, to look at active exchange of chemical components between fluid and rock and production of hydrogen and methane. We are starting by drilling a shallow section at proposed Site AMDH-02A, which is expected to represent the subseafloor environments that reflect the processes leading to this remarkable system. Other aims of the expedition are to study the processes of formation of the Atlantis Massif, including magmatism, deformation, and high temperature seawater-rock interaction, as well as the microbes living within the rocks and in the borehole waters.

Operations

Port call and transit to first site

IODP Expedition 399 officially began in Ponta Delgada, Portugal, at 0800 h on 12 April 2023 with the *JOIDES Resolution* (JR) tied up at Dock 12, NATO Berth. Port call activities were minimal because most of the activities occurred during the tie-up in Tarragona, Spain. A critical Schlumberger freight shipment arrived, including the Ultrasonic Borehole Imager (UBI) and the high-temperature logging tool flasks, and was loaded aboard. All oncoming scientists and JRSO staff were arriving, or had arrived, in Ponta Delgada and were staying in a hotel, scheduled to board the vessel on 13 April. All personnel received a COVID self-test kit to be used the following morning, before joining the group and boarding the bus to the ship.

On 13 April, oncoming Siem Offshore crew and JRSO staff were tested for COVID-19 and boarded the ship where they conducted crossover meetings with their offgoing counterparts until 1400 h, when the latter departed the ship. The Expedition 399 scientists boarded the ship as well, and after check-in met at 1300 h for a general welcome and introductions, a ship safety video, and laboratory safety tours by JRSO staff. The COVID-19 Mitigation Protocols Established for Safe JR Operations (COPE) were followed, which included daily antigen tests and mask wearing for all personnel for at least 6 days. One individual tested positive for COVID and was quarantined on the ship. On 14 April, a second individual who had quarantined with symptoms tested positive for COVID. The last two JRSO staff members boarded the ship. All scientists attended presentations on life at sea, hazard communications, and shipboard IT systems and support.

On 15 April, one member of the science party disembarked the vessel. The Captain held the first boat drill at 1030 h. At 1400 h the voyage to proposed Site AMDH-02A began. On 16 April, senior personnel from Siem Offshore met with the science management team for the pre-spud meeting where details of the upcoming operations at proposed Site AMDH-02A were discussed. The scientists participated in rig floor tours in three groups and did not interact with Siem Offshore crew members, per COVID protocol. At 0530 h on 19 April, we arrived at Site U1601 (proposed Site AMDH-02A), completing the 937 nmi transit from Ponta Delgada with an average speed of 10.7 kt. The ship was in dynamic positioning (DP) mode by 0551 h, starting operations at Site U1601. The COVID mitigation period ended at 1815 h.

Hole U1601A

The objective at Site U1601 is to core a 200 m deep hole through the detachment fault at the Atlantis Massif. We chose IODP Site 357-M0069 as a reference location, which was drilled in 2015 with the British Geological Survey RockDrill 2 during IODP Expedition 357 on the RSS *James Cook*. The operational plan called for a reentry system installation, which required drilling a ~50 m deep pilot hole to assess the formation.

In the morning of 19 April, the rig crew assembled a bottom-hole assembly (BHA) with a rotary core barrel (RCB) and C-7 drill bit and lowered the drill string to 854 meters below rig floor (mbrf) near the seafloor. The precision depth recorder (PDR) depth of 848.4 mbrf corresponded well with the 849.6 meters below sea level (mbsl) seafloor depth reported by the remotely operated vehicle (ROV) *Jason* in 2018. The upper guide horn was removed and the subsea camera was deployed at 1150 h to ~14 m above seafloor for a brief seafloor survey. Site M0069 was immediately located thanks to several meters of pipe sticking out of the 2015 hole as well as various skid marks and sampling spots left by ROV *Jason* in 2018. Our survey line extended 60 m southwest of Site M0069 and showed sand waves along the seafloor, as were also seen more clearly on the 2018 ROV footage. No prohibitive obstructions or hazards were identified. After triggering the two Niskin bottles attached to the camera frame to collect bottom water samples, and tagging the seafloor at 861 mbrf, the camera and samples were retrieved. Back on the ship,

the Niskin water samples were immediately subsampled by the scientists for shipboard and shorebased analyses.

At 1810 h operations in the pilot Hole U1601A began by pushing the bit into the sediment with minimal rotation (5 rpm) and minimal pump (5 strokes/min) for 2.4 m. The coring line was damaged during the attempt to retrieve the first core barrel and 250 m of line had to be removed. The core barrel for Core U1601A-1R was retrieved at 2045 h and was empty. Core U1601A-2R was advanced 9.7 m, and subsequent Cores U1601A-3R through U1601A-12R, recovered on 20–21 April, were advanced 4.8 m or 4.9 m each to a total depth of 60.6 meters below seafloor (mbsf). Recovery ranged from 1% to 72%, with an average of 26% and increasing downhole. Starting at 25 m, 20 bbl sepiolite mud were pumped after each core recovery (every 4–5 m).

Although the objective of drilling a 50 m pilot hole had been achieved, we hoped to advance the hole further for at least another day given the increasing rate of recovery of the sought-after mantle rocks. However, at 1245 h on 21 April and 56.3 mbsf, the bit became stuck. The rig crew tried to free the bit at ~50 mbsf by maximizing overpull, torque, and pump pressure, attempting to move the drill string every hour, and offsetting the vessel 90 m north trying to break the drill pipe connection, without success. At 0045 h on 22 April the decision was made to deploy the Schlumberger pipe severing tool. Two severing attempts at 0705 h and 1035 h failed. The third attempt at 1243 h succeeded in severing the pipe at 10.1 mbsf. The tool was back on deck at 1330 h. The drill string was retrieved and the end of pipe cleared the rig floor at 1730 h, ending operations at Hole U1601A and starting Hole U1601B. The ship remained at the Hole U1601A location for the assembly of the drill-in casing system. The upper guide horn was removed to create the space needed to assemble the system. During the remainder of the night, the hydraulic release tool (HRT) was readied, and the 13⅜ inch casing was rigged up.

Scientific results

Preparations

During the port call and transit to Site U1601, the scientists attended numerous introductory presentations, including an Expedition 399 project overview, science objectives for the first site, outreach plans, scientific reports to be written during the expedition, and sampling and curatorial procedures. Meetings to coordinate sampling for microbiology, fluids, and rock geochemistry were held. Training sessions were offered for the operation of the physical properties multisensor core logger (MSCL) and other instruments, paleomagnetic instrumentation, core description, including configuration of description templates, microscopy, imaging, and handheld X-ray fluorescence (XRF) measurements.

Igneous petrology

Much of the first part of the week was spent constructing the macroscopic and microscopic templates for describing cores in hand specimen and thin section, respectively. These templates were edited as necessary while describing core. A spreadsheet for quantifying portable X-ray fluorescence spectrometer (pXRF) data through standardization was developed based on those used during IODP Expeditions 352 and 393. The first draft of the igneous petrology methods section also was developed. Later in the week, macroscopic features of Cores U1601A-1R through U1601A-12R were described. The section comprises a series of peridotites (harzburgite to dunite) with subordinate diabase, gabbro, and magmatic veins.

Alteration petrology

The Alteration Petrology team discussed the methods of core description, constructed GEODESC worksheet templates to log background alteration and hydrothermal vein formation, and wrote a draft of the Methods chapter. The team described Cores U1601A-2R through U1601A-12R following the procedures described in the Methods chapter. The rocks consist of partially to completely altered diabase, gabbro, harzburgite, and dunite. In shallower sections, hydrothermal alteration of harzburgite and dunite (i.e., serpentinization) was followed by oxidative aqueous alteration (i.e., weathering). The main alteration and vein-forming minerals observed are epidote and chlorite in diabase, amphibole and chlorite in gabbro, and serpentine and magnetite in dunite and harzburgite. Late-stage carbonate-bearing veins are also present throughout the peridotite sections.

Structural geology

The week was spent developing, improving, and uploading GEODESC templates for structural observations, preparing the structural geology methods section, and completing detailed macroscopic observations for Cores U1601A-2R through U1601A-12R (2.4 to 60.6 mbsf). Section 2R-1 recovered diabase, hosting 1 mm veins with increasing density of fractures downhole. Section 3R-1 had minimal recovery, and no observations were made. In Section 4R-1, a short (15 cm) interval of serpentinized harzburgite was recovered, hosting sheared, subvertical composite serpentine veins. Section 5R-1, with serpentinized harzburgite and dunite, hosts chromite segregations subparallel to the weak protogranular fabric (dip 27°). Two sets of serpentine and magnetite veins are noted, with subvertical and moderate dips. Section 6R-1 includes a short interval of altered, coarse-grained gabbroic rocks, with a localized crystal-plastic fabric (Interval 6R-1, 22–61 cm; 26.8–27.2 mbsf). Cores U1601A-7R through U1601A-12R recovered variably serpentinized harzburgite hosting protogranular to moderately developed, subhorizontal mantle fabrics, and serpentine mesh textures. The entire lower section (27.2–60.6 mbsf) hosts up to 3 generations of thin (typically less than 3–5 mm thick) veins with moderate, subvertical, and subhorizontal dips. Some veins exposed at piece-ends display slickenfibers with a normal sense of fault displacement.

Geochemistry

The Geochemistry team set up and revised the analytical methods for fluid and rock analyses. One bottom seawater sample recovered using a Niskin bottle was analysed for chlorinity, alkalinity, and pH. One basalt and one dunite sample from Hole U1601A were selected and processed for shipboard analyses.

Microbiology

Microbiology samples were collected from Hole U1601A bottom water using a Niskin bottle, and from Cores U1601A-2R, 5R, 6R, 8R, 9R, 10R, and 12R. Potentially contaminated exteriors of microbiology whole-round core samples were chiselled away on a clean bench, and the interior zones of the samples were crushed to mm-scale (roughly matching the crystal grain size of the rock). Outside pieces of the core samples were returned to the Core Description Laboratory to be characterized. Bottom water and crushed core samples were subsampled for future microbiological and geochemical analyses including DNA sequencing, enumeration of microbial cells, microscope imaging, metabolic activity assays, enrichment culturing, and organic characterization.

Petrophysics

The Petrophysics team trained on several instruments and developed methods for the whole-round section, section half, and discrete sample workflow. All cores from Hole U1601A were analyzed using the Whole-Round Multisensor Logger (WRMSL; magnetic susceptibility (MS) and gamma ray bulk density), the Natural Gamma Radiation Logger (NGRL), and the Section Half Multisensor Logger (SHMSL; point MS and color reflectance). Six cube samples were cut for discrete measurements and are being processed. Downhole measurement preparations included the assembly of the Novel Multi-Temperature Fluid Sampler (MTFS) for deployment in Hole U1309D later in the expedition. Whole-round measurement results indicate low natural gamma ray activity. Point MS and whole-round MS show values below 6000 IU with higher values at shallow and deeper intervals and intermediate and variable values at intermediate depths. Gamma ray attenuation (GRA) density has a generally decreasing trend with depth.

Paleomagnetism

Paleomagnetism sampling strategies were discussed among the Curatorial Specialist, senior technician, and scientists. Training and calibration for multiple instruments was carried out, including the JR-6A spinner magnetometer, DTech alternating field (AF) demagnetizer, superconducting rock magnetometer (SRM), MFK2 KappaBridge susceptibility meter, MS2B dual frequency susceptibility meter, and pulse magnetizer. Seven out of 12 archive section halves from Hole U1601A were analyzed using the SRM. The other five section halves contained units that were not suitable for SRM analysis because they were <8 cm long. Of the sampled lithologies, the ultramafic rocks (i.e., dunite, harzburgite) were found to have magnetic

intensities of ~1.5 A/m. This is two or three orders of magnitude stronger than the magnetic intensity of the sampled diabase. Overall, the magnetic intensity trends correspond relatively well with the MS trends measured with the MS2B. In the samples measured so far, inclinations trend toward the expected polarity direction (Matuyama reversed chron) with increasing AF fields and then begin to drift towards the direction of the current polarity direction (Brunhes normal chron). This suggests that the cores contain multiple remanent components.

Outreach

The shipboard Outreach Officer team posted on Instagram, Facebook, and Twitter, provided ship-to-shore broadcasts, hosted a Live Twitter Chat, wrote posts for the expedition log, sent postcards around the world, and published an education resource web page for teachers to supplement their Zoom connection with the ship.

Social Media

- The Outreach team's social media posts received 70,389 impressions (+277%), 4.2% engagements, and 251 profile visits.
- Facebook received three new photo posts, three new stories, and seven new reels. The JR account had 15,000 impressions (+153%) with 5,000 engagements (+122%) over the past week.
- Instagram received three new photo posts, three new stories, and 7 new reels, has reached 6,026 accounts (+423%), engaged 495 accounts (+190%), and has 4,000 (+0.4%) and 12,000 followers, respectively. Total number of views for Instagram in Week 1: 13,000 (+272%).

Ship-to-Shore Broadcasts

- During Week 1, we led five ship-to-shore broadcasts for ~200 people in four states (US).

Expedition Log (blog posts)

- Expedition 399 Log has one new blog post: Heading to the Atlantis Massif (22 April 2023), https://joidesresolution.org/heading-to-the-atlantis-massif/

Postcards

- A total of 310 postcards were sent to 41 states and 13 countries prior to embarking on the expedition. Another 18 people signed up to receive a postcard since the ship left port and will be mailed when we return to Ponta Delgada.

Feedback from Community

- "Ship looks beautiful!!! Thank you, endlessly, for taking us with you in your pockets."
- "I used to send a Bisset Berman down…(to) measure resistivity/temps salinity etc… Nice to see this clip, brought back memories! Thank you!"
- "I'm a geoscientist myself, or at least aspiring to be. Can I ask how to become eligible for one of the expeditions?"

Technical Support and Health, Safety, and Environment (HSE) Activities

Siem Offshore/Crew

- Engineers installed a filtration system on the chill water system, which is removing large amounts of debris from the water. The filtration started a week ago and requires the filter be changed every 6 h initially but is now down to twice per day. No more issues were reported on our chill water systems since this process started.
- Began ice preparations for the upcoming high latitude expeditions.

Miscellaneous Hardware Repairs

- Repaired the electric lifting mechanism on a core description table.
- Cleaned out the chill water line and the unit is now running well.
- Replaced all the blades from the rock saws and super saw.
- Assisted the microbiologists in chiseling samples.
- Placed Nitrogen bottles in the Radiation Van and Downhole Measurements Laboratory.

Downhole Laboratory

- Processed multibeam and GEBCO bathymetric data using QGIS for display in Petrel and Helmsman (for contingency planning).
- Successfully deployed Niskin bottles and the Conductivity-Temperature-Depth (CTD) instrument to collect bottom water samples prior to tagging Hole U1601A.
- Tested the Kuster water samplers and timers and serviced both units.
- Tested the Elevated Temperature Borehole Sensor (ETBS). Created a Confluence page for running the ETBS.
- Set up the Multi-Temperature Fluid Sampler (MTFS).

XSCAN:

- The modifications to the foundation worked well on the transit to control sway. Additional security attachments for severe rolls are being designed.

- As predicted, scanning of hard rock and image processing has been challenging. Power settings must be set much higher to get sufficient penetration, but this affects the white-dark correction and "burns" the edges of the rock image. Both raw and processed images of Expedition 399 igneous rock samples do show bands of denser minerals.
- A user guide page and technical documentation were added to Confluence. Presentations and training were given.

Core Description

- Core describers received laboratory, software, and instrument orientations this week and are working through descriptions for Hole U1601A.
- A GEODESC bug impacted two structural geology description templates that were significantly customized by scientists. We are working on three mitigation paths: recreate the templates and copy data over (limited confidence in success), find and fix the bug in Template Manager (most desirable path, requires shorebased developer support), and refresh the catalog with the desired configurations so scientists don't need to make changes in Template Manager (effective but less desirable workaround because it requires current EPM and shore support).

Curation

- A new downhole tool tag, "NB," was implemented in the SampleMaster and Catwalk programs for borehole water data from Niskin bottle samples. The first Niskin bottle run carried out so far in Hole U1601A had no issues.

Magnetics

- Testing of SRM IMS results for working and archive measurements is ongoing.
- Intensive training is required on all laboratory equipment for both scientists.
- Measurement protocols are currently being developed for AF and thermal demagnetization, sample dunking in nitrogen, isothermal remanent magnetization (IRM) acquisition, and back field experiments.

Imaging

- Established protocols for imaging microbiology samples before and after they are removed from the whole-round sections.

IRIS

- Debugging and testing of the Driller's Worksheet app (DWS) continued and included modification to support new functions.

- The Tracer pump app is working well in both standard and auto track mode. The latter is maintaining the correct concentration of tracer and mud pump rates and is shutting down the tracer pump when the mud pump has stopped.
- Continued to have problems running the data collector on a virtual machine. The program has now been moved to a dedicated workstation setup in the Marine Computer Specialist (MCS) office until a better solution is found.

Safety

- Held the weekly fire boat drill.
- Safety shower and eye stations tested.