IODP Expedition 399: Building Blocks of Life, Atlantis Massif

Week 6 Report (21–27 May 2023)

Operations

Hole U1601C

Week 6 began on 21 May while tripping the drill string to the seafloor for the fourth coring bit run (overall bit run 5). Hole U1601C was reentered for the fourth time at 0020 h. At 0105 h the camera was back on deck and the drill string continued to be lowered to the bottom of the hole. The drill string packed off at 944.5 meters below seafloor (mbsf) and was worked to 959.1 mbsf. A 20 bbl mud sweep was pumped at 973.0 mbsf. The core barrel was retrieved to confirm it was fully functional and dropped once more down the pipe.

At 0800 h coring resumed with Core U1601C-198R from 973.6 mbsf and continued to Core 240R at 1182.2 mbsf when, on 25 May, the bit had reached 50 h on bottom and needed to be replaced. At 1330 h, a final 30 bbl mud sweep was pumped, and the hole was replaced six times with seawater (2223 bbl, 19,000 strokes). The hole was then replaced with freshwater (drill water) (5550 bbl, 4710 strokes) in preparation for wireline logging. The last core barrel was on the rig floor at 1800 h. The drill string was retrieved to 55.5 mbsf where another 20 bbl of freshwater was pumped to top off the hole. Retrieval of the drill string continued, and the bit was on the rig floor at 2355 h. The tips off all four roller cones were lost. One of the cones had kicked inward, losing parts of the bearing including the plug seal. Dozens of tungsten carbide teeth were missing or damaged. This concluded the fourth coring bit run in Hole U1601C, which advanced the hole by 208.6 m and recovered 129.6 m, with core recoveries ranging from 22% to 94% (average recovery 62%).

We decided to conduct a full suite of wireline logging operations as well as borehole water sampling in Hole U1601C before attempting a final coring run in this hole. The intent of this sequencing was to minimize the various risks of not gathering the logging data for this >1 km deep legacy hole. On 26 May, a 3-stand bottom-hole assembly (BHA) with a logging bit was assembled, without floating valve and including a large bore landing saver. The rig was serviced and at 0145 h we began deploying the drill string. The subsea camera was launched at 0248 h and Hole U1601C was reentered for the fifth time at 0406 h. The bit was positioned at 30.9 mbsf and the camera was back on deck at 0448 h.

The first wireline logging tool string was assembled including the Schlumberger logging equipment head-mud temperature tool (LEH-MT) for borehole and tool temperature, the Hostile Environment Natural Gamma Ray Sonde (HNGS) tool, and the Hostile Environment Litho-Density Sonde (HLDS) for bulk density and photoelectric factor. We also added the IODP Elevated Borehole Temperature Sensor (ETBS) to the bottom of the tool string. The ETBS does

not transmit data in real time. Logging started at 0715 h and ended at 1530 h on 26 May. The log down tagged hard at 1077 mbsf (105 m above bottom). During both the log down and the log up the tool string was held every 100 m for 10 min for the ETBS to acquire temperature equilibration time series.

The second logging tool string, including the neutron Accelerator Porosity Sonde (APS), the High-Resolution Laterolog Array (HRLA) resistivity tool, and the Ultrasonic Borehole Imager (UBI) started at 1700 h and was completed at 0225 h on 27 May. The tool string tagged at 1071.5 mbsf, slightly shallower than the first run. Logging with the third tool string, including the HNGS and the Magnetic Susceptibility Sonde (MSS), began at 0300 h and ended at 0830 h. This run reached 1075.5 mbsf. For the fourth tool string, including the Versatile Seismic Imager (VSI), we targeted the daylight hours to comply with the wildlife protection protocols. At 1030 h the protected species watch and preparation of the air guns began. At 1400 h the logging attempt was aborted and postponed due to issues with cabling or software. Instead, we deployed the Formation MicroScanner (FMS) and Dipole Shear Sonic Imager tool (DSI) as the fourth logging tool string. This run began at 1445 h and ended at 2350 h with two log-up passes completed. This fourth run reached 1070.0 mbsf.

Core handling and shipboard sampling remained challenging and limited. The Environmental Health and Safety protocols implemented last week to handle cores in a safe manner resulted in the reestablishment of subsampling and yielded ~30 samples extracted from up to 16 shrink-wrapped section halves per day over six days. These protocols call for halting and reassessing procedures should any putative chrysotile fibers be identified on any laboratory surface. Fifty-five swab samples of laboratory surfaces and floors on 25 May and an additional 23 swabs were collected on 26 May. The presence of potential chrysotile fibers in a subset of these samples led to the halt of all core handling including splitting, description, and sampling, so that procedures could be reassessed. In the interest of continuing shipboard scientific work, suggestions for the assessment were sent to shore for consideration on 26 May, including the regular cleaning of laboratory surfaces and the floor, monitoring airborne particle counts, and collection and analysis of airborne particles onto filters during regular core handling and sampling activities.

Scientific Results

Igneous Petrology

The Igneous Petrology team described Cores U1601C-187R through 234R. The proportion and diversity of gabbros are elevated in these cores compared to those encountered shallower in the hole. Grain sizes are mostly medium to coarse, with clinopyroxene crystals exceeding 10 cm in a few cores. Troctolitic and other olivine-bearing gabbros are rarer here, and oxide gabbros and gabbronorites are more common, suggesting that the magmas intruding the peridotites are generally more differentiated deeper in Hole U1601C. Harzburgite alternates with dunite through

the cores described this week, with orthopyroxene proportions commonly, but not always, decreasing towards contacts with gabbroic rocks. All these mantle rocks are heavily serpentinized. The remaining thin sections from Hole U1309D and several of the gabbroic rocks from the shallower parts of Hole U1601C were fully described. The latter were noteworthy in the complex juxtapositioning of olivine-rich and olivine-poor areas, illustrating complex interactions between serpentinized mantle, intrusion, and deformation.

Alteration Petrology

The team performed macroscopic descriptions of Cores U1601C-177R through 234R. The dominant lithologies are serpentinized harzburgite and altered gabbro with subordinate amounts of serpentinized dunite, altered olivine-bearing gabbro, olivine gabbro, troctolite, gabbronorite, and oxide-bearing gabbro. Olivine is altered to serpentine and magnetite in mesh texture. Orthopyroxene is altered to serpentine and, in some instances, serpentine and talc in bastite texture. Veins chiefly consist of serpentine and serpentine plus magnetite. Almost all serpentinite cores feature one or more hydrothermally altered magmatic veins that range in size from <1 mm to >10 cm. Altered magmatic veins are commonly cut by picrolite veins. In gabbro, clinopyroxene is partially to completely replaced by amphibole, or assemblages composed of amphibole, chlorite, and clay minerals. Plagioclase is altered to chlorite, secondary plagioclase, and minor prehnite. Olivine in mafic rocks is altered to serpentine and magnetite, or assemblages made of clay minerals and sulfides. Common veins in gabbro include amphibole, chlorite, zeolite, and late talc, talc-carbonate, or talc-carbonate-prehnite-sulfide veins. Generally, the extent of hydrothermal alteration in gabbro increases close to the talc-bearing veins and locally at the contact with the serpentinite. Secondary mineral assemblages are indicative of hydrothermal alteration at amphibolite facies to subgreenschist facies conditions. Serpentinization varies in extent from ~70 vol% to >90 vol%. In general, the extent of alteration appears to be highest where mafic and ultramafic rocks are juxtaposed.

The team also examined and documented microscopic observations made in thin sections of gabbroic rocks from Cores U1601C-131R through 153R. In mylonitic gabbro, brown amphibole coexists with fine-grained granulitic pyroxene neoblasts, which form elongated trails of clinopyroxene porphyroclasts. Regardless of the degree of deformation, static alteration products, including green to colorless amphibole and chlorite/clay after pyroxene and olivine, are localized and typically occur in proximity to hydrothermal amphibole or chlorite/clay veins.

Structural Geology

Cores U1601C-187R through 234R (920–1153 mbsf) recovered serpentinized harzburgite and dunite, cut by progressively thicker intervals of troctolite, olivine and olivine-bearing gabbro, gabbronorite, and oxide and oxide-bearing gabbro. A ~30 m thick zone of variable dip (10°–80°) ductile deformation (protomylonite to ultramylonite) with dominantly reverse-sense shear was recovered between Cores 228R and 234R (1119–1151 mbsf). Throughout this interval the dip

progressively increases with depth. Brittle deformation (thin zones of cataclasis, piece end faults, etc.) is concentrated away from this zone and shows reverse-sense slip. Mantle fabrics defined by the shape preferred orientation of orthopyroxene throughout this interval have dominantly subhorizontal (0° ± 10°) dips, with rare short intervals <1 m that have dips up to 40°.

Vein intensity through the described interval decreases with depth. Talc veins with variable dips (15°–70° dip) are common, cutting gabbroic host rocks; undeformed steep dark amphibole veins commonly cut intervals with mylonitic fabrics. Subhorizontal, thin white chrysotile veins are common throughout recovered harzburgite.

Geochemistry

The fluid geochemists prepared for downhole logging and seafloor and borehole water sampling at Hole U1601C.

Sixty-five samples of serpentinized peridotite and gabbro from Hole U1601C, collected primarily for microbiology studies, were processed for shipboard geochemical analyses, in addition to 12 gabbro samples that were primarily selected for shipboard geochemistry analyses. Ninety-six samples of serpentinized peridotite and gabbro from Site U1601 were analyzed by inductively coupled plasma–atomic emission spectroscopy (ICP-AES) for major and minor elements. Fifty-six samples of serpentinized peridotite and gabbro from Site U1601 were analyzed for carbon and water contents. A new method for the analyses of carbon depleted samples using coulometry was developed. The results are currently being assessed.

Microbiology

Microbiology samples were collected from 20 cores from Cores U1601C-199R through 240R. Potentially contaminated exteriors of microbiology rock samples were chiselled away in a fume hood with a KOACH air purifier and an air ionizer for static dust removal. Interior zones of the samples were crushed to millimeter-scale. The crushed interior core material was subsampled for future microbiological analyses including DNA sequencing, enumeration of microbial cells, microscope imaging, metabolic activity assays, enrichment culturing, and organic geochemistry.

As before, microbiological analyses, including enumeration of microbial cells, single-cell activity assays, and filtering for DNA sequencing, were conducted with bottom water near Hole U1601C that was sampled with Niskin bottles during recovery of the drill bit and after reentry of the hole. In addition, microbiological subsamples for enumeration of microbial cells and single-cell activity assays were collected from small volumes of water collected from core liners.

Because the processing of core samples required less time this week, the Microbiology team was able to conduct cultivation experiments and to examine previously collected samples under the microscope. Microbial cells stained with acridine orange (a DNA-binding fluorescent stain) were

observed in samples of serpentinite core material from Hole U1601C and in minerals that were collected earlier in the expedition with the Multi-Temperature Fluid Sampler in Hole U1309D.

On May 28, the Microbiology team was preparing to collect and analyze water samples from Hole U1601C collected with the Kuster Flow Through Sampler.

Petrophysics

The Physical Properties team measured bulk density, magnetic susceptibility (MS), and natural gamma radiation (NGR) on whole round Cores U1601C-197R through 240R (968–1182 mbsf). Bulk density ranges from 2.45 g/cm^3 to 2.7 g/cm^3 in serpentinized peridotite and from 2.6 g/cm^3 to 3.0 g/cm^3 in gabbro. This is an increase in density for both rock types compared to the top of the hole. The MS is typically ~7000 IU in serpentinized peridotite and does not vary. The MS is variable in gabbro with some values approaching 0 IU in gabbro and olivine gabbro and much higher values in Fe-Ti oxide gabbro. The highest MS value in this interval occurs in Section U1601C-211R-1 (~1037 mbsf) with a value of 20,000 IU in an Fe-Ti oxide gabbro interval. Fe-Ti oxide gabbro is more abundant in this interval compared to the rest of the hole. NGR is typically low with values <1 counts/s. The highest NGR values occur in Section 220R-1 (1081 mbsf) with values of ~2.5 counts/s.

Fifty-one discrete samples were measured, including 6 cubes and 45 cuttings from microbiology samples. Grain density, porosity, and *P*-wave velocity were measured on the cubes. The cuttings are irregular and most useful for determining grain density. Grain density ranges from 2.6 to 2.7 g/cm^3 in serpentinized peridotite and between 2.7 and 3.2 g/cm^3 in gabbro. Grain density generally increases with depth in the serpentinized peridotite. Grain density in gabbro is variable and does not follow a general pattern with depth. Porosity from cube samples has only been completed for gabbro and ranges from 0.3% to 2.8%.

P-wave velocity was measured on 33 cubes from Cores U1601C-131R through 215R (649–1061 mbsf) and 61 archive section half pieces from Cores 137R through 215R (678–1061 mbsf). *P*-wave velocity in those intervals ranges from 3.8 km/s (dunite, Section 161R-2, 796.4 mbsf) to 6.5 km/s (olivine gabbro, Section 139R-1, 688.4 mbsf). The apparent anisotropy of *P*-wave velocity measured on the cube samples ranges from 1.3% in olivine gabbro (Section 139R-1, 678.4 mbsf) to 11.8% in harzburgite (Section 148R-3, 734.9 mbsf) with the mean *P*-wave velocity of 5.3 km/s, where velocity parallel to the *z*-axis (5.0 km/s, vertical) was 0.6 km/s slower than the velocity parallel to the *x*-axis (5.6 m/s; horizontal, into the core).

Thermal conductivity was measured on 47 archive section half pieces. This included 21 gabbroic samples (gabbro, gabbronorite, olivine gabbro, olivine-bearing gabbro, and oxide-bearing gabbro) and 26 serpentinized peridotite samples (harzburgite, dunite, and orthopyroxene-bearing dunite). Thermal conductivity values for all samples ranged from 1.835–4.180 W/(m·K) with a mean of 2.938 ± 0.5881 W/(m·K). Values for gabbroic samples ranged from 1.835–4.09 W/(m·K) with a mean of 2.638 ± 0.642 W/(m·K). On average, thermal conductivity was

higher and less variable in serpentinized peridotite, ranging from 2.594–4.195 W/(m·K) with a mean of 3.179 ± 0.4131 W/(m·K). Thermal conductivity generally decreases with depth, likely due to a shift in lithology from primarily serpentinized peridotite to primarily gabbroic rocks. This is in good agreement with values and trends seen in the upper portions of Hole U1601C.

The first wireline logging run was completed in Hole U1601C, including the ETBS, which indicated a temperature of ~70°C at 1077 mbsf in the hole.

Paleomagnetism

Measurements of natural remnant magnetization (NRM) and remanences following stepwise AF demagnetization were conducted on archive section halves of Cores U1601C-126R through 202R using the superconducting rock magnetometer (SRM). Initial magnetizations were progressively demagnetized up to 50 mT. Inclination values were found to be more widely distributed below 400 mbsf than those above 400 mbsf. Some intervals within this week's sampling range were found to have positive inclination values, even with increasing demagnetization. The validity of these results has yet to be verified.

During the earlier part of the week, we were able to obtain ~6 cubes per day for discrete measurements. Samples with a wide range of susceptibility values were selected. All samples from Cores U1601C-129R through 215R were measured for their anisotropy, bulk susceptibility, and NRM, and all samples were subjected to low temperature pretreatment. To comply with safety measures, harzburgites samples were only subjected to AF demagnetization, whereas gabbro samples were also subjected to thermal demagnetization experiments.

Outreach

An article was published in Science Magazine following interviews with shipboard scientists. The article highlighted the achievement of drilling the deepest IODP/ODP/DSDP Hole (Hole U1601C) in mantle rocks, and the importance of this to the scientific community (https://www.science.org/content/article/long-last-ocean-drillers-exhume-bounty-rocks-earth-s-mantle).

This week, the Outreach Officers posted on Instagram, Facebook, and Twitter, provided ship-to-shore broadcasts, edited videos, interviewed members of the expedition, and wrote posts for the expedition log.

Social Media

- The Outreach team has posted to Twitter with 44,854 impressions (+103%) and 3.7% engagements (−0.2%), with 92 profile visits (+179%).
- Facebook has received 5 new photo posts, 1 new story, and 1 new reel, and has reached 163,200 accounts (+132%), engaged 87,700 accounts (+56%), and has 12,000 followers.

- Instagram has received 2 new photo posts, 2 new stories, and 4 new reels, has reached 5,129 accounts (+42.9%), engaged 381 accounts (+34.1%), and has 4,000 (+0.5%) followers. Total number of views for Instagram in Week 6: 7,100.

Ship-to-Shore Broadcasts

During Week 6, we led 10 ship-to-shore broadcasts for ~230 people in two states (US), Australia, South Africa, China, France, Germany, Spain, and Antarctica.

- Orange High School, New South Wales, Australia
- Parklands College, Cape Town, South Africa
- Shanghai Jiao Tong University, Shanghai, China
- Academie of Montpellier, Montpellier, France
- University of Halle, Halle, Germany
- Allerton Library, New York City, NY, USA
- IES Delicias, Valladolid, Spain
- FDR High School, New York City, NY, USA
- US Antarctic Program, Denver, Antarctica (remote)

Expedition Log (blog posts)

The Expedition 399 Log has 1 new blog post:

- Processing Microbiology Samples Onboard (26 May 2023): https://joidesresolution.org/processing-microbiology-samples-onboard/

Feedback from Community

“Thank you very much for your cooperation in today’s big event at the exhibition booth and for your cooperation in many test communications and adjustments! We had a wonderful time! I’m deeply impressed! We had a great time. We had a lot of participants and so many interested people stopped by the booth. I would like to express my sincere thanks to all of you.” (JpGU 2023, Japan)

“We have to thank you for the exciting tour of the ship! The students were enthusiastic about it.” (Chieti-Pescara University, Italy)

“A HUGE thank you for the most wonderful tour this morning! Our learners thoroughly enjoyed learning more about the research you are doing and the different roles the various scientists and engineers have on board. They loved seeing the ins and outs of the ship and wish you all the best for the rest of your voyage. Thank you again for taking the time to meet with us.” (Parklands School, South Africa)

“Thank you so much for the amazing tour of the JR earlier today! It was an incredible experience and overall we were really fortunate to have a good connection. So sorry for losing you at the end! We were able to see and hear you after you reconnected, but it seemed that our connection dropped? We all were saying goodbye and wanted to thank you for taking the time out of your busy schedules, it really means a lot for all of us!

Also, please say thank you from us to Kuan-Yu Lin and Haiyang Liu for taking their time for the Q/A session! This was really awesome for the students to have a chance to talk with you on the ship!

Wishing you all the best and much success! Safe travels and take care :)” (Shanghai Jiao Tong University, China)

“A big thank you Margot, Rémi, Sarah and Lesley! It was incredible, not a fly was flying in the room, unfortunately towards the end of your guided tour the quality of the image degraded and the students started to gesticulate on their seats. But the experience was very enjoyable for the majority of the teachers present and the students. I think they will remember it!” (Academie of Montpellier).

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

Downhole Measurements

- No report this week as all personnel were busy with water sampling and vertical seismic profiling activities.

Curation

- Shipboard sample selection continued for three more days, and four billet cutting sessions were held. On Friday, core and sample processing ceased due to the documentation of fibrous material in the Core Laboratory. We currently have 19 unsplit sections from Hole U1601C. More cores are expected in a few days.
- A description of the special core handling and sampling processing was sent to shore to prepare for postcruise curation needs.

Imaging

- All microbiology samples were imaged on the catwalk before they were removed, including some macro images of sample details; some processing is ongoing.
- Backlogs exist for the creation of whole-round section image composites, close-up images, and weekly images to shore.

Chemistry Laboratory

- We experienced problems with the Mettler balance, which is worked on with help from shore. The balance in the X-ray Laboratory is used instead for the time being.

IT Support

- Updated various workstations and server software.
- Continued setting up Starlink for alternate internet access.
- Resolved expired email server certificate issues with TAMU Infrastructure.

IRIS

- Due to last week's activity, little testing was performed.
- After adding two more features to the OPD interface, it will be ready for user testing.

Safety

- A weekly fire boat drill was held.
- The eye wash and safety showers were tested.
- Swab survey for the presence of chrysotile fibers was conducted in the Core Laboratory and adjacent spaces. Potential chrysotile fibers were identified in several samples from the Core Description area as well as from the main stairwell outside the Core Laboratory. No other locations outside the laboratory working areas contained identifiable potential fibers. Currently working with shore management to adjust core processing.