IODP Expedition 376: Brothers Arc Flux

Week 7 Report (17–23 June 2018)

The seventh week of the International Ocean Discovery Program (IODP) Brothers Arc Flux Expedition (376) consisted of (a) rotary core barrel (RCB) coring, downhole fluid sampling, and downhole measurements in Hole U1530A, and (b) RCB coring in Holes U1531A and U1531B. All times in this report are in ship local time (UTC + 12 h).

Operations

This week began while we were RCB coring in Hole U1530A. Half-length (4.8 m advance) Cores 58R to 93R penetrated from 280.3 m to a final depth of 453.1 m by 19 June, and recovered 22 m (13%). Overall, we recovered 76.8 m (17%) of core material in Hole U1530A. We pumped 30-barrel high-viscosity mud sweeps on every other core to keep the hole clean, and hole conditions were good throughout coring. Given the trend of decreasing recovery without a change of formation combined with the successful penetration to a depth significantly deeper than the caldera floor, we decided to terminate coring in Hole U1530A so that we could take advantage of the good hole conditions for downhole measurements. After circulating two 30-barrel mud sweeps to clear cuttings out of the hole, we lowered the rotary shifting tool (RST) on the core line to release the bit in the bottom of the hole. The bit released at 0645 h on 19 June, and we lowered a RCB core barrel to confirm the bit release. At 0945 h, we noticed the core line was frayed, which we fixed by cutting off 150 m of line.

Our downhole measurement plan for Hole U1530A consisted of running (1) the Elevated Temperature Borehole Sensor (ETBS) tool, (2) the Kuster Flow-Through Sampler (KFTS) tool, and (3) the triple combination logging tool string ("triple combo:" natural gamma ray, porosity, and density sondes). At 1030 h on 19 June, we assembled the ETBS for downhole temperature measurements and lowered the tool on the core line to the seafloor at 20 m/min until it reached the bottom of the hole, where we held it stationary for 15 min. Upon recovery, the ETBS had recorded a temperature of 40°C. We then deployed the KFTS to collect borehole fluids and lowered it at half the normal core line speed to ~20 m above the bottom of the hole with circulation stopped. We waited 15 min for the mechanical clock of the KFTS to trigger the closure of the valves and then pulled it back to the rig floor. Unfortunately, the valves failed to close completely and did not recover a sample. We then raised the end of the drill string to a logging depth of 67.1 m, started preparing the triple combo tool string, and lowered it into the hole, where it reached a fill at 442 m at 2015 h on 19 June. After a short calibration pass, we lowered the tool back to 442 m and started a full logging run up to the seafloor. The tool string cleared the seafloor at 2300 h and returned to the rig floor just before midnight. After disassembling the triple combo logging tool string, we ran the Formation MicroScanner (FMS)-

sonic logging tool string in Hole U1530A, where it encountered fill at 442 m, ~11 m above the bottom of the cored hole. We then conducted two logging passes to just below the end of the pipe at 51.8 m. After the FMS-sonic tool string returned to the rig floor at 0725 h on 20 June, we lowered the end of the drill string to 416.2 m, picked up the top drive, and deployed the KFTS to sample borehole fluid. We lowered it at half the normal core line speed to ~20 m above the bottom of the hole with circulation stopped. We waited 15 min for the mechanical clock of the KFTS to trigger the closure of the valves, pulled it back to the rig floor, and recovered the fluid sample on the core receiving platform. At 1245 h on 20 June, we rigged up the third-party Petrospec spool-in Thermocouple Memory Tool (TCMT) and deployed it on the wireline into the hole at half the normal core line running speed. We started circulating at 20 strokes per minute to cool the temperature-sensitive TCMT data logger while it was inside the drill string and then lowered it 8 m past the end of the drill pipe to 447 m and waited 10 min. After recovering the tool back to the rig floor, this first deployment of this newly designed high-temperature TCMT had recorded a temperature of 20°C. We set back the top drive and started pulling the drill string out of the hole, clearing the seafloor at 1540 h. As we continued to recover the drill string further, we began moving the vessel to shallower water Site U1531 (proposed Site LC-1A) using the dynamic positioning system. At 1806 h on 20 June, we arrived at Site U1531, located on the saddle between the Lower and Upper Cone of Brothers volcano. The end of the drill string (mechanical bit release) arrived back on the rig floor at 2005 h on 20 June, officially ending Hole U1530A. We then reassembled the rig floor and conducted a routine cut and slip of the drilling line before we had to stop operations due to storm-force winds and high seas. The following 35.75 h were spent waiting on weather to improve enough to continue operations. At 1000 h on 22 June, we made up a RCB bottom-hole assembly (BHA) and lowered it to the seafloor at Site U1531. At 1430 h, we deployed the subsea camera system to perform a seafloor survey and verify the exact seafloor depth at three potential hole locations. After retrieving the subsea camera system and picking up the top drive, we started RCB coring in Hole U1531A at 2030 h on 22 June. Core U1531A-1R penetrated from the seafloor to 15 m, but we experienced excessive torque and overpull and had to pull the drill string out of the hole. After the bit cleared the seafloor (at 2330 h), we lowered the core line to recover Core U1531A-1R (1.5 m recovered; 7%) at 0045 h on 23 June. We then started RCB coring in Hole U1531B. Cores U1531B-1R to 3R penetrated from the seafloor to 26 m and recovered 4.0 m (15%). Drilling conditions were very poor with high torque, overpull, and frequent stalling of the top drive; the drill string became stuck several times. These conditions forced us to start pulling the drill string out of the hole before Core U1531B-3R could be retrieved. After the bit cleared the seafloor at 1420 h on 23 June, we recovered Core U1531B-3R, deployed the subsea camera system, offset the vessel 110 m to the northeast, and started a seafloor survey at 1730 h. During the survey, we tagged the seafloor in two locations to verify the exact seafloor depth. We then retrieved the subsea camera and started coring in Hole U1531C at 1930 h on 23 June. Core U1531C-1R penetrated to 15 m and just before midnight we circulated a 30-barrel high-viscosity mud sweep to clean the hole.

Science Results

This week, scientists continued to describe and process cores from Hole U1530A and worked on collecting, analyzing, and writing up results from Holes U1530A and U1528D. Scientists submitted their Site U1528 Reports. Also, the second sampling party for postcruise research was held.

Core Description

The Igneous Petrology/Volcanology team described Cores 376-U1530A-56R to 93R (271–449 m) and selected samples for shipboard analyses together with other laboratory specialty groups (Cores 39R to 93R). Cores 56R to 93R comprise a sequence of intensely altered volcaniclastic and completely altered volcanic rocks. In the lower part of Hole U1530A, five distinctive lava horizons were defined based on the texture of pseudomorphs after glomerocrysts. Microscopic descriptions of Hole U1530A (thin sections TS85 to TS120, Cores 1R to 91R, 0–439 m) confirmed that the rocks exhibit a strong hydrothermal overprint such that no primary igneous minerals remain and primary igneous textures are uncommon. The strong hydrothermal overprint is also evident in the portable X-ray fluorescence (pXRF) data (Cores 1R to 93R, 0 to 449 m; $n = 86$). Despite intense alteration, Ti/Zr retrieved from pXRF data are similar to the unaltered dacites from Brothers volcano. The stratigraphy of Site U1530 was subdivided into five igneous units. Later in the week, we described cores recovered from Site U1531 located at the Lower Cone (Cores U1531A-1R and U1531B-1R to 3R). They consistently consist of unaltered to slightly altered fragments of moderately vesicular, plagioclase-pyroxene phyric dacite lava as well as polymict ash and lapilli tephra. Shipboard analyses are in progress to further characterize the rock material recovered from Holes U1531A and U1531B.

The Alteration Mineralogy group continued to describe and document alteration mineralogy and textures of material recovered from Hole U1530A (Cores 51R–93R). These consist of blue-gray, green-gray, and buff-brown colored altered volcaniclastic rock, intercalated with more massive units that are classified as intensely altered. From Cores 39R to 59R, a new alteration type was identified consisting of buff to brown, anhydrite- and silica-rich but pyrite-poor alteration. Silicification continued to be highly variable with brown-buff alteration generally exhibiting higher degrees of silicification than blue-green units. Pyrite remained ubiquitous in blue-gray units throughout Hole U1530A. A total of 35 thin sections from Hole U1530A reveal an intense, pervasive silicification throughout the hole. Silica occurs as quartz, chalcedony, or minor cristobalite, forming discrete veins, intergrown with clay in the matrix or infilling vugs. Anhydrite continued to be the dominant sulfate phase, forming disseminated euhedral grains within the matrix or as aggregates associated with pyrite. The latter is the most abundant sulfide mineral, forming coarse-grained, subhedral to euhedral disseminated crystals. In some instances, pyrite also contains visible inclusions of sphalerite. X-ray diffraction (XRD) data has been obtained and interpreted to a depth of 315.0 m and shows a transition from cristobalite- to quartz-rich intervals with increasing depth and the occurrence of pyrophyllite below 191.0 m.

Illite, smectite, and chlorite form the dominant clay phases and pyrite is present throughout. Based on macroscopic observations, XRD, and thin section analysis, we have proposed the subdivision of Hole U1530A into five Alteration Types, primarily based on the dominant alteration assemblage. Initial fluid inclusion studies indicate cooling of the system by about 100°C, from 350°C in primary fluid inclusions in closed veins to about 250°C in quartz in open vugs. We also started to describe the dacite lava recovered from Site U1531, which has only a slight alteration if any. The alteration assemblage consists of iron-oxyhydroxide, clay, and minor zeolite, forming a light grayish to reddish brownish tint.

The Structural Geology team completed data acquisition on Hole U1530A cores, including both macroscopic and microscopic observations. The main structures are volcanic fabrics, alteration veins, and fractures. A few intervals have volcanic fabrics defined by elongated vesicles, filled by secondary phases. Volcanic fabric dips are usually greater than 45°. Alteration veins are typically filled with either anhydrite and pyrite, or silica/quartz and pyrite. In some examples, silica/quartz and pyrite veins have been reopened by anhydrite veins and vice versa. Veins have a wide range in dip from horizontal to vertical that varies downhole. The large majority of veins have a dip greater than 60°. There are some zones where there is a wide range in dip and a large abundance of veins, and in other zones there are fewer veins with a more limited range of dips. Vein thickness ranges from 0.05 to 2 cm and has an average of ~0.2 cm. There are fewer fractures compared to veins, and they also have a large range in dip. Five slickenlines were measured, all with relatively steep rakes and a normal sense of shear.

Geochemistry

Geochemical analysis of 68 powders from Hole U1530A was performed via inductively coupled plasma–atomic emission spectroscopy (ICP-AES) for major, minor, and trace elements, and elemental analysis for total carbon, total nitrogen, and total sulfur. Results of these analyses were used to assess major geochemical changes during hydrothermal fluid-seawater-rock interactions in Hole U1530A. Variable extent of depletion and enrichment in alkalis (potassium, sodium), magnesium, iron, and manganese, as well as strong enrichment in sulfur (up to 25 wt%), occur throughout Hole U1530A. There also is significant enrichment in Zn (up to 5.2 wt%), Ba (up to 3.2 wt%), As (up to 660 ppm), Pb (up to 100 ppm), and Mo (up to 560 ppm). The geochemical data were described in tandem with Igneous Units and Alteration Types boundaries. After coring in Hole U1530A, the 600 ml KFTS tool was deployed two times; the second one successfully recovered a borehole fluid sample from 435 m in Hole U1530A. The in situ fluid temperature was estimated at less than 37.6°C based on ETBS downhole temperature measurements that preceded the collection of the fluid sample by 5 h. Initial assessments of fluid chemistry have indicated that the fluid is slightly acidic, with a pH value of 6.7, and has a salinity of 3.6% that is near seawater values.

Paleomagnetism

This week has been dedicated to measuring the magnetic properties of archive section halves and discrete samples from Hole U1530A. The trend of natural remanent magnetization (NRM) intensity before demagnetization experiments has shown a strong correlation with the subdivisions of Igneous Units. Thermal demagnetization and alternating field (AF) experiments have shown that Igneous Units 1, 2, and 4 are characterized by low NRM intensities with low coercivities and complex thermal curves with changes in the magnetic minerals occurring after heating the samples at temperatures >400°C, producing a significant increase in the NRM intensities and magnetic susceptibilities (MS). Igneous Units 3 and 5 are characterized by slightly larger NRM intensities and simple AF and thermal curves, indicating a primary stable magnetization component with very minor overprint. The magnetization directions at Site U1530 are shallower than at Sites U1527 and U1528, but generally consistent with the inclination of the current geomagnetic field at the location of Brothers volcano, with the exceptions of positive inclinations that have been measured in the interval of Igneous Unit 2.

Petrophysics

In Hole U1530A, high porosity and low bulk density occur in the sedimentary subunits within Igneous Unit 2 and also in the clay-rich material at the top of Igneous Unit 4 that is associated with the lowest *P*-wave velocities. This clay-rich material also has high grain densities of up to 3.5 g/cm^3. The transition from Igneous Unit 4 to 5 is marked by higher bulk densities, lower porosities, higher *P*-wave velocities, and higher MS, which remain consistent throughout Unit 5. Thermal conductivity values increase steadily with depth throughout Igneous Unit 4 and remain high but with some scatter within Igneous Unit 5. No peaks in natural gamma ray (NGR) of >30 counts/s are seen below a depth of ~30 m. The NGR peak of ~340 counts/s detected in Core U1530A-4R therefore remains the highest value observed at this and other Brothers drill sites to date.

A series of downhole measurements was acquired in Hole U1530A. An ETBS temperature measurement recorded at 428 m showed an increase from 32°C to 40°C within 15 min after stopping circulation. This was followed by an unsuccessful KFTS tool deployment due to a problem with a screw blocking a valve. We then conducted two wireline logging runs. The triple combo wireline logging tool string (temperature, density, porosity, resistivity, and spectral gamma ray) recorded a maximum temperature of 92.5°C at 453.5 m. This temperature was 6 h after stopping circulation; 1.5 h later, this increased to 94.4°C at the start of the second upward logging pass. Capillary tube thermometers inserted in the wireline logging tools recorded maximum temperatures between 80° and 115°C. The borehole was found to be enlarged by up to 17 inch down to 350 m (drilled diameter is 9.725 inch). The transition from altered volcaniclastic rocks to altered volcanic rocks with intercalated lava identified by the core description team is clearly detectable on the resistivity log. Due to the sufficiently low temperature, the FMS-sonic tool string could be deployed to acquire resistivity images, sonic velocities (V_p, V_s, and Stoneley

waves) and temperature. Without circulating seawater between the logging runs, the temperature was found to have decreased to 40.5°C at 454.2 m within the 6 h after the triple combo logging run, and then decreased to 37.6°C at the start of the second upward logging pass log that took place 3 h after the first one. A successful fluid sample was then collected, followed by a successful test of the Petrospec TCMT, which measured a temperature of 20°C at both measurement points (1 m above the end of pipe at 427 m, and 8 m below the end of the pipe). We received the processed downhole logs and interpretation will continue during Week 8.

Microbiology

During Week 7, eight whole-round samples from Hole U1530A were chosen, subsampled, and stored by microbiologists for postcruise research. Perfluoromethyl decaline (PFMD) contamination tests for core and drilling fluid samples from Hole U1530A were performed. For most of the samples, PFMD was detected at low levels. However, a sample from Core 49R (U1530A-49R-1, 56–63 cm) showed high concentrations of PFMD in both outside and inside layers of core (>290 ppb). In addition, the concentrations of PFMD in three drilling fluid samples were measured lower than expected. For this reason, at Site U1531 we plan to increase the PFMD tracer pump rate 10× and collect contamination test samples from every core.

Education and Outreach

Week 7 saw the number of live events continue to taper off with the conclusion of the U.S. school year. In total, we conducted six events to France, Germany, and Canada. The GEOMAR Helmholtz Centre for Ocean Research Kiel linked up with us twice as part of a local festival in Kiel, Germany. These were hosted on the R/V *Alkor*, which was docked in the port of Kiel. An audience of several hundred attended a live ship-to-shore event with the Resources for Future Generations (RFG) 2018 conference in Vancouver; this event generated a lot of Twitter activity. Another event was conducted with the Society of Economic Geologists (SEG) Student Chapter at TU Bergakademie Freiberg, Germany.

With the workload for live events decreasing, additional time could be spent on producing outreach content and developing ongoing projects. This resulted in the production of several videos and blog posts consisting of science content, scientist profiles, and *JOIDES Resolution* (JR) operations not yet covered during this expedition. One of these videos was a first for IODP: a broad-scope video about the JR's global operations produced and narrated in Te Reo Māori, the indigenous language of New Zealand. Three blogs were posted on the JR web page (http://joidesresolution.org), covering the topics of microbiology, thermal conductivity, and waste management. We also created our fourth classroom activity about navigation, latitude, and longitude.

It was a very successful week for our social media. On Facebook (https://www.facebook.com/joidesresolution), our posts reached 22,736 people (an increase of 164%) and engaged 6,053 (an increase of 174%). The most popular post was a photograph of a segment of bottom-hole assembly pipe that had been extensively damaged by the hot corrosive fluids from Site U1528. This post reached 16,100 people and engaged 1,800, our most popular post of the expedition so far. Our videos on Facebook accrued a total of 4,529 views (an increase of 132%). We produced two "Scientist Spotlight" videos (covering volcanology/sedimentology and alteration mineralogy) in a series that we plan to continue to cover the key science specialties of Expedition 376. Twitter (https://twitter.com/TheJR) saw four posts during this week, with 51 total likes and 17 retweets. Instagram (http://instagram.com/joides_resolution) had two posts, with a total of 113 likes; the most popular photo was that of the derrick at night.

Technical Support and HSE Activities

During this week, IODP JRSO technical staff continued to support Site U1530 and Site U1531 science operations and sampling of material recovered from Site U1528.

Laboratory Activities

- Chemistry Laboratory: We faced issues with the quality of Coulometer data that are possibly related to out-of-date cell solutions. A recommendation has been made to shore to replace all current stock.

Application Support Activities

- Superconducting Rock Magnetometer: Updates to the software requested by TAS staff on Expedition 375 have been made and will be deployed after the current expedition.
- *P*-wave velocity caliper gantry: Updates to the Sample Information were made that will allow the user to select discrete samples recorded in the Laboratory Information Management System (LIMS). This version will be deployed after the current expedition.
- Site Fix Navigation Software: A new version has been developed addressing issues with the previous version and increasing accessibility of Navigation data. We are currently using the last sites of this expedition to run comparisons with the old version of this application.

IT Support Activities

- Printer operations on the Sharp copier are unavailable for the remainder of the expedition. A transfer belt in the copier has failed, causing the copier to jam repeatedly, and we do not have replacements for it on board. Scanning functions are still working.

HSE Activities

- Technical staff completed the weekly check of safety showers and eyewash stations.
- We held the weekly fire and boat drill as scheduled.