**IODP Expedition 382: Iceberg Alley and Subantarctic Ice and Ocean Dynamics**

**Week 4 Report (7–13 April 2019)**

Week 4 of the International Ocean Discovery Program (IODP) Expedition 382, Iceberg Alley and Subantarctic Ice and Ocean Dynamics, was spent coring at Holes U1536A (0–354.4 m below seafloor [mbsf]); 364.3 m recovered, 103%), U1536B (0–226.1 mbsf; 230.7 m recovered, 102%), and U1534C (0–16.1 mbsf, 15.8 m recovered, 98%) in the southern Scotia Sea, with the aim to document variations in iceberg activity, sea ice cover, sea surface temperature, and water mass properties over the Pleistocene and Pliocene. During the week, drilling operations stopped for about 20 h due to bad weather and sea state, and for about 16 h due to approaching icebergs. All times in this report are in ship local time (UTC – 3 h).

## Operations

At the start of the week, the drill string was being raised back to the ship in order to inspect the bottom-hole assembly (BHA) after the piston corer had misfired while attempting to start Hole U1536A. At 0815 h on 7 April 2019, with the bit at 77 m below the rig floor, sea conditions became too rough to continue operations and we waited on weather until 1500 h. At 1000 h, we had to move 500 m to the north to avoid an iceberg. When the BHA was raised to the rig floor, it was inspected and no obstruction was found. Everything appeared to be functioning normally. Rough sea conditions returned at 1800 h and we waited until 0730 h on 8 April for the weather to improve sufficiently to restart operations. We made up the BHA and tested that the piston corer was landing correctly. The rest of the drill string was assembled and lowered to the seafloor, and the top drive had been installed by 1830 h. The first piston core run broke the shear pins mechanically before it could be shot as planned. The second piston corer was run with three shear pins in order to test that the system pressured up without problems. The third piston core was successful in recovering sediments.

Hole U1536A started at 0005 h on 9 April. Core 1F was run with a half-length barrel, and recovered 4.5 m (100%). The core was almost full but it appeared to recover a mudline, giving a water depth for Hole U1536A of 3219.5 m. Cores U1536A-1F to 53F penetrated from the seafloor to 354.4 mbsf and recovered 364.3 m (103%). All full-length piston cores (Cores 2H to 23H) were oriented. Formation temperature measurements were made while taking Cores 7H, 10H, 16H, 19H, and 22H. The coring line parted during the Core 13H run, so 50 m of line was cut and the core barrel was fished. Cores 22H and 23H were difficult to pull out of the formation, so we switched to half-length piston coring with Core 24F. At 2115 h on 11 April an iceberg approached to within 5.7 nmi (5.5 h) from the ship, so we stopped coring and raised the drill string to ~50 m below the seafloor, following the previously established protocol for icebergs entering the “red zone.” The red zone is defined as a projected Closest Point of Approach (CPA)

of less than 3 nmi and a time to reach that point as less than twice the T-time (the time required to pull up the drill string to within 50 m of seafloor). At 0130 h on 12 April, when the iceberg was 1.7 nmi away, we raised the drill string above the seafloor and moved ~1 nmi to the east–northeast to avoid the path of the iceberg. This ended operations at Hole U1536A. By 0320 h the iceberg had passed and we started to move back to Site U1536, while monitoring a second iceberg and a growler (a small iceberg the size of a truck). At 0615 h the location was free of ice and we started lowering the drill string to the seafloor.

Hole U1536B started at 0930 h on 12 April. Cores U1536B-1H to 25H penetrated from the seafloor to 226.1 mbsf and recovered 230.7 m (102%). All cores were oriented and formation temperature measurements were made while taking Cores 5H, 8H, and 13H. At 1130 h on 13 April we started to raise the drill string because of approaching ice, which consisted of a large iceberg and a flotilla of smaller icebergs that had calved from the main iceberg. At 1325 h the drill string cleared the seafloor, ending Hole U1536B. At 1340 h we moved to avoid the small icebergs and continued to monitor the large iceberg until it passed us. Rig floor operations resumed at 1800 h.

Hole U1536C was started at 2035 h on 13 April. Cores U1536C-1H to 2H penetrated from the seafloor to 16.1 m and recovered 15.8 m (98%). At the end of the week we were continuing coring operations at Hole U1536C.

## Science Results

### *Lithostratigraphy*

Cores from Holes U1536A and U1536B were described visually and imaged with the X-ray scanner. One major lithologic unit was identified. This unit is composed of alternations between gray-green diatom ooze (with 10%–40% terrigenous component) and gray silty-clay, commonly containing diatoms (up to 40%). Color banding with shades of blue-green were present throughout, especially within the clay intervals. Diatom ooze dominated the unit to ~120 mbsf. Below ~250 mbsf the sediment is almost exclusively silty clay with varying amounts of biosilica. Yellowish layers were found to contain diagenetic carbonate and are interpreted as being devitrified tephra. On the whole, the cores appeared to exhibit only minor coring disturbance. Bioturbation is evident as mottling on the surface of split cores and pyritized burrows within the X-radiographs. Specific ichnofossils are rare. Iceberg-rafted debris (IRD), including dropstones, is rare on the split core surface, but common in the X-radiographs. While being also present in the diatom ooze intervals, IRD is more common in the silty clay intervals.

### *Biostratigraphy*

Siliceous microfossils: Diatoms and radiolarians were identified in all core catcher samples from U1536A-1F-CC to 23F-CC and every second core catcher sample in the half-length piston cores

from 28F-CC to 52F-CC, as well as 53F-CC (the sample at the bottom of the hole). Additional samples were collected in order to refine the age model. Reworked older diatoms were detected in most samples and, although noted, were excluded from biostratigraphic age estimations. Reworked radiolarians were found only between Samples U1536A-10F-CC and 17F-CC. Samples for the study of ancient DNA were also collected from Cores U1536B-1H to 12H and 20H.

Palynomorphs (dinocyst, acritarch, prasinopytes, pollen, spores, copepod, and fungi remains) were detected in every sample that was analyzed (on average for every second core). The palynomorphs were moderately to well preserved and reworked material occurred frequently. *Brigantedinium*, *Selenopemphix* spp., and trilete spores are dominant taxa. No taxa useful for biostratigraphic age estimation were detected.

Biostratigraphic models from the different microfossil groups agree with each other and show that Hole U1536A records a continuous or near-continuous Pleistocene record. The transition to Pliocene sediments occurs at Section U1536A-46F-3, 75 cm (~319.75 mbsf).

*Paleomagnetism*

Paleomagnetic investigations focused on measuring the natural remanent magnetization (NRM) of archive-half sections from Holes U1536A and U1536B. Initially, samples were demagnetized at 10, 15, and 20 mT peak alternating field (AF) demagnetization steps; however, the 20 mT step was dropped after the first few cores because the drill string overprint could generally be removed by the 10 mT step. All polarity zones of the 2012 Geologic Timescale have tentatively been identified in Hole U1536A through the Lower Gauss (C1n–C2An.3n) except for the Reunion Subchron (C2r.2n). Ongoing investigation of Hole U1536B aims to identify polarity transitions that are missing in U1536A due to coring disturbance or coring gaps.

Discrete samples were taken from almost every core section in Hole U1536A and in select intervals from Hole U1536B to establish continuous coverage. Initial discrete sample investigation is currently underway to ground-truth the archive-half measurements and further investigate the AF demagnetization behavior of the NRM. Discrete samples will also be used to investigate sedimentary fabric using the anisotropy of magnetic susceptibility.

*Geochemistry*

Samples for headspace gas, interstitial water (IW) chemistry, and bulk sediment geochemistry were analyzed at Hole U1536A. Headspace methane concentrations were generally low (2–4.6 ppmv) throughout the sedimentary sequence. Ethane, propane, and other higher molecular weight hydrocarbons were below the detection limit.

Hole U1536A is characterized by generally reducing sedimentary conditions, as indicated by the disappearance of dissolved sulfate concentrations below ~100 mbsf. The microbially mediated sulfate reduction in the upper section exerts strong control over the IW profiles of several

parameters measured in our analyses, including alkalinity, Ca, $PO_4$, and Fe. Alkalinity increases from 10 mM at the seafloor to a maximum of 39 mM at 134 mbsf. The steady increase in alkalinity, associated with highest phosphate concentrations in the upper 100 mbsf, are a direct consequence of organic-matter degradation associated with sulfate reduction. Elevated dissolved Mn concentrations (maximum 42 $\mu$M at 20 mbsf) in the upper 60 mbsf alongside a lack of associated elevated dissolved Fe imply that sedimentation rates at this site are rapid relative to sulfate reduction rates. As a result, at least some of the reactive iron (oxy)hydroxides are buried throughout the primary iron reduction zone and also the sulfate reduction zone. Ca displays a dramatic decrease in the sulfate reduction zone from ambient seawater concentrations (10.5 mM) to 2 mM at 100 mbsf. This Ca depletion is either a function of authigenic carbonate or gypsum formation, both of which are commonly observed in reducing sedimentary conditions. Mg remains relatively constant over the uppermost 100 mbsf at concentrations of ~52 mM. This behavior creates highly elevated Mg/Ca values in the IW shallower than 100 mbsf due to authigenic Ca precipitation. Highly concentrated Ba concentrations in the sulfate-depleted interval between 100 and 300 mbsf strongly point towards bacterial barite dissolution in this interval. Below 100 mbsf, Na/K suggests preferential K removal, indicating authigenic clay formation. Increases in Sr seem to follow the Ba enrichment profile between 100 and 280 mbsf.

Bulk sediment total organic carbon (TOC) and total nitrogen (TN) contents are generally low with concentrations ranging from 0.1 to 0.8 wt% and from 0.02 to 0.09 wt%, respectively, but are sufficient for biomarker studies. Calcium carbonate ($CaCO_3$) contents are also low (<1 wt%), except in a few narrow horizons where an enrichment of $CaCO_3$ takes place (these levels were identified as volcanic tephra layers) along with an increase of organic carbon/total nitrogen ratios (TOC/TN) suggesting possible surge of terrigenous input and/or very abundant diatom opal. In summary, the diverse geochemical trends seen at Site U1536 are highly encouraging for further shore-based geochemical studies.

*Petrophysics*

In Holes U1536A and U1536B, the Whole-Round Multisensor Logger (WRMSL) was used to measure density, *P*-wave velocity, and magnetic susceptibility (MS) at 2.5 cm resolution. Natural gamma radiation (NGR) measurements were also made on the whole-round core sections. X-ray images were made on all the archive-half split cores, in addition to some of the whole-round sections from the top of Hole U1536A. Discrete measurements were collected in section halves, and include *P*-wave velocity (at least three per core) and a total of 61 thermal conductivity measurements (one per core). Moisture and density measurements were made on 128 discrete samples. Color reflectance, digital image, and point MS measurements were made at 2.5 cm intervals on archive-half split cores. Six downhole temperature measurements were made with the advanced piston corer temperature tool (APCT-3) in Hole U1536A with Cores 7H, 10H, 13H, 16H, 19H, and 22H, and three additional APCT-3 measurements were made in Hole U1536B with Cores 5H, 8H, and 13H. Cores U1536A-7H and U1536B-5H did not provide

reliable temperature estimates because there was too much sensor movement at shallow depths. The remaining measurements yielded a temperature gradient of 85°C/km.

Downhole sediment compaction is reflected in gradually increasing density and *P*-wave velocity with depth. All physical properties measurements, including color reflectance and RGB values, likely show orbital scale variations that can be useful for stratigraphic correlation. The amplitude of NGR cyclic changes decrease below 195 mbsf. A general trend to higher peak MS values is observed deeper than 244 mbsf. Large amplitude features in the bulk density and *P*-wave velocity records correlate with main reflectors and structures observed in multichannel seismic and TOPAS (TOpographic PArametric Sonar echosounder) subbottom profiles in this location.

*Stratigraphic Correlation*

Holes U1536A and U1536B provide a continuous splice to ~92 m (core composite depth). Core recovery for Hole U1536A was 103%, so with a further deep-penetration hole at this site there are good prospects for a reasonably complete splice section to at least 354 mbsf. Seven tephra layers identified in Hole U1536A can be correlated to Hole U1536B. They are associated with high carbonate concentrations and some are cemented, causing incomplete strokes in some of the piston cores that encountered them. A sediment slump is seen in Cores U1536A-7H and U1536B-7H. The yellow-blue color reflectance parameter, b*, and NGR provide good proxies for identifying glacial–interglacial cycles and making interhole correlations. We identify the Marine Isotope Stage (MIS) 19 interglacial based on the occurrence of the Brunhes–Matuyama boundary at 141 mbsf. Between the seafloor and MIS 19, there are an appropriate number of high b*/low NGR peaks to match the expected number of interglacials, and this suggests that there is a complete stratigraphy for the Brunhes Chron.

**Outreach**

*joidesresolution.org*: We posted four blogs this week, including an introduction to the expedition's five laboratory groups, and a post about the Greenland–Antarctic research connection.

*Twitter (https://twitter.com/TheJR)*: We posted 11 original tweets, including links pointing to the blog posts. A photo collage of the iceberg-rafted dropstones received 21 retweets and 77 likes.

*Facebook (https://www.facebook.com/joidesresolution)*: We uploaded nine posts, including posts linking to the blogs, photos from the video links to schools in Germany, and a post about avoiding icebergs.

*Instagram (http://instagram.com/joides_resolution)*: We uploaded five posts and three Instagram stories, including about how far south we are (277 views), and a diatom photo gallery (177 likes).

*Live Events*: We conducted 10 video conferences with schools, universities, and the American Museum of Natural History, reaching a total of 432 students.

**Technical Support and HSE Activities**

*Laboratory Activities*

- The X-ray source on the X-ray Imager failed on 9 April. The new, spare source was installed and the Integrated Measurement System (IMS) software was configured for image acquisition. Some settings have to be notably different in order to produce equivalent images; for example, the voltage for the new source is set at 60 V, whereas for the old source it was set at 120 V. The X-radiographs will be used to quantify the IRD content of the Iceberg Alley cores. The images are also proving to be useful for identifying sedimentary layering, bioturbation, and core disturbance.
- X-ray images are showing variable top-of-core offsets that are identified in the IMS processed images (the top of the core image is placed between 0 to 2 cm according to the virtual ruler in the images). We replaced the MDrive motor on the X-ray Imager in an attempt to address the issue. After replacing the motor and cycling the source as noted above, the top-of-core offsets are within range. Continuing to monitor the images.
- On the NGR instrument, technicians noticed that the K-40 peak is being observed in higher energy channels on Detector 7, compared to the other detectors and compared to where Detector 7 used to observe the peak. Shore personnel have been contacted for assistance on this issue.

*Application Support Activities*

- We tested a modification of the superconducting rock magnetometer (SRM) IMS software to prevent the initialization INI file from being rewritten with defaults each time the application is launched. The modifications did not work so we rolled back to previous version of the application.

*HSE Activities*

- Performed radiation survey around the X-ray Imager after new the new X-ray source was installed.
- Conducted weekly fire and abandon ship drill.
- Safety showers and eyewash stations were tested.