IODP Expedition 379: Amundsen Sea West Antarctic Ice Sheet History

Week 4 Report (2–9 February 2019)

This week was spent coring in Holes U1532B (93.1–180.3 m below seafloor [mbsf]; 91.9 m recovered, 105%) and U1532C (178.3–392.3 mbsf; 179.6 m recovered, 84%). Drifting ice, occasionally combined with adverse weather, caused multiple interruptions to coring operations that totaled 3.1 d and forced us to abandon Hole U1532B. All times in this report are in ship local time (UTC – 3 h).

Operations

This week began while we were continuing to adjust our position as required to maintain a safe distance from ice until 0015 h on 2 February when the drill floor was cleared to resume operations. We offset the ship 20 m to the east of Hole U1532A and started drilling in Hole U1532B at 0125 h. We drilled from the seafloor down to 93.1 m without coring, recovered the extended core barrel (XCB) core barrel with center bit, and resumed advanced piston corer (APC) coring. The first core in Hole U1532B (Core U1532B-2H) arrived on the rig floor at 0415 h on 2 February. While we were taking the next core (3H), we had to pause coring again due to approaching ice. We raised the bit up to 50.5 mbsf and waited for the ice to clear from 0800 to 1515 h. We then resumed APC coring, and Core 4H (112.1–121.6 mbsf; with a formation temperature measurement) arrived on deck at 1800 h. Before it was laid out on the rig floor, approaching ice forced us to stop coring again. We raised the bit back up to 50.5 mbsf and waited from 1830 h until 2215 h on 2 February before being able to lower the bit back to the bottom of the hole and resume coring at 2300 h.

We continued APC coring and recovered Cores U1532B-5H to 9H (121.6–169.1 mbsf; with a formation temperature measurement on 7H). After recovering Core 9H, approaching ice forced us to pause coring again at 0600 h on 3 February, and the bit was raised back up to 50.5 mbsf. We were able to resume operations at 0900 h, so we lowered the bit back to 169.1 m and resumed coring. Core 10H was a partial stroke, and the lowermost core liner deformed and a crack extended up the entire core liner. Core 10H recovered 6.48 m, so we advanced the bit 6.5 m and switched to half-length APC (HLAPC) coring. After Core 11F (175.6–180.3 mbsf) was recovered, approaching ice once again forced us to pause coring again at 1315 h on 3 February, and we had to raise the bit back up to 50.5 mbsf. Unfortunately, the ice kept converging on our location, so we eventually had to pull the bit completely out of the hole at 1715 h on 3 February. We spent the rest of the day positioning the ship as required to avoid the drifting ice. Overall, Hole U1532B was drilled without coring from the seafloor to 93.1 mbsf and then APC/HLAPC coring penetrated 87.2 m (93.1–180.3 mbsf) and recovered 91.9 m (105%).

At 0000 h on 4 February we were able resume operations. The ship was offset 20 m south of Hole U1532B, and at 0035 h on 4 February we started drilling into the seafloor at Hole U1532C. We drilled without coring from the seafloor and by 0415 h had reached 178.3 m. After retrieving the core barrel with the center bit used during the drilling, we started HLAPC coring. Core U1532C-2F (178.3–183.0 mbsf) arrived on deck at 0630 h. It was positioned to overlap with the deepest core from Hole U1532B (Core U1532B-11F; 175.6–180.3 mbsf). Cores U1532C-2F to 11F (178.3–225.3 mbsf) were recovered, but approaching ice forced us to pause coring at ~1630 h on 4 February. The barrel for Core 12F had already been deployed and had to be recovered before we pulled the bit up to 61.9 mbsf. We received approval to resume operations at 1900 h on 4 February, so we lowered the bit back down to the bottom of the hole and resumed HLAPC coring. After Cores 12F to 18F penetrated from 225.3 to 258.2 mbsf, we switched to the XCB. Cores 19X to 22X penetrated from 258.2 to 291.0 mbsf (10.18 m recovered; 31%), after which Cores 20X and 21X only recovered 6 cm. At 1445 h on 5 February, as Core 22X arrived at the rig floor, approaching ice forced us to pause coring and raise the bit up to 50.5 m below the seafloor. We were able to resume operations at 1715 h on 5 February. After lowering the bit back down to the bottom of the hole, we took Cores 23X to 24X (291.0–310.1 mbsf; 18.05 m recovered, 95%).

Just as Core U1532C-24X arrived on the rig floor at 2355 h on 5 February, we had to stop coring again and raise the bit back up to 50.5 m due to approaching ice. At 0530 h on 6 February, we resumed operations and started lowering the bit back to the bottom of the hole. The bit encountered a bridge in the hole at 172.5 mbsf, so we deployed an XCB core barrel with a center bit to drill through it and then washed the bit down to the bottom of the hole at 310.1 m. We circulated 25 barrels of mud to clean cuttings out of the hole and retrieved the center bit to resume XCB coring. Just as we were about to drop the XCB barrel to start coring, approaching ice put operations back on hold. This time, however, we kept the bit near the bottom of the hole. At 1545 h on 6 February, the ice moved away and we resumed XCB coring. After Cores 25X to 33X penetrated from 310.1 to 392.3 mbsf, approaching ice and diminishing visibility due to snow forced us to pause coring and Core 33X was pulled after only penetrating 5.5 m. At this point, we decided to abandon further XCB coring and switch to rotary core barrel (RCB) coring since (a) penetrating deeply at this site is a primary objective and will require RCB coring, (b) RCB coring may result in better quality core at the current hole depths, and (c) we wanted to take advantage of the time spent waiting for ice and environmental conditions to improve. We started recovering the drill string at 1315 h. The bit cleared the seafloor at 1520 h on 7 February and we continued raising the drill string. Overall, Hole U1532C was drilled without coring from the seafloor to 178.3 mbsf and then HLAPC/XCB coring penetrated 214.0 m (178.3–392.3 mbsf) and recovered 179.6 m (84%).

We finished recovering the drill string and the APC/XCB bottom-hole assembly (BHA), and the bit arrived back on the rig floor at 0045 h on 8 February. After laying out the APC/XCB specific parts of the BHA (seal bore and nonmagnetic drill collars), the drill crew started putting together the RCB BHA. Some extra time was required to fix a couple of issues identified by routine

verification of the drill collar interior diameter and core barrel space out within the BHA. From 0700 to 1430 h on 8 February 2019, we lowered the bit until it was 21.5 m above the seafloor. We then installed the top drive, deployed a center bit, and adjusted the drill string to prepare for starting Hole U1532D. We planned to start RCB coring at ~362 m to overlap with the deepest cores from Hole U1532C. Unfortunately, at 1545 h on 8 February, we had to pause operations due to approaching ice. We maneuvered the ship as required to avoid the ice until it cleared the area. We were finally able to start drilling into the seafloor at 2142 h on 8 February. We drilled without coring until we reached 247.2 mbsf at 0730 h on 9 February. Unfortunately, at this time, approaching ice forced us to raise the bit up to 55.5 m below the seafloor. The rig floor was cleared to resume operations at 1530 h on 9 February and we lowered the bit back down to the bottom of the hole. At 1715 h, we dropped an RCB core barrel with a center bit and resumed drilling from 247.2 mbsf. At 2300 h on 9 February, the bit had reached 362.7 mbsf and we started to recover the center bit to prepare for RCB coring.

Science Results

Coring in Holes U1352A–U1532C penetrated to 392.3 mbsf. All whole-round core sections were X-rayed and the images were examined for sedimentary structures, clast occurrence and drilling disturbance. The core sections were then split, imaged, analysed for magnetic susceptibility and color reflectance, and described. Discrete samples were taken for thin sections, inorganic and organic geochemical measurements, and XRD clay mineral analyses. Petrographic analyses were also carried out on sieved residues of core catcher micropaleontology samples.

Lithostratigraphy

The sediments recovered from the upper 92 m in Hole U1532A consist predominantly of horizontally laminated and color-banded brown and gray silty clays. Some intervals bear biosiliceous material and foraminifers. Pebbles and granules are present but rare. The sediments from 92–101 mbsf in Hole U1532A, 93–180 mbsf in Hole U1532B, and 178–392 mbsf in Hole U1532C comprise thick intervals of dark gray silty clays with common silt laminae throughout that alternate with greenish gray, partly bioturbated silty clay interbeds. Concentrations of pebbles occur in the upper parts of the greenish gray interbeds, whereas pebbles are rare in the laminated dark gray silty clays. Occurrences of siliceous microfossils in these sediments are mainly restricted to some of the greenish gray interbeds and very dark gray thin layers within the laminated silty clays. Coring induced deformation occurs in APC and HLAPC cores from 149–262 mbsf in Holes U1532B and U1532C, and in XCB cores from 262–392 mbsf in Hole U1532C.

Biostratigraphy

In order to establish biostratigraphic ages, all core catcher samples were sampled for diatom, nannofossil, radiolarian, and foraminiferal analysis. Additional samples were taken when needed from the ends of core sections and split core sections.

Diatoms: The mudline water sample from Site U1532 contains a typical modern Southern Ocean diatom assemblage. However, below this surface sample, most samples examined from the upper part of the sequence recovered in Holes U1532A–U1532C were barren of diatoms or contained only trace occurrences. In this upper part of the section, sufficient diatoms for biostratigraphic age assignment were present only at 4.2 m, and indicate an age of Middle to Late Pleistocene (0–0.6 Ma). Below this level, the abundance and preservation of diatoms varied greatly, with abundance increasing greatly below ~90 m. The interval from between ~92 and 156 mbsf was assigned a mid–Late Pliocene age of 3.2–3.8 Ma, and the interval between ~156 and 224 mbsf was assigned an Early Pliocene age of 3.8–4.4 Ma. Trace occurrences of highly fragmented diatoms in samples below ~224 mbsf make it difficult to determine the biostratigraphic age of the lowest part of the Hole U1532A–U1532C sequence. However, the occurrence of *Rhizosolenia costata* and *Thlassiosira inura* indicates the interval between ~224 and 332 mbsf is <4.7 Ma (Early Pliocene) in age.

Calcareous nannofossils: Most foraminifer-rich intervals, which were limited to the Pleistocene, contained rare to common coccolith plates. These included Samples U1532A-3H-2W, 85, 92 and 102 cm; U1532A-3H-3W, 71 cm; and U1532A-3H-6W, 95 cm. No calcareous nannofossils were noted in the remainder of diatom smear slides from Holes U1532A, U1532B, and U1532C.

Radiolarians: Most samples from Holes U1532A, U1532B, and U1532C were barren of radiolarians or contained trace amounts of no age-diagnostic radiolarians, with the exception of eight samples containing assemblages with frequent to common radiolarians. The uppermost sample of these at 100.54 mbsf contained a few specimens of *Helotholus vema* (2.4–4.59 Ma) and was thus assigned to the Upsilon Zone. The sample at 155.99 mbsf was the first to also contain *Larcopyle polyacantha titan* (LAD: 3.48 Ma) and thus belongs to the lower subzone of the Upsilon Zone. Similarly, Samples from 180.19 mbsf in Hole U1532B and 180.11 and 199.44 mbsf in Hole U1532C also contained fragments of *Lampromitra coronata* (LAD: 3.72 Ma). The lowermost sample of Hole U1532C that contains a radiolarian assemblage was taken at 223.84 mbsf and still belongs to the Upsilon Zone (<4.59 Ma).

Palynology: Marine palynomorphs were rare in most samples from Holes U1532A, U1532B, and U1532C. The possibly in situ assemblage was of very low diversity: principally *Brigantedinium* and *Selenopemphix* spp., neither of which have biostratigraphic utility in these Pliocene sediments. Some reworked Paleogene dinocysts were identified. Most samples contained rare to common reworked Paleogene pollen, and a few samples contained abundant and diverse pollen assemblages, including lower Upper Cretaceous forms. A non-hydrofluoric

acid (HF) processing method was tested for 23 samples from Holes U1532A and U1532B. This method had some success at extracting palynomorphs from the nonindurated muds, but a significant disadvantage is the large volumes of biosiliceous material that remain on certain slides. An additional method was tested to process the sieved (non-HF processed) residue with HF to remove the biosiliceous material. This has the advantage of requiring considerably less HF and is therefore safer, but it was unsuccessful as the volume of the residue is too small to be retained through the many processing steps. We reverted to standard HF methods for samples from Hole U1532C, which has generally produced cleaner slides that are considerably easier to examine.

Foraminifers and Ostracods: Only three intervals contained foraminifers with high abundance and high diversity, all located in Hole U1532A. A few other samples contained planktonic foraminifers, but only one species, *Neogloboquadrina pachyderma*. Only one entire ostracod (*Henryhowella caligo*) was found in one of the intervals containing foraminifers, at 5.98 mbsf. This species is reported exclusively from the Southern Ocean deeper than 1,570 m water depth.

Paleomagnetism

The natural remanent magnetization (NRM) of 311 archive-half core sections from Holes U1532A, U1532B, and U1532C was measured and then subjected to stepwise alternating field (AF) demagnetization at 5, 10, 15, and 20 mT. In addition, NRM was measured for 60 discrete samples before and after stepwise AF demagnetization up to a peak field of 100 mT. NRM data of XCB-cored sediments have a drilling-induced vertical overprint that is easily removed by 5–10 mT AF demagnetization. This drilling overprint is not observed in the APC or HLAPC cores.

The paleomagnetic data (at the 20 mT demagnetization level) reveal a clear magnetostratigraphy with several magnetic polarity reversals. Results from discrete sample demagnetization confirmed these findings. Combined with biostratigraphic datums, a preliminary age model was developed. According to this, the oldest sediments from the base of Hole U1532C would tentatively represent magnetic polarity Chron C3n.2n (4.493–4.463 Ma).

Bulk susceptibility and anisotropy of magnetic susceptibility (AMS) were measured before AF demagnetization of discrete samples. Maximum susceptibility axes (κ_{max}) of all samples show an excellent grouping, exhibiting higher values of magnetic lineation, while minimum susceptibility axes (κ_{min}) are perpendicular to it.

Six representative samples were selected to measure anhysteretic remanent magnetization (ARM) and isothermal remanent magnetization (IRM) to characterize magnetic grain size, mineralogy, and concentration of the magnetic mineral assemblages. These suggest that samples above Section U1532A-5H-3 have smaller magnetic particle sizes and/or include a second, magnetically more stable mineral phase.

Petrophysics

Density, magnetic susceptibility (MS), and *P*-wave velocity were measured using the Whole Round Multisensor Logger (WRMSL) with a measurement interval of 2.0 cm. *P*-wave velocity was not measured on XCB cores (as well as HLAPC Section U1532C-12F-1) due to incomplete filling of the core liner. Natural gamma radiation (NGR) was also measured on whole-round cores at an interval of 10 cm. Additionally, 60 thermal conductivity measurements were conducted. Moisture and density measurements were made on 117 discrete samples, and 162 *P*-wave velocity measurements were made on split core sections. Five downhole temperature measurements made with the advanced piston corer temperature tool (APCT-3; at 34, 52, 91, 121, and 150 mbsf) combined with core thermal conductivity measurements yield a geothermal heat flow of 63 mW/m^2.

Downhole sediment compaction is reflected in decreasing porosity and increasing density and *P*-wave velocity with depth. Superimposed on this general trend are physical properties changes related to the variable amounts of detrital material. Decreases in MS, density, and NGR values were seen in biosiliceous-rich mud and biosiliceous ooze intervals.

Continuous and distinctive variations in MS were used to constrain the overlap between the three holes. The lowermost 6.7 m of Hole U1532A overlaps with the first core of Hole U1532B. The lowermost 2.6 m of Hole U1532B overlaps with the uppermost core of Hole U1532C.

Geochemistry

Geochemical measurements on Site U1532 samples included headspace gas analysis, interstitial water (IW) chemistry, and bulk sediment geochemistry. Headspace gas analyses reveal only very low methane concentrations in all cores. Pore water from 50 whole-round samples was analyzed for alkalinity, pH, chlorinity, salinity, major cations and anions, trace elements, and nutrients. The amounts of IW in all samples were sufficient to accommodate all shipboard and planned postexpedition analyses. Pore water sulfate concentration varied between 9 and 28 mM, indicating that the sulfate–methane transition zone (SMTZ) has not yet been recovered at this site. Alkalinity increases to ~10 mM at ~150 mbsf and then decreases downhole to values similar to those near the seafloor. The downhole profiles of Cl, Ca, Li, and Sr concentrations showed increasing trends with depth, whereas Na, Mg, K, and B concentrations decreased. Discrete samples were analyzed for total carbon, total nitrogen, and total sulfur, as well as inorganic and organic carbon contents. Overall, the organic carbon and carbonate are very low in Hole U1532A and there is increasing inorganic carbon downhole in Hole U1532B. Total sulfur values decrease from the seafloor to 40 mbsf, possibly indicating more reducing conditions and sulfate reduction. Samples for microbiological analyses (including cell counts, intact polar lipids, metagenomics, and culture experiments) were collected from whole-round and syringe samples and stored for later shore-based research.

Outreach

The Outreach Officers continued to document onboard activities. Two new comics were posted and photos and text were sent to shore to update social media. Blogs and social media posts from scientists were also sent to shore for the website and institutions promoting our expedition. The expedition trailer came out and received a huge spike in interest on social media and from interested media and institutional PR offices. Stories about the expedition are being discussed with the media, and several high-profile geology blogs and organizations are looking to promote our expedition through their websites and social media, including BBC Earth, which has a global following of millions of people. Japanese and Hindi translations of comics are being prepared by shipboard scientists. The U.S. National Science Foundation press release was promoted, and the NSF Office of Polar Programs did a long post about our expedition featuring comics.

Technical Support and HSE Activities

Staff continued supporting science activities at Site U1532.

General Activities

- Caver Hydraulic Jacks: Staff pulled all of the spare jacks, verified that they work, attempted to repair those that do not, and came up with a list of parts that need to be ordered.

Laboratory Activities

- CHNS Analyzer: we encountered several problems at the beginning of our work:
    - Noisy baseline, unable to detect valid sulfur peaks in some samples.
    - Calibration of standards, especially the sulfur and nitrogen, was poor during the first and second batch trial. After replacing the CHNS column and water trap column, there were some issues with leaks that were finally resolved. Calibrations became normal and acceptable.
- Coulometer: Encountered clogged airflow in the reaction vial. A new reaction vial and fresh solution resolved the issues.
- Velocity Experiments: Staff continue to collect data requested from shore to investigate the propagation of errors.
- Palynology Preparation: Scientists report good results with the HF acid-free alternative preparation methods in unconsolidated materials. Otherwise preparation with HF is still required.

Application Support Activities

- Java 11 Migration: Work continued for the following applications: Correlation Downloader, SEM Uploader, FilesR, and FileW.
- Titra_man: Fixed issues that incorrectly uploaded 500 tests against one sample.
- IMS: Updated the web service "SampleFamilyGetIMS" to respond with distinct error messages that result in no records.

IT Support Activities

- Passwords: Updated all instrument hosts with a new "DEV" account password.
- CommVault: Unusual error message. During a backup restore operation, the application is requesting a password for the backup database. Have ticket open with CommVault and investigating matter.
- Malicious traffic: Notified by TAMU Campus of malicious traffic originating from a workstation on JR. Attempted remedial actions unsuccessfully. Pulled workstation off shipboard network and replaced with different unit.

HSE Activities

- Conducted weekly fire and boat drill.
- Completed HF emergency response training for the ship's fire team.