IODP Expedition 379: Amundsen Sea West Antarctic Ice Sheet History

Week 7 Report (24 February–2 March 2019)

This week, we conducted coring operations in Holes U1533A, U1533B, U1533C, and U1533D. In Hole U1533A, APC Cores 1H–3H penetrated from the seafloor to 28.5 m and recovered 29.54 m (104%). In Hole U1533B, we (a) drilled without coring to 25.5 m, (b) installed a free-fall reentry system with casing to 24.35 m, and (c) APC/HLAPC/XCB cored from 25.5 to 283.9 m (236.10 m recovered; 91%). In Hole U1533C, we took a single mudline APC core (0–7.7 m). In Hole U1533D, APC Cores 1H–5H penetrated from the seafloor to 40.0 m and recovered 40.01 m (100%) All times in this report are in ship local time (UTC – 3 h).

Drifting ice caused multiple interruptions to coring operations that totaled 3.29 d. This week we also experienced significant ship heave due to large ocean swells that also significantly impacted our operations. Collectively, these (a) forced us to abandon Hole U1533A after coring to 28.5 m, (b) forced us to temporarily pull out of Hole U1533B, (c) forced us to stop further coring in Hole U1533C, and (d) impacted coring and core quality at Holes U1533C and U1533D.

Operations

The week started with the final assembly of a free-fall reentry system (free-fall funnel, mud skirt, and 24.35 m of 10.75 inch casing). The reentry system was centered in the moonpool at 0330 h on 24 February. We attached an advanced piston corer (APC) bit to the bottom-hole assembly (BHA) and lowered it through the reentry system. The bit we used this time is an APC polycrystalline diamond compact (PDC) bit; it has a smaller outside diameter (9.875 inch) than our normal APC bits, so it can pass through the 10.75 inch casing. While lowering the bit to the seafloor, we had to stop for 2 h (0800–1000 h) to repair a line in the rig floor compressed air system. After the bit arrived at ~90 m above the seafloor at 1500 h on 24 February, we had to pause operations due to approaching ice. At 1715 h, we installed the top drive and adjusted the bit to start coring. Unfortunately, we had to stop operations again at 1930 h on 24 February due to approaching ice.

After ice cleared the area at 0515 h on 25 February, we adjusted the bit depth and started APC coring in Hole U1533A at 0640 h. We knew ice was approaching but wanted to use the limited time before it arrived to obtain some surficial cores and penetrate deeply enough to deploy the free-fall reentry system. Cores U1533A-1H to 3H penetrated to 28.5 m and recovered 29.54 m (104%). Ice approached more quickly and directly than estimated, and we had to pull out of Hole U1533A at 1045 h on 25 February before we were able to deploy the reentry system.

We resumed coring at 1300 h on 25 February and offset the ship ~1620 m to the west (264°) of Hole U1533A since the ice conditions would allow us to start operations sooner at this location.

Hole U1533B was started at 1355 h on 25 February and drilled without coring to 25.5 m. Then, APC Cores U1533B-2H to 7H penetrated to 82.5 m. While retrieving Core U1533B-4H, we deployed the free-fall reentry system with 10.75 inch casing.

After Core U1533B-7H arrived at the rig floor (0050 h on 26 February), approaching ice caused us to pause operations and raise the bit up to 50.4 m below the seafloor. We resumed operations at 0230 h on 26 February and Cores 8H to 12H penetrated to 130.0 m. After recovering Core 12H, approaching ice forced us to pause operations again at 1100 h, and the bit was raised back up to 50.6 m. At 1415 h on 26 February, we lowered the bit back to the bottom of the hole and resumed APC coring. Cores 13H to 18H penetrated to 187.0 m before we had to pause operations again at 2330 h on 26 February. We raised the bit up to 50.6 m below the seafloor to wait for ice to clear the area.

At 0330 h on 27 February, we had to pull completely out of Hole U1533B due to approaching ice. Since the ice situation would not allow us to reenter Hole U1533B soon, we decided to make use of this time to take a few surficial APC cores. We offset the ship to a more ice-free portion of the seismic profile and adjusted the bit for a mudline core. As we prepared to shoot Core U1533C-1H at 0805 h, the core fired early due to significant ship heave. However, we recovered what appeared to be a good 7.7 m long mudline core. Before we could take any more cores, increasing ship heave forced us to stop operations at 0900 h on 27 February. We raised the bit ~100 m above the seafloor and had to wait until 0645 h on 28 February for the seas to subside enough to resume coring operations. Our preference was to reenter Hole U1533B and continue to deepen it; however, this required calmer seas because we did not want to risk the bit heaving down on the reentry funnel and damaging our ability to reenter. So, we offset the ship 15 m to the east of Hole U1533C and started APC coring from the seafloor at Hole U1533D. APC Cores U1533D-1H to 5H penetrated to 40 m and recovered 40.01 m (100%). As this was deep enough to provide overlap with the first Hole U1533B cores and the swell had decreased, we terminated Hole U1533D at 1545 h on 8 February. We moved back to Hole U1533B, deployed the camera system, and reentered at 1838 h. The top of the cone was observed to be roughly level with the seafloor, but clear on all sides, from a depression made by the 96 inch square mud skirt. We recovered the camera system and lowered the bit toward the bottom of the hole. The bit encountered some resistance at 160 m, so we installed the top drive and rotated/circulated the remaining 27 m to the bottom of the hole (187.0 m). We resumed coring at 2215 h on 28 February and Cores U1533B-19F to 20F penetrated to 196.4 m. After Core 20F arrived on the rig floor at 0055 h on 1 March, we had to stop coring due to approaching ice. At 0130 h, we raised the bit up to 165.6 m, removed the top drive, and continued raising the bit up to 50.6 m below the seafloor. At 0600 h on 1 March, we resumed operations, lowered the bit to the bottom of the hole, and started coring again. After taking two half-length APC (HLAPC) cores (21F–22F; 196.4–205.8 m), we decided to switch to extended core barrel (XCB) coring. Unfortunately, we had to stop operations at 1115 h on 1 March due to approaching ice. We raised the bit back up to 50.6 m below seafloor and waited until 1515 h on 1 March to resume operations. We lowered the bit back to the bottom of the hole and Cores 23X–28X penetrated from 205.8 to 262.1 m. After

Core 28X arrived back on the rig floor, we had to stop operations at 0915 h on 2 March due to approaching ice. We raised the bit back up to 50.6 m below seafloor and waited until 1315 h to resume operations. While lowering the bit back to the bottom of the hole, it encountered hard fill at 232.6 m. We installed the top drive, deployed an XCB core barrel with a center bit, and drilled back down to 262.1 m. After recovering the center bit, we resumed coring at 1645 h and Cores 29X–31X penetrated to 283.9 m. At 2145 h on 2 March, we had to stop coring again due to approaching ice. Instead of waiting for the ice to leave the area to resume XCB coring, we decided to make use of this time to retrieve the drill string and switch to rotary core barrel (RCB) coring. We pulled the bit out of the hole at 2303 h and continued to retrieve the drill string. At midnight on 2 March, the bit was at 3877 m below the rig floor. Core 31X arrived on the rig floor with the BHA the following day.

Science Results

Lithostratigraphy

In Holes U1533A, U1533C, and U1533D, cores were recovered with stratigraphic overlap for the upper 40 m. Cores U1533A-1H to 3H, U1533C-1H, and U1533D-1H to 5H within this interval were X-rayed and described. Cores U1533B-2H to 22F, collected between 25 and 205 m, were also X-rayed and described. Core U1533B-2H was correlated on a bed-by-bed scale to Core U1533D-5H using descriptions of sedimentary structures and digital images. Magnetic susceptibility data were used to constrain the correlation of the uppermost portions of Holes U1533A–U1533D.

In the upper 32 m, the sediments consist of brown bioturbated muddy diatom ooze, foraminifer ooze, and color-banded and laminated silty clay. Color banding is on a decimeter to centimeter scale and color boundaries are moderately bioturbated. Below 32 m, sediments consist of interbedded brown to dark greenish gray laminated clay and pale brown to light greenish gray massive biosiliceous clay. Some massive units have pebbles concentrated near the top. Centimeter to millimeter-scale color banding occurs within some dark greenish gray laminated clay units. Sediments occasionally contain a volcaniclastic component. Dispersed gravel and intervals of interlaminated silt and clay, thin normally graded sand beds, and one bed of reverse graded granule conglomerate are also present.

A color change from brown to green is clearly visible in Section U1533D-5H-6 at 38 m, i.e., below the facies transition at 32 m. Dark mottling is especially common above the color transition. The color change observed during core description may correlate to a shift observed in the a* measurements. The color change does not coincide with the change in facies and is possibly due to a change in the oxidation state of the sediment.

Biostratigraphy

Micropaleontologic work in the past week concentrated on analysis of new samples from Site U1533. Core catcher and selected split core samples were prepared and analyzed for diatoms, foraminifers, radiolarians, dinocysts, terrestrial palynomorphs, and calcareous nannofossils from Cores U1533A-1H to 3H (~0 to 29 m), U1533B-2H to 23X (~25 to 209 m), U1533C-2H (~0 to 8 m), and U1533D-1H to 5H (~0 to 40 m).

Most samples analyzed contain diatoms and radiolarians, ranging from well preserved to poorly preserved. Diatoms range from absent to abundant, but are particularly abundant in greenish-colored, bioturbated to massive units. Radiolarians occur sporadically throughout the section, but preservation is poor in many samples. Planktonic foraminifers range from rare to abundant in the uppermost part of the sequence between 0 and 19.3 m in Holes U1533A, U1533C, and U1533D, but foraminifers are largely absent from deeper intervals. Only one complete assemblage of benthic foraminifers is present in Sample U1533C-1H-1, 88–90 cm (0.88 m). Rare in situ marine palynomorphs were observed below Sample U1533B-4H-CC (~54 m), whereas reworked terrestrial palynomorphs are present in all samples and sometimes in frequent abundance. No calcareous nannofossils were observed at this site.

In the sequence recovered at Site U1533 between 0 to 209 m, the consistent occurrence of diatoms allows recognition of Pleistocene to Early Pliocene biozones, supported by radiolarian biostratigraphic age constraints in some intervals. An abundant, and uncharacteristically diverse, modern radiolarian assemblage was recovered in the mudline sample from Core U1533D-1H (0 m), as well as a common radiolarian assemblage of Omega to uppermost Psi Zone (Pleistocene: 0 to 0.64 Ma). The last appearance datum of the diatom *F. barronii* is identified at ~22 m, defining the base of the *Actinocyclus ingens* Zone (1.3 Ma). A succession of Pliocene diatom datums are identified downhole, defining the *F. interfrigidaria* Zone (~54 to 87 m; 3.2–3.8 Ma) and the *F. barronii* Zone (~87 to 121 m; 3.8–4.4 Ma). Radiolarian assemblages in the interval between ~50 and 145 m also indicate an Upsilon Zone Pliocene age (2.4–4.59 Ma). Although highly fragmented in most samples, diatoms are present down to ~209 m and indicate an age of <5.3 Ma (Early Pliocene) for Core U1533B-23X.

Paleomagnetism

Natural remanent magnetization (NRM) was measured before and after alternating field (AF) demagnetization on all archive-half sections from Holes U1533A, U1533C, and U1533D, as well as those from Hole U1533B down to Core U1533B-22F. In addition, 48 oriented discrete samples were measured to confirm the archive-half measurements as well as for bulk and anisotropy of magnetic susceptibility (AMS). Intensity of NRM ranges from ~10^{-4} to ~10^{-1} A/m. Demagnetization of NRM at the 20 mT level identifies the Brunhes/Matuyama transition (0.781 Ma), the termination and beginning of the Jaramillo subchron (C1r.1n; 0.988 and 1.072 Ma, respectively), and the termination and beginning of the Cobb Mountain subchron (C1r.2n; 1.173 and 1.185 Ma, respectively) for Hole U1533A. The magnetostratigraphy for Hole

U1533B is complex. So far, a tentative interpretation identifies the beginning of the Olduvai subchron (C2n; 1.945 Ma), the termination and beginning of subchron C2An.1n (2.581 and 3.032 Ma, respectively), the termination and beginning of subchron C2An.3n (3.330 and 3.596 Ma, respectively), the termination and beginning of the Cochiti subchron (C3n.1n; 4.187 and 4.300 Ma, respectively), and the termination and beginning of the Nunivak subchron (C3n.2n; 4.493 and 4.631 Ma, respectively). Subchron C2An.2n (3.116 to 3.207 Ma) may have been recovered in very condensed form. For Hole U1533C, no magnetic polarity reversals were recorded, suggesting that the recovered sediments are younger than the Brunhes/Matuyama transition (0.781 Ma). For Hole U1533D, the Brunhes/Matuyama transition (0.781 Ma), the beginning and termination of the Jaramillo subchron (C1r.1n; 0.988 and 1.072 Ma, respectively), the beginning and termination of the Cobb Mountain subchron (C1r.2n; 1.173 and 1.186 Ma, respectively), and the beginning and termination of the Olduvai subchron (C2n; 1.778 and 1.945 Ma, respectively) were identified.

Petrophysics

For Site U1533, bulk density (GRA), magnetic susceptibility (MS), and *P*-wave velocity were measured using the Whole-Round Multisensor Logger (WRMSL) with a measurement interval of 2.0 cm. Natural gamma radiation (NGR) was also measured on whole-round (WR) cores at an interval of 10 cm. Additionally, 35 thermal conductivity measurements were conducted on split core sections. Moisture and density (MAD) measurements were made on 66 discrete samples, and 102 *P*-wave velocity measurements were made on split core sections with the *x*-caliper, and *y*- and *z*-bayonets. Continuous and distinctive variations in MS provided clear correlation tie points between Holes U1533A–U1533D.

A geothermal gradient was estimated using five downhole formation temperature measurements (APCT-3), and postprocessing of all WR MS, GRA, and NGR data was completed.

Geochemistry

Thirty-two interstitial water (IW) samples were collected from Holes U1533A and U1533B down to 194.56 m. The extracted water volume ranged from 18 to 30 ml (average = ~20 ml) and was analyzed for salinity, alkalinity, pH, chlorinity, and PO_4. pH shows a fairly constant value of 7.6 ± 0.1 throughout. The alkalinity profile shows a steady increase from a nearly seawater value of 2.4 mM at 1.4 m to 10.48 mM at 184.7 m. The chlorinity profile shows a steady increase from a nearly seawater value of 560 mM at 1.46 m to 572.2 mM at 21.96 m. The PO_4 profile increases from 5.0 M at 1.46 m to 38.0 M at 17.79 m, after which it decreases sharply to 0.7 M at 169.35 m.

Headspace gas analysis of samples from Holes U1533A to U1533C documents persistently low methane concentrations (~4 ppmv). Sediments from Holes U1533A to U1533D have low total carbon, total organic carbon, total nitrogen, total sulfur, and carbonate contents; all show only little variation with depth. Total organic carbon to total nitrogen ratios indicate a predominantly

algal-derived nature of the sedimentary organic matter. Sampling for onshore microbiological analysis and tracer experiments was carried out continuously in Holes U1533A to U1533D.

Outreach

The Outreach Officers continue to document the expedition with photos, videos, writing, and comics. Work continued on two comics involving glacier development and ice-rafted debris. Plans solidified for the production of postcruise publications. Comic translations in Mandarin and Filipino were posted on social media, as was a giant comic about Julia Wellner's work leading two simultaneous research cruises in the Amundsen Sea, microscope photos of diatoms, and photos of visiting humpback whales. The Wellner comic was shared with Climate Central, the New York Times, the Guardian, Huffington Post, AGU, and SCAR. Media interviews and university group broadcasts have been scheduled for the final week of the trip. Interviews for postcruise videos and articles continue to be conducted with shipboard scientists. Filming has been completed for a Brazilian IODP (CAPES) promotional video. Final preparations were made for filming interviews for inclusion in postcruise videos. Photos have been distributed to BBC Earth, The British Antarctic Survey, and The Geological Society of London.

Technical Support and HSE Activities

Staff continued supporting science activities at Site U1533.

Logistics

- Preparation of offgoing shipments has started.

Laboratory Activities

- Chemistry:
    - ICP-AES: Replaced plasma torch.
    - Spectrophotometer: Replaced probes.
- Physical Properties:
    - NGR:
        - Replaced pre-amp on detector #7 with no change in the issue reported last week. Further testing is planned on transit into port.
        - Found damaged pins on a spare pre-amp and spare base extender in drawer. The items will either be returned for repair or replacement parts will be ordered. Waiting on a direction from shore.
- Underway Geophysics:
    - Cleaned obsolete level-wind electronics and motor controllers.

- X-Ray Imaging:
    - Added requested utilities to the IMS code;
    - Work on documentation has started.

Application Support Activities

- X-Ray Imaging: Discussions have started regarding the best approach to uploading images into the LIMS.
- SampleMaster and Drill Report: Created a new "Polycrystalline Diamond Compact XCB Bit (PDC)" as a Drill Shoe option.
- Java-11 updates:
    - CorrelationDownloader: Work started on repackaging code for pending Java-11 upgrade.
    - LimsM and SampleLib: Fixed issues caused by Java 11.
    - LDAQ: testing Java-11 Actors.
- LORE: Changed the NGR expanded report to include the configuration_asman_id and configuration_filename data.
- pXRF Report: Removed "PPM" from headers (as some data is in percentages instead of parts per million) and expanded to five decimal places for more accuracy.

IT Support Activities

- Expedition 382 preparation: Created email, server, and DLists accounts.
- Enterasys: Worked with Enterasys' system engineer to resolve issues with self-registration by scientists. Enterasys engineering is evaluating logfiles from last session.
- CommVault: Closed service ticket pertaining to MySQL error message encountered during a restore session of file system files. The error did not pertain to a MySQL restore. Error message not repeatable and log files showed no MySQL error messages. Case closed awaiting further incident.
- Offgoing freight: Worked with Assistant Laboratory Officer to get all I.T. freight paperwork organized for equipment from Expeditions 368X, 379, and transit.

HSE Activities

- Weekly fire and boat drill was held as scheduled.