IODP Expedition 379: Amundsen Sea West Antarctic Ice Sheet History

Site U1532 Summary

Background and Objectives

Site U1532 (proposed Site ASRE-08A) is located on the western upper flank of a large sediment drift (herewith named "Resolution Drift") on the continental rise, 270 km north of the Amundsen Sea Embayment shelf edge. This drill site was chosen as the first Expedition 379 site upon arriving to the Amundsen Sea, because the sea ice distribution did not allow drilling at any of the other primary or alternate sites at the beginning of the expedition. The Resolution Drift belongs to a system of five parallel sediment drifts on this rise that are characterized by gentle western and steep eastern flanks. Sediment drifts are commonly formed by deposition of suspended sediments transported by ocean-bottom contour currents. Deep-sea channels, originating at the foot of the continental slope and reaching far into the abyssal plain, separate the sediment drifts in the Amundsen Sea. Sedimentary material is transported downslope through these channels via turbidity currents, slumps, and other gravity-driven processes that supply a large portion of the detritus deposited in the drifts (Nitsche et al., 2000; Dowdeswell et al., 2006). Sedimentation rates of drift deposits along the Antarctic margin have been observed to be extremely high, which makes them high priority drill targets to obtain continuous paleoceanographic and paleo-ice sheet records of high-temporal resolution (Uenzelmann-Neben and Gohl, 2012). Seismic stratigraphic interpretations of seismic lines across the sediment drifts of the Amundsen Sea (e.g., Nitsche et al., 2000; Scheuer et al., 2006; Uenzelmann-Neben and Gohl, 2012, 2014) are so far only constrained by long-distance correlation to drilled records of drift deposits on the Antarctic Peninsula rise (ODP Leg 178; e.g., Acton et al., 2002), but they suggest equally high sedimentation rates for the Pleistocene, Pliocene, and Upper Miocene.

Operations

Seven holes (Holes U1532A–U1532G) were drilled in a water depth of 3962 m. The deepest hole (Hole U1532G) drilled to 794 m. Overall core recovery was 90%. Although sea ice was not a problem at this site for the *JOIDES Resolution*, frequent approaches of icebergs of various sizes, from large tabular icebergs to smaller fragments and growlers, were the primary reason for the large number of holes. Holes U1532E and U1532F were nothing more than unsuccessful attempts to start coring at depth before being forced to avoid another iceberg approach.

Principal Results

Lithostratigraphy

Deposits recovered at Site U1532 include silty clay with dispersed sand and gravel and variable biogenic content from five holes down to a recovered core depth of 787.4 m. Six lithofacies were identified based on visual characteristics of the sediments combined with information from smear slides and thin sections. Whole core X-radiographs aided in observations of sedimentary structures, clast occurrence, and drilling disturbance. The dominant lithofacies assemblages are planar thinly laminated silty clay with episodic occurrences of massive and bioturbated silty clay typically less than 1.5 m thick. Dispersed sand grains, granules, and occasionally pebbles were observed throughout but appear mainly concentrated within the massive and bioturbated facies. Minor lithofacies include foraminifer-rich and biosiliceous-rich mud to ooze.

We identified one lithostratigraphic unit with three subunits, which include Subunit IA (0–92.6 m; Pleistocene–Pliocene), Subunit IB (92.6–400.6 m; Pliocene) and Subunit IC (401.0–787.4 m; Pliocene–Miocene), based on changes in facies assemblages. The sediments are largely unconsolidated in the upper 150 m, and become increasingly more consolidated below this depth. Intervals of carbonate-cemented laminae and very thin beds of coarse siltstone and sandstone are present below 400 m.

Biostratigraphy

In the upper part of the section recovered at Site U1532 (i.e., from 0 to 92 m), sufficient microfossils for biostratigraphic age assignment were only present in the upper ~10 m, providing an age of Middle Pleistocene to Recent (0.0–0.6 Ma). Based on diatom and radiolarian biostratigraphy, the interval between ~92 and 156 m is assigned a mid-to-Late Pliocene age of 3.2–3.8 Ma, and the interval between ~156 and 224 m is assigned an Early Pliocene age of 3.8–4.4 Ma. The absence of microfossils, or only trace occurrences of highly fragmented and/or recrystallized siliceous microfossils in samples below ~224 m in Hole U1532G, precluded shipboard biostratigraphic age determination at most levels. Exceptions include short intervals with poorly preserved but identifiable diatoms in the interval between ~224 and 332 m (Early Pliocene, <4.7 Ma), and between ~332 and 510 m (Early Pliocene to near the Miocene/Pliocene boundary, <5.5 Ma).

Some light green, biosiliceous-rich intervals coincide with higher concentrations of coarse sands and gravels, inferred to be ice-rafted debris, and are generally bioturbated. Other intervals that were sampled based on their lower density than the laminated silty clay(stones) have a greenish color and show evidence of bioturbation, but lack identifiable siliceous material, which we infer, at least in part, to reflect diagenetic loss of diatoms and other siliceous microfossils. Organic microfossils occur throughout the Site U1532 sequence. A possibly in situ dinocyst assemblage of very low diversity and low abundance is present throughout the section, but is most persistent below 591.77 m. Calcareous microfossils including foraminifers, calcareous nannofossils, and ostracods, occur generally in the absence of biosiliceous material in thin intervals in the Pleistocene section.

Paleomagnetism

The interpreted magnetic polarity of Site U1532 was correlated to the geomagnetic polarity timescale (GPTS) of Gradstein et al. (2012). The resulting key paleomagnetic data were then integrated with biostratigraphic data to produce an age model.

For Hole U1532A, a reliable shipboard magnetostratigraphy was obtained consisting of four normal and four reversed polarity intervals. The Brunhes–Matuyama polarity transition (0.781 Ma), the termination and beginning of the Olduvai Subchron (1.778 and 1.945 Ma, respectively), the Matuyama–Gauss polarity transition (2.581 Ma), the termination and beginning of the Kaena Subchron (C2An.1r; 3.032 and 3.116 Ma, respectively), and the termination and beginning of the Mammoth Subchron (C2An.2r; 3.207 and 3.330 Ma, respectively) were identified. Paleomagnetic measurements for Hole U1532B identified the beginning of the Mammoth Subchron (C2An.2r; 3.330 Ma) and the Gauss–Gilbert polarity transition (3.596 Ma). Paleomagnetic measurements for Hole U1532C identified the termination of the Nunivak Subchron (C3n.2n; 4.493 Ma), but no clear Cochiti Subchron (C3n.1n; 4.187 to 4.300 Ma). Natural remanent magnetization measurements for Hole U1532G identified the beginning of the Nunivak Subchron (C3n.2n; 4.631 Ma), the termination and beginning of the Sidufjall Subchron (C3n.3n; 4.799 and 4.896 Ma, respectively), and the termination and beginning of the Thvera Subchron (C3n.4n; 4.997 and 5.235 Ma, respectively). Reversed magnetic polarity continues down to the bottom of Hole U1532G, and the beginning of Chron C3r (6.033 Ma) was not observed. Therefore, the oldest sediments recovered at Site U1532 are presumably of late Miocene age.

Geochemistry

At Site U1532, 65 interstitial water (IW) samples were collected and measured for salinity, alkalinity, pH, major ions (Na, K, Ca, Cl and SO_4), nutrients (NH_4 and PO_4), $H_4Si(OH)_4$, and trace elements (Sr, Li, Fe, Mn, B, and Ba). Drilling fluid contamination was detected in a few IW samples taken from extended core barrel (XCB) cores. Higher abundances of perfluorocarbon tracer in these samples are in line with this observation. The SO_4 downhole profile shows a sharp linear decrease from ~28 mM near the surface to ~2.3 mM at ~664 m depth; however, it did not reach zero at this site, indicating a low SO_4 reduction rate. The Ca and Sr profiles show an overall increasing trend, whereas the K and Mg profiles display the reverse trend. Silica ($H_4Si(OH)_4$) concentrations are relatively high from 8.5 to 238 m, coinciding with intervals where a higher abundance of diatoms was observed. Diagenesis of diatoms through reaction with the IW likely results in higher silica concentrations.

Calcium carbonate ($CaCO_3$) occurs only in low concentrations in the sediments of Subunit IA; discrete maxima in $CaCO_3$ content observed in the upper section of Subunit IA are linked to layers rich in calcareous foraminifer tests. Subunit IB is characterized by a general increase in $CaCO_3$ content downhole. Total organic carbon content is generally low at Site U1532 but displays a stepwise increase from Subunit IA to Subunit IC. Total nitrogen is generally low throughout all subunits. Total sulfur (TS) values decrease throughout Subunit IA and stay generally low throughout Subunit IB. TS displays a downhole increase in the uppermost section of Subunit IC (until ~533 m). Thereafter, total sulphur (TS) values decline again and show a shift to particularly low values below ~670 m. This shift in TS values is associated with a near depletion of IW sulfate concentrations, which may limit sulfate reduction.

Headspace gas samples to monitor for the presence and abundance of C_1 to C_3 hydrocarbons show that methane occurs in only very low concentrations throughout the first ~650 m cored. At ~667 m, methane concentrations increase rapidly, exceeding 5000 ppmv below ~713 m and reaching a maximum concentration of 9517 ppmv at ~771 m. The increase of methane at ~667 m coincides with a pronounced minimum in sulfate, suggesting that methane may be biogenic at Site U1532.

Physical Properties

Physical properties data collected include magnetic susceptibility (MS), natural gamma radiation (NGR), gamma ray attenuation (GRA) bulk density, discrete moisture and density (MAD), *P*-wave velocity, thermal conductivity, in situ formation temperature (APCT-3), and spectral color reflectance. Whole-round MS trends follow those observed in GRA bulk density and NGR, likely indicating changes in terrigenous sediment content. MS data were used as a primary tool for correlating cores from adjacent holes. A pronounced downhole increase in bulk density from ~1.5 to ~1.8 g/cm^3 is observed in the upper 65 m, followed by a more gradual increase to ~2.2 g/cm^3 in the deeper section, reflecting increasing compaction. Intervals of significantly lower density correspond to greenish gray units in lithostratigraphic Subunits IB and IC. Sediment porosity decreases downhole from 77% to 60% between 0 and 30 m, and decreases further with depth to 35% at the bottom of Hole U1532G, reflecting the downward compaction trend of marine sediments. *P*-wave velocity increases with depth, ranging from ~1460 m/s at the seafloor to ~2000 m/s at the base of Hole U1532G. No major changes in *P*-wave velocity are observed across the lithostratigraphic subunit boundaries. Overall, thermal conductivity values increase with depth from ~1 W/(m·K) at the seafloor, down to ~1.8 W/(m·K) at ~390 m, corresponding to a downhole increase in dry bulk density and decrease in porosity due to compaction. Formation temperature measurements from 34.0 to 150.0 m in Hole U1532A were used to estimate a geothermal gradient of ~54°C/km.

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