IODP Expedition 379: Amundsen Sea West Antarctic Ice Sheet History

Site U1533 Summary

Background and Objectives

Site U1533 (proposed Site ASRE-09A) is located 62 km west-southwest of Site U1532 on the westernmost lower flank of Resolution Drift, the same sediment drift as for Site U1532 on the continental rise of the Amundsen Sea. This lowermost flank is bound by a north–south oriented deep-sea channel west of Site U1533 (Uenzelmann-Neben and Gohl, 2012). The channel is likely the path of sediment transported downslope from the shelf via turbidity currents and mass transport deposits and, as such, is likely the major source of sedimentary components to the drill site (e.g., Dowdeswell et al., 2006). Bottom currents transported the finer fractions of the sediments and deposited them to form a drift (e.g., Nitsche et al., 2000). A reliable horizon correlation from Site U1532 could be performed via three connected seismic lines, indicating that sedimentary sequences of the same age are more condensed at Site U1533.

Operations

Four holes (Holes U1533A–U1533D) were drilled at Site U1533 in water depths between 4179 and 4184 m. The deepest penetration (Hole U1533B) reached a depth of 383 m with an overall core recovery of 70%. As with Site U1532, frequent approaches of icebergs of various sizes were the primary reason for the number of holes.

Principal Results

Lithostratigraphy

Sediments recovered at Site U1533 consist mainly of silty clay with varying biogenic content and amount of bioturbation, and with rare occurrences of diamict and conglomerate. Thin sand and silt beds and laminae occur throughout, and intervals of carbonate cementation and volcaniclastic material are also observed. The recovered sediments are categorized into seven lithofacies based on visual characteristics and lithologic information supported by smear slide observations. The drilled sequence is divided into Lithostratigraphic Subunits IA and IB based on changes in facies assemblages. Whole-core X-radiographs were used to aid in the identification of sedimentary structures, clast occurrence, and drilling disturbance. Site U1533 is dominated by deposition of fine-grained sediments interpreted to be initially supplied by sediment gravity flows from the continental shelf and subsequently reworked by contour currents. Silt and sand lamina beds are interpreted to be deposited during submarine channel overflow. Additionally, a significant amount of biosiliceous material in the sediments is supplied from the overlying surface waters.

The association of facies in Lithostratigraphic Subunit IA predominantly reflects the interplay of downslope and contouritic sediment transport with phases of relatively higher pelagic sediment input during seasonally open marine conditions. The amount of biogenic material is generally high throughout Subunit IA, suggesting relatively sustained periods of high marine productivity. Deposits related to downslope transport are present throughout the sedimentary record at Site U1533. Within Subunit IA, coarse-grained layers probably indicate overspill deposition originating from downslope transport through the adjacent deep-sea channel. Within Lithostratigraphic Subunit IB, generally higher amounts of clasts and pebbles in comparison to Subunit IA were observed. Dispersed granules and pebbles as well as clast nests and discontinuous bands of coarse sand and granules in Subunit IB are inferred to indicate persistent but likely low-intensity ice rafting. This style of ice rafting may have increased periodically during warmer periods. This is particularly evident by the deposition of ice-rafted debris within diatom ooze intervals.

Biostratigraphy

In contrast with Site U1532, which contains significant intervals that are barren of microfossils, the majority of Site U1533 samples from the mudline to the lowermost sediments contain microfossils. Preservation and abundance of microfossils is highly variable, including some unfossiliferous intervals noted in the uppermost Pliocene–lowermost Pleistocene and lower Pliocene sections. A similar general pattern of alternating gray-beige to brownish sediments (Lithostratigraphic Subunit IA) and gray-beige to greenish sediments (Lithostratigraphic Subunit IB) as observed at Site U1532 is commonly observed at Site U1533, consisting of gray, laminated, microfossil-poor largely terrigenous mudstones, punctuated by thinner brownish to greenish, bioturbated, variably biosilica-bearing intervals, some with sand to pebble-sized material interpreted as ice-rafted debris. However, the brownish and greenish, bioturbated units have a higher overall concentration of biosiliceous material than at Site U1532.

The upper ~40 m of Site U1533 spans the Pleistocene and contains variable concentrations of diatoms, radiolarians, and foraminifers, along with rare marine and reworked terrestrial palynomorphs and very rare calcareous nannofossils. Diatoms and radiolarians are present in most samples examined from this interval. Foraminifers are present only within a few intervals in the upper ~10 m of the sequence. Marine and terrestrial palynomorphs are absent in the upper ~40 m of Site U1533, except for rare occurrences of marine palynomorphs and reworked terrestrial palynomorphs.

Pleistocene to Upper Miocene sediments were recovered in Hole U1533B, dated primarily by diatoms and radiolarians. Diatoms and radiolarians are documented with variable abundance, from the top to the bottom of Hole U1533B. Samples from the lowermost cores generally contain common to abundant diatoms, although the assemblages are highly fragmented. Diatoms and radiolarians provide a latest Miocene age (6.2–6.7 Ma) for the basal sediments recovered in Hole U1533B; combined with magnetostratigraphic constraints, the basal sediments in Hole U1533B are ~6.4–6.75 Ma. Foraminifers and calcareous nannofossils were not observed in the Pliocene sediments from Hole U1533B, whereas rare to common marine and reworked terrestrial palynomorphs are present throughout the hole.

Paleomagnetism

For Hole U1533A, demagnetization of natural remanent magnetization 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).

The magnetostratigraphy for Hole U1533B is more complex than Hole U1533A as a result of reduced core recovery and drilling disturbance of some intervals. The shipboard 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) might be present in very condensed form in Core U1533B-5H at ~58 m. Further downhole, paleomagnetic measurements revealed 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). Below an interval without core recovery, the oldest Cores U1533B-39R and 43R are of mainly normal polarity, suggesting a bottom age for Hole U1533B between the termination of Subchron C3An.1n (6.033 Ma) and the beginning of Subchron C3An.2n (6.733 Ma). Oscillating values of normal and reversed polarity at the bottom of Hole U1533B provide no clear evidence that Subchron C3Ar was recovered.

For Hole U1533C, no magnetic polarity reversal was recorded, suggesting that the recovered sediments are younger than the Brunhes–Matuyma transition (0.781 Ma).

For Hole U1533D, paleomagnetic measurements identified the Brunhes–Matuyama transition (0.781 Ma), the termination and beginning of the Jaramillo Subchron (C1r.1n; 0.988 and 1.072 Ma, respectively), the termination and beginning of the Cobb Mountain Subchron (C1r.2n; 1.173 and 1.186 Ma, respectively), and the termination and beginning of the Olduvai Subchron (C2n; 1.778 and 1.945 Ma, respectively).

Chronostratigraphy

Combining biostratigraphy and magnetostratigraphy, the interval above ~37 m is assigned a Pleistocene age, the interval between ~37 and 265 m is assigned a Pliocene age, and the interval from ~265 to 383 m (base of recovery at Site U1533) is assigned a latest Miocene age. The combined data indicate an age of 6.4 to 6.75 Ma for the base of Hole U1533B at 381.23 m.

Geochemistry

Pore water salinity at Site U1533 has a constant value of 35 from the seafloor to ~235 m and a slightly lower value (33 to ~34) from 255 m to 375 m. Chloride (Cl) concentration ranges between 557 and 596 mM, with the latter concentration being slightly higher than the average value of modern seawater (~559 mM). The elevated Cl concentrations could be due to hydration reactions during clay formation. Sodium (Na) concentration ranges between 440 and 483 mM throughout the section. Below ~17 m, SO_4 decreases continuously with depth and reaches a minimum value (~1.6 mM) at 375 m. However, SO_4 concentration is still detected in the lowermost sediments recovered at the site. Pore water alkalinity increases linearly with depth from 1.5 m to a maximum (~10.5 mM) at ~185 m, which is the opposite trend to that of SO_4 concentration. Below ~185 m, alkalinity slightly decreases with depth to 255 m.

Strontium (Sr) concentrations show an overall increase from 85 μM at 1.5 m to 196 μM at 255 m, reaching maximum values ~2× higher than that of the modern seawater value (87 μM). The higher Sr indicates either higher fluid-rock reaction with volcaniclastic material or dissolution of carbonates.

Methane concentrations are ~4 ppmv, close to the instrumental background signal, in Hole U1533A and most of Hole U1533B. At ~325.60 m, there is an abrupt downhole increase in methane concentrations, which peak at 6373 ppmv at 375.02 m. No hydrocarbons other than methane were detected at Site U1533. Increased methane concentrations were found only at the base of Subunit IB, where the lowest sulfate values were observed. Together with the absence of higher hydrocarbons this suggests a biological source of methane at Site U1533.

Total carbon contents vary from 0.02 to 0.5 wt% and show an increasing trend with depth. Calcium carbonate is low at Site U1533 and ranges from 0.02 to 2.54 wt%. Total organic carbon content varies between 0.01 and 0.41 wt% and is similar in terms of trends and abundances to the total carbon record, indicating that organic carbon constitutes most of the total carbon pool.

Samples for contamination testing were collected from the exterior and the center of freshly exposed core sections or whole-round samples. Tracers were present in variable concentrations in samples taken from most advanced piston corer (APC) core exteriors due to the direct exposure of the core surface to circulating drilling fluids. However, tracer concentrations are approximately four orders of magnitude lower in these samples than the target concentrations of tracers in the drilling fluid. Tracers were below detection in the interior of most APC and half-length APC (HLAPC) cores. The absence of tracers from the central parts of most APC/HLAPC cores and their generally low presence in core exteriors suggest low overall contamination. Extended core barrel (XCB) cores generally showed low contamination in both the interior and exterior samples but, in contrast to APC/HLAPC cores, contamination was consistently present in the center of the cores. The sampled rotary core barrel (RCB) cores generally showed higher levels of tracer contamination than APC/HLAPC and XCB cores.

Physical Properties

Measured whole-round magnetic susceptibility (MS) values range from ~4.7 to ~804.6 × 10^{-5} SI; average MS values increase downhole from ~50 to ~100 × 10^{-5} SI until ~55 m, where the boundary between Lithostratigraphic Subunits IA and IB is present. Within this general downhole increase, the upper ~15 m of Holes U1533A, U1533C, and U1533D exhibit a "sawtooth" pattern of MS cyclicity, wherein a sharp increase in overall MS values is followed by a more gradual decline. MS data were used as a primary tool for correlating cores from adjacent holes for creation of a shipboard splice for the top ~44 m of the site. Measured natural gamma ray (NGR) values range from ~13.5 to ~235.1 counts/s with an overall average of ~56.1 counts/s. Average NGR values increase downhole from ~20 counts/s at the mudline to ~75 counts/s at ~55 m, at the boundary between Lithostratigraphic Subunits IA and IB. Below ~55 m there are cyclical downhole variations between ~20 and 75 counts/s. NGR trends follow those observed in MS and gamma ray attenuation (GRA) bulk density values (except for the sawtooth variability observed in the upper holes), likely indicating changes in the ratios between biogenic and terrigenous sediment content. The GRA bulk density record shows a sharp downhole increase in average values from ~1.3 to ~1.8 g/cm^3 in the first ~55 m that corresponds to Lithostratigraphic Subunit IA. Below this depth, GRA density values exhibit several stepwise changes. The overall increase in GRA bulk density with depth at this site reflects the increasing compaction of sediment with depth. Smaller scale variability denotes changes in sediment lithology, and correlates well with NGR and MS variability. Moisture and density (MAD) bulk densities increase sharply downhole from ~1.3 g/cm^3 at the seafloor to ~1.7 g/cm^3 at ~50 m, corresponding to a sharp decrease in porosity and void ratio. From ~50 m to the bottom of Hole U1533B at ~383 m, the bulk density increases more gradually.

P-wave logger (PWL) velocities increase with depth, ranging from ~1480 m/s at the seafloor to ~1620 m/s at ~205 m. *P*-wave caliper (PWC) measurements track well with the PWL measurements for the upper ~205 m, showing a gradual increase with depth. PWC velocities continue to increase with depth as consolidation increases to an average velocity of ~1780 m/s at ~380 m.

Thermal conductivity values increase with depth from ~0.7 W/(m·K) at the seafloor to ~1.4 W/(m·K) at ~375 m, corresponding to a downhole increase in dry bulk density and decrease in porosity from compaction.

References

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