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

Site U1537 Summary

Background and Objectives

International Ocean Discovery Program (IODP) Site U1537 (proposed Site SCO-18A) is located 265 km northwest of the South Orkney Islands at 59°6.65′S, 40°54.37′W in 3713 m of water. The site lies in the northeast part of the Dove Basin, in a ~1 km thick contourite drift, and is situated at shot point 4900 on multichannel seismic reflection profile SCAN 2014/07, 5 km west–northwest of crossing line SCAN 10/04. The objective was to obtain a second sedimentary record in Dove Basin with a similar overall seismic structure (Units I–V) but with less stratigraphic disturbance than observed at Site U1536. Site SCO-18A was originally an alternate site but was selected for drilling because the top ~150 m of the stratigraphy appeared to be uninterrupted by the thin slumped intervals observed in the other possible sites in the Dove Basin (as seen in the seismic and echo sounder profiles). The goals were to reach Reflector B at ~350 mbsf as well as to reconstruct the Plio–Pleistocene ice and ocean dynamics.

Sediments in the southern Scotia Sea are primarily deposited by contourite currents along the pathway of the Antarctic Circumpolar Current (ACC). Specifically in Dove Basin, contourite deposition is also assumed to be influenced by Weddell Sea Bottom Water (WSBW) flowing from the south through bathymetric gaps around the South Orkney Plateau after exiting the Weddell Sea (Maldonado et al., 2003). The contourites at Site U1537 are lens shaped in seismic profiles and up to 800 m thick in the center of the small trough. They thin toward the eastern edge.

Interpretation of seismic line 2004/07 identifies Reflectors A, B, and C (Perez et al., 2017). In Dove Basin, three seismic lines indicate a basin-like structure with several small-scale ridges and continuous reflectors in the central to northern part of the basin. The seismic reflectors show overall parallel lamination with occasionally undulating structures, indicative of minor synsedimentary downslope transport. This is a fairly common feature in the basin, and none of the expedition's proposed sites were able to avoid these disturbances completely.

At Site U1537 the main objective was to obtain a late Neogene record of ice and ocean dynamics from the center of Iceberg Alley in the more southerly of our two drilling areas in the Scotia Sea. Specific objectives include (1) the reconstruction of past variability in Antarctic Ice Sheet (AIS) mass loss and the related sea level history; (2) a study of the water mass composition of the Drake Passage throughflow and WSBW inflow; and (3) a study of north–south shifts of the frontal systems in response to changing climate conditions, including changes in water mass properties, ocean temperature, and sea ice extent. An additional goal is to reconstruct changes in dust-climate couplings between Patagonia and Antarctica as well as related atmospheric circulation changes throughout the Plio–Pleistocene in a distal location relative to the source (e.g., Patagonia).

Operations

We arrived at Site U1537 at 0515 h on 26 April 2019. We started to make up the advanced piston coring (APC) bottom-hole assembly, but high heave and roll forced us to pause operations for ~7 h. Additionally, we had to move ~1 nmi to the northwest to allow an iceberg to pass over the site location. Operations resumed at 1430 h and we lowered the drill string to the seafloor.

We started Hole U1537A at 0140 h on 27 April, at 3712.9 m below sea level as calculated from the mudline. Cores U1537A-1H to 31F penetrated from the seafloor to 264.0 mbsf and recovered 268.9 m (102%). After Core 26H was difficult to pull out of the formation and had to be drilled over, we switched to half-length APC coring (HLAPC) for Core 27F at 240.0 mbsf. An iceberg moved into the red zone at 1830 h on 28 April, so we raised the drill string to 38 mbsf, and at 2020 h, after further encroachment of the iceberg, we ended Hole U1537A. Although we could not core at depth in Hole U1537A, we could take a mudline core because this operation does not require the drill string to be below the seafloor, and the iceberg was not close enough to be within the termination zone.

Hole U1537B started at 0010 h on 29 April and consisted of a single core taken for high-resolution pore water sampling. Core U1537B-1H penetrated from the seafloor to 7.4 mbsf.

Hole U1537C started at 0135 h on 29 April and Cores U1537C-1H to 2H penetrated from the seafloor to 15.3 mbsf and recovered 11.9 m (78%). After the Core 2H liner shattered and two large icebergs entered the red zone at 0400 h, we decided to end Hole U1537C. We raised the drill string clear of the seafloor and moved aside in dynamic positioning mode to let the icebergs pass. By 1500 h we were able to move back to the site location.

Hole U1537D started at 1945 h on 29 April. Cores U1537D-1H to 50F penetrated from the seafloor to 354.3 mbsf and recovered 349.0 m (99%). We took two HLAPC cores (Cores 20F and 21F) across a hard layer that had been found in Hole U1537A at ~182 mbsf, before returning to full-length APC coring for Cores 22H to 27H. Below 244 mbsf the formation was too hard for APC coring, so we used HLAPC coring from that point down to the bottom of the hole. Icebergs were monitored on 30 April and 1 May, but none of them posed a hazard to operations. From 1345 to 1430 h on 2 May we paused coring while monitoring an iceberg that was at the edge of the red zone, but it turned away from the ship and we resumed coring. Because high winds and swell were forecast for 3 May, we decided to end Hole U1537D in the early evening of 2 May to leave enough time to raise the drill string to the ship and also to leave sufficient time for the coring and logging program at the next site (Site U1538, proposed Site SCO-11) in the Pirie

Basin area. The bit cleared the seafloor at 2140 h and was raised to the ship by 1030 h on 3 May, which completed operations at Hole U1537D.

Principal Results

Piston cores from Holes U1537A and U1537D provided near continuous stratigraphic coverage down to 264 and 354 mbsf, respectively. Based on these cores, three major lithologic units were identified. Unit I, from the seafloor to ~180 mbsf, consists of interbedded diatom ooze and silty clay. The unit is subdivided into three subunits, depending on the relative abundance of diatom ooze and silty clay. Unit II, from ~180 to ~260 mbsf, is almost exclusively silty clay with varying amounts of biosilica and contains discrete color-banded intervals. Unit III, from ~260 to ~354 mbsf, is more lithified and consists of interbedded silty clay and diatom ooze. Unit III contains a series of slumps with inclined and folded beds, interbedded with horizontally layered sediment. Throughout the cores, ice-rafted debris (IRD) was rare to common and was particularly visible in the core X-ray images as granule to pebble-sized shapes with sharp edges. Bioturbation was also rare to common with abundant thin (mm thick) pyritized burrows visible in the X-ray images.

Diatom, radiolarian, foraminifer, and palynomorph biostratigraphic results were consistent for all samples from Holes U1537A and U1537D, and showed 81 biostratigraphic events. Based on these events, we estimate sedimentation rates of ~14.8 cm/ky between the seafloor and 180 mbsf (~1.5 Ma), and ~6.1 cm/ky from 180 mbsf to the base of Hole U1537D at 354 mbsf (~4.45 to ~5.0 Ma). Diatom and radiolarian biostratigraphy indicates that Site U1537 has a continuous stratigraphy from the early Pliocene to the Holocene as no major hiatuses were detected. There was considerable reworking of diatoms and radiolarians, especially from 287 to 311 mbsf. Overall preservation was relatively good in all samples, and fragmentation was more common than dissolution. Palynomorphs (dinocyst, acritarch, prasinopytes, pollen, spores, copepod, and fungi remains) were identified in the 23 samples processed for palynology. Dinocyst diversity was generally low with relative abundance varying from abundant/common in the upper 155 m to few/barren in the lower half of Holes U1537A and U1537D. An exception was Samples U1537D-38F-CC through 42F-CC (296–316 mbsf), which had a relatively high dinocyst abundance.

All paleomagnetic polarity zones of the 2012 Geologic Time Scale (GTS) were identified in the combined paleomagnetic records from Holes U1537A and U1537D, spanning the Brunhes Chron (C1n) to the base of the Mammoth Subchron (C2An.2r; 3.33 Ma). Deeper than C2An.2r we measured ~5 m of normal polarity, which we interpret as the early Gauss Chron (C2An.3n). This interpretation places the base of this polarity zone between 3.33 and 3.60 Ma on the 2012 GTS timescale. Intervals of slumped sediments underlie this normal polarity zone, but the intervening flat-lying sediments include a polarity transition and ~20 m of reverse directions, which we interpret to be the late Gilbert Chron (C2An and C2Ar). The two lowermost cores of Hole

U1537D, Cores 49F and 50F, have scattered paleomagnetic directions and cannot be assigned to a polarity zone at this time. This suggests that the base age for Hole U1537D above these two cores is between 3.6 and 4.2 Ma.

Samples were collected for headspace gas and pore water chemistry analyses in Hole U1537A. Downhole profiles of headspace gas and bulk inorganic and organic carbon in Site U1537 are very similar to those from Site U1536. Methane concentrations in headspace gas were low in all cores, and concentrations of ethane and propane were below the detection limit throughout the hole. Hole U1537A had relatively low contents of total organic carbon, total nitrogen, and calcium carbonate. Site U1537 has comparable trends to Site U1536 but with some subtle differences. The sulfate-depleted zone is significantly less expanded than at Site U1536, encompassing <80 m. Dissolved Ba contents at those depths are significantly lower than at Site U1536, and alkalinities reach <30 mM (compared with almost 40 mM at Site U1536). Ammonia concentrations are also lower. Systematic Mg and K depletion downhole suggests that continuous authigenic clay formation occurs throughout the sediment column. Calcium is precipitated from pore water in the upper section and replenished below the sulfate reduction zone. Other major and trace elements, such as B, Si and Sr, increase downhole. Fe contents are generally low, whereas Mn is somewhat elevated in the uppermost 30 m. Overall, the observed geochemical patterns suggest only moderate diagenesis, which is encouraging for a variety of planned postexpedition geochemical analyses.

Distinct cyclic changes were observed in physical properties records in Holes U1537A and U1537D, especially for natural gamma radiation (NGR) and magnetic susceptibility (MS). These cycles are up to 10 m long in the upper 180 m. Below that depth, cycles are shorter, have lower amplitude, and are superimposed on longer scale changes. Cyclic changes are likely controlled by insolation-driven climate variations and are useful for stratigraphic correlation. Downhole sediment compaction is reflected in the overall increasing trend in density and *P*-wave velocity with depth. Step changes in the physical properties records line up with main discontinuities in seismic and echo sounder profiles. In particular, a baseline increase in GRA, MS, and NGR at ~180 mbsf is associated with Reflector B in the preexpedition seismic interpretation. Additionally, an increase in velocity and density observed at 230 mbsf is coincident with an increase in reflectivity in the seismic data.

References

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