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

Site U1534 Summary

Background and Objectives

International Ocean Discovery Program (IODP) Site U1534 (proposed Site SFSD-3A) is located at 53°11.38′S, 58°45.65′W, in 605 m of water. The site is situated on the northern flank of a large trough, ~660 km east of the Magellan Straits, at common depth point 10005 on seismic reflection profile SGFI93. Site U1534 is the first of a pair of sites. The second, Site U1535 (proposed Site SFSD-2A), 8 km to the east, targeted an expanded copy of the upper part of the Site U1534 stratigraphy, down to 120 m below seafloor (mbsf).

The primary objective at Site U1534 was to recover a continuous ~300 m sedimentary section from a contourite drift, where the crest is currently being deposited beneath the Subantarctic Front (SAF) at 600 m water depth. The drift is bathed with Antarctic Intermediate Water (AAIW) as it begins its northward penetration into the Atlantic Ocean. The principal scientific motivation to core this drift is to better understand the role of AAIW in climate change on millennial, glacial-interglacial, and longer term timescales.

AAIW is one of the primary water masses characterizing the northward-flowing upper limb of the Atlantic meridional overturning circulation (AMOC). Counterbalancing the southward flow of North Atlantic Deep Water (NADW), AAIW currently penetrates as far as 20°N in the North Atlantic Ocean. Despite a recent surge in research effort (e.g., Voigt et al., 2016; Roberts et al., 2017; McClymont et al. 2016), a consensus on the role of AAIW in contributing to AMOC variability has not been reached.

Today, AAIW is primarily formed in the southeast Pacific and southwest Atlantic Oceans. AAIW and its precursor, Subantarctic Mode Water, are advected eastward through the Drake Passage along the SAF. This injection of cold, low salinity Pacific water into the South Atlantic Ocean is commonly referred to as the “cold water route.” Variability in the connectivity between the Pacific and Atlantic Oceans via this cold water route may modify the physical properties of AAIW forming in the southwest Atlantic Ocean, in turn affecting the heat and salinity budget of the AMOC. Proxy records from Sites U1534 and U1535 will provide the first constraints on past variability in endmember physical and geochemical properties of AAIW as it enters the upper limb of the AMOC.

Site U1534, at the thickest part of the contourite drift, targeted the highest sediment accumulation rates to optimize temporal resolution of subsequent reconstructions. Four laterally offset sedimentary units indicate that the drift was deposited under an evolving bottom current regime (Koenitz et al., 2008; Perez et al., 2015). Seismic interpretation of drift deposits throughout the Scotia Sea area suggests that drift deposits began forming beneath the Antarctic

Circumpolar Current (ACC) in the early Miocene and that unconformity-bounded sedimentary units represent deposition under different oceanographic configurations. To test hypotheses about the conditions under which these units were deposited, a key objective at Site U1534 was to core all three of the reflectors and determine the ages of the unconformities. Furthermore, confirming whether these reflectors are synchronous with their proposed counterparts in the Scotia Sea will enable a regional reconstruction of oceanographic evolution of the ACC in this sector of the Southern Ocean.

Operations

The first core of Expedition 382 was taken at Hole U1534A at 2250 h on 29 March 2019, in a water depth of 605.1 m below sea level (mbsl). We used the advanced piston corer (APC) to take Cores 1H to 14H (to 115.7 mbsf), drilled through a hard layer, and switched to half-length APC (HLAPC) coring for Cores 16F to 44F (to 256.7 mbsf). The extended core barrel (XCB) was used to take the final cores, Cores 46X and 47X. Overall, Cores U1435A-1H to 47X penetrated from the seafloor to 266.3 mbsf and recovered 271.7 m (102%).

Hole U1534B started at 0245 h on 1 April. Core 1H recovered 1.5 m of sediment, but the core liner shattered and no clear mudline could be observed, so we ended the hole.

Hole U1534C started at 0345 h on 1 April. Cores 1H to 19H penetrated from the seafloor (606.3 mbsl) to 168.0 mbsf and recovered 159.6 m (95%).

Hole U1534D started at 0045 h on 2 April. The purpose of this hole was to fill a stratigraphic gap and to provide more material for sampling in the upper part of the stratigraphy. Cores 1H to 3H penetrated from the seafloor to 28.5 mbsf and recovered 29.6 m (104%).

Principal Results

Late Pleistocene strata (0–84 mbsf) are characterized by interbedded foraminifer-bearing green-gray silty clay and clayey silt. A distinctly lighter colored sediment interval spanning several sections within Core U1534C-5H contained almost 50% carbonate (composed of nannofossils and foraminifers) and likely represents interglacial Marine Isotope Stage 11 (MIS 11). Centered at 40 mbsf, this interval is interpreted to represent Reflector A in the seismic profile. Other intervals where planktonic foraminifers are more abundant are tentatively assigned to interglacials MIS 5e, 9, and 17, as supported by paleomagnetic and biostratigraphic data, and by cyclicity in physical properties data such as natural gamma radiation (NGR) and bulk density. Sediments with lower NGR and bulk density values are interpreted to be more microfossil-rich and represent interglacials.

The most common biogenic components, sponge spicules and diatoms, generally comprise between 10% and 25% of the sediment. Calcareous microfossils such as foraminifers, ostracods, and coccoliths are concentrated in meter-scale layers and are present down to ~84 mbsf. Several well-preserved macrofossils were found throughout the cores, including solitary cold-water corals, gastropods, and mollusk shell fragments. Ice-rafted clasts are present but rare.

A downhole shift to early Pleistocene–late Pliocene radiolarian and diatom species below 84 mbsf (Section U1534C-10H-3), the depth expected for Reflector B, indicates that this reflector represents a hiatus. The absence of a clear magnetic reversal from 0 to 84 mbsf suggests that the age above the unconformity is no older than 0.78 Ma. Below Reflector B, paleomagnetic normal polarity extends down to 233 mbsf and may constrain most of this interval to the Gauss subchron C2An.1n (2.58–3.03 Ma), implying sedimentation rates of ~40 cm/ky. Green-gray silty clay continues to dominate below Reflector B. Carbonate remains below 1 wt% from 110 to 233 mbsf, and increases up to 5 wt% below 233 mbsf.

A hiatus is indicated by the diatom and radiolarian biostratigraphy at ~257 mbsf and is interpreted to be Reflector C. Below Reflector C, diatom and radiolarian biostratigraphic markers date the two lowermost cores of Hole U1534A (257–266 mbsf) as Early Pliocene (4.1–4.7 Ma).

Pore water and headspace gas samples were taken from all APC cores and every second HLAPC core from Hole U1534A, showing a normal headspace gas depth profile. There is relatively low salinity from ~30 to 150 mbsf, and the highest alkalinity (up to 30 mM) is at 20–30 mbsf, coinciding with the methane/sulfate transition zone.

Four formation temperature measurements were made with the advanced piston corer temperature tool (APCT-3) while taking Cores U1534A-4H, 7H, 10H, and 13H. Combining the formation temperature measurements with the laboratory thermal conductivity measurements yields a preliminary heat flow estimate of 49 mW/m^2 for Site U1534.

In summary, cores collected at Site U1534 will give new insights into the evolution of the contourite drift deposit and ice sheet-ocean-climate interactions in the southwest Atlantic Ocean, an area where long paleoclimatic records are relatively sparse. Dating the seismic reflectors and the sediment units between these unconformities will allow us to reassess the local ice sheet and oceanic regimes under which sediment supply and current configuration led to drift deposition. High sediment accumulation within the late Pliocene interval will provide insights into the history of the Patagonian ice sheet in addition to AAIW export as Northern Hemisphere glaciation intensified. Late Pleistocene sedimentation rates of ~10 cm/ky will allow millennial-scale reconstructions of the position of the SAF as well as AAIW export to be extended back to at least MIS 17. The prominence of MIS 11 at Site U1534 and all the other sites cored during Expedition 382 provides an opportunity to reconstruct a transect across the ACC during this superinterglacial in unprecedented temporal resolution. Comparison of the records from Site U1534 with recent records from Amundsen Sea Expedition 379 and Ross Sea Expedition 374 will provide a critical link between processes on the Antarctic continent, South American glaciations, and the upper limb of the AMOC. Interhemispheric and interbasin comparison of these records will determine how variable transport via the "cold-water route" may affect AAIW export in the South Atlantic and the rate of AMOC on multiple timescales.

References

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