IODP Expedition 383: Dynamics of the Pacific Antarctic Circumpolar Current (DYNAPACC)

Site U1543 Summary

Background and Objectives

Site U1543 (proposed Site ESP-1B) is located in the eastern South Pacific at 54°35.06′S, 76°40.59′W, ~110 nmi west of the Chilean coast and ~120 nmi south–southwest of Site U1542 at a water depth of ~3860 m. The site is situated west of the Chile trench on a topographically elevated ridge ~300 m above the trench axis (~4200 m water depth). The basement at this location is oceanic crust with an age greater than ~20 Ma.

Site U1543 lies at the intersection of two seismic lines with a sediment thickness of 600–700 m, on multichannel seismic (MCS) profile AWI-20160501 ~1 nmi southwest of the intersection with profile AWI-20160503. Sediments are mostly well stratified, with only slightly irregular reflectors. Sediment cover is drape-type and entirely covers the underlying basement morphology. Sediment echo sound (Parasound) profiles reveal moderate penetration (~70 m) with distinct layering suggesting a succession of fine-grained sediments with varying lithological composition.

Site U1543 is located at the offshore reach of the southward flowing Cape Horn Current (CHC), a northern branch of the Antarctic Circumpolar Current (ACC) that continues towards the Drake Passage and provides a major fraction of the present day northern Drake Passage transport. Satellite-tracked surface drifters reveal that, after crossing the East Pacific Rise, Subantarctic Surface water of the ACC is transported northeastward across the Southeast Pacific towards the Chilean coast at ~45°S, 75°W. Here, presently only a minor part of ACC water is deflected northward into the Humboldt Current System (CHS), whereas the major fraction deviates southward towards the Drake Passage. The CHC thus transports a significant amount of northern ACC water towards the Drake Passage within a narrow belt of ~100–150 km width along the coast. Modern surface current velocities within the CHC reach up to >35 cm/s at the continental margin (Site U1542) but decrease offshore towards Site U1543.

Site U1543 is presently located at the lower limit of Lower Circumpolar Deep Water (LCDW) and might have been affected by Antarctic Bottom Water (AABW) in the past. The site is located ~4° north of the present Subantarctic Front. Modern mean annual sea-surface temperature (SST) in this area is ~8.5°C and the seasonal range is 6° to 9°C.

The main objectives at Site U1543 were:

- Recover a Plio/Pleistocene undisturbed, continuous sediment record with medium to high sedimentation rates;
- Reconstruct the strength of the CHC (Subantarctic ACC) before entering the Drake Passage;

- Investigate AABW, CDW, and Pacific Deep Water (PDW) water mass properties;
- Investigate changes of continental paleoclimate;
- Recover a potential near-field record of Patagonian ice sheet variability over the past several million years.

Operations

The *JOIDES Resolution* completed the 119 nmi transit from Site U1542 to Site U1543 at 1717 h on 8 July 2019, in 10.5 h and averaging 11.3 kt. A water depth reading using the precision depth recorder set the preliminary seafloor depth at 3877.4 m below rig floor (mbrf) for Hole U1543A. The operations plan for Site U1543 initially included three holes to a depth of 400 mbsf. This was modified due to time lost to weather during the expedition, shallowing the penetration depth to 250 mbsf for each hole. While coring Hole U1543A, it was decided to continue deepening the hole until APC refusal, and to core only two holes to APC refusal at this site.

Hole U1543A was spudded at 0325 h on 9 July and coring with the APC system continued to 339.6 mbsf. Coring was terminated after 90,000 lb of overpull were needed to retrieve Core U1543A-36H. The drill string was pulled out of the hole, clearing the seafloor at 1830 h on 11 July. Overall, 350.6 m was recovered with a recovery of 103%.

The vessel then was offset 20 m to the east of Hole U1543A and Hole U1543B was spudded at 2010 h on 11 July. The seafloor depth was calculated at 2876.4 mbrf (3865.3 m below sea level [mbsl]) based on the recovery from Core U1543B-1H. Hole U1543B was cored entirely with the APC system, with two drilled intervals used to cover coring gaps between Holes U1543A and U1543B. The first drilled interval (1.9 m) followed Core 1H and the second drilled interval (1.5 m) followed Core 23H. Core 33H reached a total depth of 286.5 mbsf. Overall, a 283.1 m interval was cored with 104% recovery.

The drill string was retrieved to the surface, clearing the seafloor at 1800 h on 13 July and the rotary table at 0045 h on 14 July. The rig floor was secured for transit at 0110 h and the *JOIDES Resolution* began transiting to Site U1544 (proposed Site CHI-1C).

Principal Results

A 376.3 m long spliced sedimentary sequence was recovered from Site U1543. The sedimentary record comprises five lithofacies, which were identified at previous Expedition 383 sites. This includes major biogenic lithologies (such as nannofossil ooze [lithofacies 4]; clay-bearing to clayey diatom ooze [lithofacies 6]; and diatom-, clay-, and/or silt-bearing to rich nannofossil or calcareous ooze [lithofacies 10]) and mainly siliciclastic sediments (diatom-bearing to rich clay [lithofacies 7], and silt-bearing clay to clay-bearing silt [lithofacies 8]). The biogenic lithofacies

were first characterized in the central South Pacific, whereas the pure siliciclastic sedimentary lithofacies were observed at the northern Chilean margin Site U1542. Their definition is expanded according to the variety of lithofacies observed at this site. The sedimentary sequence at Site U1543 is characterized by moderate average sedimentation rates of ~5 cm/ky. Site 1543 comprises two lithostratigraphic units, Unit I (0–115 m core composite depth below seafloor, CCSF-A) and Unit II (115–376.3 m CCSF-A), which span the early Pleistocene to Holocene and late Miocene to early Pleistocene intervals, respectively. Unit I largely consists of greenish gray to dark greenish gray silt-bearing clay (lithofacies 8) that contains prominent 10–30 cm thick beds of light gray to light greenish gray carbonate-, clay-, and/or diatom-rich nannofossil ooze. Below 115 m CCSF-A, the abundance of diatomaceous sediments increases, mostly in the form of diatom-bearing silty clay (lithofacies 7) and carbonate and silt-bearing diatom ooze (lithofacies 6). The latter often occurs in association with decimeter-scale beds of nannofossil ooze. Diatom mats and dropstones are rare, whereas burrows and mottling due to diagenetic overprints are frequent. Lithification, secondary carbonate precipitation, and microfracturing increasingly occur below 275 m CCSF-A.

Diatoms and radiolarians are abundant throughout the sediment succession; silicoflagellates are absent to few, but locally abundant; nannofossil abundance varies strongly with good preservation; benthic and planktonic foraminifers are absent in glacial intervals with moderate preservation when present; and ostracods are rarely present and are restricted to Miocene samples. The biostratigraphic analyses of Hole U1543A core catcher and split-core samples led to the recognition of 56 biostratigraphic events, which indicate an estimated age of 7.3–8.5 Ma at the bottom of the hole.

The natural remanent magnetization (NRM) of the archive-half core sections of Site U1543 was measured before and after alternating field (AF) demagnetization at 2 cm increments. The intensities before and after demagnetization for the upper 140 mbsf recovered from Hole U1543A are generally quite strong, varying around the 10^{-1} to 10^{-2} A/m range. A few discrete intervals have values as low as 10^{-4} A/m and are generally associated with low magnetic susceptibility values. Below 140 mbsf, intensities are slightly lower on average, falling in the 10^{-2} A/m and below range. Below 240 mbsf, intensities are more variable, with values in the 10^{-3} to 10^{-4} A/m range being much more common. Compared with previous sites, there is little difference in intensity before and after demagnetization at a peak AF field of 15 mT, suggesting a finer magnetic mineralogy with a higher coercivity that is less susceptible to the drill string overprint.

The inclination for Holes U1543A and U1543B before and after AF demagnetization at 15 mT captures a series of apparent polarity reversals, which are either directly observed or inferred from polarity changes between cores and are generally well defined when observed within a section. All polarity boundaries from the Matuyama–Brunhes transition at 0.781 Ma though C3Br.2r at 7.285 Ma (31 polarity reversals in total) are either directly observed or closely constrained and correlated to the geomagnetic polarity timescale (GPTS). Reversed and normal

polarities associated with the base of Chron C3B and the upper part of C4 (older than 7.432 Ma) are observed, but the boundaries are not constrained in the deepest cores in Hole U1543A. Shore-based studies will refine correlations to the GPTS and facilitate development of a relative paleointensity curve as the next steps in magnetic stratigraphy at Site U1543.

Close to the sediment water interface, where oxygen is available, aerobic respiration is the primary mechanism of organic matter remineralization; however, as oxygen is depleted, nitrate, Mn, Fe, sulfate, and methane serve as terminal electron acceptors in organic carbon oxidation. Biologically mediated anaerobic oxidation of organic matter is evidenced in the pore water by the presence of reduced Fe and Mn, high alkalinity and pH, as well as high ammonium concentrations. Further downhole, pore water chemistry may be additionally impacted by oxidative processes either deep in the hole or below the cored depth with upward diffusion. This is supported by decreases in ammonium and increases in sulfate with depth. The deeper parts of the hole show evidence of carbonate dissolution as well as interplay of dissolution and precipitation of Fe- and Mn-bearing minerals.

Calcium carbonate content at this site is low but highly variable, with several peaks fluctuating between a minimum of 0.1 wt% and a maximum of 86.8 wt%. A linear correlation between $CaCO_3$ concentrations and RGB blue and L* data is observed at this site for samples above 1 wt%. Organic carbon contributes a maximum of 0.43 wt% to the total carbon pool throughout this site. Total nitrogen is very low at this site never exceeding 0.05 wt%, and total organic carbon is also low with concentrations reaching a maximum of 0.43 wt%. The TOC:TN ratio ranges between 0.34 to 19.91, suggesting a predominance of marine derived organic matter.

Physical properties data acquired from whole-round measurements for Site U1543 are generally in good agreement with those from split-core measurements. Magnetic susceptibility (MS), gamma ray attenuation (GRA) bulk density, and natural gamma radiation (NGR) have higher values when there is a higher terrestrial component in the sediment (lithofacies 7 and 8) and lower values when there are increased biogenic components (lithofacies 4, 6, and 10). While some minima in those physical properties correspond to changing lithofacies, the physical properties also record subtle changes between terrestrial and biogenic components at high temporal frequency and on long terms, allowing a precise reconstruction of warm and cold intervals and a precise correlation with isotopic stratigraphy. Furthermore, GRA bulk density and *P*-wave velocity show different patterns for increased nannofossil and diatom contents within lithofacies 8; both values decrease with increasing nannofossil content, and bulk density decreases while *P*-wave velocity increases with increasing diatom content. It is thus possible, by combining the different high-resolution physical properties records, GRA bulk density, MS, and *P*-wave velocity, to interpret the large to smaller variations of these records as variations of either diatom or nannofossil content within terrigenous lithofacies 8.

We constructed a preliminary age model based on biostratigraphic and paleomagnetic age markers. These data suggest that the sedimentary sequence recovered at Site U1543 spans the

past ~8.4 Ma. Sedimentation rates are overall relatively constant and average ~4.5 cm/ky. This age model is generally consistent with the preliminary stratigraphic tuning performed aboard, based on physical properties data such as color measurements (RGB Blue) and GRA bulk density.

Overall, the Site U1543 undisturbed, continuous sediment record with medium to high sedimentation rates extending into the Miocene is exceptional. It is an important eastern end-member locality of the central south Pacific sites recovered on Expedition 383 that can be used to evaluate past oceanographic and climate changes from the late Miocene to the present. The observed variations in lithology and physical properties are at least in part driven by glacial–interglacial climate change that consistently impacts the delivery and nature of sediment deposited at Site U1543. The longer term evolution of these depositional processes recorded at Site U1543 will illuminate the multimillion year history of Patagonian ice sheet growth and retreat, ACC transport, and the underlying climatic conditions in which these processes evolved.