IODP Expedition 318: Wilkes Land Glacial History

Site U1359 Summary

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Site U1359 (WLRIS-04A) is located in the continental rise at 4003 m water depth. The main objective at Site U1359 was to obtain an expanded record for the late Neogene to Quaternary to provide a history of climate and paleoceanographic variability and to test the stability of the East Antarctic Ice Sheet during the middle Miocene to Pleistocene extreme warm periods (e.g., Miocene Climate Optimum, early Pliocene, and Pleistocene Isotopic Stages MIS 31 and MIS 11). This record was to also provide the timing and nature of deposition of the upper seismic units (i.e., above the WL-U6 unconformity) defined on the Wilkes Land margin (De Santis et al., 2003; Donda et al., 2003. These units include a shift in sedimentary depocenters from the continental rise to the outer shelf, possibly corresponding with the transition from a dynamic wet-based to a more persistent cold-based EAIS (Escutia et al., 2002; De Santis et al., 2003), and inferred to occur during the late Miocene–Pliocene (Escutia et al., 2005; Rebesco et al., 2006). At Site U1359, unconformities WL-U6, WL-U7 and WL-U8 lie at about 4.61s, 4.44s, and 4.23s TWTT, respectively (about 520, 323 and 126 mbsf, respectively).

Site U1359 is located on the eastern levee of the Jussieau submarine channel. The Jussieau channel is one of the intricate networks of slope canyons that develop down slope into channels and coalescing deep-sea fans (Escutia et al., 2000). Site U1359 is located an upper fan environment where the levee relief (measured from the channel thalweg to top of the levee) is about 400 m. Multichannel seismic profiles across the site show that widespread channels with high-relief levees occur on the Wilkes Land margin above unconformity WL-U5 (Escutia et al., 1997, 2000; Donda et al., 2003). The fine-grained components of the turbidity flows travelling through the channel and hemipelagic drape are inferred to be the dominant sedimentary processes building these large sedimentary levees (Escutia et al., 1997; 2000; Donda et al., 2003). Bottom currents can further influence sedimentation in this setting (Escutia et al., 2002; Donda et al., 2003). Similar depositional systems were drilled during ODP Leg 178 in the Antarctic Peninsula (Barker, et al., 1999) and ODP Leg 188 in Prydz Bay (O'Brien, et al., 2001).

Holes U1359A, U1359B, U1359C and U1359D were drilled to a total depth of 193.5, 252.0, 168.70, and 602.2 mbsf, respectively. In Holes U1359A and U1359B, the Advanced Piston Corer (APC) system was used to refusal, followed by Extended Core Barrel (XCB) drilling. Only the APC was used in Hole U1359C. Hole U1359D was drilled using the Rotary Core Barrel (RCB) and core was only recovered below 152.2 mbsf. Silty clay with dispersed clasts is the dominant lithology observed at Site U1359. There are noticeable variations in the amount of biogenic components, bioturbation, and sedimentary structures – in particular the presence or absence of packages of silt/fine sand laminae and large variations in diatom abundance. Five distinct lithofacies are identified based on variations in the style of laminae, bioturbation, or the relative abundance of the biogenic component. Three lithostratigraphic units are defined on the basis of observed changes in facies associations. Lithostratigraphic Unit I (0 and 43.5 mbsf) consists of dm-scale alternations of yellow brown and olive gray diatom-rich silty clays with dispersed clasts with occasional foraminifera-bearing clayey silt and sandy silt. Unit II (43.5 to 247.1 mbsf) consists of bioturbated diatom-bearing silty clays interbedded with olive gray diatom-bearing silty clays that are mostly massive but contain dm-scale packages of olive brown silty clay with silt laminae. Unit III extends from 247.1 mbsf to the bottom of the cored section at 596.32 mbsf and consists of bioturbated diatom-bearing silty clays interbedded with laminated silty clays. The laminated silty clays contain more subtle, but persistent, sub-mm- to mm-scale laminae compared with Unit II. Clasts more than 2 mm in size occur throughout all Lithostratigraphic Units, and are mostly dispersed in nature (i.e., trace to 1% in abundance).

The sedimentology of Units I and II is consistent with levee deposition by low density turbidity currents, whereas the facies associations in Unit III probably represent deposition in an environment influenced by periodic variations in contour current strength or saline density flows related to bottom-water production, with turbidity currents having less influence than the overlying units. The regular nature of the interbedding (i.e., beds 2-5 m thick) of the laminated and bioturbated facies within all three lithostratigraphic units suggests that the sedimentary record recovered at Site U1359 is cyclic in nature. The diatom-bearing and diatom-rich silty clays (Facies 1, Facies 2) were probably deposited by hemipelagic sedimentation in a higher productivity environment relative to the other facies. The clays and silty clays (Facies 3-5) indicate high terrigenous sedimentation rates and/or lower biogenic productivity, perhaps related to the duration of seasonal sea-ice cover regulating light availability in surface water; or wind-regulated control of the mixed layer depth which in turn controls productivity. The opposite scenario may apply for the diatom bearing to diatom-rich silty clay facies (Facies 1 and 2). An increase in terrigenous input may result from ice advance across the shelf or increase in sedimentation from bottom currents. The passage of cold saline density flows related to bottom water production at the Wilkes Land margin (e.g., High

Salinity Shelf Water flowing from the shelf into the deep ocean to form Antarctic Bottom Water) should also be considered as a potentially important sediment transport mechanism. The deposition model for recovered sediments at Site U1359 may represent a continuum of all three processes, in addition to pelagic and ice rafted components as indicated by the presence of diatom remains and dispersed clasts throughout.

Combined micropaleontology assigns the recovered successions at Site U1359 to the upper Middle Miocene to Upper Pleistocene. Integrated diatom, radiolarian, foraminiferal, and magnetostratigraphic data highlight a Late Pliocene to Early Pleistocene hiatus (~2.5 to 1.5 Ma) and a lower to mid-Upper Miocene condensed interval (representing ~9.8 to 7 Ma).

Miocene diatom assemblages mainly include open water taxa. In addition, a notable increase in the abundance of stephanopyxid specimens may be interpreted as either an indication of shallowing water depths or an increase in reworking of shallower water sediments. The lack of planktonic and benthic foraminifers suggests that late Middle Miocene bottom waters were corrosive to calcareous foraminifers except for brief periods (e.g., around ~10 Ma represented when calcareous benthic foraminifers were preserved). Also during the Pliocene open water taxa and variable abundances of benthic, neritic and sea-ice associated taxa dominated diatom assemblages. The dinocyst assemblages predominantly comprise heterotrophic taxa indicating that the biosiliceous-rich sediments were deposited in a high productivity and sea-ice influenced setting. High abundances of sporomorphs reworked from Paleogene, Mesozoic and Paleozoic strata suggest strong erosion in the hinterland. The general lack of planktonic and calcareous benthic foraminifers suggests that Pliocene bottom waters were corrosive to the thinshelled tests of planktonic foraminifers. Diatom and radiolarian Pleistocene assemblages at Site U1359 are dominated by typical Neogene Southern Ocean open water taxa with variable abundances of benthic, neritic and sea ice-associated diatom taxa. This indicates a pelagic, well-ventilated, nutrient-rich, sea-ice influenced setting, corroborated by the presence of heterotrophic-dominated dinocyst assemblages. The preservation of planktonic foraminifers in the Pleistocene indicates that bottom waters were favorable to the preservation of calcium carbonate. Further, pervasive reworked sporomorphs of Paleogene, Mesozoic and Paleozoic age again point to continuing strong erosion in the hinterland.

Paleomagnetic investigations at Site U1359 involved analysis of discrete samples from Holes U1359A, U1359B and U1359D and measurement of archive halves from all four holes. A composite polarity log was correlated to the Geomagnetic Polarity Time Scale of Gradstein et al. (2004), documenting a complete Pliocene section from the top of Chron C2An to the bottom of Chron C3An. There is a gap including Chron Cn2 and a period of extremely slow (and probably discontinuous) sediment accumulation from Chron C3Ar to the top of C5n, in-line with the biostratigraphic assessments.

Routine headspace gas analyses were carried out on samples from Holes U1359 A-D, and seventy-one samples were taken for analyses of percent carbonate, carbon, nitrogen and sulfur content, as well as major and trace element analyses. Furthermore, fifty-one interstitial water (IW) samples were taken in close collaboration with the microbiology samples from the top ~20 m (0.1 to 20.1 mbsf) of Hole.

$CaCO_3$ contents for most samples vary between <1 and 3.2 wt% A distinct carbonate-rich layer, with $CaCO_3$ of 39.7 wt%, was found at 372.45 mbsf and corresponds to a minor lithology of diatom-bearing nannofossil ooze. On the basis of the distribution patterns of the major and trace elements, four broad intervals can be distinguished, viz between 0 to ~200 mbsf, ~210 and ~310 mbsf, ~310 to 536 mbsf, and between 547.39 and 594.79 mbsf.

The interstitial water measurements reveal chemical gradients that are consistent with active diagenesis of buried organic matter within the sulfate reduction zone (SRZ). Significant levels of sulfate at the bottom of the observed profile (~23 mM at 20.1 mbsf) imply that the sampled interval did not reach the carbon dioxide (methanic) reduction zone.

Microbiological sampling was conducted on Hole U1359B and supported with pore water sampling. A total of 52 ten-centimeter whole rounds were taken from the top 20 m and frozen at -80^{o}C for onshore phospholipid analyses and molecular 16S rRNA sequencing. Between 20 and 200 mbsf, seventeen 5-cm^3 samples were taken and preserved for onshore molecular 16S rRNA sequencing.

The physical properties program for Site U1359 include routine runs on the Whole Round Multi-Sensor Logger (WRMSL), which includes the Gamma-Ray Attenuation Bulk Density (GRA), Magnetic Susceptibility (MS), and *P*-Wave velocity Logger (PWL) sensors, as well as natural gamma radiation (NGR) measurements. *P*-wave velocity was also analyzed and samples taken for moisture, density, and porosity measurements from Holes U1359A, U1359B and U1359D. Thermal conductivity measurements were taken in cores from all holes. Of particular note is the cyclicities at several scales recorded in the intervals where the magnetic susceptibility ranges between 40 and ~100 instrument units throughout the section. Furthermore, the NGR data were together with the magnetic susceptibility and the GRA density used to correlate the four holes drilled at Site U1359 and to define a composite record. In addition, pronounced lower density values between 50 and 65 mbsf (50 and 65 CCSF-A), below the Lithostratigraphic Unit I to II transition, a sudden drop at ~99.5 mbsf (~101 CCSF-A), which coincides with the lithological change from diatom-bearing to diatom-rich silty clays (Lithostratigraphic Unit IIa to IIb transition), as well as a shift to slightly lower values at ~248 mbsf (~264 CCSF-A) (Lithostratigraphic Unit II/Unit III boundary).

Downhole logging measurements in Hole U1359D were made after completion of RCB coring to a total depth of 602.2 mbsf (DSF). Three tool strings were deployed in Hole U1359D: the triple combo, FMS-sonic, and VSI. Hole U1359D was divided into two units (0-260 and 260-606 mbsf) on the basis of the logs. The upper logging unit is characterized by high amplitude swings in bulk density, natural gamma radiation, and resistivity values. It is also characterized by a lack of a compaction trend with depth: the mean bulk density value remains quite constant, while the resistivity values decrease with depth. The transition to the unit below is gradual. Logging unit 2 is characterized by generally lower amplitude bulk density and resistivity variations than the unit above, but the several-m-scale alternations are still clearly defined. A normal compaction trend resumes in bulk density and sonic velocity. Natural gamma radiation continues to show quite high variability, and several large drops in NGR values are observed between 350 to 450 mbsf. Near the base of the hole at 574 to 580 mbsf there is a 6 m interval of higher bulk density and resistivity, indicating a cemented bed or series of cemented beds. Heat flow at Site U1359 was estimated as 62.4 mW/m^2, a typical value for the ocean floor.

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