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Dynamics of the Oligocene Southern Ocean: dinocysts as surface paleoceanographic tracers

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The Oligocene Epoch (33.9-23 Ma) is the time interval in the Cenozoic that saw the establishment of a continental-scale Antarctic ice-sheet. There remains a controversy about whether this early episode of a glaciated Antarctica was stable, or whether dynamic ice conditions prevailed. Most of this controversy persists due to the absence of chronostratigraphically well-dated sedimentary archives from close to the east Antarctic ice sheet, which has recorded a direct signal of glacial dynamics. Another major question is how the Oligocene Southern Ocean responded to the glaciation and subsequent evolution of the ice sheet, as the Southern ocean is a major player in global ocean circulation.

Numerical modelling studies suggest that alongside the buildup of continental ice on Antarctica, first sea-ice conditions may have started along the East Antarctic Margin, but this conclusion lacks support from field evidence. Other numerical models predict that hysteresis effects within the ice sheet will make a continental-size Antarctic ice sheet rather insensitive to warming. In contrast, deep-water benthic foraminiferal oxygen isotope records across the Oligocene suggest dramatic waxing and waning of Antarctic ice sheets. This paradox is as yet not solved

Integrated Ocean Drilling Expedition 318 drilled the Antarctic Margin in 2010, and recovered sediments from the early phase of Antarctic glaciation. With this record, we can now evaluate the robustness of the results of the numerical models and the oceanographic changes with field data. Sediments recovered from Site U1356 yield a thick and relatively complete (albeit compromised by core gaps) Oligocene succession both of which are chrono-stratigraphically well-calibrated with use of nannoplankton- dinocyst- and magnetostratigraphy. Notably, this record yields well-preserved dinoflagellate cysts (dinocysts), which we can use to investigate surface-water condition changes across the Eocene-Oligocene to provide answers to these outstanding questions.

In the earliest Oligocene, just after the onset of Antarctic glaciation, we document the installation of dinoflagellate cyst assemblages that bear remarkable similarity with those of the present-day Southern Ocean. We interpret this as a regime-shift in plankton communities in response to the installation of the seasonally highly productive sea-ice ecosystem. Throughout the Oligocene the pattern of eutrophic, influence continues, but the sea-ice-related cysts disappear about 1.5 Myrs following their appearance, consistent with a major rebound phase of the deep-sea oxygen isotopes. Surprisingly, throughout the Oligocene, the heterotrophic, sea-ice dinocysts are accompanied by episodically even abundant oligotrophic species. These results suggest fundamental differences in the physical oceanographic condition of the ACC compared to present-day and may explain why the Oligocene icehouse world is as dynamic as suggested by deep-water benthic foraminiferal oxygen isotopes. The direct field evidence definitely confirm a dynamic Oligocene icehouse, and imply that some fundamental physics or feedbacks are missing in the ice sheet models that predict a stable ice sheet.