Cenozoic major climate shifts in the Southern Ocean

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Abstract

The Southern Ocean plays a very important role in the global climate system on the present and geologic past. To resolve the causes and processes of atmospheric CO_2 change, it is important to understand mechanisms and processes of sub-systems in the Antarctic Cryosphere such as a change of biological productivity, sea surface temperature, surface water frontal system, sea-ice distribution, and the East Antarctic Ice Sheet during the glacial-interglacial climate cycle. In addition, the evolution and dynamics of the Antarctic Cryosphere, from its inception during the Eocene-Oligocene transition (~34Ma) and other major climate shifts during the Cenozoic, is still poorly understood. The key motivation for IODP Southern Ocean drilling stems from a lack of knowledge of the complex role the Antarctic cryosphere (ice sheets, ice shelves and sea-ice) plays in the global climate system. Understanding the history of ice volume variation and associated cryospheric changes during the Cenozoic is of very importance because ice-volume and distribution variations: (a) lead to changing global sea-levels, (b) affect Earth's albedo, (c) control the latitudinal gradient of the Southern Hemisphere and thus heat transport via atmospheric and oceanic circulation, and (d) influence the distribution of ice shelves and seasonal sea-ice, which are commonly attributed to forming cold-bottom waters that drive global ocean circulation. Drilling target area will focus to the Indian sector of the Southern Ocean. The area is close to the Syowa Station, which is the mother station of Japanese Antarctic Research Expedition (JARE) on East Ongul Island, Lutzow-Holm Bay of the East Antarctica. Therefore, large amount results of JARE are accumulated on the Antarctica, such as ice sheet dynamics from geological and geomorphological approach and climate change records from Dome Fuji ice core. These records have great advantages to investigate the relationship between Antarctic climate change and Southern Ocean paleoceanographic variability.

Background in Antarctic Cryosphere

The Southern Ocean plays a very important role in the global climate system on the present and geologic past. The Southern Ocean has also become a region of paleoceanographic focus because of its key role in global deep-water circulation and its potential significance for the global carbon. For example, it has been proposed that primary production was higher and utilization of preformed nutrients in surface waters was more efficient in the glacial Southern Ocean than today, effectively lowering the glacial atmospheric CO_2 concentration. To resolve the causes and processes of atmospheric CO_2 change, it is important to understand mechanisms and processes of sub-systems in the Antarctic Cryosphere such as a change of biological productivity, sea surface temperature, surface water frontal system, sea-ice distribution, and the East Antarctic Ice Sheet during the glacial-interglacial climate cycle. In addition, the evolution and dynamics of the Antarctic Cryosphere, from its inception during the Eocene-Oligocene transition (~34Ma) and other major climate shifts during the Cenozoic, is still poorly understood. The transition from Greenhouse to Icehouse Earth was the most significant step in large-scale climate change, impacting global sea level, albedo, and oceanographic and biotic evolution.

The key motivation for IODP Southern Ocean drilling stems from a lack of knowledge of the complex role the Antarctic cryosphere (ice sheets, ice shelves and sea-ice) plays in the global climate system. Understanding the history of ice volume variation and associated cryospheric changes during the Cenozoic is of very importance because ice-volume and distribution variations: (a) lead to changing global sea-levels, (b) affect Earth's albedo, (c) control the latitudinal gradient of the Southern Hemisphere and thus heat transport via atmospheric and oceanic circulation, and (d) influence the distribution of ice shelves and seasonal sea-ice, which are commonly attributed to forming cold-bottom waters that drive global ocean circulation. We recognize that efforts to understand the role of Antarctic drivers on global climate variability require a fundamental knowledge of Antarctic cryospheric evolution. Although a number of sedimentary archives that record past ice sheet behavior have become available recently from the Cape Roberts Project (e.g. Naish et al., 2001) and from ODP legs 178 in Antarctic Peninsula (e.g. Domack et al., 2001) and 188 off Prydz Bay (e.g. Grutzner et al., 2003), they remain too few to allow a comprehensive understanding of Antarctica's influence on global climate.

Scientific objectives in Antarctic Cryosphere

The revised timing of the earliest Arctic cooling events coincides with those from Antarctica, supporting arguments for bipolar symmetry in climate change (e.g., Moran et al., 2006). However, evolution history of sea ice and ice sheets in the bipolar cryospheres are largely unknown from direct evidence. Specific paleoceanographic objectives were to

- Document the initial onset and subsequent history of sea-ice presence/absence;
- Determine the evolution history of the Antarctic Circumpolar Current (ACC) system;
- Obtain the nature and age of the changes in extent of the East Antarctic Ice Sheet (EAIS);
- Document the evolution history of the AABW/NADW during the late Neogene and Quaternary; and
- Obtain a high-resolution record of Antarctic climate variability and sea ice distribution during the late Neogene and Quaternary.

The Southern Ocean drilling project will be investigated the collective behavior of several major climate cycles and climate shifts such as Younger Dryas (YD)/Antarctic Cold Reversal (ACR), Dansgaard-Oeschger cycle, mid-Brunhes climate shift (~0.4Ma), late Miocene cooling, major Antarctic glaciation around the Oligocene/Miocene boundary (Mi-1 glaciation; ~24Ma), first ice sheet inception around the Eocene/Oligocene boundary (Oi-1 glaciation; ~34Ma). In particularly, we need to investigate the Antarctic cryospheric evolution in the Indian sector of the Southern Ocean where is significantly affected regions of the EAIS variability.

Drilling target area

1. Off Lutzow-Holm Bay

Drilling target area will focus to the Indian sector of the Southern Ocean. The area is close to the Syowa Station, which is the mother station of Japanese Antarctic Research Expedition (JARE) on East Ongul Island, Lutzow-Holm Bay of the East Antarctica. Therefore, large amount results of JARE are accumulated on the Antarctica, such as ice sheet dynamics from geological and geomorphological approach and climate change records from Dome Fuji ice core. These records have great advantages to investigate the relationship between Antarctic climate change and Southern Ocean paleoceanographic variability.

2. Conrad Rise Drift

Based on the bathymetric mapping, subbottom profiling, and multi-channel seismic reflection survey during the KH07-4 cruise, a dune-like bedform (mudwave) exists on the southwest slope of the Conrad Rise. The wave-field is located in water depths of 2000-3200 m. The similar wavy sedimentary structures are recognized below the seafloor in the seismic profile on the Conrad Rise. Such deep-sea mudwaves have been reported at the northern Weddell Sea, which influenced by the Antarctic Bottom Water (AABW) (Howe et al., 1998), and at the Gardar Drift in the North Atlantic, where is also influenced by the North Atlantic Deep Water (NADW) (e.g., Manley and Caress, 1994).

Lithology of piston core COR-1PC from Conrad Rise is diatom ooze, and sedimentation rate is very high up to about 40 cm/ka. Thus, the sediment drift was deposited with mudwaves on the Conrad Rise, which was developed by influences of NADW and/or AABW. The Conrad Rise Drift is one of the key regions for analysis of the long- and short-term behavior of the Antarctic Circumpolar Current (ACC), polar front system, sea ice coverage, and marine productivity in the Southern Ocean.

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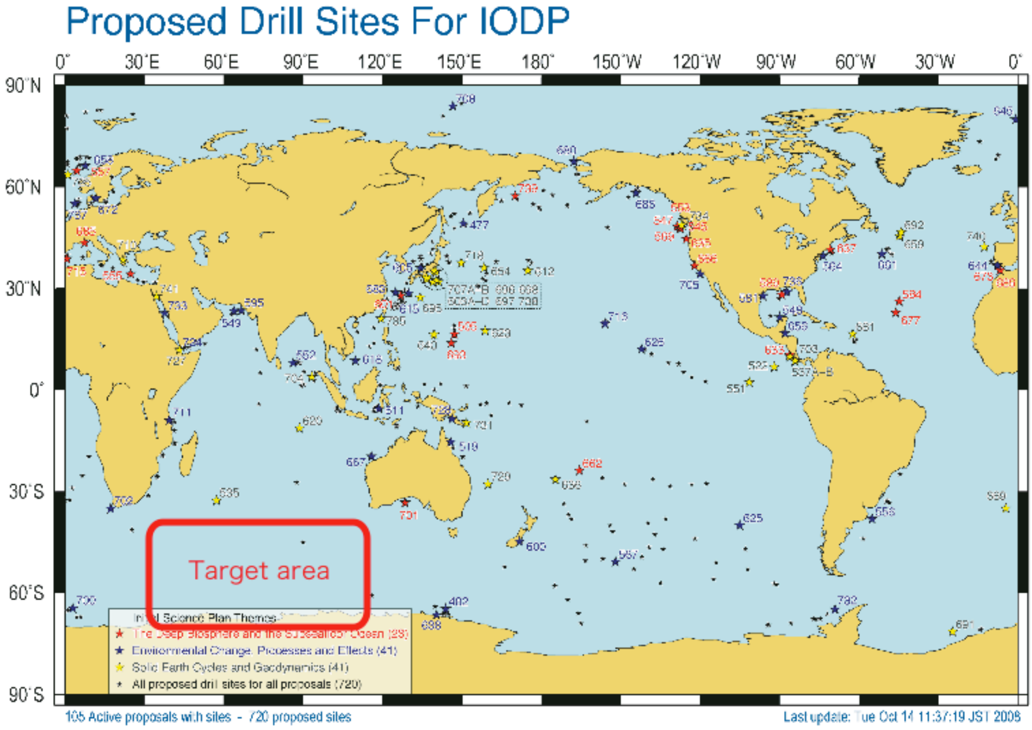

Fig.1. Target area