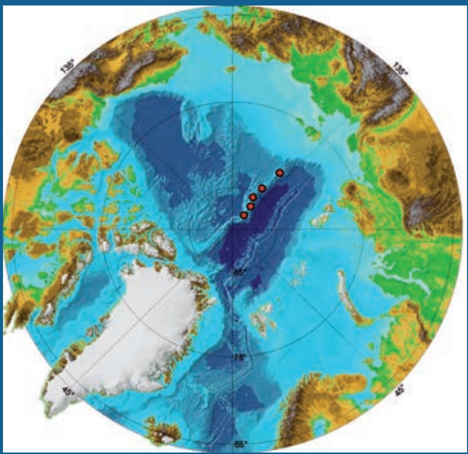
Arctic Coring Expedition

Expedition 302 Arctic Coring (ACEX) was the first IODP mission-specific platform operation managed by ECORD. The offshore operations took place in the late summer 2004, followed by the Onshore Science Party at the Bremen Core Repository in November of the same year. The expedition was carried out in cooperation with the Swedish Polar Research Secretariat (SPRS).



The drillsites were located on a submarine high, the Lomonosov Ridge, at a point only 250 km from the North Pole. ACEX was a huge logistical challenge because the drillship had to hold its position while surrounded by the moving sea ice of the Arctic Ocean. This required two icebreakers, the ***Oden*** and ***Sovetskiy Soyuz*** to crush large ice-floes into small pieces which allowed a third icebreaker, the ***Vidar Viking***, specially converted for the task, to maintain position and undertake the coring.

Scientific goals

The primary goal was the continuous recovery of a sedimentary sequence more than 400 m-thick draping the crest of the Lomonosov Ridge in the central Arctic Ocean between 87°N and 88°N. The fundamental paleoceanographic objectives were to determine the Cenozoic paleo-environmental evolution in the central Arctic Ocean and to decipher the Arctic's role in the global development from the Paleogene greenhouse to the Neogene icehouse. Another major goal was to sample the transition across the regional unconformity to establish the pre-Cenozoic tectonic setting of the ridge.

ACEX drilled five holes at three sites into the Cenozoic sediment drape, one of which continued into the underlying sedimentary bedrock. A total of 495.5 m was cored at these sites, yielding a total recovery of 339.1 m (68.4% recovery), providing the first long record of Cenozoic sediments from the central Arctic Ocean, which allowed the expedition scientists to present fundamentally new insights about the Arctic's Cenozoic paleo-environmental evolution.

Dates: 7 August - 13 September 2004
Platforms: *Vidar Viking* (drillship), *Oden* and *Sovetskiy Soyuz*
Deepest hole: 427.9 m
Number of boreholes: 5
Number of cores: 119
Core recovery: 339.1m (68.4%)
http://www.ecord.org/expedition302/

Ice management

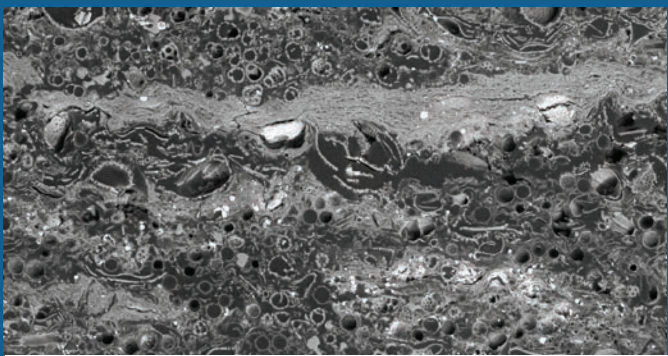
A key aspect of the success of ACEX was the ice-management programme including the coordination of the activities of the whole fleet. During transit to and between coring sites, the *Sovetskiy Soyuz* led the convoy through the ice, finding the best paths through the least difficult sea-ice conditions, and broke the ice so that the *Oden* and *Vidar Viking* were able to follow at a good pace. While coring was being conducted, the *Soyuz* operated 'upstream' breaking kilometre-large floes into smaller bits that were further crushed into 10 m-sized pieces by the *Oden*, which the *Viking* had the power to manage. The *Oden* was also the command centre for the Expedition from which the ice and fleet management were conducted. It was also the base for the limited number of scientists that could be accommodated during the offshore phase of the expedition. Three scientists were flown by helicopter to the *Vidar Viking* for each shift, but the micropaleontologists that formed the bulk of the scientists had their laboratory on the *Oden* and received core-catcher samples every 12 hours.

The Sovetskiy Soyuz (SS) is shown on the left of the image breaking large ice floes, the Oden is in the middle crushing mid-sized ice floes and the Vidar Viking (VV) is on the right side of the image maintaining station over the drillsite.

Scientific results

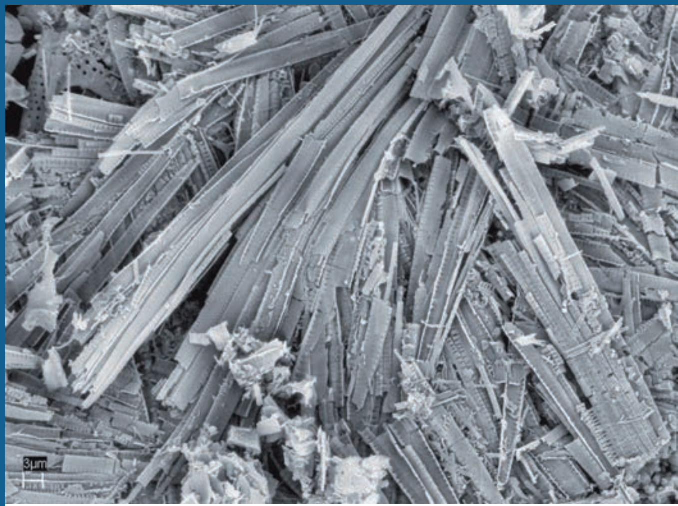
Since 2004, a wealth of results have been generated from the sediments recovered during ACEX. The results have addressed all of the critical pre-cruise scientific objectives and improved our understanding of the Cenozoic paleoceanographic and paleoclimatic evolution in the central Arctic Ocean. So far, ACEX results have been published in eight *Nature* and *Nature Geoscience* articles, as well as in other prominent journals such as *Earth and Planetary Science Letters*, *Geophysical Research Letters*, *Marine and Petroleum Geology*, etc.. 20 articles were published in a special ACEX issue in *Paleoceanography* in 2008 and 10 papers in a special issue in *Micropaleontology* in 2009.

Key results include the onset of seasonal sea ice in the middle Eocene, the onset of perennial sea ice during the middle Miocene, the discovery of sub-tropical temperatures during the Paleocene-Eocene Thermal Maximum (PETM), the fresh-water episode marked by the so-called *Azolla* event at the early/middle Eocene boundary, and the oxygenation of the deep Arctic Basin in the early Miocene.



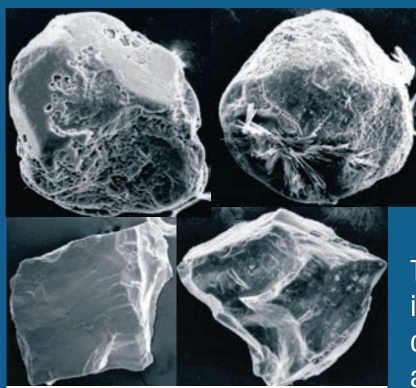
TEM picture of the microlayering in the Azolla interval, showing alternations between Azolla-rich layers and siliceous plankton-rich laminae (courtesy of M. Collinson and H. Brinkhuis). Azolla is a free-floating fern growing in fresh-water and sub-tropical environments.

The ACEX drilling effort has provided a solid, albeit fragmentary, framework for our understanding of the large-scale development of Cenozoic paleoenvironmental conditions in the sea around the North Pole. Moreover, ACEX has also provided obvious targets for future drilling expedition(s) to the central Arctic Ocean, for example, in order to fill the stratigraphic gaps not recovered by ACEX (about 70-75 % of Cenozoic time is still completely unrepresented in recovered sediment sections), or to begin sampling its Mesozoic (Cretaceous) archives. Finally, a plethora of major tectonic questions remain to be investigated via ocean drilling.



SEM image of part of an aggregate of near-whole needle-shaped Synedropsis sp. valves (Stickley et al, 2009).

In reconstructing Arctic climate change it is critical to differentiate between the presence of sea ice and glacial ice, because the climate system feedbacks differ depending on the type of ice present. The occurrence of sand and pebbles in otherwise fine-grained marine sedimentary sequences are good indicators of the presence of past ice, but since this ice-rafted debris (IRD) can be transported by icebergs (derived from land-based ice) as well as sea ice, additional proxies must be used to interpret whether such ice was sea ice or glacial ice. An extraordinary abundance of a group of sea-ice-dependent fossil diatoms (*Synedropsis spp.*) were the necessary proxy needed to confirm the presence of middle Eocene Arctic sea ice. Analysis of quartz grain textural characteristics of the IRD further supports sea ice as the dominant transporter of IRD at this time.



SEM images of IRD with textural characteristics of sea-ice transport (upper row) and iceberg transport (lower row) (Stickley et al, 2009).

Together with new information on cosmopolitan diatoms and existing IRD records, these data strongly suggest a two-phase establishment of sea ice: initial episodic formation in marginal shelf areas 47.5 Myr ago, followed 0.5 Myr later by the onset of seasonally paced sea-ice formation in offshore areas of the central Arctic.

April 2017 - credits: ECORD/IODP, Per Frejvall and Martin Jakobsson/IBCAO

Further reading

- Backman J, Moran K, McInroy D, Mayer LA and the Expedition 302 Scientists, 2006. Proc. IODP, 302: Edinburgh (Integrated Ocean Drilling Program Management International, Inc.). doi:10.2204/iodp.proc.302.2006
- Moran K et al, 2006. The Cenozoic palaeoenvironment of the Arctic Ocean. Nature, 441, 601-605. doi:10.1038/nature04800
- Jakobsson M.et al, 2007. Opening of the Fram Strait in the early Miocene initiates ventilated circulation in the Arctic Ocean. Nature, 447, 986-990.doi:10.1038/nature05924
- Stickley CE, 2014. Palaeoclimate: the sea ice thickens. Nat. Geosci., 7, 165-166. doi:10.1038/ngeo2080
- März C et al, 2011. Variable Eocene-Miocene sedimentation processes and bottom water redox conditions in the Central Arctic Ocean (IODP Expedition 302). Earth Planet. Sci. Lett., 310(3–4),526-537. doi:10.1016/j.epsl.2011.08.025
- Stickley C et al, 2009. Evidence for middle Eocene Arctic sea ice from diatoms and ice-rafted debris. Nature, 460, 376-380.doi:10.1038/nature08163