ECORD
European Consortium for Ocean Research Drilling

IODP
INTEGRATED OCEAN DRILLING PROGRAM

Scientific Drilling in the Arctic Ocean

A summary document to encourage Academic and Industry collaboration

January 2011

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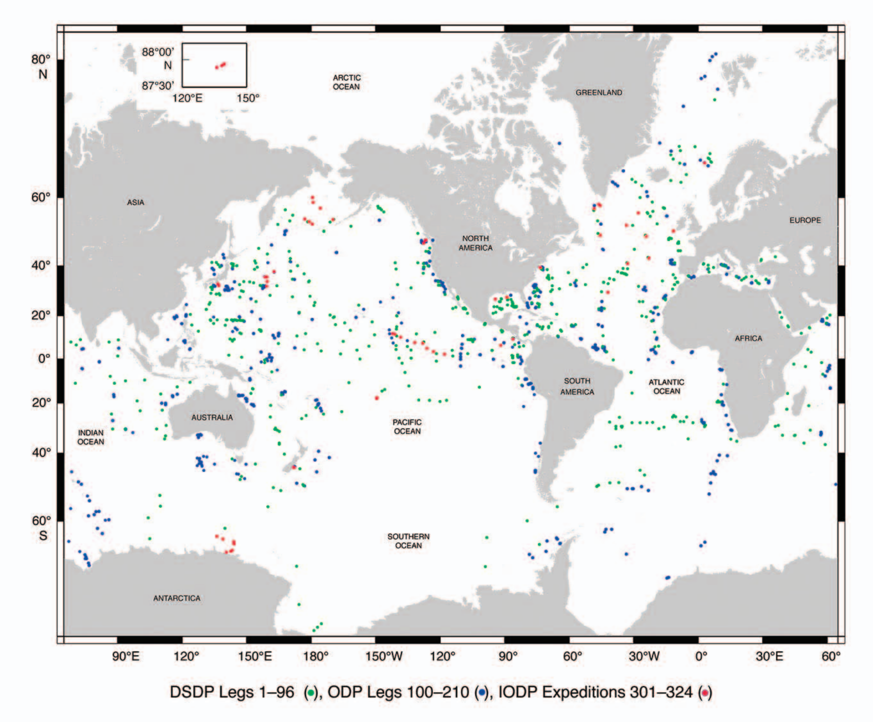


Introduction and History

This document is intended to stimulate industry interest in Arctic scientific drilling. The Arctic is seen as the ideal environment for industry/academic collaboration due to the abundance of shared and complementary interests in the region.

Industry participants have the opportunity to gain first-hand logistical and technical experience in Arctic sea ice drilling conditions.

The Integrated Ocean Drilling Program (IODP) is an international scientific research program. It builds upon the earlier successes of the Deep Sea Drilling Project (1968–1983) and the Ocean Drilling Program (1983–2003). These earlier drilling programs revolutionised our view of Earth history and global processes.

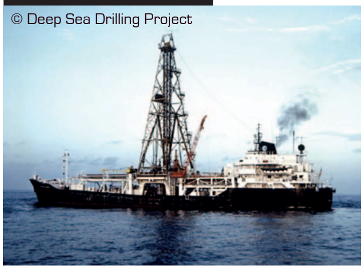
Now IODP is taking the research much further

Vidar Viking

Jakobsson, M © ECORD/IODP

Discovering Earth's Secrets

Glomar Challenger

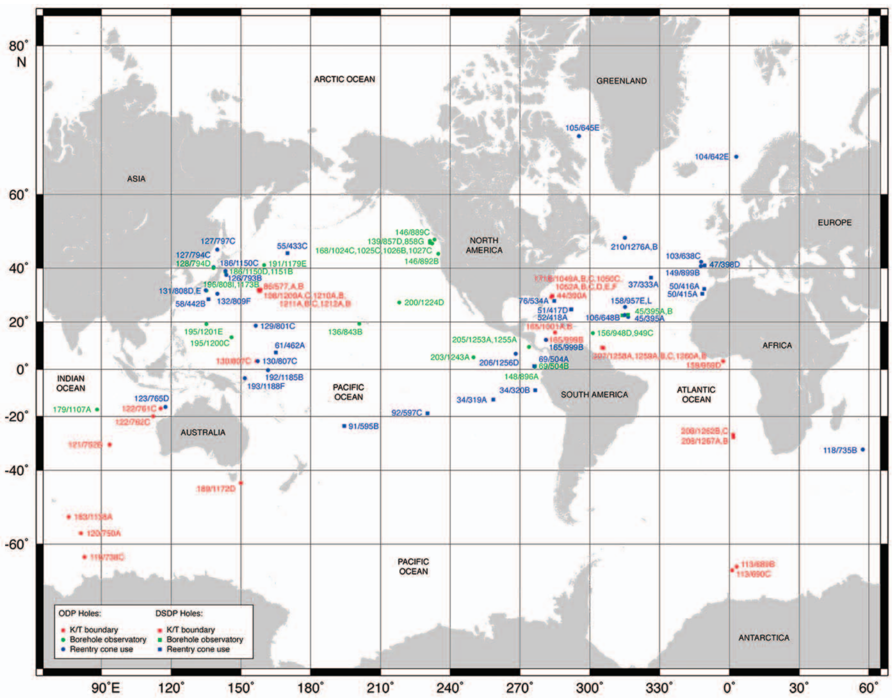


In 1957 a proposal to drill through the sea floor to the Mohorovicic discontinuity was submitted to the National Science Foundation in the United States of America. In 1961, at a location west of Mexico, Project MOHOLE cored through 200 m of sediment and 14 m of basalt in 3800 m water depth, only possible with the invention of dynamic vessel positioning.

In 1964 the Joint Oceanographic Institutions for Deep Earth Sampling *(JOIDES)* formed an ocean drilling consortium and in 1968 the *Glomar Challenger* set sail on the first Deep Sea Drilling Project (DSDP) cruise. Over the course of 18 years DSDP expeditions proved the theory of sea-floor spreading (Leg 3), proved that the Mediterranean was a dry basin in the Late Miocene (Leg 13), and sampled the Mariana Trench (Leg 60).

In 1985 the *JOIDES Resolution*, the workhorse of ocean research drilling for more than 20 years, set sail on the first Ocean Drilling Program (ODP) cruise (Leg 100) in the Gulf of Mexico. From 1985 until 2003 the ODP proved the establishment of a permanent West Antarctic ice sheet around 5 million years ago in the Weddell Sea (Leg 113), sampled the oldest oceanic crust (Jurassic in age) in the northwest Pacific (Leg 129), discovered large volumes of gas hydrates on the eastern margin of North America (Leg 164) and documented abrupt climate change during the Paleocene/Eocene Thermal Maximum and Eocene hyperthermals in the Pacific Ocean (Legs 198 and 199).

IODP will continue in its present form until 2013. It combines the resources of the *JOIDES Resolution*, the *Chikyu* and the European Consortium for Ocean Research Drilling (ECORD) operated mission-specific platforms, which utilises vessels of opportunity to go where the two larger drill ships cannot sample.



IODP Platforms

Chikyu
The Japanese deep-sea-drilling vessel *Chikyu* is the first riser-equipped drilling vessel built specifically for science. It has permanent drilling, laboratory and storage facilities. Using riser technologies, the *Chikyu* can drill far deeper than the other platforms – up to 7000 m – investigating the Earth's mantle and seismogenic zone (where earthquakes originate).

JOIDES Resolution
The *JOIDES Resolution* began life as an oil-exploration vessel. It was converted for scientific research in the mid-1980s and began working for the Ocean Drilling Program. Like the *Chikyu*, it has permanent drilling, laboratory and storage facilities. The vessel is named after Captain James Cook's HMS *Resolution*, which explored the Pacific Ocean, its islands, and the Antarctic region over 200 years ago. The ship is 143 m long, 21 m wide and is fitted with a derrick standing 62 m above the waterline. The *JOIDES Resolution* underwent extensive refurbishment in 2007–08 and returned to IODP for the Pacific Equatorial Age Transect Expedition 320 in March 2009.

Chikyu

JOIDES Resolution

William Crawford, IODP/TAMU

Mission–Specific Platforms: Vidar Viking & Sovetskiy Soyuz Exp 302

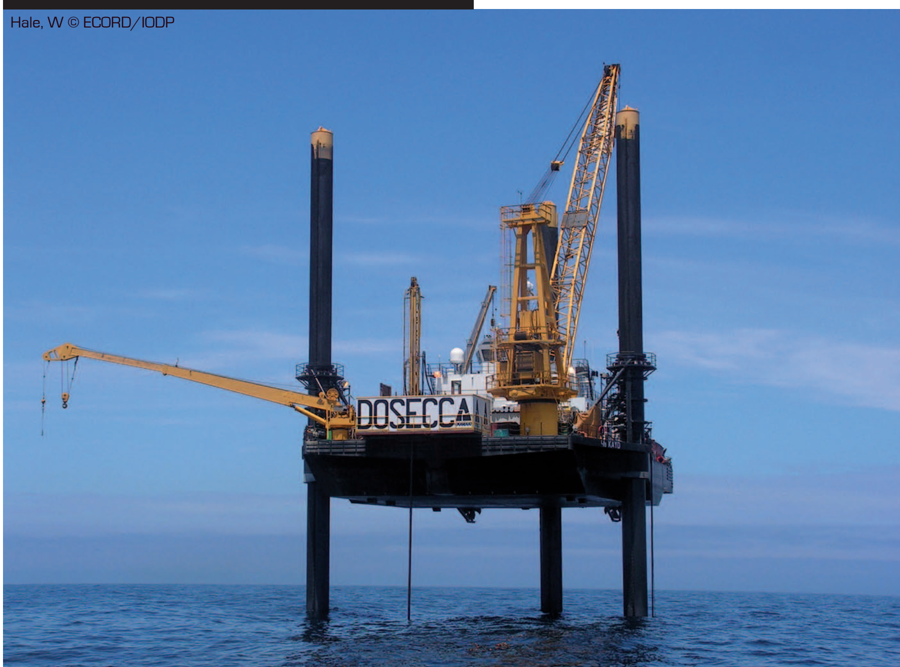
McInroy, D © ECORD/IODP

Mission–Specific Platforms (MSPs)
Europe contributes drilling platforms for particular scientific challenges. In most cases, this means modifying other platforms, perhaps a ship or a drilling rig. The ECORD Science Operator, which is responsible for these platforms, has carried out expeditions in shallow waters off New Jersey and around Tahiti and also ice-covered Arctic waters–where other platforms cannot work. The flexibility of mission–specific platforms has allowed ocean–drilling science to expand ambitiously.

Mission–specific platforms require a more flexible approach in terms of scientific participation and organisation as each mission is unique and requires hiring and fitting out a different drilling platform that may have more restricted on-board facilities than the two dedicated drill ships.

Mission–Specific Platforms: L/B Kayd Exp 313

Hale, W © ECORD/IODP



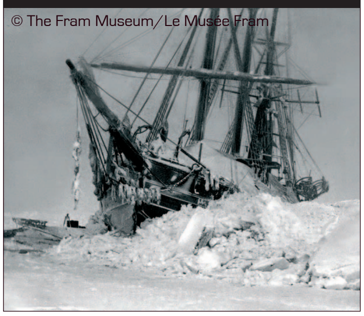
Brief History of Scientific Drilling in the Arctic

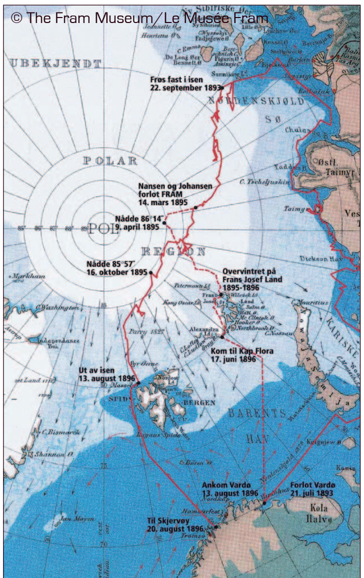
O B. Boggild (1906), who was entrusted with the examination of the first four sediment samples ever recovered from the deep Arctic Ocean basin during Nansen's drift with *Fram*, published his results 'in the hope that a tolerably clear idea thereby be obtained of the lithology of the bottom of the North Polar Sea'.

Drilling in the Arctic has been prevented by many factors, but none more significant than the presence of perennial ice cover. The ice cover also impedes the acquisition of geophysical data that underpins any drilling proposal, and the hypotheses on which they are based; not to mention the geophysical site–survey investigations necessary to ensure safe drilling operations.

Whereas Industry has demonstrated capability drilling in near–shore environments around the perimeter of the Arctic Ocean, due to environmental limitations very little drilling has been attempted in the central Arctic Ocean.

The polar ship Fram





Fridtjof Nansen's first voyage to the Arctic from 1893 to 1896

Arctic Margins

There has been continuous exploration for petroleum in the Arctic marginal seas over the last several decades, resulting in the recovery of primarily pre-Quaternary core and leading to a better understanding of local stratigraphy. The history and details of this commercial work however are too extensive for description here.

Notable in the early stages of scientific exploration of the marginal seas were the Russian drilling programmes of the 1980s-1990s including: Arctic Murmansk Government of Exploration Drilling (AMURB), Arctic Marine Engineer-Geological Expedition (AMIGE), and the prolific drilling conducted from R/V *Bavenit* and R/V *Kimberlit*. All of this work led to a greater understanding of the thickness, composition and age of the sediments of the Barents and Kara seas.

ODP Leg 151
Escorted by the icebreaker *Fennica* in 1993 the *JOIDES Resolution* set off on **ODP Leg 151** to investigate the Norwegian-Greenland Sea, Yermak Plateau and the marginal Arctic Ocean, with the aim of better understanding oceanic pathways between the Arctic Ocean and North Atlantic i.e. North Atlantic-Arctic gateways.

'The major successes of ODP 151 include: (1) a complete and detailed coverage of the preglacial paleoceanography of the Norwegian-Greenland Sea; (2) the identification of the onset of the ice cover in the northern North Atlantic to the south of the Greenland-Scotland Ridge, in the western Norwegian-Greenland Sea, in Fram Strait, and on Yermak Plateau; and (3) the description of patterns of variability of sedimentation in response to the cyclical behaviour of the depositional environment (Milankovitch frequencies). Scientific results of ODP Leg 151 (July to September 1993) are presented in (Thiede et al.,1996).

Central Arctic

Perennial Ice Cover

Pilot Project-University of Bergen
Prior to the well known success of the Arctic Coring Expedition (ACEX), the Swedish icebreaker *Oden* was used by proponents from University of Bergen, Geo Drilling A/S, and Stockholm University in a shallow drilling attempt on the Lomonosov Ridge. Although no core was ultimately recovered during the expedition, this was a successful 'proof of concept', particularly with regards to position-keeping in ice.

Statoil
It is understood that *Statoil* has recently undertaken marine drilling on the East Greenland Shelf, though the operation is classified and results are not known.

IODP Expedition 302, Arctic Coring Expedition (ACEX)

Central Arctic

During the summer of 2004, a fleet of 3 Arctic–Class vessels worked to recover continuous core from the Lomonosov Ridge. The icebreakers *Sovetskiy Soyuz* and *Oden* worked to break up upstream ice floes, allowing the ice–strengthened *Vidar Viking* drill vessel to keep station in 90% multi–year ice. The expedition was a great success. A total of ~340m of core (68.4% recovery) was recovered from three sites.

Sediments from ACEX provided the first ground-truthing of the Cainozoic paleoenvironmental history of the central Arctic Ocean. Published results have shown that ACEX sediment records hold fundamental implications for both climate and regional tectonics.

ACEX cores have:

- Provided the timing of the 'ventilation'(deep–water connection to the North Atlantic Ocean) of the Arctic Ocean. This deep–water exchange is a key driver of the deep–water formation in the North Atlantic and Arctic Oceans, which in turn is a key driver of global climate.
- Confirmed that the Lomonosov Ridge is constructed of continental crust, genetically linked to the Barents Shelf.
- Revealed the transition from a warm 'greenhouse' climate to a colder 'icehouse' climate approximately 46 million years ago. This date suggests that this Cainozoic cooling in the Arctic occurred synchronously with that in the Antarctic, contrary to previous hypotheses.

Clearing ice from the moon–pool

Sovetskiy Soyuz and Oden breaking ice for Vidar Viking

Specification and Cost

- 5 holes from 3 sites.
- Water depths 1200–1300 m.
- Maximum penetration of ~430 m using geotechnical drilling techniques.
- Drilling took place over 24 days and cost approximately $13 million in 2004.

Lessons learned on ACEX will provide substantial operational benefits to future Arctic MSP drilling expeditions *e.g.* improved knowledge of ice management and utilisation of geotechnical drilling with ~2000 m maximum drill string length (water column + sub-seabed sections). If deeper holes are necessary then a different drilling style is required, resulting in substantial increases in cost.

Oden & Vidar Viking at North Pole

Krylov, A © ECORD/IODP


Van Der Fecht, H © ECORD/IODP


Cotterill, C © BGS

Overview of current IODP proposals in the Arctic

No	Title	Geographic Region	Principal Investigator	
645	Arctic Ocean–North Atlantic Gateway: tectonic and paleoceanographic evolution of the Fram Strait, and the East Greenland margin during Cainozoic times	Fram Strait North Atlantic	W. Jokat Wilfried.Jokat@awi.de	
680	The Bering Strait, Global Climate Change, and Land Bridge Paleoecology	Bering Strait	S. Fowell ffsjf@uaf.edu	
708	A Paleoceanographic Transect across the Central Arctic Ocean: Towards a Continuous Cainozoic Record from a Greenhouse to an Icehouse World (ACEX-2)	Lomonosov Ridge	R. Stein Ruediger.Stein@awi.de	
746	The Mesozoic–Cainozoic Arctic: Transition from a Greenhouse to an Icehouse Earth.	Alpha-Mendeleev Ridge	W. Jokat Wilfried.Jokat@awi.de	
750	Chukchi Shelf to Slope Transect: Linking Beringian and Arctic Ocean History	Chukchi Sea	L. Polyak Polyak.1@osu.edu	
753	Late Quaternary paleoceanography and glacial dynamics in the Beaufort Sea	Canadian Beaufort Sea	M. O'Regan oreganM1@cardiff.ac.uk	
756	Morris Jesup Rise: Drilling the Arctic Ocean Exit Gateway	Morris Jesup Rise	M. Jakobsson Martin.jakobsson@geo.su.se	

The table below summarises expedition specifics of the 8 active IODP proposals in the Arctic. Further proposals are expected though as new projects were born out of the 2008 Bremerhaven workshop on Arctic Scientific Drilling (Coakley, B, Stein, R. 2008).

	Geographic Coordinates	Water Depth (m)	Penetration Depth (m)	Brief Site-Specific Objectives
	2 holes/site			
	82° 48.03'N, 12° 15.19'E	2780	1000	Paleoceanographic (Miocene)
	80° 54.05'N, 0° 40.82'E	2460	1000	Paleoceanographic (Neo/Miocene)
	77° 14.81'N, 0° 53.86'E	3250	1010	Paleoceanographic/tectonic (Early Cainozoic)
	73° 21.83'N, 14° 24.23'W	2420	910	Paleoceanographic/tectonic (Cainozoic)
	63.77430°N, 166.14483°W	30	800–1000	Recovery of expanded section of Miocene and younger age
	63.78127°N, 166.94507°W	30	800–1000	
	63.82201°N, 166.05471°W	30	800–1000	
	67.43738°N, 167.67823°W	45	800–1000	
	67.5057°N, 166.94383°W	45	800–1000	
	67.34568°N, 167.11474°W	45	600–800	Recovery of section of Middle Miocene and older age
	67.15272°N, 167.31605°W	30	800	Recovery of Eocene and potentially Upper Cretaceous section
	83° 48.03'N, 146° 28.5'E	1334	700	Cainozoic paleoceanography
	80° 46.6'N, 142° 46.9'E	1752	1000	Neogene/Quaternary, high–resolution records
	84° 34.1'N, 149° 49.7'E	1639	850	Cainozoic paleoceanography
	85° 05.9'N, 98° 17.8'W	1920	150	Mesozoic environment (FL533)
	85° 59.5'N, 129° 58.5'W	1590	150	Mesozoic environment (FL437)
	84° 53.3'N, 124° 32.5'W	2050	150	Mesozoic environment (FL422)
	85° 49.6'N, 109° 04.9'W	1500	150	Mesozoic environment (CES-6)
	85° 09.0'N, 171° 34.0'W	1500	520	Mesozoic Arctic Ocean/tectonic
	70° 41'N, 167° 21'W	55	50–60	Recovery of valley infill of Quaternary or older age
	70° 47'N, 167° 45'W	55	50–60	Recovery of valley infill of Quaternary or older age
	70° 55'N, 167° 36'W	55	50–60	Recovery of valley infill of Quaternary or older age
	71° 15'N, 166° 42'W	45	50–60	Recovery of valley infill of Quaternary or older age
	73° 40'N, 167° 10'W	120	800–1000	Recovery of the entire stratigraphic range of prograding sequences
	74° 40'N, 168° 50'W	200	800–1000	Recovery of expanded record of at least Quaternary to Pliocene age
	75° 00'N, 174° 00'W	350	800–1000	Recovery of expanded record of at least Quaternary to Pliocene age
	69° 45'N, 137° 50'W	100	200	High–resolution deglacial and Holocene records
	70° 07'N, 138° 42'W	350	400	Pleistocene paleoceanography and ice-sheet dynamics
	79° 24'N, 139° 19'W	670	200	Deep–water late Pleistocene paleoceanography
	85° 08'N, 14° 30'W	1039	390	Neogene paleoceanography and tectonics (basement I)
	85° 22'N, 14° 16'W	1200	750	Neogene–Paleogene? paleoceanography (water depth picked from multibeam)
	85° 24'N, 12° 56'W	1198	390	Neogene paleoceanography and tectonics (basement II) (water depth picked from multibeam)

Benefits of Academic and Industry Collaboration

In a region that is becoming increasingly relevant to global politics, commerce, science and the general public, the Arctic is the ideal location for collaboration between industry and academia on future scientific drilling. New drilling will inevitably lead to fundamental discoveries ranging from tectonics, regional stratigraphy, and paleoclimate, to providing industry with a regional context in a poorly understood hydrocarbon province.


Sheykin, I © ECORD/IODP

It is envisaged that this partnership offers substantial benefits for both communities, including:

- Participation in the program will offer industry a valuable opportunity to gain first-hand experience of in-ice operations and associated ice-management techniques in a range of pack-ice conditions. It is envisaged that this will be of use to their drilling departments that are contemplating exploration drilling campaigns. Operations may be planned to yield geotechnical data that will be of high value to drilling engineers involved in developing designs for exploration wells and assessing seabed conditions for rig moorings.

- Making significant discoveries in a poorly understood region that is one of the last true global frontiers. Prime areas of interest concern structural evolution, sedimentology and paleoclimate studies, as well as categorising changes in the present environment.

- Potentially accelerated project timescale (quicker delivery of scientific results). Cooperation between industry who need results today and academia who are less time-table driven should impact speed of delivery and hence efficiency of the whole program.

- Advancing our understanding of the history of the Arctic, a region that is becoming increasingly visible to, and prioritised by, science planners and the public.

Evans, D © ECORD/IODP

Cotterill, C © BGS

Objectives for consideration:

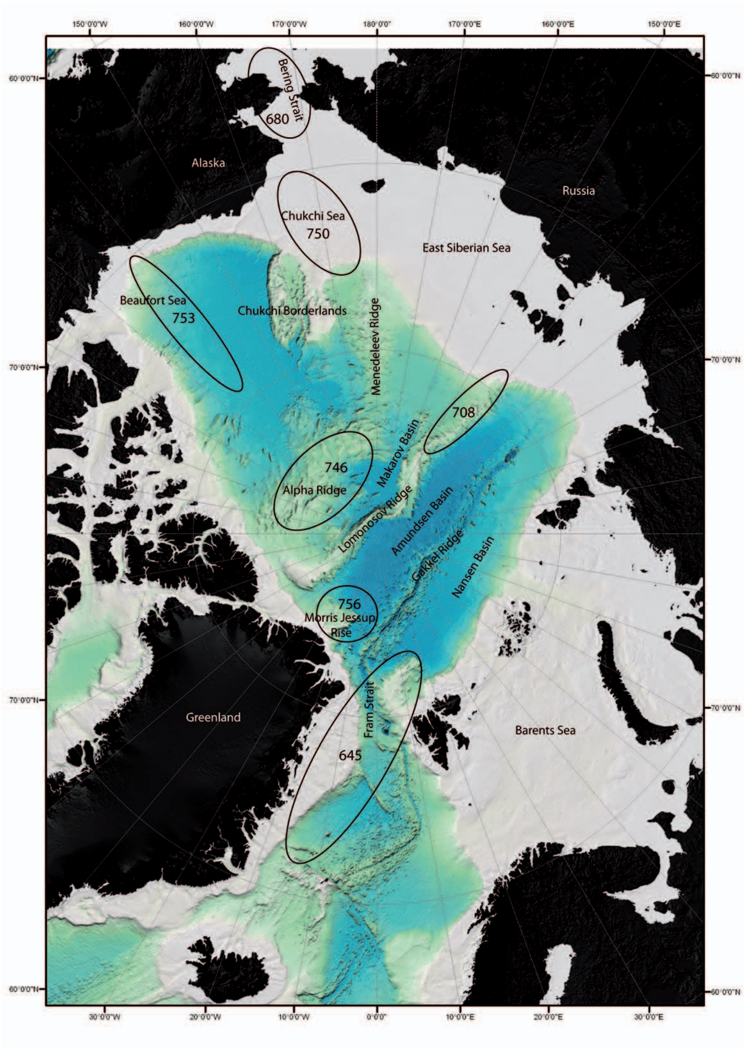
- Identifying common objectives between industry and academia (or sites/geographic areas that appeal independently to each group).
- Minimising operational/technical and scientific risks, thus maximising potential for scientific success.
- Range of potential scientific goals to address *e.g.* paleoclimate, paleoceanography, tectonics, geohazards.
- Scientific discoveries that illuminate the geological history of the Arctic provide industry with a regional context to better inform regional prospectivity.
- Take lessons from past Arctic drilling operations to provide guidance for future successes (variables: type of drilling, ice conditions, water depth, expected/proposed penetration depth, number of holes, budget).
- Data confidentiality–develop a protocol that is acceptable to both industry and academia.
- Social relevance.

Next Steps

Industry partners supported the recent workshop on Arctic scientific drilling (Coakley, B, Stein, R. 2008), which stimulated multiple new drilling proposals. Also ECORD has partnered with Eurogia+, a public/private partnership that supports research and development in sustainable energy technologies, optimising energy production from fossil fuels to renewables. Eurogia+ has focussed on the Arctic for one of its master projects, encouraging research into anything from adaptation of tools to extreme conditions, to new resource discovery, to understanding past climate change.

Building on these early developments, the next step will be to build a community of interested industry and academic partners. The ECORD Industrial Liaison Panel (ILP) along with other groups will deliver this message with the intention of spreading awareness of IODP and the potential benefits to industry and academia.

A workshop will be planned where the community can come together to discuss the benefits, limitations, and practicalities of this joint effort into Arctic scientific drilling.



Bathymetric map of the Arctic showing the locations of active IODP proposals.

Final Statement

by Catherine Mével, ECORD Managing Agency Director

The sea floor of the Arctic Ocean is still largely unknown territory. The one IODP expedition implemented by ECORD provided very exciting results and the scientific community is pushing to acquire new data.
This interest is obviously shared by industry to which the Arctic is one of the last frontiers. The 'Mission-Specific Platform' concept developed by ECORD within IODP is particularly appropriate to build joint projects on specific scientific targets and the ECORD Science Operator has demonstrated its 'know how' for drilling in ice-covered areas. The ECORD Council will favour all initiatives to jointly fund operations and advance knowledge of this remote area. The mutual interest is there, and working together will help us progress faster and more effectively.


Jakobsson, M © ECORD/IODP

ECORD

ECORD is a consortium of 16 European countries (Austria, Belgium, Denmark, Finland, France, Germany, Iceland, Ireland, Italy, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, UK) and Canada formed to join IODP as a single member. By pooling the funds of its member countries, ECORD is able to play a major role and operate mission-specific platforms in IODP.

The ECORD Industrial Liaison Panel (ECORD ILP)

This panel acts as a link between academia and industry, forging and fostering mutually beneficial relationships. The panel mainly comprises representatives from interested industries (mainly in Europe, but with wider international participation). It also includes the IODP Engineering and Development Panel (**www.iodp.org/edp**) representative to provide the ECORD ILP with a link to international IODP-related technology development.

The panel's terms of reference include providing support and offering guidance to the academic community on the appropriateness of the program for meeting industrial and related scientific objectives, to identify within the emerging program topics of interest to the industrial community and to suggest others that might be initiated by industrial members but developed jointly with academics; facilitation of mutual communication and cooperative scientific activities between IODP and related industries, (petroleum, mining, technology-development and innovation, engineering etc.) with the aim of benefiting deep-sea drilling science and technology. The ECORD ILP seeks to maximise economic benefits from sharing resources, such as manpower, the drilling of sites, the development of joint drilling and sampling technologies, core and data analysis, and improved downhole measurement and observatory capabilities. Finally, the aim is to facilitate the development of joint academic and industry drilling proposals from the ECORD countries.


Farell, J © ECORD/IODP

Useful Websites

European Consortium for Ocean Research Drilling (ECORD)
www.ecord.org

ECORD Industrial Liaison Panel
www.ecord.org/ecord-ilp.html

ECORD Science Support & Advisory Committee
www.essac.ecord.org

Integrated Ocean Drilling Program (IODP)
www.iodp.org

UK-IODP
www.ukiodp.bgs.ac.uk

Initial Science Plan for IODP
www.iodp.org/isp

IODP's Implementing Organizations (Platforms)

Center for Deep Earth Exploration *(Chikyu)*
www.jamstec.go.jp/chikyu/eng/index.html

ECORD Science Operator (Mission-Specific Platforms)
www.eso.ecord.org

US Implementing Organization *(JOIDES Resolution)*
www.iodp-usio.org

Legacy programs

Ocean Drilling Program (ODP)
www.odplegacy.org

Deep-Sea Drilling Project (DSDP)
www.deepseadrilling.org/

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Eurogia+: http://www.eurogia.com/files/WhiteBook_%201_V1-164210A.pdf

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