IODP Proposal Cover Sheet

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Arctic Atlantic Gateway Paleoclimate

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Title	THE OPENING OF THE ARCTIC-ATLANTIC GATEWAY: TECTONIC, OCEANOGRAPHIC AND CLIMATIC DYNAMICS
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Area	Norwegian-Greenland Sea, NE Greenland Continental Margin, Boreas Basin

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Abstract

Today's polar cryosphere reflects a climate state that developed during a stepwise global cooling during the Cenozoic greenhouse-to-icehouse climate transition. Polar ocean gateways such as the Drake Passage in the Southern Hemisphere and the Arctic-Atlantic Gateway (AAG) in the Northern Hemisphere played pivotal roles in changing the global climate through their influence on oceanic circulation, heat transport and ice sheet development. The Arctic Ocean was isolated from the global oceanic thermohaline circulation system during most of its geological history. This gradually changed when Greenland and Svalbard began to move apart from each other, initiating the opening of the AAG through the Fram Strait. Although this gateway is known to be important in Earth's past and modern climate, little is known about its Cenozoic development. Indeed, the opening history and AAG's consecutive widening and deepening must have had a strong impact on circulation and water mass exchange between the Arctic Ocean and the North Atlantic.

As a first order approximation, the timing of Fram Strait opening can be inferred from geophysical and stratigraphic records as well as modelling studies which form the basis of the hypotheses to be tested with this proposal. Climate and tectonic modelling studies suggest that a certain width and depth of the Fram Strait are required to allow the bi-directional exchange of water masses of Atlantic and Arctic origin through the AAG. To test these models, direct geological evidence from ocean drilling sediment records from four primary sites between 73°N and 78°N are needed to constrain the age of the opening, widening, and deepening of this deep-water Arctic-North Atlantic Oceans connection.

These sites will provide unprecedented sedimentary records from the Eocene/Oligocene through the Pliocene that will unveil (1) the history of shallow-water exchange between the Arctic Ocean and the North Atlantic and its impact on the global cryosphere evolution, and (2) the development of the AAG to a deep-water connection and its influence on global climate changes. By filling the current time gap of ~20 million years in the AAG region with new, well-dated borehole material, we will address these large uncertainties and gaps in the paleoclimate record.

The proposed drilling addresses a number of key questions raised in the IODP Science Plan 2013-2023. It is specifically linked to the Research Theme "Climate and Ocean Change: Reading the Past, Informing the Future".

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Scientific Objectives

This proposal has two major objectives: (1) constrain the geological history of the only deep-water connection to the Arctic Ocean and its impacts on the Earth's Cenozoic climate evolution. (2) understand the role of the Arctic-Atlantic Gateway (AAG) region for the cryosphere-ocean evolution of the Northern Hemisphere.

Scientific drilling is the only approach that can test the following hypotheses:
1. The timing of initial opening and later deepening of the AAG correlates with the Cenozoic development of the global cryosphere.
2. The Northern Hemisphere cryosphere-ocean evolution is linked to regional tectonic (AAG deepening and widening) or global climate and atmospheric CO2 concentrations.

With our four primary sites (FR-19A, FR-11A, FR-06A, FR-21A), we will provide new baseline knowledge for improved climate model simulations for high-latitude ocean gateway changes and assess the role of the AAG in Cenozoic climate evolution with new and complete stratigraphic records from the Oligocene through the Pliocene (~34 Ma through 2.7 Ma). This will allow us to examine the interaction and consequences of AAG dynamics for the history of bi-directional (surface and deep) ocean circulation between the northern North Atlantic and the Arctic Ocean and its impact on the evolution of the East Greenland ice sheet and initial expansion of Arctic sea ice.

Non-standard measurements technology needed to achieve the proposed scientific objectives

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Proposed Sites (Total proposed sites: 19; pri: 4; alt: 15; N/S: 0)

Site Name	Position (Lat, Lon)	Water Depth (m)	Penetration (m)			Brief Site-specific Objectives
			Sed	Bsm	Total	
FR-19A (Primary)	73.4605 -14.3375	2358	1300	20	1320	Recovery of a complete sediment sequence from Eocene to Quaternary and potentially the top of the oceanic basement. This site will address hypotheses 1 (Initial opening of the AAG), and 2 (Deepening and widening of the AAG), allowing the reconstruction of the complete transition from the isolated Arctic Ocean to the modern gateway and the relation of uplift and glaciations in East Greenland. The recovery of basement/magmatic rocks will allow to test the current plate-kinematic models.
FR-06A (Primary)	75.2197 -10.8764	2423	1200	0	1200	Recovery of a complete sediment sequence from Late Eocene to Oligocene. This site will address hypotheses 1 (Initial opening of the AAG), allowing the reconstruction of the complete transition from the isolated Arctic Ocean to the early gateway. A reconstruction of the full history (including the deepening and widening, hypothesis 2) towards the modern gateway will be possible in combination with Sites FR-04A and FR-05A.
FR-11A (Primary)	76.4472 -0.6448	3102	800	0	800	Recovery of a complete middle/late Miocene to Quaternary section which will allow to address hypothesis 2, the deepening and widening of the AAG. Recovered drift deposits will enable high-resolution paleoceanographic studies on ocean circulation, sea-ice cover, deep-water formation and continental ice sheets.
FR-21A (Primary)	77.3946 0.0499	2843	137	232	369	Recovery and dating of basement rocks will allow testing the current plate kinematic model (hypothesis 1).
FR-04A (Alternate)	75.2967 -11.3048	1600	1300	0	1300	Recovery of a complete sediment sequence from Late Oligocene to Quaternary. This site will address hypothesis 2 (Deepening and widening of the AAG), allowing the reconstruction of the complete transition from the isolated Arctic Ocean to the modern gateway in combination with Sites FR-05A and FR-06A, and the relation of uplift and glaciations in East Greenland.
FR-05A (Alternate)	75.2487 -11.0376	2089	1000	0	1000	Recovery of a complete sediment sequence from Early Oligocene to Early Miocene. This site will address hypotheses 1 (Initial opening of the AAG) and 2 (Deepening and widening of the AAG), allowing the reconstruction of the complete transition from the isolated Arctic Ocean to the modern gateway in combination with Sites FR-04A and FR-06A.
FR-03A (Alternate)	73.3562 -14.3341	2431	1300	20	1320	Recovery of a complete sediment sequence from Eocene to Quaternary and potentially the top of the oceanic basement. This site will address hypotheses 1 (Initial opening of the AAG), and 2 (Deepening and widening of the AAG), allowing the reconstruction of the complete transition from the isolated Arctic Ocean to the modern gateway and the relation of uplift and glaciations in East Greenland. The recovery of basement/magmatic rocks will allow to test the current plate-kinematic models.
FR-15A (Alternate)	73.4006 -14.1015	2468	1300	20	1320	Recovery of a complete sediment sequence from Eocene to Quaternary and potentially the top of the oceanic basement. This site will address hypotheses 1 (Initial opening of the AAG), and 2 (Deepening and widening of the AAG), allowing the reconstruction of the complete transition from the isolated Arctic Ocean to the modern gateway and the relation of uplift and glaciations in East Greenland. The recovery of basement/magmatic rocks will allow to test the current plate-kinematic models.
FR-16A (Alternate)	73.2257 -14.2778	2464	1300	20	1320	Recovery of a complete sediment sequence from Eocene to Quaternary and potentially the top of the oceanic basement. This site will address hypotheses 1 (Initial opening of the AAG), and 2 (Deepening and widening of the AAG), allowing the reconstruction of the complete transition from the isolated Arctic Ocean to the modern gateway and the relation of uplift and glaciations in East Greenland. The recovery of basement/magmatic rocks will allow to test the current plate-kinematic models.

Proposed Sites (Continued; total proposed sites: 19; pri: 4; alt: 15; N/S: 0)

Site Name	Position (Lat, Lon)	Water Depth (m)	Penetration (m)			Brief Site-specific Objectives
			Sed	Bsm	Total	
FR-17A (Alternate)	73.1662 -14.2056	2484	1300	20	1320	Recovery of a complete sediment sequence from Eocene to Quaternary and potentially the top of the oceanic basement. This site will address hypotheses 1 (Initial opening of the AAG), and 2 (Deepening and widening of the AAG), allowing the reconstruction of the complete transition from the isolated Arctic Ocean to the modern gateway and the relation of uplift and glaciations in East Greenland. The recovery of basement/magmatic rocks will allow to test the current plate-kinematic models.
FR-07A (Alternate)	76.5909 -1.3729	2991	800	0	800	Recovery of a complete middle/late Miocene to Quaternary section which will allow to address hypothesis 2, the deepening and widening of the AAG. Recovered drift deposits will enable high-resolution paleoceanographic studies on ocean circulation, sea-ice cover, deep-water formation and continental ice sheets.
FR-12A (Alternate)	76.9056 -2.1056	3058	800	0	800	Recovery of a complete middle/late Miocene to Quaternary section which will allow to address hypothesis 2, the deepening and widening of the AAG. Recovered drift deposits will enable high-resolution paleoceanographic studies on ocean circulation, sea-ice cover, deep-water formation and continental ice sheets.
FR-14A (Alternate)	76.4906 -0.0024	3171	800	0	800	Recovery of a complete middle/late Miocene to Quaternary section which will allow to address hypothesis 2, the deepening and widening of the AAG. Recovered drift deposits will enable high-resolution paleoceanographic studies on ocean circulation, sea-ice cover, deep-water formation and continental ice sheets.
FR-10A (Alternate)	77.1173 1.6345	3198	400	20	420	Recovery and dating of basement rocks will allow testing the current plate kinematic model (hypothesis 1).
FR-09A (Alternate)	77.1737 1.3165	3206	1000	20	1020	Recovery of a complete middle/late Miocene to Quaternary section which will allow to address hypothesis 2, the deepening and widening of the AAG. Recovery and dating of basement rocks (basalts) will allow testing the current plate kinematic model (hypothesis 1).
FR-02A (Alternate)	77.2243 1.0292	3206	900	0	900	Recovery of a complete middle/late Miocene to Quaternary section which will allow to address hypotheses 2, the deepening and widening of the AAG.
FR-08A (Alternate)	77.2158 1.0756	3205	1000	20	1020	Recovery of a complete middle/late Miocene to Quaternary section which will allow to address hypothesis 2, the deepening and widening of the AAG. Recovery and dating of basement rocks (basalts) will allow testing the current plate kinematic model (hypothesis 1).
FR-23A (Alternate)	77.2407 1.5023	3192	500	20	520	Recovery and dating of basement rocks will allow testing the current plate kinematic model (hypothesis 1).
FR-24A (Alternate)	77.1387 0.8986	3190	760	20	780	Recovery and dating of basement rocks will allow testing the current plate kinematic model (hypothesis 1).