IODP Proposal Cover Sheet

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Arctic Fluid Flow Systems

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Title	Pleistocene evolution of Arctic gas hydrates and fluid flow systems - PATH
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Abstract

We present a drilling proposal that focuses on the Pleistocene evolution of fluid flow, gas hydrate and methane seepage systems in the Fram Strait. The Fram Strait is the major gateway between the Arctic and the North Atlantic. This peculiar setting has been well known for its importance to paleoceanography, global climate and its ultra-slow mid-ocean ridge system (Knipovich and Molloy Ridges). More recent work discovered large gas hydrate and fluid flow systems situated on young and hot oceanic crust extending from the upper continental slope off Svalbard to the mid-ocean ridge. Seafloor and subseafloor depressions on seismic data and authigenic carbonate samples document past and ongoing seepage of hydrocarbons. Here we hypothesize that carbon has been remobilized several times in response to mid-ocean ridge tectonics, hydrothermal circulation, and ice sheet dynamics of the glacial/interglacial cycles. Carbon inventories in this Arctic fluid flow system are unique as they may not only include microbial and thermogenic hydrocarbons but also abiotic methane derived from the serpentinization of ultramafic rocks. However, the relative importance of these hydrocarbon sources is not known. Deep biosphere microbes and ecosystems in the Arctic remain largely unexplored and the possibility of co-existing hydrothermal and cold seep microbial communities may hold some very unique interaction among these populations.
Large sediment drifts, named Vestnesa and Svyatogor Ridge, situated on the continental slope and on the western flank of the Knipovich Ridge respectively, have trapped fluids, formed gas hydrate and developed active seepage systems associated with exceptional chemosynthetic communities. These ridges resemble unique archives for the evolution and interaction of crustal processes and the shallow earth system, gas hydrate and seepage dynamics, the deep biosphere and global climate change. Here, we propose to study these interactions thereby providing new insights into how these processes dynamically interplay and transfer carbon from one system to another.
Our proposed drilling program involves logging and coring at six sites in the eastern Fram Strait on a strategic transect from the continental slope off western Svalbard to the mid-ocean ridge. Four of the six sites are defined by high-resolution 3D seismic site survey data allowing very exact targeting of subseafloor features including an oceanic detachment. Recovering sediment cores from high latitudes presents one of the most important challenges for scientific ocean drilling and would fill the need for data in this underrepresented region.

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Scientific Objectives

The overall goal is to quantify the links between large scale geological and climate change events that drive fluid expulsion in a tectonically active, glaciated Arctic margin; the microbial response to these changes; and the consequential impact on global carbon cycling. Primary objectives are:
To constrain the timing of methane gas release to the hydro- and atmosphere since the intensification of Northern Hemisphere glaciation, 2.7 Ma ago, with focus on how paleoclimatic evolution and ice sheet dynamics have influenced gas hydrate stability, fluid flow dynamics, and the response of the biosphere to changes in methane flux;
To study the genesis of methane that has sustained Arctic gas hydrate accumulations and fluid expulsion for millions of years, particularly quantifying the role of methane formed by microbial and thermogenic methanogenesis, long-range transport through maturation of organic matter, and serpentinization of ultra-mafic rocks as a source of abiotic methane;
To compare variations in microbial communities, the chemical and physical factors that shape community change, including varying sources of carbon and electron acceptors, and the microbial contribution to carbon cycling in the deep biosphere of an Arctic setting;
To better understand the geodynamic and hydrological processes at ultra-slow mid-ocean ridges and with potential impact for fluid flow, biosphere response, and cycling of carbon in Arctic continental margin sediments;
To Investigate the dynamics of gas hydrates in ultra-slow mid-ocean ridge settings with high heat flow where the “fast” evolution of a gas hydrate system provides unique insight into methane dynamics, fluid flow and ecosystem response.

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

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Proposed Sites (Total proposed sites: 6; pri: 6; alt: 0; N/S: 0)

Site Name	Position (Lat, Lon)	Water Depth (m)	Penetration (m)			Brief Site-specific Objectives
			Sed	Bsm	Total	
VST-01A (Primary)	78.9968 6.9635	1200	700	0	700	VST-01 penetrates flat, stratified, undisturbed sediments down to the Plio-Pleistocene boundary which is at ca. 700 mbsf. The BSR appears weak or non-existent in the surrounding of this site. Reference site with objectives related to stratigraphy, paleoclimate, methanogenesis at a non-vent site, geomechanics.
VST-02A (Primary)	79.0071 6.9041	1200	400	0	400	VST-02 will penetrate the Lunde pockmark-chimney structure, one of the focused fluid flow features with active seepage of gas. Location coincides with MeBo core that penetrated 22 m and recovered gas hydrates and MDAC (Bohrmann et al., 2107). Objectives relate to geochemistry of pore water and hydrates, MDAC, fluid flow pathways and their physical properties (including permeability), variation in methane fluxes, hydrocarbon composition and hydrocarbon sources, carbon cycles, vent biosphere,
VST-03A (Primary)	79.2121 4.5203	1500	600	0	600	VST-3 lies at the western termination of the Vestnesa Ridge. Important objectives are extending the stratigraphic and paleoclimate record into the Pliocene and possibly the Miocene over a condensed sedimentary section. Site is also closer to the mid-ocean ridge and therefor residing on warmer oceanic crust with hydrological and geothermal consequences for fluid flow and hydrate system in the sedimentary overburden of the crust. Objectives relate to the thermal structure of the sediments close to the MOR, hydrocarbon composition of and hydrocarbon sources, Exact location of this site might change with the acquisition of high-resolution 3D seismic data in summer 2018.
SVG-01A (Primary)	78.2596 5.8375	1800	500	50	550	SVG-01 is located in an inactive pockmark on the Svyatogor Ridge, western flank of the Knipovich MOR. The intended drilling penetrates a chimney and is supposed to reach and go through a detachment fault. Objectives relate to geochemistry of pore water and hydrates, MDAC, fluid flow pathways and their physical properties (including permeability), variation in methane fluxes, hydrocarbon composition and hydrocarbon sources, dynamics of hydrates over young and warm oceanic crust, serpentinization, carbon cycles, hydraulic communication between crust and sediment, heat budget, hydrothermal and cold vent microbial communities, their potential co-existence and their response to fluid leakage.
SVG-02A (Primary)	78.2453 5.7076	1800	500	50	550	SVG-2 site will penetrate stratified, undisturbed sediments beyond the western extent of a BSR. Objectives relate to stratigraphy, paleoclimate, sediment physical properties (including permeability), microbial methanogenesis, hydrocarbon composition and hydrocarbon sources, hydrological interaction between crust and sediment, deep biosphere
SVG-03A (Primary)	78.2656 5.8985	1800	700	50	750	SVG-03 site penetrates stratified, undisturbed sediments through the Plio-Pleistocene boundary east of the investigated Svyatogor gas hydrate system. This site will function as a reference site for pore-water geochemistry and petrophysical analysis. The intended drilling is supposed to reach and go through a detachment fault. Objectives relate to stratigraphy, paleoclimate, sediment physical properties (including permeability), microbial methanogenesis, hydrocarbon composition and hydrocarbon sources, serpentinization, carbon cycles, hydraulic communication between crust and sediment, heat budget, deep biosphere