# 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 - POLARIS |
| Proponents | Stefan Bünz, Andreia Plaza-Faverola, Sunil Vadakkepuliyambatta, Jochen Knies, Joel Johnson, Fumio Inagaki, Michael Riedel, Marta Torres, Giuliana Panieri, Timothy S Collett, Helge Niemann, Javier Escartin, Gerhard Bohrmann, Dan Condon, Aivo Lepland, Carolyn Ruppel |
| Keywords | hydrates, paleoclimate, carbon cycling, biosphere |
| Area | Fram Strait |

## Proponent Information


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|---|---|
| Proponent | Stefan Bünz |
| Affiliation | Centre for Arctic Gas Hydrates, Environment and Climate, Arctic University of Norway |
| Country | Norway |


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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 as well as authigenic carbonate samples document past and ongoing methane discharges to the ocean. Here we hypothesize that significant amounts of carbon have been remobilized during multiple episodes in response to mid-ocean ridge tectonics, hydrothermal circulation, and ice sheet dynamics since the onset of glaciations 2.7 Ma ago. 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 remains unknown. Deep biosphere microbes and ecosystems in the Arctic remain largely unexplored and the possibility of co-existing hydrothermal and cold seep microbial communities may indicate some very unique interaction among these populations.

Large sediment drifts, named Vestnesa Ridge 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 constitute 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 four sites in the eastern Fram Strait on a strategic transect from the continental slope off western Svalbard to the mid-ocean ridge. All four primary 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, formerly 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 release to the hydro- and atmosphere since the intensification of Northern Hemisphere glaciation, with focus on how paleoclimatic evolution, ice sheet dynamics and tectonic stresses have influenced carbon inventories, geochemical fluxes, and the response of the biosphere to changes in carbon fluxes;
- To better understand past climates and the growth and collapse of polar ice sheets, understanding rates and magnitudes of climate variability in high latitudes and its implication for global climate;
- To study the genesis and origin 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 and serpentinization of ultra-mafic rocks as a source of abiotic methane;
- To better understand the geodynamic and hydrological processes at sediment covered, ultra-slow mid-ocean ridges and assess their global significance and potential impact for fluid flow, biosphere response, and cycling of carbon within and between crustal, sedimentary, and oceanic carbon reservoirs;
- To compare variations in microbial communities in both sedimentary and crustal habitats affecting biogeochemical element cycling, and their contribution to carbon cycling in the deep biosphere of an Arctic setting and its role in the global biogeography of vent communities.

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

Non-standard measurements include the T2P (Temperature-Two Pressure) probe for in-situ temperature and pressure, logging-while-drilling tools, and sterile laboratories for microbiological subsampling.

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Proposed Sites (Total proposed sites: 12; pri: 4; alt: 8; 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 | 500 | 0 | 500 | VST-01 penetrates flat, stratified, undisturbed sediments down to the Plio-Pleistocene boundary which is at ca. 500 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 | 250 | 0 | 250 | 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). Penetration aims to go through base of gas hydrate stability. 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-03B (Alternate) | 79.1826 4.5700 | 1536 | 650 | 0 | 650 | VST-03B 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. |
| VST-04A (Alternate) | 78.8723 7.5116 | 1129 | 600 | 0 | 600 | VST-04 penetrates flat, stratified, undisturbed sediments down to the Plio-Pleistocene boundary which is at ca. 600 mbsf. Reference site with objectives related to stratigraphy, paleoclimate, methanogenesis at a non-vent site, geomechanics. |
| VST-05A (Alternate) | 79.0321 7.0581 | 1293 | 550 | 0 | 550 | VST-05 penetrates flat, stratified, undisturbed sediments down to the Plio-Pleistocene boundary which is at ca. 550 mbsf. Reference site with objectives related to stratigraphy, paleoclimate, methanogenesis at a non-vent site, geomechanics. |
| VST-06A (Alternate) | 79.0109 6.8813 | 1210 | 250 | 0 | 250 | VST-06 will penetrate a pockmark-chimney structure, located NW of VST-02. This pockmark is inactive, no gas seepage detected. Additionally, bathymetric data shows that the pockmark depression is slightly infilled with recent sediments. Penetration aims to go through base of gas hydrate stability. 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-07A (Alternate) | 79.0172 6.8386 | 1213 | 250 | 0 | 250 | VST-07 will penetrate a pockmark-chimney structure, located NW of VST-02. This pockmark is inactive, no gas seepage detected over multiple year surveys. Penetration aims to go through base of gas hydrate stability. 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, |
| SVG-01A (Primary) | 78.2596 5.8375 | 1522 | 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 (Alternate) | 78.2453 5.7076 | 1589 | 350 | 0 | 350 | 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 |

Proposed Sites (Continued; total proposed sites: 12; pri: 4; alt: 8; N/S: 0)

| Site Name | Position (Lat, Lon) | Water Depth (m) | Penetration (m) | | | Brief Site-specific Objectives |
|---|---|---|---|---|---|---|
| | | | Sed | Bsm | Total | |
| SVG-03A (Primary) | 78.2656<br>5.8985 | 1572 | 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<br>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 |
| SVG-04A (Alternate) | 78.2683<br>5.8766 | 1556 | 650 | 50 | 700 | SVG-04 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<br>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 |
| SVG-05A (Alternate) | 78.2643<br>5.8351 | 1523 | 500 | 50 | 550 | SVG-05 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. |