

**Addendum to the scientific programme of**

**ARK-XXV/3**

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**Reykjavik - Bremerhaven**

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## **CONTENTS**

- 1. Structure and evolution of the crust of the northwestern Greenland continental margin and sedimentary basins**
- 2. Aeromagnetic measurements of north Baffin Bay for studying volcanic and magmatic phases during the crustal evolution**
- 3. Geological field work and rock sampling of coastal outcrops**

**Updated Map of Survey Activities during ARK-XXV/3**

# 1. STRUCTURE AND EVOLUTION OF THE CRUST OF THE NORTHWESTERN GREENLAND CONTINENTAL MARGIN AND SEDIMENTARY BASINS

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## Objectives

Due to lack of data the plate boundary between the North American plate and the Greenland plate is not well defined and the nature of the continent-ocean transition zone is widely unknown. The thick pre-Cenozoic and Cenozoic sedimentary basins in the area were formed and influenced by crustal extension and compression in their temporal sequence and are sparsely analysed. The tectonic evolution of northern Baffin Bay is still disputed.

By means of multi-channel seismic, wide angle seismic, gravimetric and magnetic methods the structural inventory of the crust in the Greenland continental margin in NW Baffin Bay is planned to be investigated. Data will be acquired along profiles extending from the deep oceanic basin in the central part of North Baffin Bay onto the Greenland continental margin in an area which is bordered by the Kane Basin in the North and Disco Island in the South.

Additionally, heat flow data and sediment cores will be collected at selected positions along lines across the Greenland continental margin. The cores will be extracted for geochemical and geomicrobiological analysis to be used for basin modeling and studying the hydrocarbon potential and microbial hydrocarbon degradation. Aeromagnetic data will be acquired covering part of the marine survey area to investigate magnetic signatures of the oceanic crust and the Greenland continental margin.

Main questions and tasks are:

- Is the West Greenland margin a typical passive continental margin
- is there segmentation into volcanic and non-volcanic margins
- what is the origin and evolution of possible margin segments and
- where is the continent-ocean-transition in the eastern North Baffin Bay and can we detect seafloor spreading anomalies
- can we detect pre- and synrift sediments and/or distinct phases of rifting
- compilation of all data to derive a crustal evolution model for the Baffin Bay since Paleozoic times,
- derive a model for the evolution of thick sedimentary basins in the area and estimate their hydrocarbon potential.

The results of the multi-disciplinary survey work will be integrated into a regional synthesis of the Greenland rift margin, sedimentary basin development and evolution, and the implications on the hydrocarbon resource potential.

## Work at Sea

The modified plan of operations comprises marine geophysical profile work including aeromagnetic surveying plus geological field work in coastal areas.

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Proposed profiles of the original working plan were adjusted to only Greenland territorial waters. This resulted in the following modifications of the originally submitted project (see Fig.1):

Refractions seismic lines:

- instead of 3 lines within Canadian and Greenland waters => now 4 lines in only Greenland waters

Reflection seismic lines:

- instead of 6 lines within Canadian and Greenland waters => now 21 lines covering the Greenland margin between Disco Island and Kane Basin

Magnetic and gravity surveying:

- instead of 6 profiles within Canadian and Greenland waters => now more than 25 lines covering selected areas with line spacings of 5 nm.
- additional aeromagnetic surveying in Greenland territorial waters (see below)

Heat flow and sediment coring:

- additional sampling/probing stations along 4 profiles with dense spacing of 7 to 8 nm.

Geological sampling of near coastal outcrops:

- additional sampling of more than 20 locations (see below).

*Refraction Seismic Lines (refraction seismics plus MCS, magnetic, gravity, sediment echosounding, heat flow, coring)*

Up to 30 ocean-bottom seismometers (OBS) will be deployed along each refraction profile. The spacing of the instruments ranges will be 7 and 8 nm. Three locations onshore will be equipped with seismic land-recorders. These locations will be at the west coast of Greenland in prolongation of the refraction lines to extend the lengths of the offshore profile.

*BGR10-311/BGR10-3R1* extends from the western Greenland margin and terminates at the extinct spreading axis in Northern Baffin Bay. This line was turned clockwise from its original position into a SE-NW trend.

*BGR10-302/302A/BGR10-3R2* crosses the Northern Baffin Bay from the central part to the northern end of the Melville Bay Graben. This line will identify the COB positions for the Greenland margin. The line will cross the extinct Eocene axis and (presumably) Paleocene oceanic crust. This line is a shorted original version. It is critical to the question of whether the basins along the margin are underlain by oceanic crust or attenuated continental crust.

*BGR10-313/303/BGR10-3R3* extends from normal Archean crust southward across the COB and crosses onto (presumably) Paleocene oceanic crust and continues across the extinct Eocene spreading axis. This line will establish whether the basins along the margin are underlain by oceanic crust or attenuated continental crust. It is turned counterclockwise compared to the original version.

*BGR10-309/BGR10-3R4* extends from the northern end of a BGR seismic reflection survey acquired during the previous cruise MSM09/2 in 2008 and continues onto the Greenland shelf. A portion of this new added line will be coincident with the AWI refraction line AWI20080500. Both lines tied together may be used for modelling the crustal structure of the Continent-Ocean-Boundary (COB) along this southernmost profile.

*Reflection Seismic Lines (MCS, magnetic, gravity, sediment echosounding)*

Strategy for adjusting the MCS survey was to conduct the reflection seismic survey as per schedule of the original programme as long as they are located in Greenland territorial waters. Additional lines were planned

- to tie seismic lines to profiles acquired during previous BGR/AWI expeditions in 2001 and 2008.
- to cross the Greenland margin and the suggested COB from Smith Sound in the North to Disco Island in the South.
- to allow for seismostratigraphic correlation along the Greenland margin.
- to get first seismic data ever of the Kane Basin

*BGR10-305/305A/306A/307/308* ties to other seismic refraction/reflection lines. It crosses the suggested COB in the western part and allow for additional seismostratigraphic correlation along the Greenland margin.

*BGR10-308* extends from the West Greenland margin seaward across the COB and onto (presumably) Paleocene oceanic crust and ends up at the northern end of the BGR MSM09/3 seismic survey area of 2008. This line will provide an improved cross-section of the Greenland margin and allows for seismostratigraphic correlation with the reflection seismic data of the 2008 MSM09/3 cruise.

*BGR10-314/315/318/319/320/321* - are located in the northern part of Baffin Bay extending to the Smith Sound. These lines will cover the thick sediment layers of the Baffin Bay Fan and may be used to define the position of the COB in the North. The lines extend the survey of the previous BGR cruise NARES01 of 2001 and will allow for seismostratigraphy.

*BGR10-316/317* - will provide first seismic data of the Kane Basin, an underexplored ice covered wide basin in the Nares Strait. The Kane Basin plays a key role for tracking the Wegener Fault southward into Smith Sound.

*BGR10-322* – to extend the MCS line BGR08-306 of the previous cruise MSM09/3 onto the Greenland shelf.

All seismic reflection data will be processed onboard using a ProMAX system and interpreted by means of an onboard GeoFrame interpretation system.

*Deployment of sonobuoys and land-based seismometers*

Along MCS lines we will use sonobuoys to get additional wide angle reflection and refraction data for subsequent processing of MCS data. Sonobuoys are passive seismic data recorders comparable to the ocean bottom seismometers (OBS), which are the primary recording instruments (see paragraph 4.1) during the survey to acquire wide angle seismic data. In contrary to the OBSs, which need to be retrieved from the ocean floor after data acquisition is completed to download the recorded data, sonobuoys are one-way instruments transmitting the recorded data to the research vessel via radio communication and sink after a preset time period. Compared to the original programme two more location for deployment of land station seismometers are planned. The exact positions for the deployment are subject to logistic conditions and should be located close to the following coordinates:

<u>Station</u>	<u>Latitude</u>	<u>Longitude</u>	<u>Location</u>
LS-1	77° 21' N	72° 06' W	Northumberland-Is.
LS-2	74° 17' N	57° 00' W	Nugssuaq Peninsula

Stations will be deployed using the shipboard helicopters of *R/V Polarstern*. Location of all seismic lines is outlined in Figure 2.

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## **Expected Results**

The four refraction seismic lines combined with all geophysical data are designed to investigate the crustal structure and variations of structural parameters along the Western Greenland continental margins. The seismic data will be processed to produce models of the geometry and composition of the continental/oceanic crust. The data will provide new constraints on the architecture of the Greenland continental margin and deep crustal information to reconstruct plate motions between Canada and Greenland. The results will improve the understanding of the development and evolution of the sedimentary basins and their hydrocarbon potential.

The seismic data to be acquired in Kane Basin are of special importance since they will be the first seismic information at all of this totally underexplored area.

## **2. AEROMAGNETIC MEASUREMENTS AS AN INDICATOR FOR VOLCANIC AND MAGMATIC PHASES DURING THE CRUSTAL EVOLUTION**

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### **Objectives**

Additionally to the marine magnetic measurements using the towed gradient and vector magnetometers it is intended to use the helicopters of Polarstern to perform an aeromagnetic survey in the Greenland part of the Baffin Bay and in the Kane Basin. The aeromagnetic data will cover part of the marine survey area to investigate magnetic signatures of the oceanic crust and the Greenland continental margin. The data will complement and link the marine data of this cruise in the northern Baffin Bay and the former R/V Maria S. Merian Cruise (MSM09, 2008) in the Southern Baffin Bay and in the Davis Strait and of a former cruise of R/V Louis St. Laurent (NARES 2001) in the Kane Basin. The main targets are the deep water parts of the Baffin Bay where crust of oceanic origin can be expected. The possible identification of magnetic lineations in these areas will help to constrain the timing and the direction of plate tectonic motions during the opening of the Baffin Bay. The data can also be used to delineate tectonic structures and e.g. volcanic provinces in the Greenland shelf areas.

### **Work at Sea**

The measurements will be performed using the Helicopters of R/V Polarstern with the vessel as the flight basis. The aeromagnetic equipment of BGR will be used that consists of a magnetometer (Cs vapor) bird towed 30 m below the helicopter and an aeromagnetic data acquisition system. There will also be an experimental assembly of two fluxgate magnetometers and a gyro based inertial navigation system within the helicopter.

Most profiles will be oriented approximately N-S in order to cross the expected structures in a perpendicular direction. A line spacing of 5 to 10 nautical miles should be sufficient to detect and correlate magnetic lineations. It is not planned to deploy magnetic base stations on the Greenland coast because of the moving vessel and therefore the permanent change of the

aeromagnetic survey areas. Additional flights or ship borne magnetic profiles will serve as tie lines to correct for the magnetic variations.

### **Expected Results**

The most important outcome would be the identification of lineated magnetic seafloor-spreading anomalies. This would give direct evidence of the oceanic origin of Baffin Bay crust and its age. Ideally also the direction of the opening of the basin can be determined. Successful determination of these parameters would have a fundamental impact on plate tectonic models for the history of the surrounding continents and oceans. Additionally, magnetic data provide valuable constraints on crustal structures, e.g. the presence of volcanic material, when they are evaluated together with seismic and gravity data.

## **3. GEOLOGICAL FIELD WORK AND ROCK SAMPLING OF COASTAL OUTCROPS**

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not on board: C. Spiegel, F. Lisker (Uni Bremen)

### **Objectives**

Helicopter-supported onshore fieldwork is intended to collect samples for

- a) thermochronologic techniques (apatite and zircon fission track and (U-Th-Sm) / He analyses) and
  - b) for organic geochemistry and organic petrography of potential petroleum source rocks.
- Both types of analyses will provide important clues to basin models that will form the basis of our planned numerical petroleum systems analysis (see Gas Geochemistry in the cruise booklet ARK-XXV/3) for the northeastern margin of Baffin Bay and along the southeastern Nares Strait.

### **Work at Sea**

Samples for the thermochronologic methods will be taken along two types of transect:

1. topographic transects within one structural unit, where systematic differences in fission track ages can be interpreted in terms of denudation/exhumation rates,
2. transects on a similar elevation to identify regional changes of denudation and exhumation.

In addition to that, sands from Holocene glacial outlets will be sampled. Sampling positions will be selected prior to individual sampling campaigns primarily on the basis of regional geological maps according to lithologic criteria, i.e. the likelihood to find appreciable quantities of apatite and/or zircon. Sampling campaigns should be considered whenever the ship is closer than 100 nm to appropriate geologic units. Transport and sampling is to be done by the shipboard helicopters and with at least two geologically trained persons aboard to allow for efficient use of the time windows mandated by distance and weather. Due to the lack of detailed topographic information of these remote areas, and to generally receding glaciers, individual sampling spots should ultimately be selected while underway.

Samples for organic geochemical/petrography methods shall be taken on an ad-hoc base when the ship is in the range of appropriate geologic units, e.g. the Silurian backshales of western Washington Land.

### Expected Results

The results of the two sampling programmes are expected to contribute to regional numerical basin models that will be constrained by, both offshore and onshore data. Usually, reflection seismics and the stratigraphy of adjacent drill holes provide the geometries and timing of deposition of the basin fill. However, the interpretation of major localised deposition and of erosional features, their onset, duration and rates, is commonly difficult without knowledge of the exhumation history of the basin shoulders. This history is documented in thermochronologic markers such as apatite and zircon fission tracks. Using the results of thermochronologic methods, we expect to contribute to a better understanding of the exhumation history on the northeastern margin of Baffin Bay and along the southeastern Nares Strait. Notably, we expect to decipher the relationship between the formation of the supposed Mesozoic to Palaeogene sedimentary basins (e.g. Steensby Basin; Tessensohn et al., 2006) and the source areas for the contemporary sedimentary infill.

Organic geochemical/petrography results are chief ingredients for modelling petroleum generation and migration, such as we intend to perform for the target area.

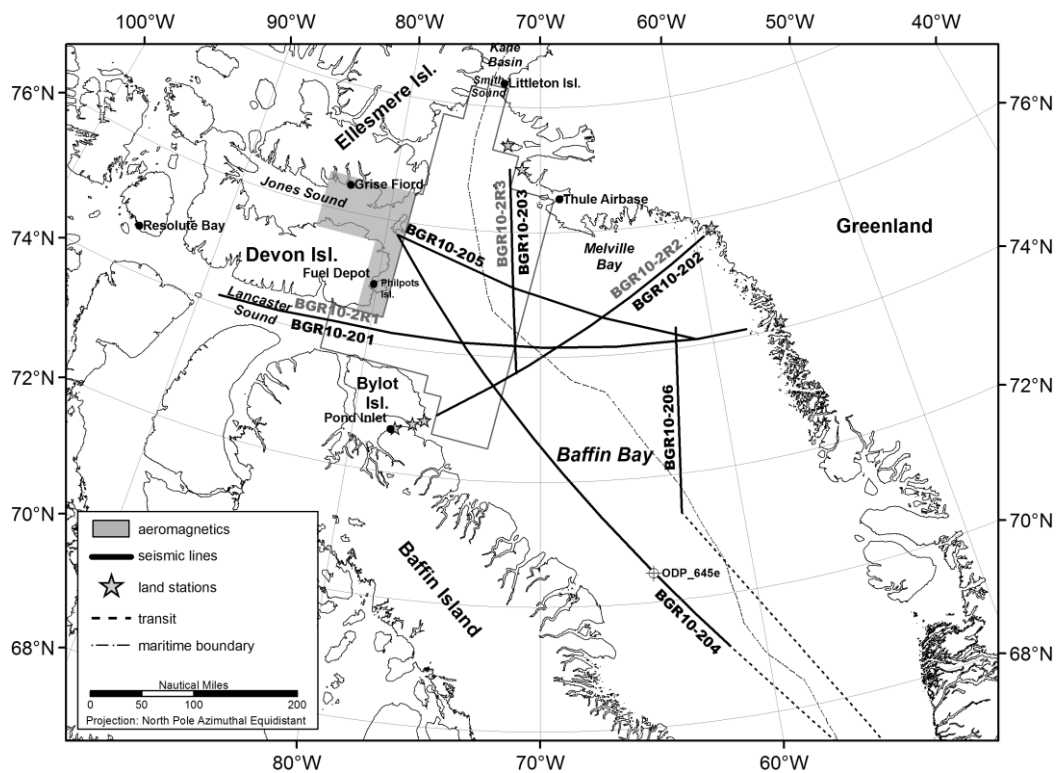


Fig. 1: Location of seismic reflection and refraction lines and land based seismic stations during Polarstern expedition ARK-XXV/3 according to the original project description.

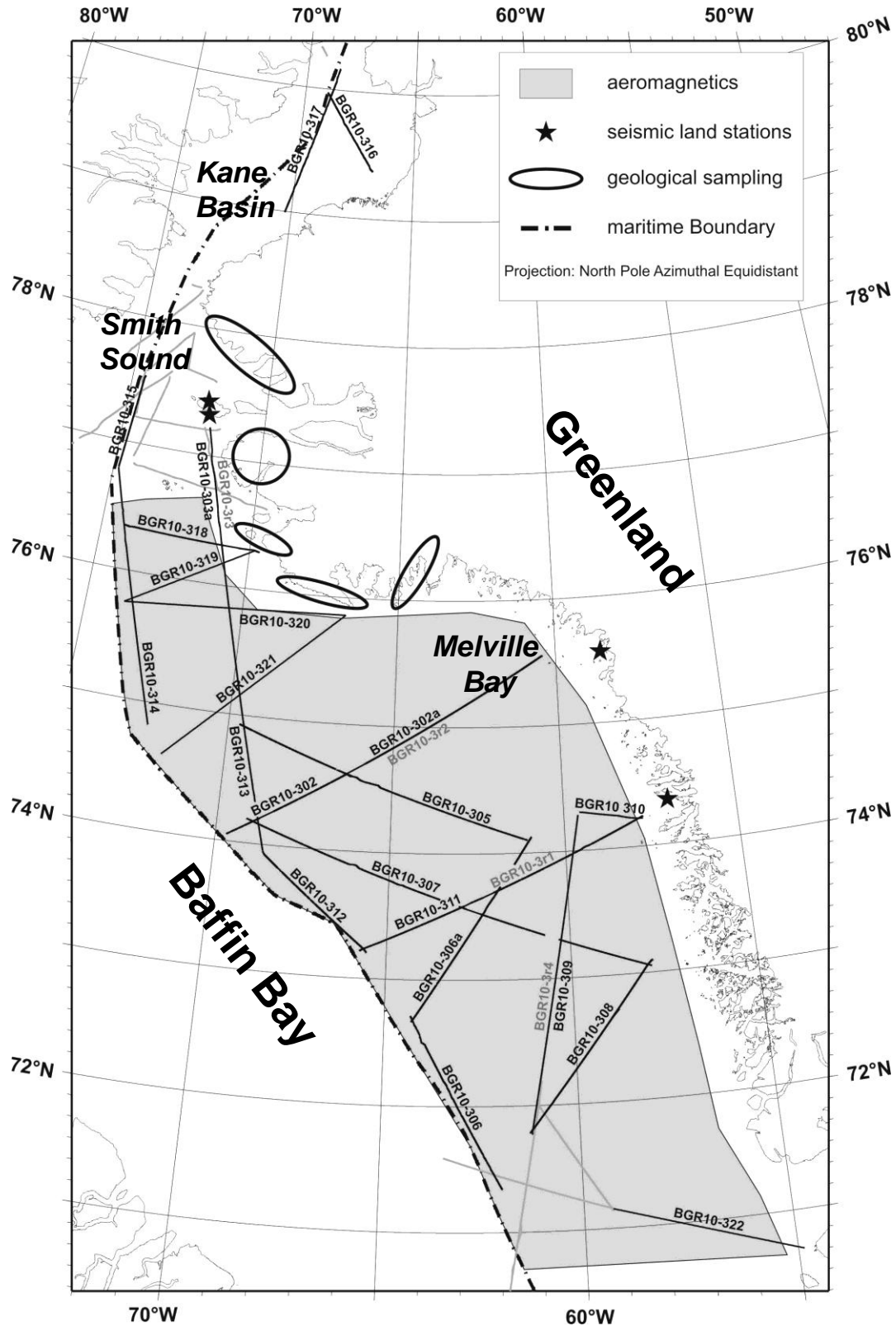


Fig. 2: Location of seismic reflection and refraction lines, land based seismic stations, aeromagnetic surveying and geological sampling during Polarstern expedition ARK-XXV/3 according to the modified project description. Gray lines indicate BGR cruises MSM09/3 (south) and NARES01 (north).