AMORE - Arctic Mid Ocean Ridge Expedition to Gakkel Ridge

Processing, Visualisation and Analysing of Multibeam Data from different systems gathered during the AMORE expedition 2001

The Gakkel Ridge is situated in the central Arctic Ocean and was object of an international expedition in the boreal summer 2001. This part of the world´s mid-ocean ridge system is of particular geo-scientific interest because of its slow spreading rate and the variety in morphology. Therefore, multibeam bathymetric measurements are of special importance regarding the scientific targets of the exploration of this deep-sea ridge. The data were acquired during a two-ship expedition by RV "Polarstern" and USCGC "Healy", the first vessel is equipped with the multibeam system Hydroseep DS-2, the latter with Seambeam 2112.

In this presentation the bathymetric data of the western part of the ridge (see Geographical Settings) were edited in order to remove the outliers and systematic errors under the use of CARIS HIPS. The processed data were used to compute a Digital Terrain Model (DTM) in the GIS ArcInfo, using a grid spacing of 100 m. This DTM covers an area of approx. 9900 km² subdivided in three bathymetric map sheets, that illustrate the topography of the seabed by contour lines (interval: 50 m, scale: 1:150,000).

Animation:

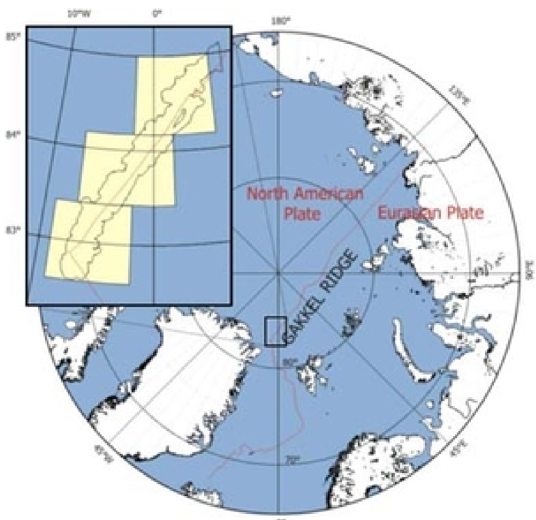
Flight along Gakkel Ridge

Data source: IBCAO; 15x height exaggeration; Gakkel Ridge (Arctic Ocean); File size: 4.7 MB. The Digital Terrain Models were animated using the IVS Fledermaus software.

Geographical and geological setting

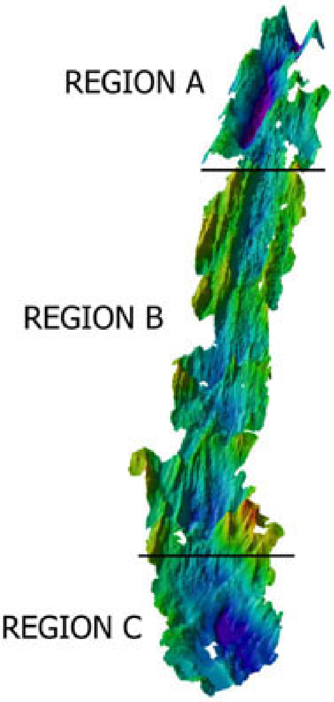
The Gakkel Ridge spreading system in the Arctic Ocean is part of the North American - Eurasian plate boundary (Kristoffersen, 1982). The Gakkel Ridge separates the approx. 4000 m deep Eurasian Basin into the Amundsen Basin and the Nansen Basin. The entire ridge is approx. 200 km wide, 1800 km long and rises up to 1000 m below sea level. The width of the central rift valley varies between 20 and 40 km and reveals a depths of 5500 m.

Mid-ocean ridges (MOR) are spreading zones (constructive plate boundaries) where lithospheric plates diverge. The spreading rate of a MOR varies along the entire ridge systems. The Gakkel Ridge is classified as an ultra-slow spreading ridge. The spreading rate is one of the lowest observed in the world (Michael et al., 2001). At the eastern termination the spreading rate is only ~6 mm/a. The rate increases towards the western termination to ~13 mm/a.



Location of the Gakkel Ridge, shape of the working area and index of the three bathymetric map sheets.

Geological Interpretation



The morphology of the Gakkel Ridge can be subdivided into three regions, A, B, C.

The morphology of spreading systems is formed by magmatic and tectonic processes. Due to the young age of the crust of the Gakkel Ridge the spreading axis is sparsely covered by sediments. The topography is of special interest, since it makes a contribution to the understanding of the geological processes on and within the solid Earth.

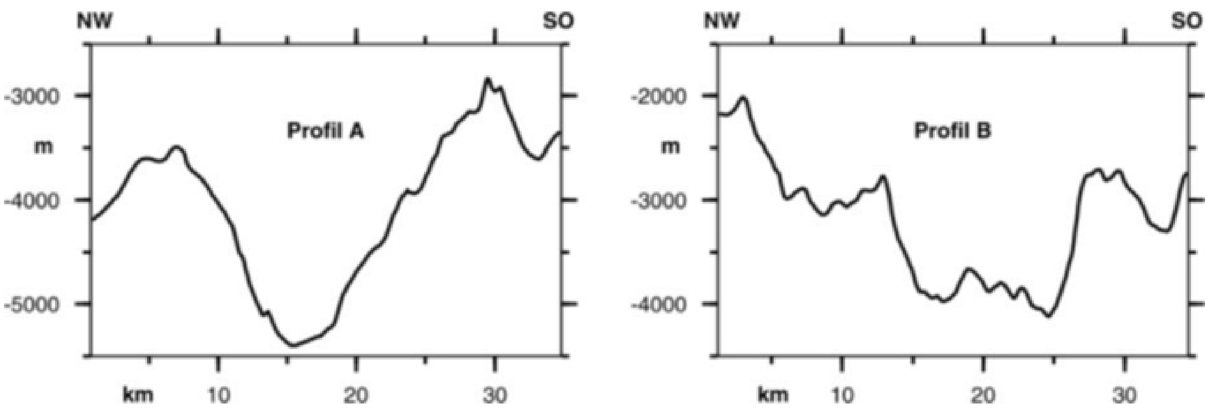
A slow spreading rate entails decreased magmatic activity at the ridge (Small, 1998). The morphological characteristics of the axial valley of MORs depend therefore mainly on the spreading rate of the ridges. While fast spreading MORs exhibit a rise along the ridge axis, slow spreading ridges are characterised by an axial depression (Frisch & Loeschke, 1993).

The topography of the rift valley shows systematic variations in dependence to the spreading rate (Small, 1998). The rift flanks on either side of the valley of slow-spreading ridges often reveal a difference in height. This asymmetry amounts up to 1500 m. Differences in height between the bottom of the valley and the ridge crest correlate with the spreading rate. The maximum observed difference in height is 2500 m and appears at slow spreading ridges. In general the difference decreases with increasing spreading rate.

The morphology of the Gakkel Ridge can be subdivided into three regions, A, B and C, that show different characteristics.

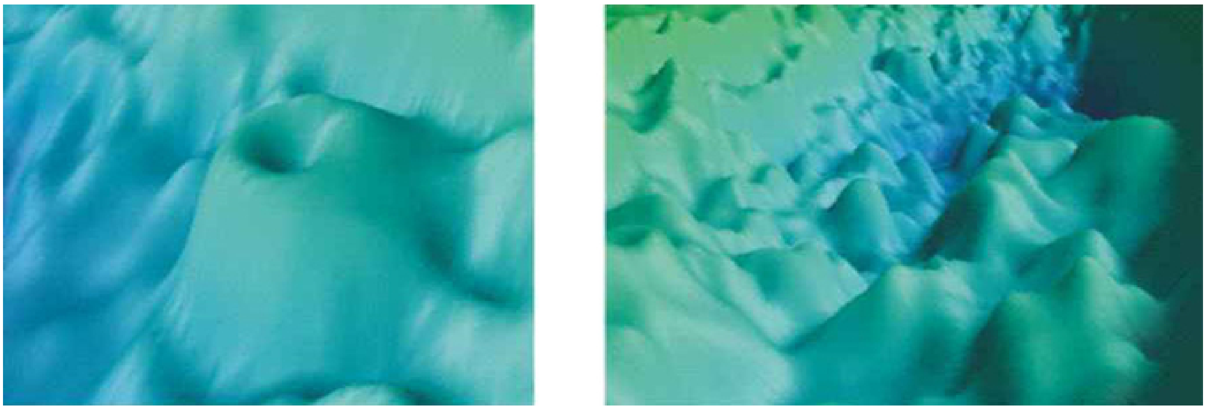
Region A: The morphology of the Gakkel Ridge in region A is characterised by structures, that are typical for a slow spreading MOR. Here, the ridge exhibits a typical valley (see chart below, profile A), that is located at 4°E. The width of the valley is about 25 km. The inner valley is about 1 km wide and 5500 m deep. The valley flanks rise with a slope of ~15°. The heights of the flanks show a clear asymmetry: The northern flank rises up to a depth of 3500 m, the southern flank to a depth of 2700 m. Therefore, the southern flank is about 800 m higher than the northern flank. The reason may be a different spreading rate on either side (Frisch & Loeschke, 1993).

Since the southern ridge crest is higher than the northern ridge crest, the lower spreading rate is expected for the south. The maximum difference in height between the valley bottom and the ridge crest in region A is 2800 m.



Bathymetric profiles across the Gakkel Ridge at Profile A: ~4°E and Profile B: ~1°W.

Region B: The boundary between region A and B marks a change in morphology. The maximum depths in the central valley in region B are about 4500 m, while the ridge crests reveal depths of about 2300 m. The valley bottom is 10 km wide and disrupted by several ridges. These ridges extend parallel to the flanks and are partly 2500 m deep. The flanks are arranged stepwise and slope with angles of up to 45°. The surface of the valley bottom shows a rough morphology (see charts, profile B), that is caused by several volcanic structures. These are interpreted as the outcrops of subrecent magmatic activity. Their tops have a height of about 200 m above the sea floor and measure ~2 km in diameter (see pictures below). The morphological differences between region A and B suggest a different spreading rate. The topography observed in region A points to a lower spreading rate, whereas the topography of region B suggests a higher spreading rate.



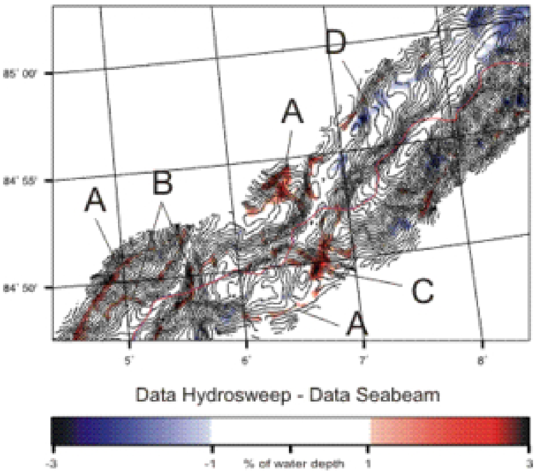
Perspective view of the topography in region B, whitch shows volcanic structures (height exaggeration 5x).

Region C: Region C is characterised by a 15 km wide valley. Several basins with depths between 4100 m and 4800 m spread over the axial valley at the northern termination of the Lena Trough. The flanks of the ridges rise stepwise as observed in region B. A striking feature is an impressive seamount in the northeast of this region, that overtops the valley with 3000 m. The top reveals the lowest depth in the working area (1224 m).

Comparison of the Hydrosweep DS-2 system and the Seabeam 2112 system

In order to compare data acquired by the vessels we calculated DTMs within a defined test area. Thereafter the difference between the DTMs was calculated by subtracting Seabeam data from Hydrosweep data. The difference is expressed in relation to the water depth, i.e. per cent of water depth.

The selection of a suitable test area is difficult due to the hydro-acoustic disturbances of the ice and a non-straight ship track (icebreaking). The Seabeam measurements exhibit a higher noise ratio than the Hydrosweep data, since the USCGC "Healy" was the leading and icebreaking vessel. The non-straight track prevented further a homogeneous distribution of the data. Notice, that the measurements of the Seabeam system within the test area show a data gap in the southeastern part.



Difference of the DTMs between Hydrosweep and Seabeam data in per cent of water depth (contour interval: 50m; track lines: blue "Polarstern", red "Healy")

The difference between the DTMs is predominantly lower than the estimated accuracy of 1 % of the water depth of the general data acquisition. Larger differences are not systematically distributed in the test area. Further on large differences occur along the borders of a multibeam fan (see A), that result from interpolation errors. The boundary of the data gap of the Seabeam system (see B) exhibit similar inaccuracies.

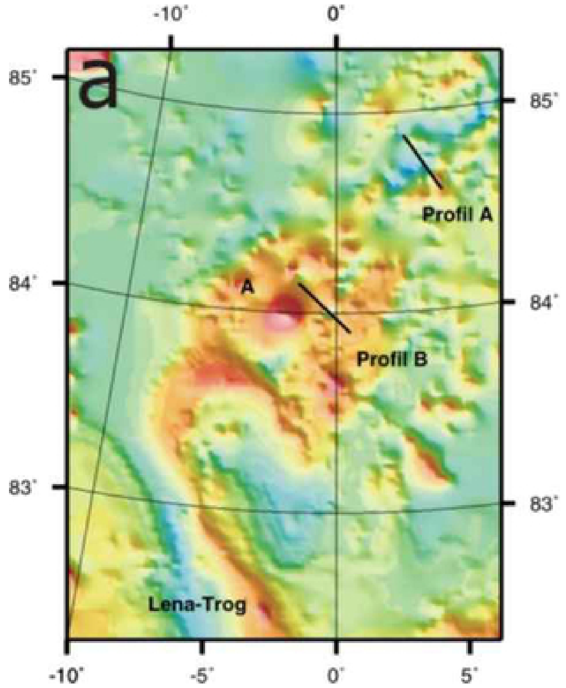
The large differences in the centre of the test area (C) is due to the inhomogeneous distribution of bathymetric data. This becomes especially obvious at steep slopes, since the interpolation errors are higher than in regions with a smooth bathymetry (see also D).

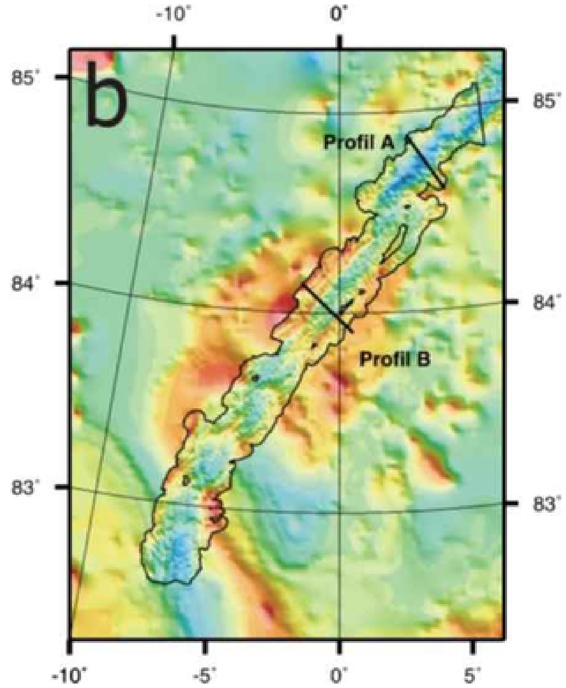
Specifications of Hydrosweep DS-2 and Seabeam 2112

Specification	**Hydrosweep DS-2**	**Seabeam 2112**
Depth range	10 m - 11 000 m	100 m - 11 000 m
Frequency	15.5 kHz	12.0 kHz
Opening angle	120° (4700 m)/90° (11 000 m)	120° (4500 m)/100° (6000 m)/90° (11 000 m)
Accuracy	<1.0% of water depth	~0.5% of water depth
Refraction correction	CTD-Profile/Crossfan calibration	CTD-Profile
Number of preformed beams (PFB)	59	121
Opening angle of a single PFB	2.3°	2.0°

Comparison with IBCAO

The International Bathymetric Chart of the Arctic Ocean (IBCAO) is a digital database, that contains all available bathymetric data north of 64° N prior to 2001 (Jacobsson et al., 2001). The figures a and b show the IBCAO grid (resolution is 2.5 km) in comparison with the DTM of the Gakkel Ridge using the newly acquired multibeam data. Fig. a shows the data of IBCAO only, while Fig. b reveals the improvements of the new high-resolution DTM compared to IBCAO data.

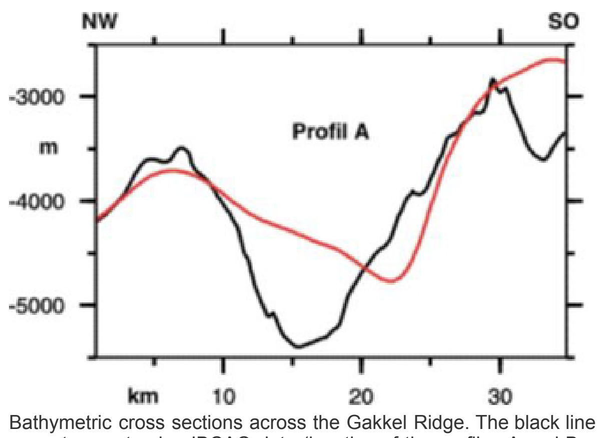


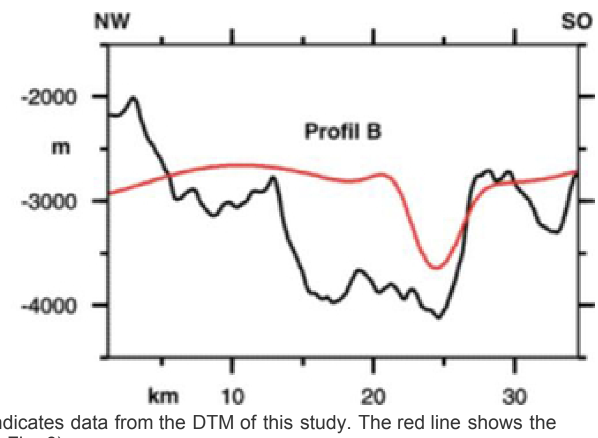


(a) Bathymetry of IBCAO and (b) Comparison of the new high-resolution DTM of the Gakkel Ridge with IBCAO data.

The improvement between both data sets for the northern part of the Lena Trough is clearly shown: Instead of continuing to the northwest, the trough trends northeast to the Gakkel Ridge. Furthermore great differences appear along the western Gakkel Ridge: The occurrence of a seamount (Fig. a, A) seems speculative regarding the new data. Formerly, the Gakkel Ridge valley was indicated by an array of depressions. The new data disclose, that a straight valley is present.

This is also obvious in profile B (see charts below). It shows, that the pretended smooth bathymetry is replaced by a ridge structure. The heights difference between both data sets amounts up to 2000 m.





Bathymetric cross sections across the Gakkel Ridge. The black line indicates data from the DTM of this study. The red line shows the same transect using IBCAO data (location of the profiles A and B see Fig. 6).

On the other hand the rift valley in the northeast (profile A) was mapped clearly by IBCAO data. The tops of the ridge flanks reveal the same position and differ in the heights about 200 m, although the axis of the valley is shifted 7 km further to the south. The valley seabed is 500 m lower than previously expected.

Data processing

- Data editing by Steffen Gauger and Thomas Hartmann (CARIS HIPS).
- DEM modelling, contouring and cartography by Steffen Gauger (ArcInfo).

References

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