

Seafloor relief inhomogeneities and the tectonics of the Greenland-Lofoten Basin in the North Atlantic

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Bathymetry and single seismic reflection methods were used to study the seafloor inhomogeneities in the Norwegian-Greenland region. North of the Mohns Ridge we have identified nearly east-west trending morphostructures (MS) in seafloor relief, which are horst ridges separated by troughs, and have provided their characteristics. We carried out a seismostratigraphic analysis to study the structure of the Cenozoic sedimentary cover and the conditions that existed during its formation. We showed that these seafloor MSs came into being after the origination of the Cenozoic sedimentary cover (during post-Quaternary time); that is to say, they are young features, and are not reflected in the magnetic anomalies of the Greenland Basin. We examined bathymetric characteristics and earthquake focal mechanisms within the Mohns Ridge to provide a preliminary identification of transverse faults (probably of the normal-oblique type) that control the blocky structure of the ridge.

KEYWORDS: Seafloor inhomogeneities; Norwegian-Greenland Basin; single seismic reflection; seismic stratigraphy.

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Introduction

The present study is concerned with an area in the Norwegian-Greenland Basin, viz., its central segment bounded by the Jan Mayen and Greenland fracture zones, as well as by the Greenland and Norwegian continental margins (Figure 1). The spreading Mohns Ridge is in the middle of the region. It forms the axis of symmetry for the Greenland and Lofoten oceanic basins that are adjacent to its flanks. Overall, the Norwegian-Greenland Sea is a young oceanic basin which has been formed during the last 56 Ma as a result of seafloor spreading.

The continental margins of Greenland and Norway are parts of the North Atlantic Volcanic Province (NAVP) [Eldholm and Grue, 1994]. It is commonly believed that the crust in volcanic margins was formed as a result of asthenospheric upwelling controlled by mantle plumes. Seismic evidence points to the presence of massive rock units in the lower crust with higher compressional velocities (7.2–7.7 km/s). Multichannel seismic profiles (MCSP) that were measured in both of these margins revealed seaward-dipping reflectors

(SDR) in the upper crust [Hinz, 1981]. The SDRs were studied in the greatest detail in the zone that is adjacent to the Voring Plateau Escarpment [Eldholm et al., 1987]. The origin of these SDRs has not been reliably determined. It is believed that they are due to basalt flows that were formed either during the terminal rifting phase or during the initial phase of seafloor spreading.

The modern tectonic ideas and the models of plate tectonic evolution for the region are based on studies reported in [Gronlie et al., 1979; Myhre et al., 1982; Talwani and Eldholm, 1974; Talwani et al., 1977]. It is believed that seafloor spreading started during Early Tertiary time about 55 Ma B.P. This was preceded by several rifting phases, with the last occurring in the Late Cretaceous (Campanian-Maastrichtian). The region between the Jan Mayen and Greenland Fracture Zones had a simple model of opening at the time of magnetic anomaly 24, which is symmetrical about the Mohns Ridge. At present the Mohns is a mid-oceanic ridge with a low spreading rate [Eldholm et al., 1987].

The region under study is comparatively well known due to geophysical surveys, especially as concerns continental margins. Marine seismic surveys were conducted in the Greenland continental margin to obtain results (seismic time sections) of high quality. The history of seismic studies in the East Greenland continental margin was reviewed in [Berger and Jokat, 2008; Hamann et al., 2005]. In this paper we made use of the results of these seismic surveys (multichannel seismic (MCS) network recorded with RV “Polarstern” in 2003), as well as of single reflection seismic profiles ob-

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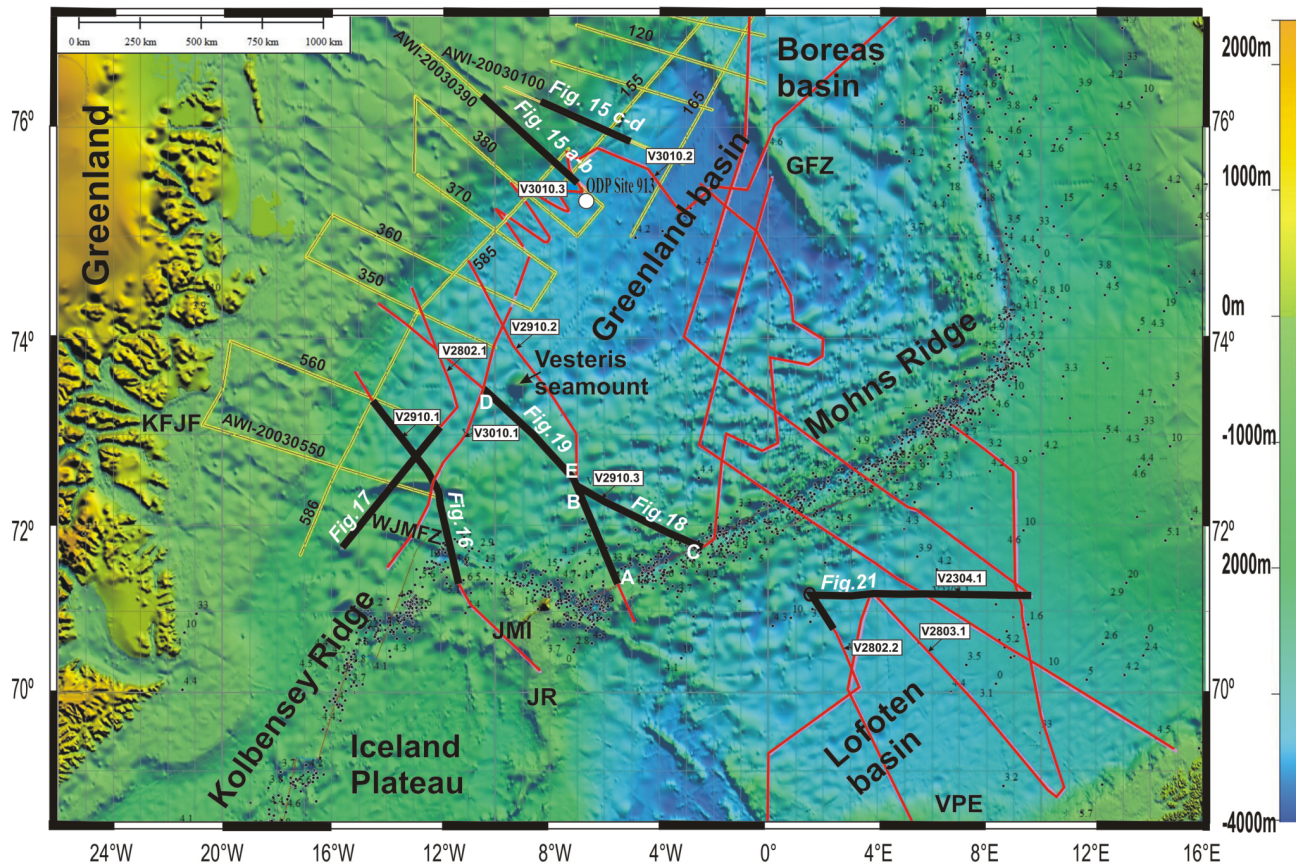


Figure 1. A map of the study area with the SRTM-30.4 bathymetric base [Becker *et al.*, 2009]. The yellow lines are parts of the multichannel seismic (MCS) network from [Berger and Jokat, 2008]; the pink lines show the single seismic cruise of the RS Vema; the open circle marks the ODP drill site 913; GFZ is short for Greenland Fracture Zone; KFJF stands for Keiser Franz Joseph Fjord, WJMFZ for West Jan-Majen Fracture Zone, JR for the Jan Mayen Ridge, and JMI for Jan Mayen Island; small red dots are earthquake epicenters with magnitudes attached (www.globalcmt.org); Figure 15–Figure 21 shows the positions of the seismic lines discussed in main text.

tained from on board the Vema vessel in the deep sea areas of the Greenland and Lofoten basins (see Figure 1). Our goal is to study lateral seafloor inhomogeneities and to find the evidence for recent tectonic movements in inner areas of the region (outside of continental margins). We used materials relating to bathymetry, magnetometry, gravimetry [Olesen *et al.*, 2007], seismic observations, seismicity, and heat flow as available in world geological and geophysical data bases accessible at Global Mapper v.10, GeoMapApp.exe (Lamont-Doherty Earth Observatory of Columbia University).

Seafloor Topography

Our study of morphologic features in the seafloor topography of the Norwegian-Greenland Basin was based on an analysis of SRTM15 bathymetric maps (Shuttle Radar Topography Mission), SRTM30.v.5

[Becker *et al.*, 2009; Smith and Sandwell, 1997; http://topex.ucsd.edu/WWW.html/mar_topo.html]. We chose SRTM30.v.4 and v.5 as a base to work. The Norwegian-Greenland Sea north of the Jan Mayen Fracture Zone consists of two deep basins, the Greenland and the Lofoten basins, that are separated by the active spreading axis of the Mohns Ridge. The Greenland Basin is 3600–3700 m deep on an average, with the figure being about 3200 m for the Lofoten Basin. There is an area north of the Mohns Ridge whose seafloor relief shows nearly east-west trending linear morphostructures (MS) that are seen as en echelon ridges and troughs (see Figure 1 and Figure 2). These MSs have not been discussed in any scientific publications that we are aware of. They strike at an apparent angle of $\sim 30^\circ$ relative to the Mohns Ridge, and some of them extend into the rift valley (see Figure 1). This area of anomalous relief is bounded from the northeast by the southern part of the Greenland Fracture Zone at the junction of the Mohns and Knipovich ridges, and is controlled by the Jan Mayen Fracture Zone (JMFZ) in the south and in the southwest.

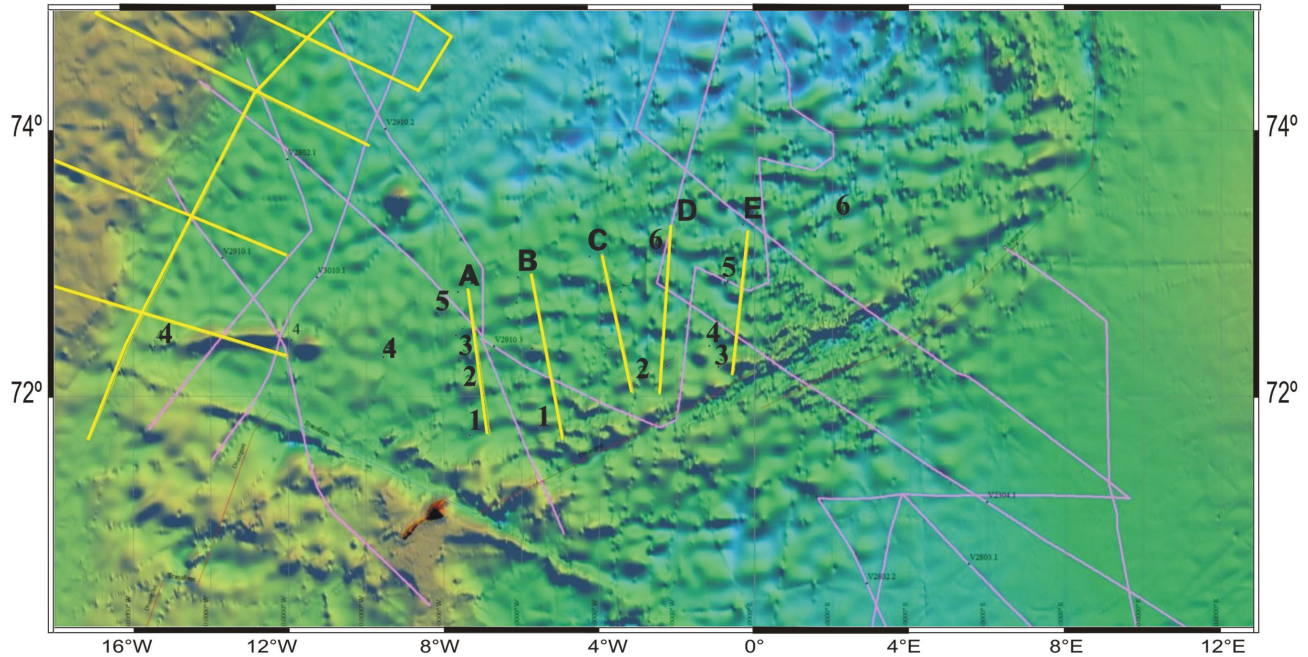


Figure 2. The positions of seafloor profiles. The yellow lines A through E are section identification letters as in Figure 3; the numerals are the identification numbers of morphologic seafloor inhomogeneities from south to north. The bathymetric base is SRTM-30.4 [Becker *et al.*, 2009].

One notes that these linear MSs look convergent in the area where the Jan Mayen Fracture Zone approaches the foot of the Greenland continental slope (against Kaiser Franz Joseph Fiord). Conversely, these MSs make a “fan-shaped” feature when seen from west to east (Figure 1 and Figure 2). Similar MSs are poorly pronounced southeast of the Mohns Ridge, it being only in the southern part, in the zone adjacent to the Jan Mayen Fracture Zone, that they become noticeable again. We have numbered these elongated MSs for convenience of description as L1 through L6 going from south to north, and made seafloor topographic cross sections across their strikes (see Figure 1, Figure 2, and Figure 3). The MSs show a “wavy” structure (Figure 3) when seen along the lines in all sections (A through D, see Figure 2), with antiforms and synforms alternating. The A, C, and E sections show the relative heights of the uplifts clearly decreasing from south to north, for instance, from 720 to 150 meters along the A section, from 1136 to 500 meters along the C section, and from 1290 to 713 meters along the E section. This tendency is less pronounced in the B and D profiles, but the overall pattern persists. Some patterns will be discernible on inspection of the values from Figure 3, viz., (1) the depths of the uplifts increase northward; (2) the relative uplift amplitudes decrease from south to north; (3) the inter-ridge distances remain comparable, with the average being 25 km (a kind of return period).

To make the linear MSs more pronounced we have lowered sea level down to -3000 m in the seafloor relief maps, that is to say, we have removed the water down to this depth (Figure 4). It can be seen in this figure that MS L4 penetrates into the Mohns rift valley. MS L3 approaches the rift valley, is then intersected by some features in the eastern side of the

valley, and reappears again in the eastern flank of the Mohns Ridge. Figure 5 shows these structural seafloor features in a 3-D image. We made regional seafloor relief profiles based on the SRTM-30.v.4 map in order to determine the regional morphostructural picture of the seafloor (Figure 6 and Figure 7).

Leg R1 (see Figure 6) traverses the entire Norwegian-Greenland Basin from the continental slope of the East Greenland margin to the Voring Plateau in the Norwegian continental margin, and intersects the spreading Mohns Ridge orthogonally. The leg is 1060 km long. Three morphologic seafloor areas can be distinguished from northwest to southeast (see Figure 7). Area I is the Mohns mid-oceanic ridge proper, its width is 160 km in this cross section. Areas III are abyssal plains: the Greenland plain (IIIg) and the Lofoten plain (III). Their respective maximum depths are comparable in this section, and are 3230–3320 m. Area II contains L3, L4, L5, and L6 (see Figure 7), its width is 195 km, and the mean hypsometric level (when measured in the basins) is 200 m above that of area III.

Leg R2 (see Figure 6) runs parallel to the axis of the Mohns Ridge, across the western Jan Mayen Fracture Zone (in its northwestern, transform-type, part); its length is 769 km. The southern part of this leg is within the Iceland Plateau and coincides with the northern Kolbeinsey Ridge, which is recognizable from a swarm of earthquake epicenters (see Figure 6) and is bounded by the Jan Mayen transform fracture, whose surface expression is a narrow deep trough (see Figure 7). The trough is 26 km wide, its depth relative to the top of Block I (see Figure 7) reaches 1420 m, and the bottom depth is 3490 m as measured from sea level. The seafloor section when followed laterally from southwest to

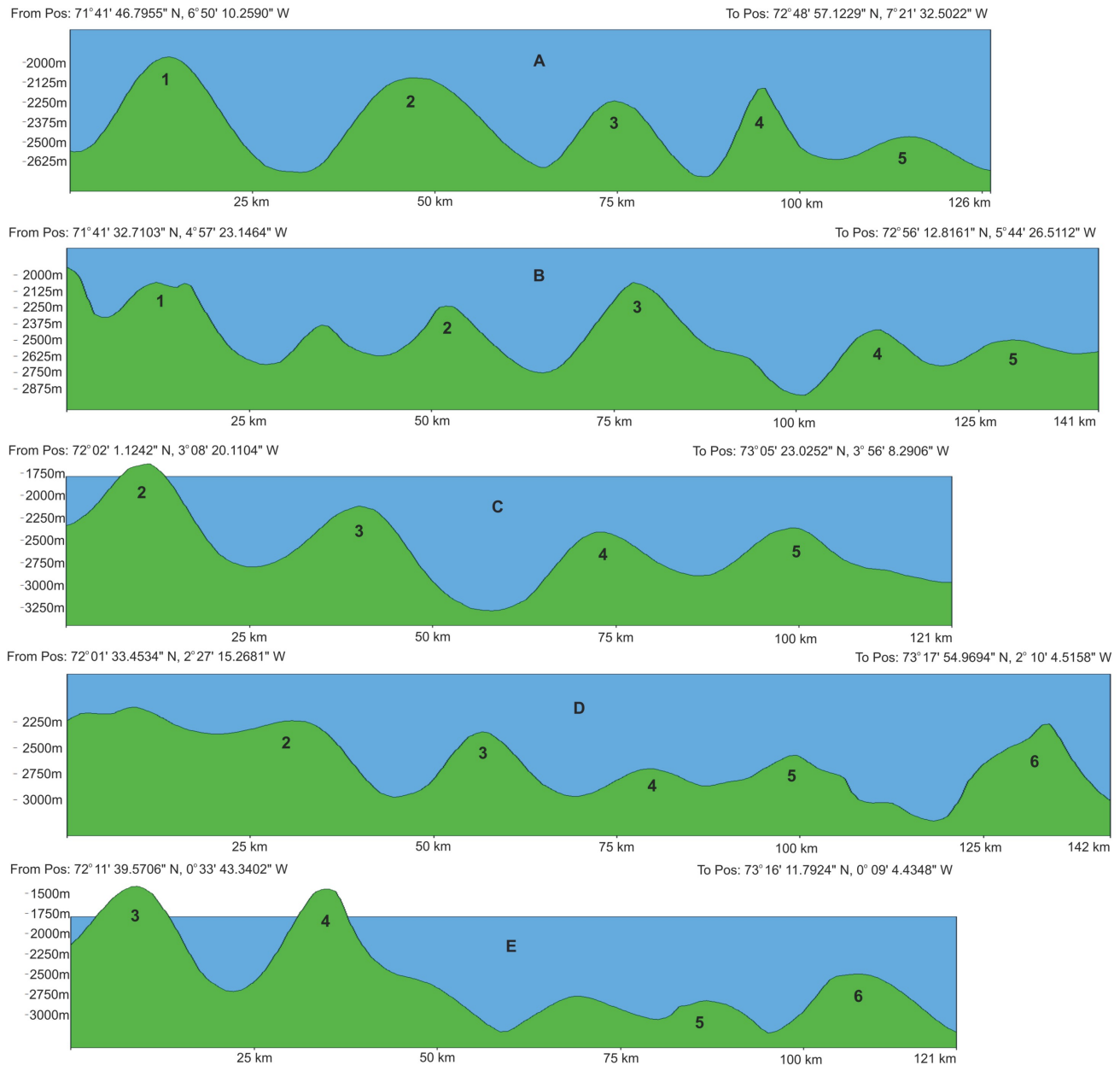


Figure 3. Profiles that characterize morphologic seafloor inhomogeneities, the numerals being their identification numbers (see Figure 2).

northeast has a pronounced blocky character and separates into four steps (I through IV) that dip northeast successively (see Figure 7). The steps have the following widths in the cross section: 182 km for I, 80 km for II, 70 km for III, and 228 km for IV. Step I can be further subdivided into two blocks, I and Ia. Step IV corresponds to the deep-sea part of the Greenland oceanic basin, with the sea depth reaching 3880 m near the Greenland Fracture Zone (see Figure 7).

Leg R3 (see Figure 6) traverses the Greenland Basin from south to north, starting from the Jan Mayen transform fault where it is abutted by the Mohns rift valley, and terminating at the junction between the Greenland Fracture Zone and

the northeastern continental slope of Greenland. Leg R3 strikes across (orthogonally to) our MS L1 through L6 in seafloor relief. The trough of the transform fault in leg R3 is more pronounced, its width is 54 km, while the relative depth between the valley shoulders reaches ~ 2420 m. Its bottom lies at a depth of 3080 m from sea level. Leg R3 reveals three steps in hypsometric level north of the Jan Mayen transform fault. Their widths are 129 km for step I, 172 km for II, and 277 km for III. The relative difference in hypsometric level between steps I and II is about 670 m, and that between II and III is 960 m. The second (II) step is complicated with pronounced uplifts that correspond to MSs L3, L4, L5, and

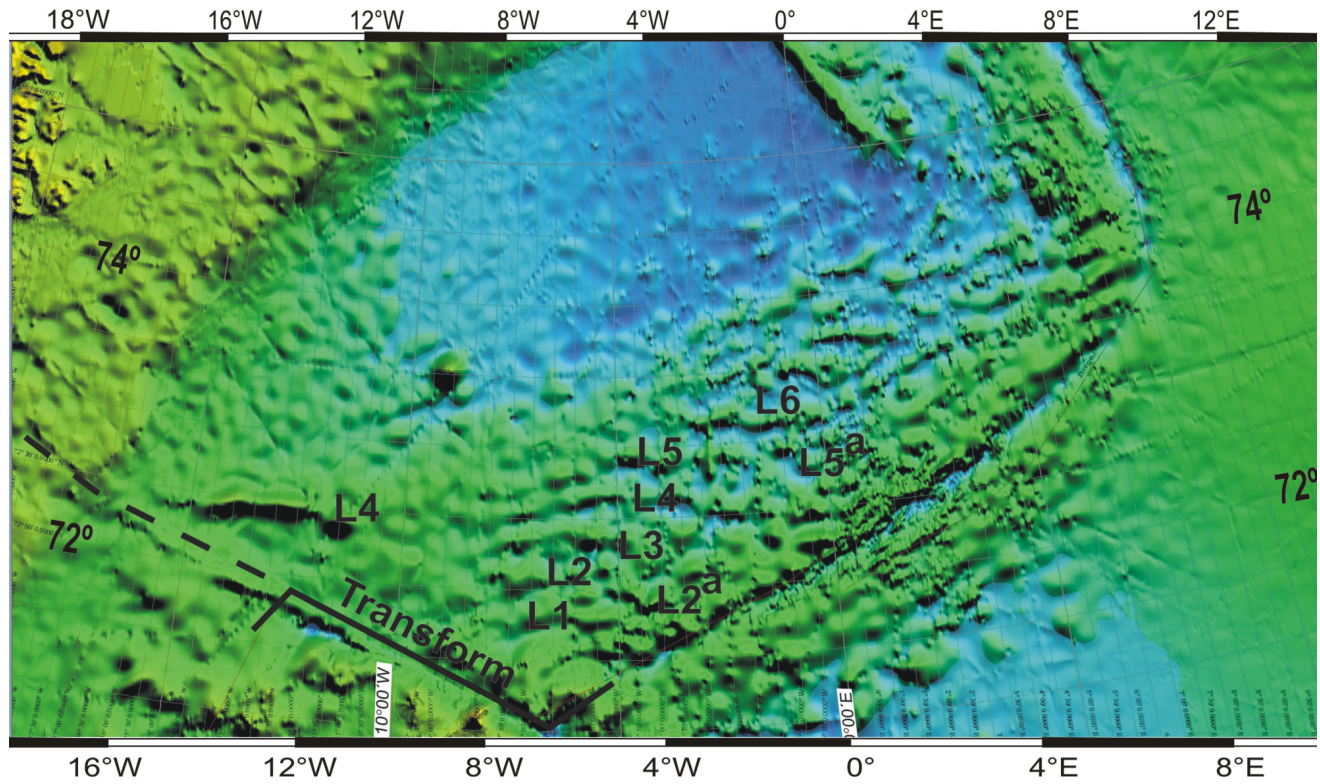


Figure 4. Seafloor relief in the area of study resulting from subtracting 3000 m from ocean depths (SRTM-30.4). L1–L6 are the linear elongate seafloor relief inhomogeneities.

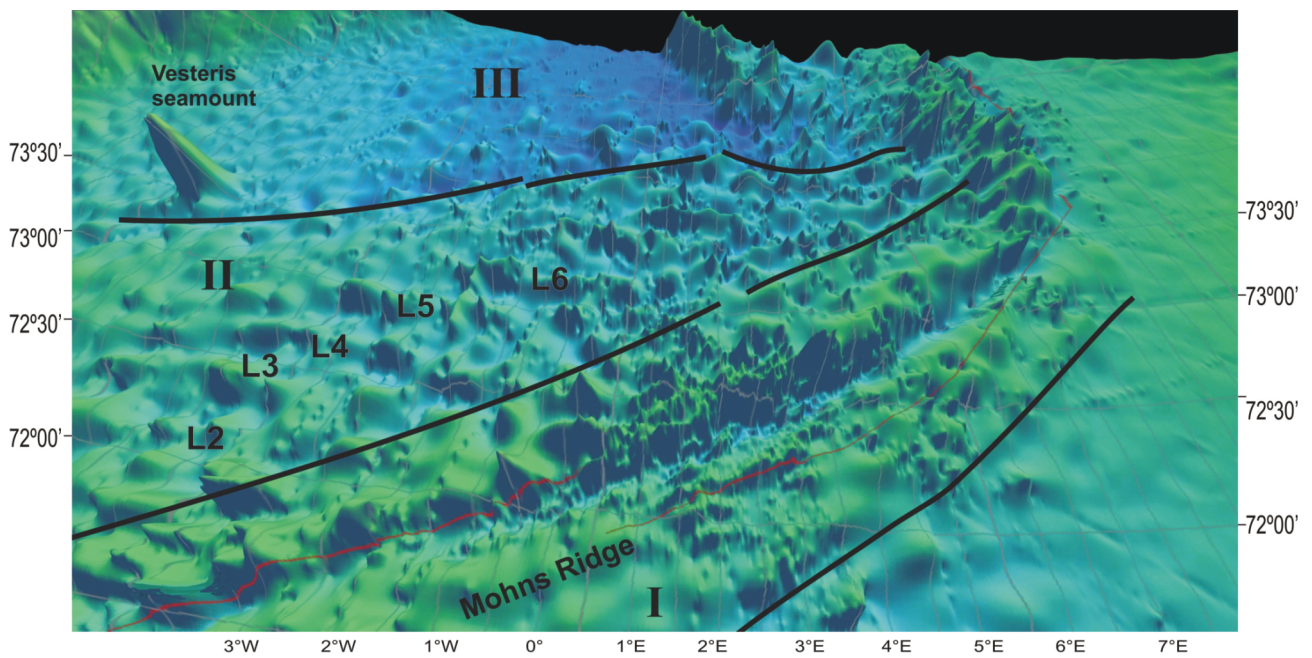


Figure 5. 3D seafloor relief. I–III are the following areas: I – Mohns Ridge, II – the area of L1–L6, III – the abyssal part of the Greenland Basin.

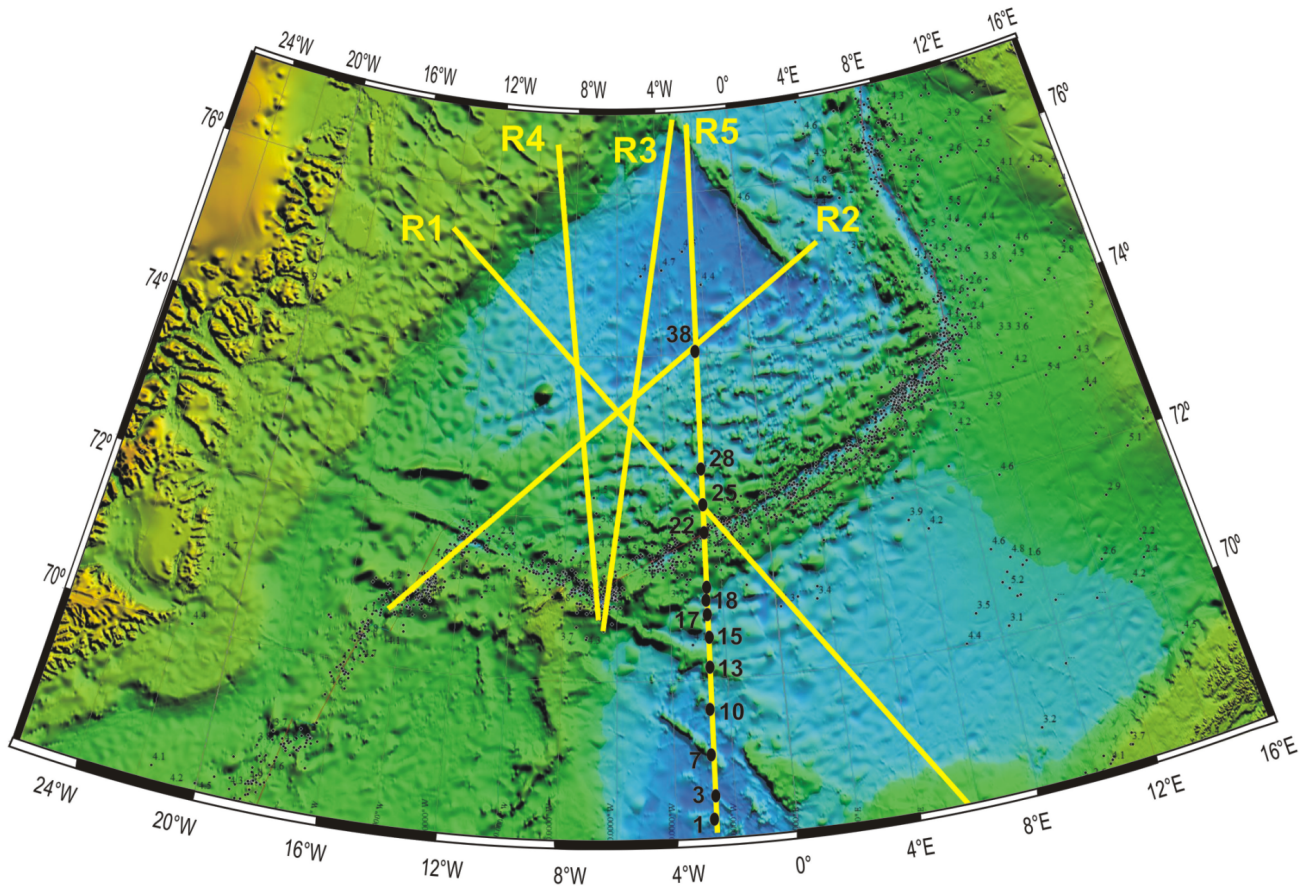


Figure 6. A map showing the regional profiles of seafloor relief R1–R5 (the topographic base is SRTM-30.4). The filled dots 1 through 38 denote control points on relief elements of section R5 (see Figure 7).

L6 (see Figure 7).

Leg R4 was run (see Figure 6) west of R3 (it traverses similar morphostructural seafloor zones in the basin) in order to evaluate lateral variations in the morphostructural plan. One can distinguish there the same three steps again in the seafloor relief of the basin, their widths are 81 km for I, 155 km for II, and 247 km for III. The trough of the transform fault is less pronounced compared with Leg R3, it is 33 km wide and its relative depth is 2000 m. Step I is a monolithic, comparatively narrow, block that stands 1370 m above step II. Step II is complicated with uplifts that correspond to the MSs we have identified. We note that section R4 contains MSs L1, L2, L3, L4, and L5 under discussion. The height contrast between steps II and II is about 580 m. The depth of step III, which is situated in the abyssal plain of the Greenland Basin, varies in the range 3242–3300 m.

Leg R5 (see Figure 6) is oriented south-north and traverses the eastern Jan Mayen Fracture Zone (EJ–MFZ), the Mohns Ridge, the area of the MSs discussed here, the abyssal plain of the Greenland Basin, and reaches the Greenland Fracture Zone (see Figure 6 and Figure 7). The section clearly exhibits a blocky structure of the seafloor. In contrast to Leg R1, there is block IIa consisting of EJMFZ in the

southern part of Leg R5. The Mohns Ridge (R5) is 154 km wide there. The height contrasts between blocks II and III in the north (the Greenland Basin) and between IIa and IIIa in the south are 600 m and 800 m, respectively. South of block IIa is the Norwegian Basin (IIIa).

The chief seafloor morphostructure in the region is the spreading Mohns Ridge with a well-developed rift valley. We sought to investigate lateral variations in the ridge structure by making bathymetric cross sections orthogonal to the rift valley trend (see Figure 8 and Figure 9) and a cross section along the valley (see Figure 10 and Figure 11). The depth of the rift valley varies laterally between 2630 and 3500 m, with the greater depths corresponding to more pronounced (in width) valley profiles (Figure 9, sections V through VII). With regard to surface expression (width and depth) of the rift valley laterally (from southwest to northeast from leg to leg), one can distinguish three different areas (I–IV), (V–VII), and (VIII–XI) (see Figure 8 and Figure 9). The area (V–VII) is situated between faults F6 and F7 that we have identified tentatively in this study. These faults enclose a seafloor block (visible in the relief, see Figure 10); this area is characterized by higher “frequencies” in relief background (a higher degree of fragmentation).

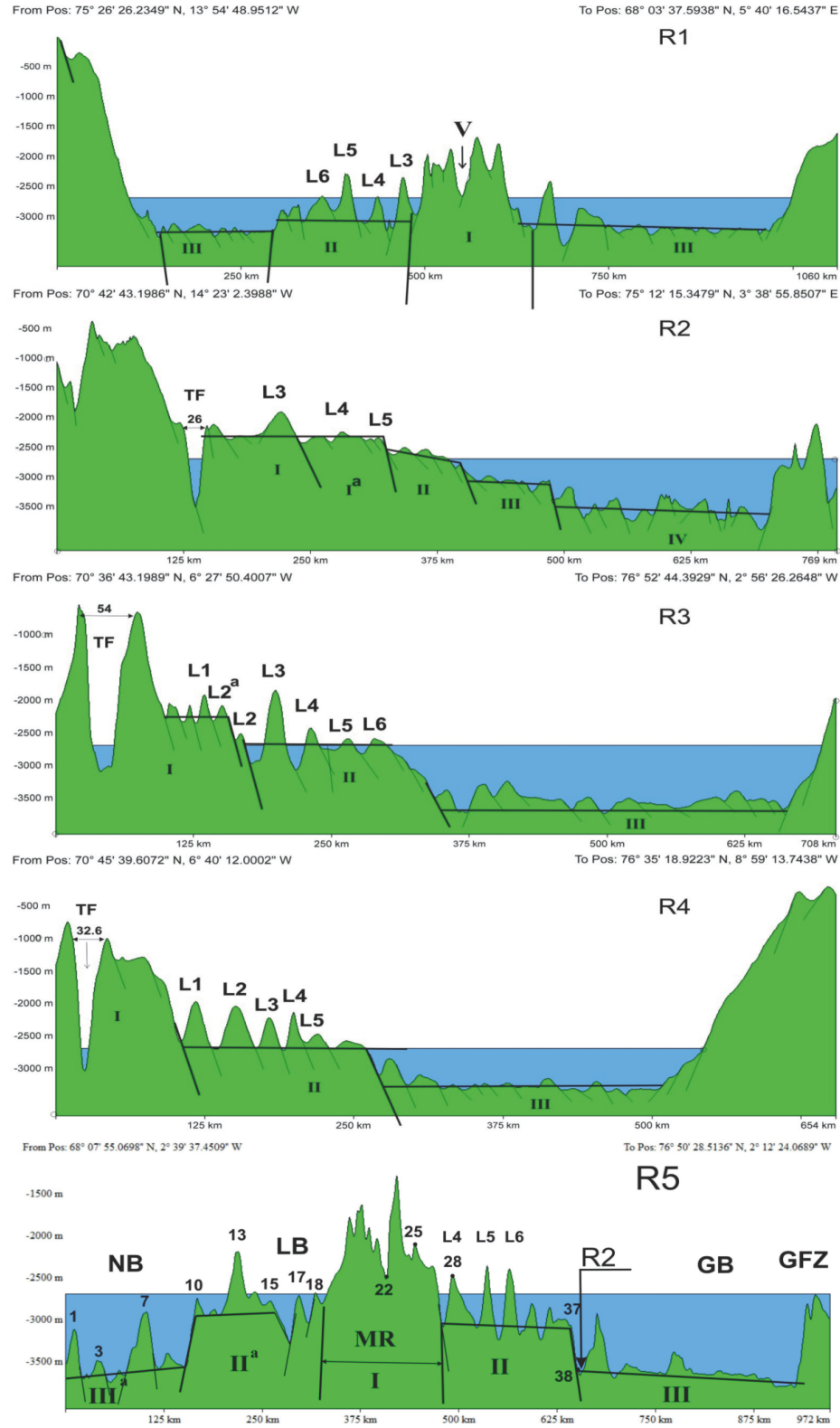


Figure 7. Regional profiles. L1–L6 are seafloor inhomogeneities under discussion; V denotes the Mohns Ridge rift valley (MR); Roman numerals denote crustal blocks; the numerals 1 through 38 are control sites (see Figure 6); NB is the Norwegian Basin; LB is the Lofoten Basin; GB is the Greenland Basin; GFZ is the Greenland Fracture Zone; TF is the transform fault (numerals: 54; 32.6 is the width in km).

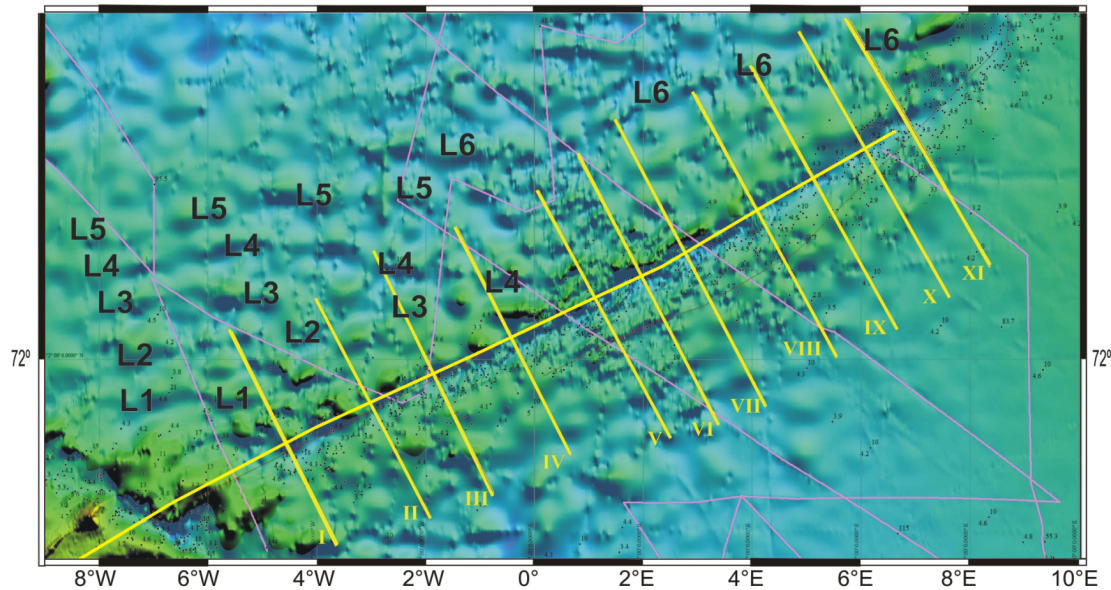


Figure 8. The seafloor relief profiles across the Mohns rift valley (I–XI) (yellow lines). The pink lines mark the Vema seismic cruise. L1 through L6 are morphostructural seafloor inhomogeneities.

The water depth in the longitudinal section of the Mohns rift valley varies between 59 m and 3304 m (Figure 11). The lowest value occurs in the uplifted Jan Mayen Ridge block, which makes the southern wall of the transform fault. The trough of the transform fault is at a depth of 2768 m. The relief in the longitudinal section of the rift valley involves four deepest narrow troughs at depths of 3102 m, 2970 m, 3305 m, and 3305 m (see Figure 11), which divide the rift valley and the ridge itself into five morphologically separate blocks. It would be reasonable to suppose that these well-pronounced troughs are confined to deep-seated fault zones. One interesting coincidence is that block III between faults F6 and F7 (see Figure 11) is confined to the location where MS L4 penetrates into the rift valley (see Figure 10). We examined the focal mechanisms of earthquakes (see Figure 12) in order to assess the character of the tectonic discontinuities as identified within the Mohns Ridge.

The Jan Mayen transform fault is reliably identified as left lateral, with its active segment between the Kolbeinsey Ridge and the Mohns Ridge being approximately 213 km.

The focal mechanisms of earthquakes along the Mohns rift valley are largely consistent with normal slip on the faults, also involving some local strike slip and normal-oblique movements, more rarely reverse (see Figure 12). Our analysis of the focal mechanism diagrams and the occurrence of the earthquakes at previously identified boundaries between blocks (see Figure 11) suggests the following correlations. The boundary between blocks I and II seems to be

subject to left lateral movements, while those between II and II and between III and IV show left lateral normal-oblique displacements (see Figure 12). Considering the earthquake mechanisms observed at boundaries between the blocks in the Mohns Ridge, and the very pronounced surface expression of transverse troughs in the rift valley that separate the blocks, one would suggest a poorly expressed transform nature of the faults.

There is no seismicity in block I, where the rift valley is not detected, and this is consistent with the inference of Francis [Francis, 1973].

Seismic Stratigraphy

The preceding section was concerned with seafloor inhomogeneities and with morphostructural characteristics of the MSs L1 through L6. One interesting problem here consists in determining the time they were formed and, if possible, estimating the character of tectonic stresses in the area where they occur. To do this we tried to study the structure of the sediments in the region, since the deposition of sedimentary units leaves an imprint of stress structure, thus furnishing a record of the tectonic conditions that existed during their generation. Direct geological information on the sediments in the region

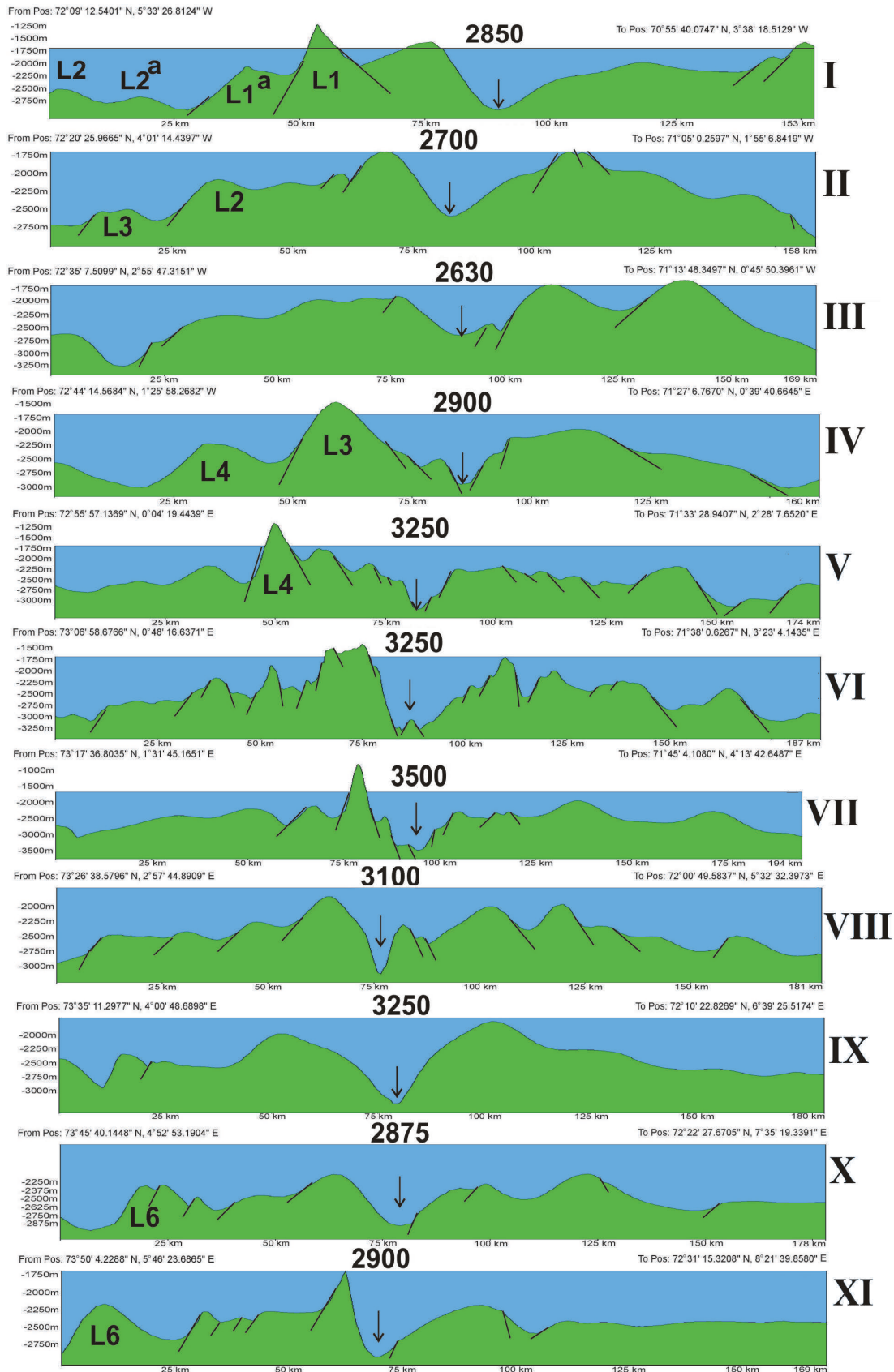


Figure 9. Transverse seafloor sections (I–XI) for the Mohns Ridge. L1 through L5 are the morphostructural seafloor inhomogeneities under discussion; arrows with Arabic numerals denote depths to the rift valley of the ridge.

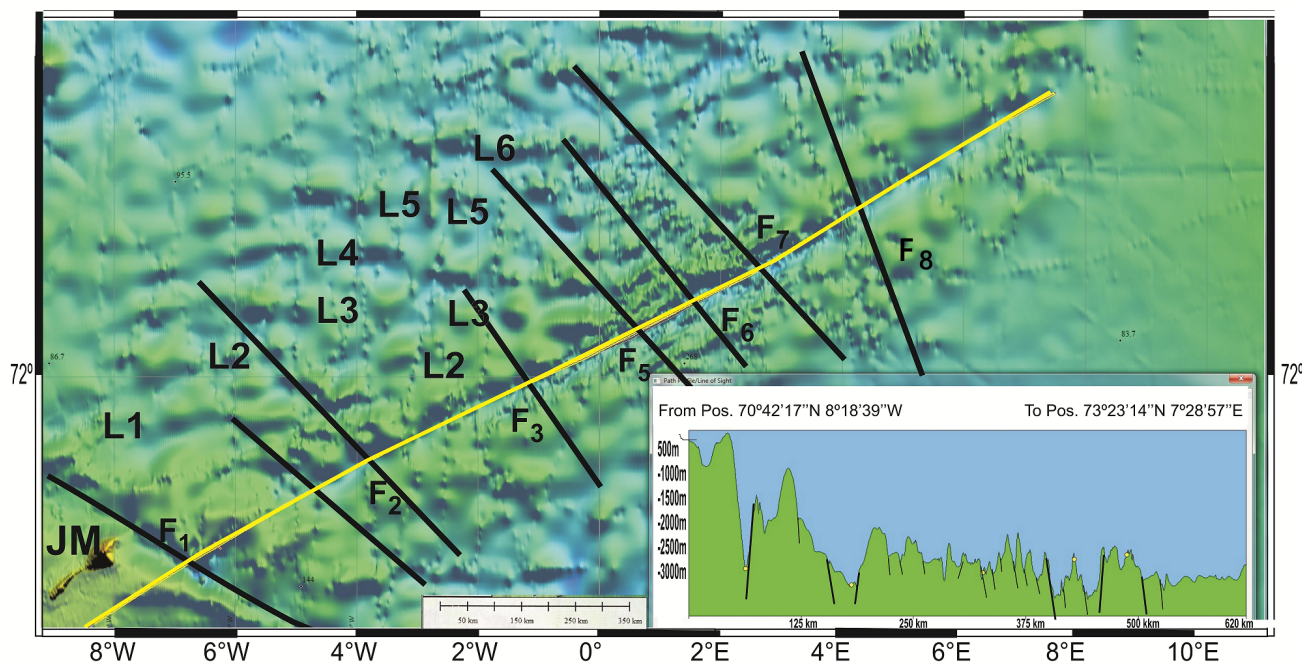


Figure 10. The position of the bathymetric profile along the Mohns rift valley (the yellow line). L1–L6 are MS, JM stands for the Jan Mayen Island; F1–F8 are faults. The inset shows the seafloor relief section; I–III are blocks of the Mohns Ridge separated by transverse depressions in the seafloor relief of the rift valley.

comes from a single well (ODP-913) that was drilled in the northwestern Greenland Basin. Seismic surveys, which are a reliable tool for studying sediments, do not provide a dense coverage of the sea areas of interest, it being the continental margins that were explored by common-depth-

point multichannel seismic techniques. The deep areas of the Norwegian-Greenland Sea were studied using the single seismic reflection method. The present work uses seismic time sections and results from the traverses shown in Figure 1 [Berger and Jokat, 2008; GeoMapApp.exe

From Pos: 70° 42' 17.2833" N, 8° 18' 38.8781" W

To Pos: 73° 23' 14.3527" N, 7° 28' 57.3699" E

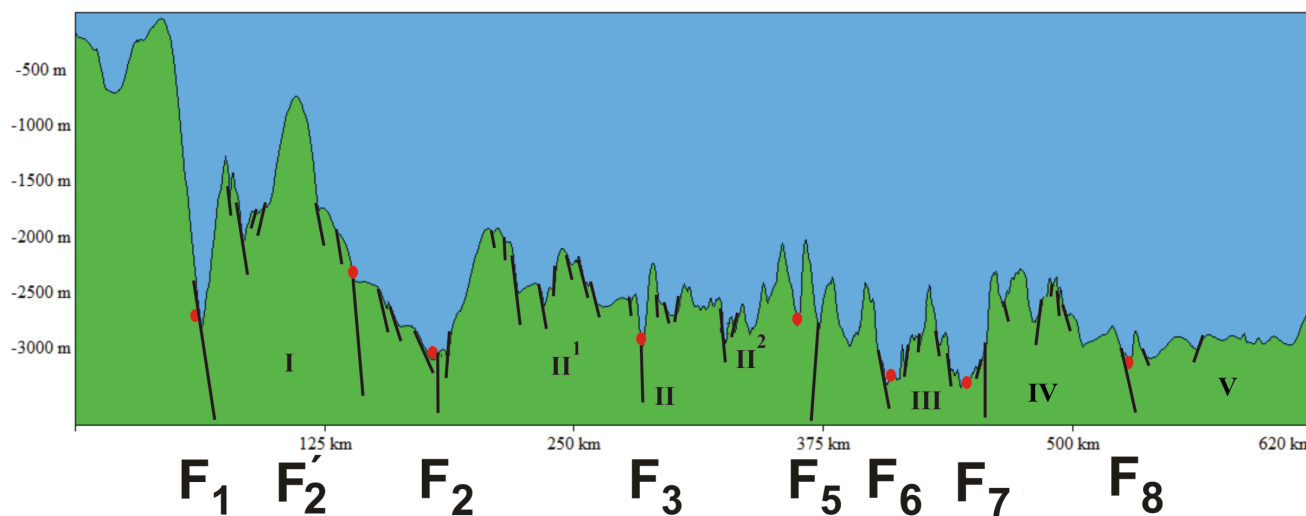


Figure 11. The seafloor relief profile along the Mohns rift valley. F1–F8 are faults; I–V denotes a possible variant identification of the ridge blocks in map view; the red circles mark technological sites in the construction of the section.

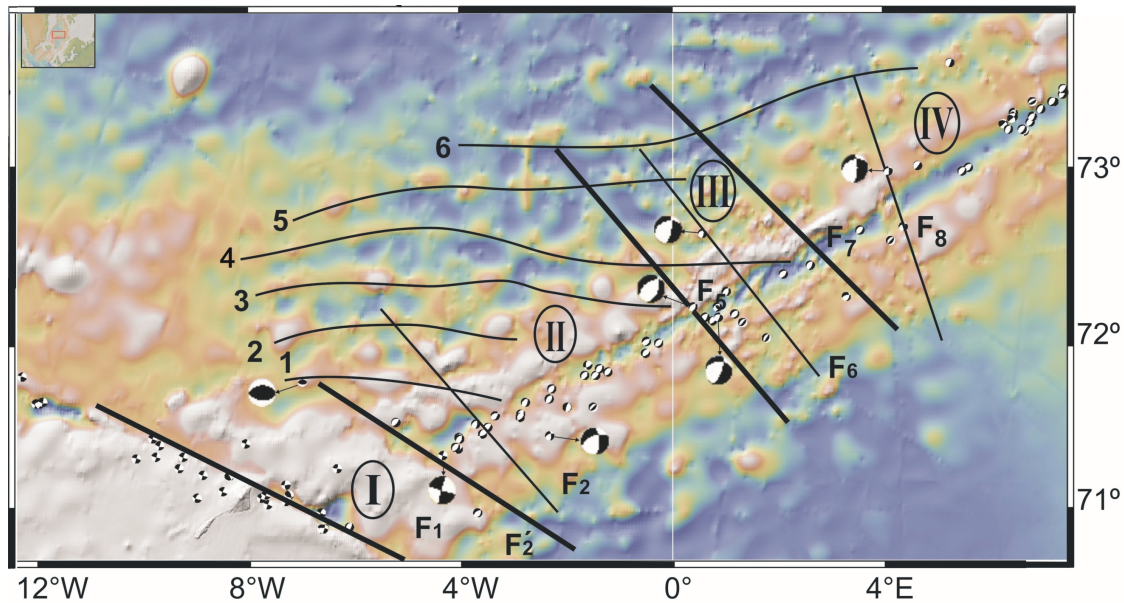


Figure 12. The distribution of focal earthquake mechanisms and fault discontinuities at the Mohns Ridge (the bathymetric base is SRTM-30 v.5). I–IV are the main blocks of the Mohns Ridge; F1–F8 are faults as tentatively identified here. Lines 1–6 mark the seafloor relief inhomogeneities discussed here.

(Lamont-Doherty Earth Observatory of Columbia University)]. Our discussion concerning the distribution of sediment thickness in the region is based on information gathered from the Internet base “Total Sediment Thickness of the World’s Oceans and Marginal Seas”, version 2 (<http://www.ngdc.noaa.gov/mgg/sedthick/sedthick.html>). We discuss the distribution of thickness for Cenozoic sediments, mostly beyond the continental shelf, where oceanic crust occurs.

The region under study contains two sedimentary basins: a southeastern (Lofoten) and a northwestern (Greenland). These basins are separated by a comparatively broad zone of thinner (less than 200 m) sediments, besides a nearly complete absence of any sediments within the Mohns Ridge. There is a well-pronounced asymmetry in the distribution of sedimentary deposits relative to the Mohns Ridge axis. The contour of 500-m thickness in the south, in the Lofoten Basin, where the ridge and the western Jan Mayen transform fault meet, is at comparable distances from the ridge axis, 148 km to the north and 138 km to the south (see Figure 13).

As one moves northeast toward the junction of the Mohns Ridge and the Knipovich Ridge, one notices the 500-m contour to approach rapidly the rift valley of the Mohns Ridge, so that sediments thicker than 500 m overlie the eastern slope of the ridge as one arrives at 74°N. As one goes from southwest to northeast in the Greenland sedimentary basin, the 500-m contour moves away from the Mohns Ridge axis to greater distances (220 km). Three depocenters of sedimentation stand out in the Greenland sedimentary basin (north of the western Jan Mayen Fracture Zone), viz., the Western I, the Central II, and the Northern III (see Figure 13).

The western depocenter in the 1000-m contour is situated along the slope of the East Greenland continental mar-

gin between 72°N and 75°N. The maximum sediment thickness (1600 m) is recorded there. The northern depocenter is a linear northwest-southeast trending trough that is adjacent from the south to the Greenland Fracture Zone (GFZ) ridge, with the maximum sediment thickness being greater than 2000 m. The central depocenter is south of Vesteris Seamount, the depocenter axis (see Figure 1) running nearly east-west. The sediments are 1100–1200 m thick.

The Lofoten sedimentary basin is more homogeneous, occupying (within the 500-m contour) the entire Lofoten Basin. The area of high (1000–2400 m) values and the contour configuration in map view has the shape of a triangle whose vertex looks westward (Figure 13). In the west, between the contours of 1000 m and 500 m, there is a series of comparatively small depocenters of isometric outlines, with the sediments being 1000–1100 m thick there. These depocenters make a chain extending from north to south and are adjacent to the eastern flank of the eastern Jan Mayen Fracture Zone (EJFZ). The presence of sedimentary basins with comparatively thick sediments in the region makes it possible to do a seismostratigraphic analysis of sedimentation to unravel the tectonic setting in the region during the formation of the sediments.

Greenland Basin

The only DSDP well that exists beyond the slope was drilled in the Greenland Basin in 1993 from on board the Joides Resolution research vessel (Leg 151), ODP-913 at 75°29′N and 6°96′W (see Figure 1). The well was drilled in a water depth of 3318 m, the geological section was pen-

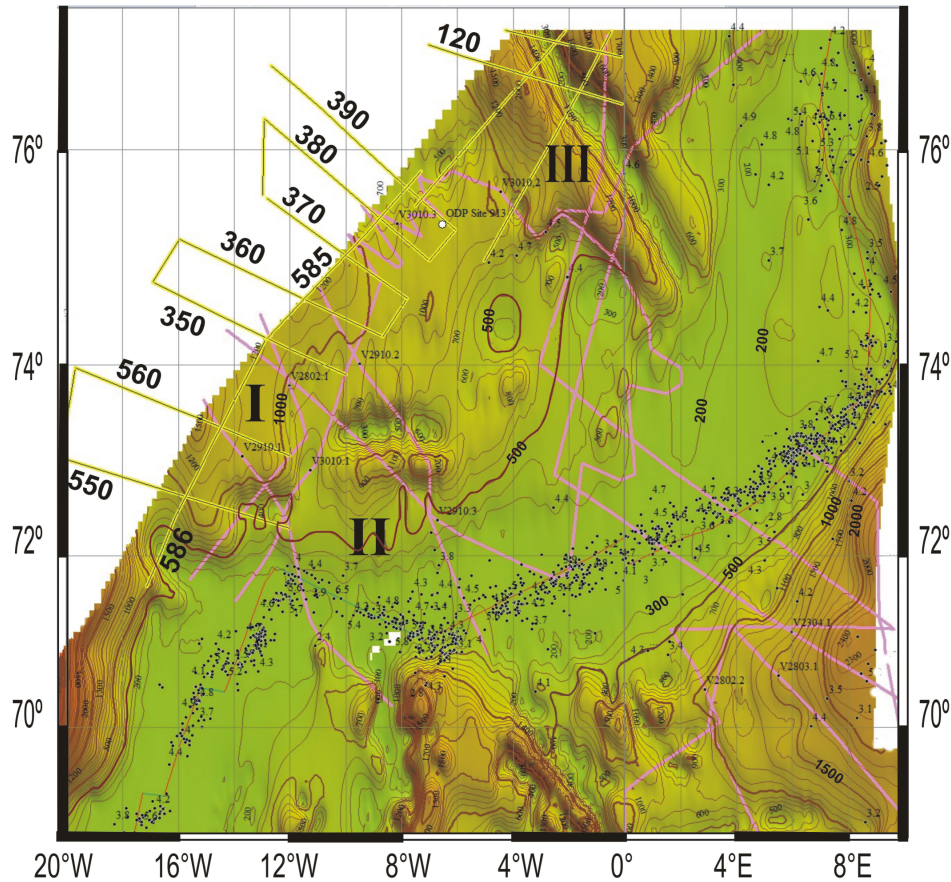


Figure 13. Sediment thickness (<https://www.ngdc.noaa.gov/mgg/sedthick/>). The isolines are in meters; I–III mark sedimentation depocenters (for explanations see text); the smaller dots with numerals attached mark earthquake epicenters.

etrated to depth 770 m [Myhre *et al.*, 1995]. Four intervals were identified in the geological section which contain seven litho-chrono-stratigraphic units, viz., IA and IB (0–144 m), Quaternary to Pliocene; II (144–379 m), Pliocene to Middle Miocene; IIIA, IIIB, IIIC (378.7–674.1 m), Pliocene (Middle Miocene?) to early Oligocene/Late Eocene; and IV (674.1–770 m), Middle Eocene.

The seismic data were correlated with deep sea drilling data (ODP-913) by Berger and Jokat [2008]. To do this they used Leg AWI-20030390 (see Figure 1, AWI-20030390), which is 17 km from ODP-913. They have succeeded in identifying a reflection with pronounced amplitudes at the boundary between units II and III in the section of the well at a depth of 379 m below sea bottom. They also used seismic velocities resulting from their analysis of the time sections in order to construct earth structures. The velocities for the upper section are 1.5 and 2.3 km/s, with 3.2 and 4.3 km/s for depths greater than 2000 m. They used results from seismic refraction measurements [Voss and Jokat, 2007]. The correlation resulted in combining the intervals IA, IB, and II [Myhre *et al.*, 1995] to form a single unit (GB-2), and the intervals IIIA, IIIB, IIIC, and IV [Myhre *et al.*, 1995] into another unit (GB-1). Considering that Miocene diatoms and radiolarians were found at a depth of 375 m in ODP-913,

the date boundary between GB-1 and GB-2 was determined to be 15 Ma. The small difference in depth between the boundary of GB-2 and GB-1 in the well (375 m.b.s.f.) and the reflector (360 m.b.s.f.) can be explained by the distance (17 km) between Leg AWI-20030390 and well ODP-913, as well as by the determination of seismic velocities during the conversion of the time section into a depth section.

The rock composition in the depth interval 308–400 m.b.s.f. suggests that the boundary between GB-1 and GB-2 corresponds to 15 Ma, when the non-glacial mode of sedimentation gave way to glacial sedimentation. Berger and Jokat [2008] used a network of intersecting seismic lines to correlate the horizon between GB-2 and GB-1 within the shelf area of the East Greenland continental margin. Their correlation thus showed that GB-1 (56 Ma to 15 Ma) is composed of non-glacial deposits, while GB-2 (15 Ma until today) consists of glacial sediments. The boundary between the two modes of sedimentation occurred during Middle Miocene time.

Berger and Jokat [2008] made a detailed study of a basement high along the eastern continental margin of Greenland using a network of CDP seismic lines (see Figure 1). The high can be followed within the continental slope of the East Greenland continental margin from the junction between the

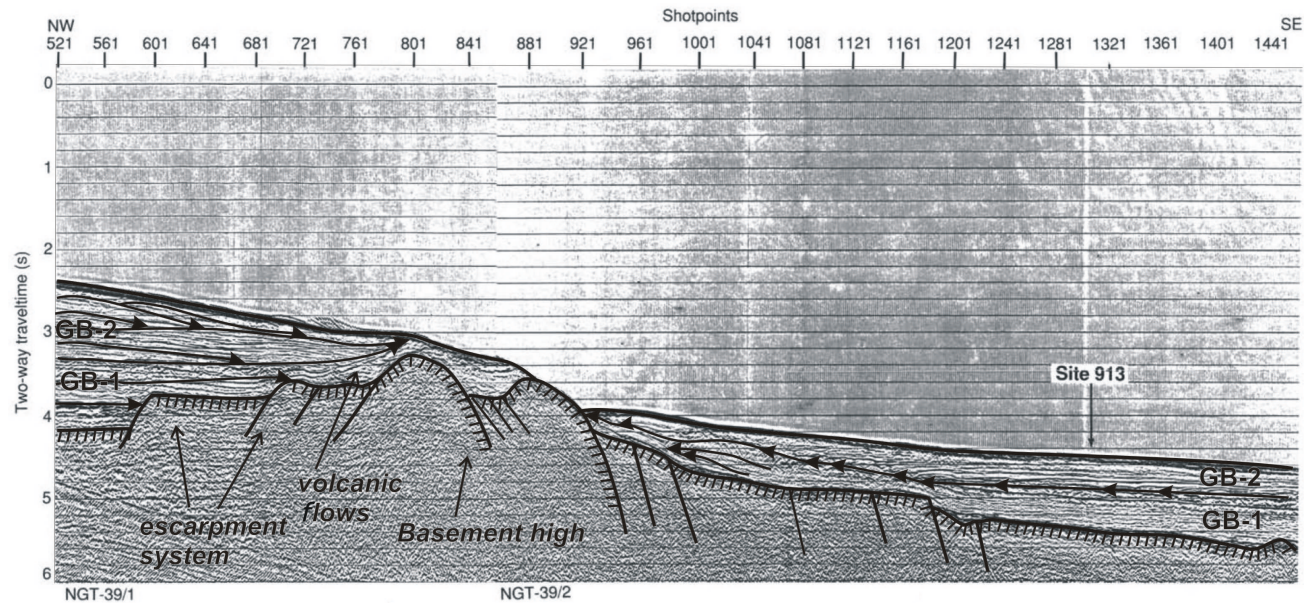


Figure 14. A seismostratigraphic interpretation of the time section along the NGT-39/1 and NGT-39/2 lines. The ODP-913 is at Shotpoint 1315 [Myhre *et al.*, 1995]; GB-1 and GB-2 are seismic units; arrows indicate an absence of reflections at interfaces of unconformity (for the discussion see text).

margin and the Greenland Fracture Zone in the north (Leg AWI-20030130) as far as Leg AWI-20030360 in the south-west. The basement high is confined either to the edge of the shelf or lies within the continental slope. The line drawings show that the basement high can be followed from north to south as far as Leg AWI-20030360, with the highs as identified on individual legs not being aligned in a straight line, but lying at different depths. The absence of apparent stratification and the high seismic velocities at the top of the high (4.0–4.3 km/s) provide evidence of a basaltic composition of this high. The basement high and the GFZ look like horsts in the depth-dependent seismic section along AWI-20030120 (see Figure 1) in the area of junction between the Greenland continental margin and the GFZ. Their heights relative to the bottom of the trough between them are comparable and amount to a little over 2 km in the basement relief.

Myhre and Thiede [1995] carried out a seismostratigraphic analysis of the CDP line between NGT-39/1 and NGT-39/2 (see Figure 14). The line has ODP-913 (Shotpoint 1315). Figure 14 shows a seismostratigraphic interpretation that we have carried out independently, and whose results are in overall agreement with those of Myhre *et al.* [1995]. The basement relief has a high that is seen as a horst with two summits in the seismic time section. The one summit is confined to the shelf edge, while the other is within the continental slope.

The landward slope of the basement high is complicated with escarpments. The upper escarpment, that nearest to the summit of the basement high, shows knobby reflections that Myhre *et al.* [1995] interpreted as volcanic flows that similar to the Voring Basin. Our seismostratigraphic interpretation uses the notation for seismic units identified by Berger and Jokat [2008].

Two unconformable interfaces are identified in the up-

per seismic section for the Cenozoic sediments in the shelf area (see Figure 14). These interfaces subdivide the sediments into three seismic units. The lower interface of unconformity has a downlap of overlying reflectors (toward the escarpment) and a toplap of underlying reflectors (this is characterized as an erosional truncation). The top interface of unconformity is characterized by downlaps of overlying rocks on the middle seismic unit. These interfaces characterize significant rearrangements of paleogeography and sedimentation in the region. Following [Hinz *et al.*, 1991; Myhre and Thiede, 1995], we treat the bottom interface of unconformity as recording deep truncation and erosion that was related to sea level lowering and was occurring before Early Miocene time within the older slope between 74° and 76°N. These interfaces of unconformity characterize the major breaks of sedimentation in the Greenland paleobasin.

The middle seismic unit (see Figure 14) in the time section (or the bottom part of GB-2) wedges out at the summit of the basement high, while its bottom (the top of GB-1) rises toward the present-day seafloor, enveloping the “basalt” flows that crop out beneath the degradation shear. Bumpy reflections are observed in the time section toward well OD P-913, seaward of the basement high. These reflections may be interpreted as due to basaltic lava flows.

One interface of unconformity can be identified between GB-1 and GB-2 in the sediments seaward of the basement high (see Figure 14). This interface was caused by erosion.

The overlying (in the seismic time section) reflectors are characterized by onlap, forming an overlying pattern toward the basement high. This indicates their transgressive origin. The interface dates back to Middle Miocene time, when non-glacial sedimentation gave way to glacial sedimentation [Berger and Jokat, 2008; Myhre and Thiede, 1995].

Examination of the seismic aspect of the basement high

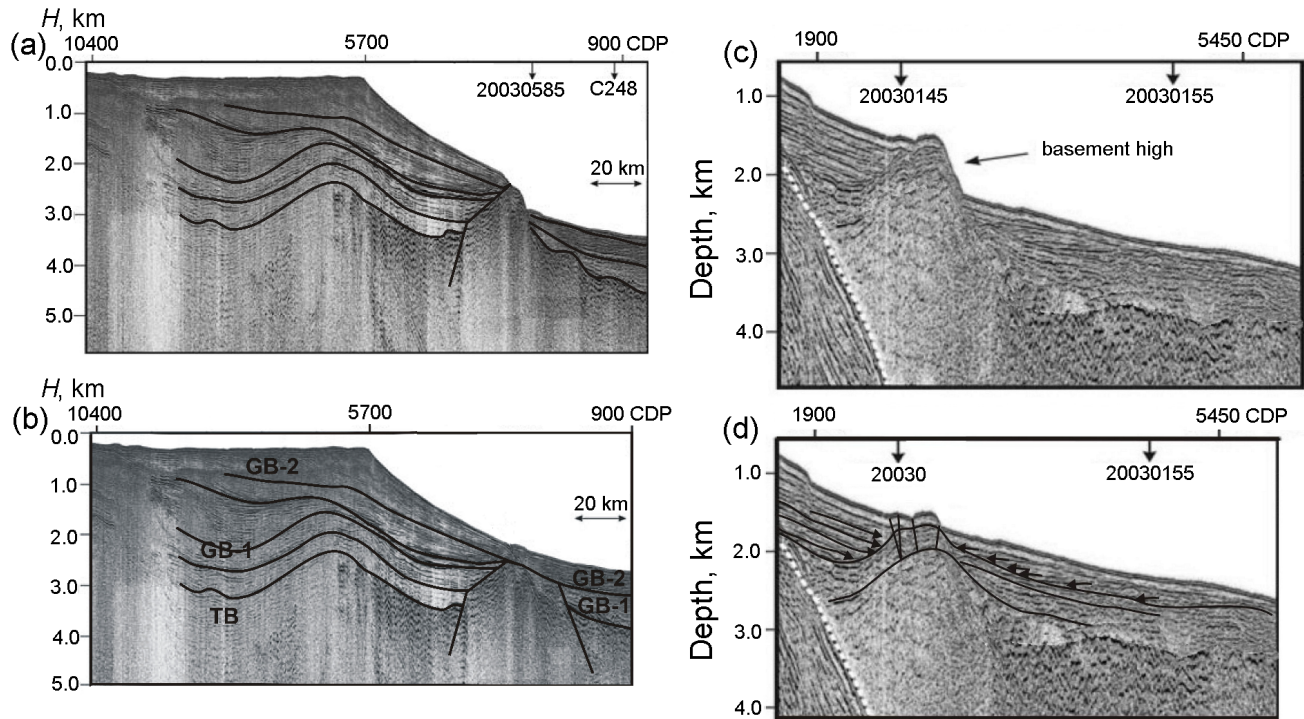


Figure 15. Paleotectonic reconstructions of normal faults on a basement high within the East Greenland continental margin. a–b for CDP-AWI-20030390 line: a – before reconstruction, b – after reconstruction; GB-1 and GB-2 are seismic units; arrows with numerals attached in the top of the section mark intersections with other lines and the number of a magnetic anomaly (C24B, 56 Ma); TB stands for Thetis Basin; c–d show results for CDP-AWI-20030100 line: c – before reconstruction, d – after reconstruction; for explanations see text. The positions of the lines are in Figure 1.

in the time sections [Berger and Jokat, 2008; Myhre et al., 1995] along the northeastern part of the continental margin (legs AWI-20030130, 120, 110, 100, and 390, see Figure 1) reveals a similarity that could be expected. The basement high lies within the continental slope. One notes a rapid rise of sea depth in seismic sections seaward along the basement high slope, as well as an absence of sediments in the top part of the basement-high slope (see Figure 14 and Figure 15) on the seaward side.

Our seismostratigraphic analysis of the seismic units (the character of the interfaces of unconformity, lateral thickness variation, the internal structure of reflectors, etc.) suggested a paleotectonic reconstruction of normal faulting along the eastern flank of the basement high (see Figure 15). The amplitude of normal movement is about 700 m. This normal faulting occurred in two phases in Legs AWI-20030390, NGT-39/1, and NGT-39/2, while Leg AWI-20030100 involved a single phase. The fact that reflections could no longer be followed at flanks of the basement high, combined with the lateral variation in thickness for the seismic units GB-1 and GB-2, suggest that the basement high was formed within the slope prior to the formation of the two lower GB-1 subunits (Figure 15). The thickness of these subunits shows no lateral variation, that is, the downwarping was compensated by sedimentation.

There is a basement high under the shelf edge between the

basement high within the continental slope and the Thetis Basin (Figure 15b). This high has the shape of a dome, and was formed during the generation of the top GB-1 subunit (consolidation growth); it was a barrier (obstacle) for washed sediments. The top of GB-1 underlies the GB-2 progradation deposits, which were accumulated during the downwarping of the older basin bottom uncompensated by sedimentation in the presence of its pre-sedimentation slope.

The escarpment amplitude along the slope of the basement high is about 780 m along Leg AWI-20030100 [Berger and Jokat, 2008], which is north of AWI-20030390 (see Figure 15c, Figure 1). The basement high was formed there after the origination of the lower GB-1 subunits whose deposits overlie the basement-high summit, have a bumpy aspect, and lie beneath the present-day seafloor. The basement high was a barrier for deposits in the top subunits of GB-1 and GB-2. The sedimentary features above the summit of the basement high are fractured by faulting and are uplifted relative to adjacent seafloor areas, which may provide evidence that the high was uplifted before being downthrown on the normal fault along the eastern flank.

Overall, some tectonic subsidence on the normal fault along the eastern slope of the basement high is observed over the entire northern part of the East Greenland continental margin. The seafloor subsidence east of the high on the seaward side is young, and was occurring during re-

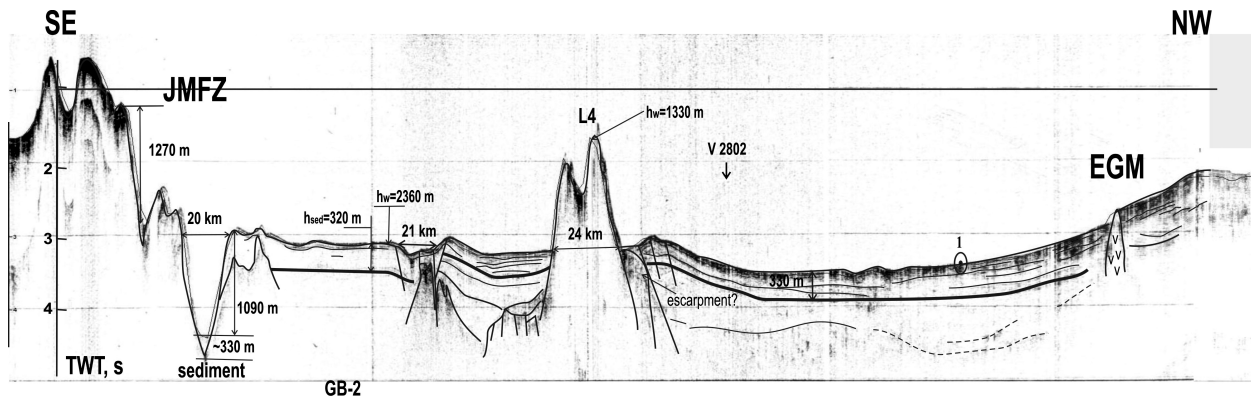


Figure 16. The seismic time section for V2910.1 line (the location is in Figure 1). JMFZ stands for the Jan Mayen Fracture Zone, EGM for the East Greenland margin; TWT, s is the double travel time of seismic waves in seconds (for explanations see text); L4 is a linear elongate seafloor relief inhomogeneity; GB-1 and GB-2 are seismic units; the dot in the circle marked 1 is the intersection of the CDP line and the cruise Vema line (see Figure 1).

cent geological time, after the Quaternary seafloor sediments came into being.

We have correlated the boundary between GB-1 and GB-2 as detected by [Berger and Jokat, 2008] in the CDP seismic sections and in single reflection seismic cruise sections at the points where these intersected (see Figure 1). The correlation was based on the following parameters: GB-2 thickness, the depth to the interface between GB-1 and GB-2, and reflection amplitudes. The seismic section along Leg 2910 (Figure 16) shows the unit to be 330–350 meters thick, the interface between GB-1 and GB-2 is represented by a reflector that is comparatively pronounced in amplitude, with the reflector being generally nearly horizontal. The leg traverses the Jan Mayen Fracture Zone, the basement high (which has the shape of a ridge in map view) which we treat as the western part of MS L4 that we have identified (Figure 2), and the foot of the continental slope of the East Greenland margin (Figure 1). The trough in the basement relief as shown by a seismic section in the Jan Mayen transform fault zone (Figure 16) has a structure similar to that along the bathymetric line (Figure 8, R2). The trough has a width of 20 km in this cross section of the line, with the water depth equal to 1090 m. Below the trough bottom the character of the seismic field suggests the presence of sediments whose thickness is about 300 meters, which is comparable with the thickness of the GB-2 seismic unit adjacent to the trough side (Figure 16). The trough is confined to the junction between the western termination of the transform fault and the northern termination of the Kolbeinsey Ridge axis. Considering that the rift valley of the Kolbeinsey Ridge is poorly expressed, and that the trough is extending along the transform fault, we believe that the trough is part of the latter feature. The trough is bounded by basement highs that have the aspect of large “intrusive” features. The northern one of these features is a seafloor high. The fact that the sedimentary features are only available on the trough bottom, added to the fact that their thickness is comparable with that of the GB-2 unit, suggests that the trough was formed

after that of GB-2 whose sediments then filled its lower part. The trough was formed during a comparatively short period of geological time, nearly simultaneously with the intrusive features mentioned above, and it is a fracture (extensional fault) in a crustal extensional area. The conjugation of reflectors within the GB-1 and GB-2 seismic units and within the slopes of the basement high at L4 shows some interesting peculiarities. The reflectors near the flanks of the high are rising, with the distance between them (the thickness of the layers that fit the sediments) remaining unchanged. A high is observed near the northern flank of the high in seafloor relief and inner reflectors in the GB-2 seismic unit; this high is of post-sedimentation origin (that is, its generation occurred after that of GB-2). This high is also observed in other cross sections along legs V-3010 and V-2802 (see Figure 1 and Figure 17). The nature (origin) of this seafloor high can be explained by the presence of an escarpment in the northern flank of MS L4, which has uplifted sedimentary deposits during the growth of L4. This hypothesis is supported by the presence of discontinuities at the summit of the high. One can thus conclude that L4 is a young feature, younger than the GB-2 deposits. A trough 21 km wide is observed in seafloor relief between the “transform” trough and the L4 high (Figure 16), this probably forming in a weakened fault zone that was composed of the basement high; the northern side of the trough is also a small seafloor high. Figure 17 shows a cross section of the basement high (L4) and of the Jan Mayen Fracture Zone (JMFZ) along leg V-2802 (see the location in Figure 1). The leg traverses the western part of the L4 high, which is very near to the Jan Mayen Fracture at the location, the fracture not being of a transform nature in the area. Overall, the discussion during the description of the seismic section along Leg V-2910 (Figure 16) is not inconsistent with the seismostratigraphic parameters of the Cenozoic sediments (GB-1 and GB-2) and with the tectonic structural setting as observed along Leg V-2802 (Figure 17).

The above discussion was concerned with lateral seafloor inhomogeneities, in particular, with MSs L1 through L6 and

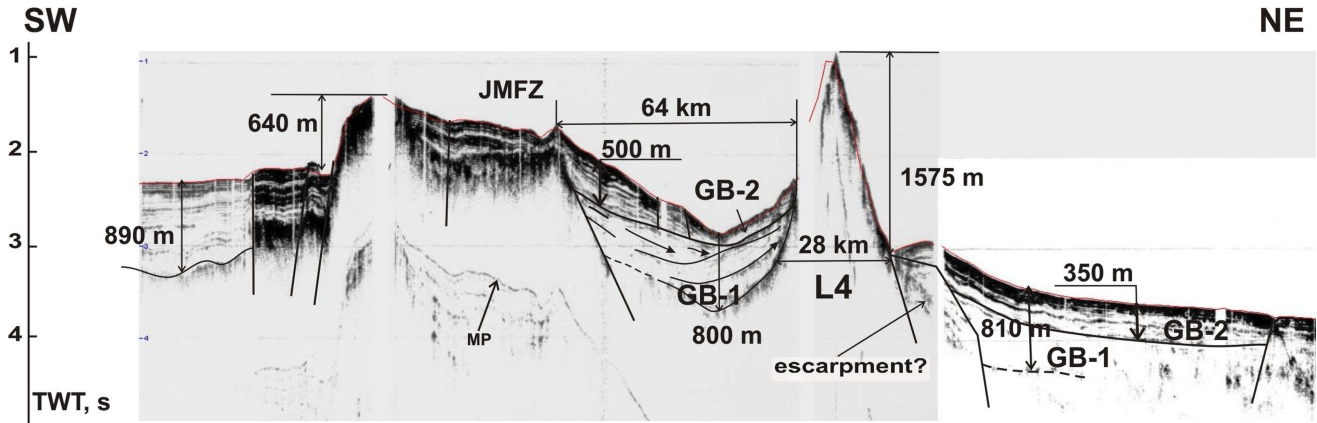


Figure 17. The seismic time section along V2802.1 (the position is shown in Figure 1) (for explanations see text). MP denotes a multiple reflection.

their external characteristics. The single seismic reflection time sections allow examination of seafloor morphostructural inhomogeneities below the sea bottom and of the sedimentary deposits where these occur (Figure 18). Figure 18 shows part of Leg V-29103. It consists of two fragments that converge at point B (see Figure 1, A-B-C). Both of the two fragments, AB and CB, start from the Mohns rift valley, traverse its northern flank, the area of the MSs discussed here, and the southern margin of the sedimentary basin (the central depocenter II, Figure 13). The Mohns Ridge has different structures along the parts of the section named AB and BC. In the first of these cases the section has the shape of a horst with a poorly pronounced rift valley; the water depth above the summit is 1074 m and the depth to the bottom of the rift valley is 1710 m. In the second case the Mohns Ridge is represented by a series of summits of equal heights (five of these in the northern flank, Figure 18), with the water depth to the summits varying between 1450 and 1820 m. The depth to the bottom of the rift valley is 2740 m at the location.

The occurrences of thicker sedimentary deposits at AB

and BC in the flank of the Mohns Ridge (Figure 18) correlates with the position of magnetic anomaly C5. This section (Figure 18) shows MSs L0 through L3; MS L0 has not been discussed above, since it occurs locally. Our analysis of seafloor topography revealed certain peculiarities. MS L1 is an uplifted (hanging-wall) block with the uplift amplitude being about 320 m. The northern flank of MS L2 in sections AB and BC is the fault plane, its visible amplitude is 530 and 830 m, respectively. MS L3 is entirely within the sedimentary cover, producing (forming) a seafloor high.

Figure 19 shows fragments AB and ED combined into a common AD profile; for its location consult Figure 1. This profile gives a depth-dependent image of most MSs identified here and their relationships to the sedimentary cover of the Greenland Basin. This profile exhibits three hypsometric levels of the seafloor, viz., the lower, the intermediate, and the upper level (Figure 19). The lower level is represented by a seafloor area in the abyssal plain, in the left part of the profile where the water depth is 3190 m. The intermediate level is a seafloor area on both sides of MS L4, while the upper level is confined to the depocenter II of the

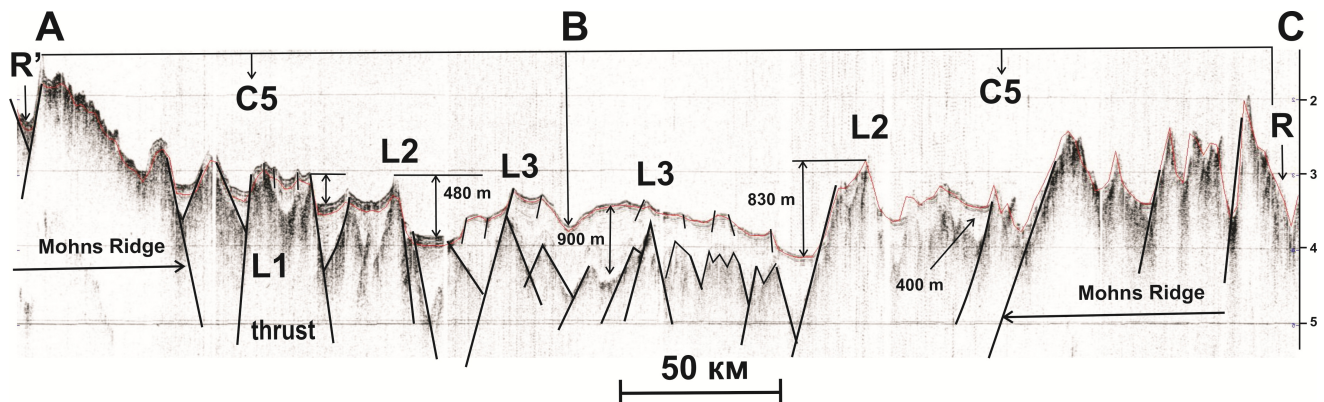


Figure 18. A fragment of the seismic time section along V2910.3 (the position is shown in Figure 1). R stands for the Mohns Ridge rift valley, L0–L3 are basement relief MSs, and C5 is a magnetic anomaly (for explanations see text).

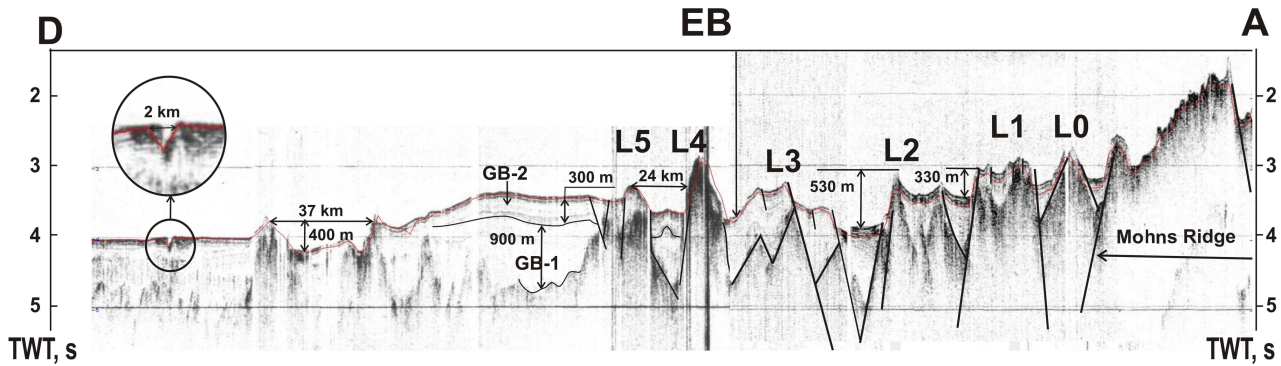


Figure 19. The seismic time section along the D–E(B)–A line (the position is shown in Figure 1) (for explanations see text).

sedimentary basin (Figure 13). It can be seen from the relationship between the morphostructural forms and the top of the sedimentary deposits (seafloor) that the tectonic movements that have formed these anomalous MSs occurred after the origination of the top of GB-2. Morphostructure L4 penetrates as it were the sediments in the area of depocenter II of the sedimentary deposits and stands above the seafloor, while MSs L1, L2, L3, and L5 did not succeed in coming out of the sedimentary cover, strongly deforming its top and producing faults. The seafloor stands above the “abyssal” area by about 500 m in the area where the sedimentary cover is the thickest. This difference in hypsometric level of the seafloor was most likely produced by uplifting of the acoustic basement. There is a depression in seafloor relief in the northwestern part of the AD profile (the left part of Figure 19), in the zone where the area of the MSs under discussion abuts the flat seafloor surface of the abyssal part of the Greenland Basin. This depression is limited, and seems to have been formed by vertical bodies that had been intruded into the deposits of the sedimentary cover. The bodies were formed in a similar manner to the MSs under discussion, while the depression itself when inspected in map view is a regional negative feature confined to the northern boundary of the area where the east-west trending MSs occur (Figure 5), and has relief expression from Vesteris Seamount to the Greenland Fracture Zone (Figure 1). The depression is 38 km wide in this cross section, with the depth being about 400 m (Figure 19). There is a narrow incision in the seafloor 2 km wide and 55 m deep at a distance of 34 km from this depression somewhat northwest toward the Greenland continental margin. The incision is a long channel when seen in map view, with the channel extending from the landward slope of the Greenland continental margin into the Greenland Basin (Figure 20).

The Lofoten Basin

We chose a stratotype section to illustrate our seismostratigraphic analysis for the Lofoten Basin. This is the seismic time section along Leg V2304.1 (for the location see

Figure 1). The leg is in the middle of the Lofoten Basin, it extends east-west, across the lines of equal sediment thickness in the northwestern part of the sedimentary basin (see Figure 13). The time section shows several unconformable interfaces in the sedimentary cover as identified from an absence of reflections; these interfaces subdivide the Cenozoic deposits into two units, LB-1 (the lower) and LB-2 (the upper), see Figure 21. The upper seismic unit (LB-2) contains three subunits, the lower, the intermediate, and the upper. Overall, the sediments in the Lofoten Basin have a structure that is similar to that of the Greenland Basin sediments. The lower seismic unit LB-1 is underlain by an acoustic basement that exhibits a strongly stratified structure complicated with discontinuities. The basement consists of bodies more than 1000 m high (see Figure 21).

These features occasionally penetrate through the sedimentary deposits and stand above the seafloor. In other cases they lift structures of the LB-1 and LB-2 seismic units and form low highs in the seafloor relief. The LB-2 seismic unit when occurring in such areas consists of deposits of the upper subunit only, and is rather thin (below 200 m). The deposits of the lower LB-2 subunit are represented (in the time section) by nearly horizontal reflectors that seem to lean on the uplifted LB-1 block. This suggests that the LB-1 deposits (the uplifted block) had experienced an uplift prior to the formation of the nearly horizontal deposits in the LB-2 lower subunit. The reflectors in the intermediate and upper LB-2 subunits in the eastern part of the section (Figure 21) are clearly transgressive, thus providing evidence of sea level rising during their formation. The LB-2 deposits at the location are subject to weak folding deformation. Overall, one notes similar features in the structure of the Cenozoic sedimentary cover in the Lofoten and the Greenland basins. To a first approximation, one can infer the age of the unconformable interface between the LB-1 and LB-2 units as Middle Miocene (15 Ma). This interface of unconformity dates back to the time when the character of sedimentation was changed from terrigenous to glacial. For the Greenland-Lofoten basin this phenomenon was regional in character, and was due to a change in paleogeographic and paleotectonic conditions.

Our seismostratigraphic analysis suggests the following conclusions:

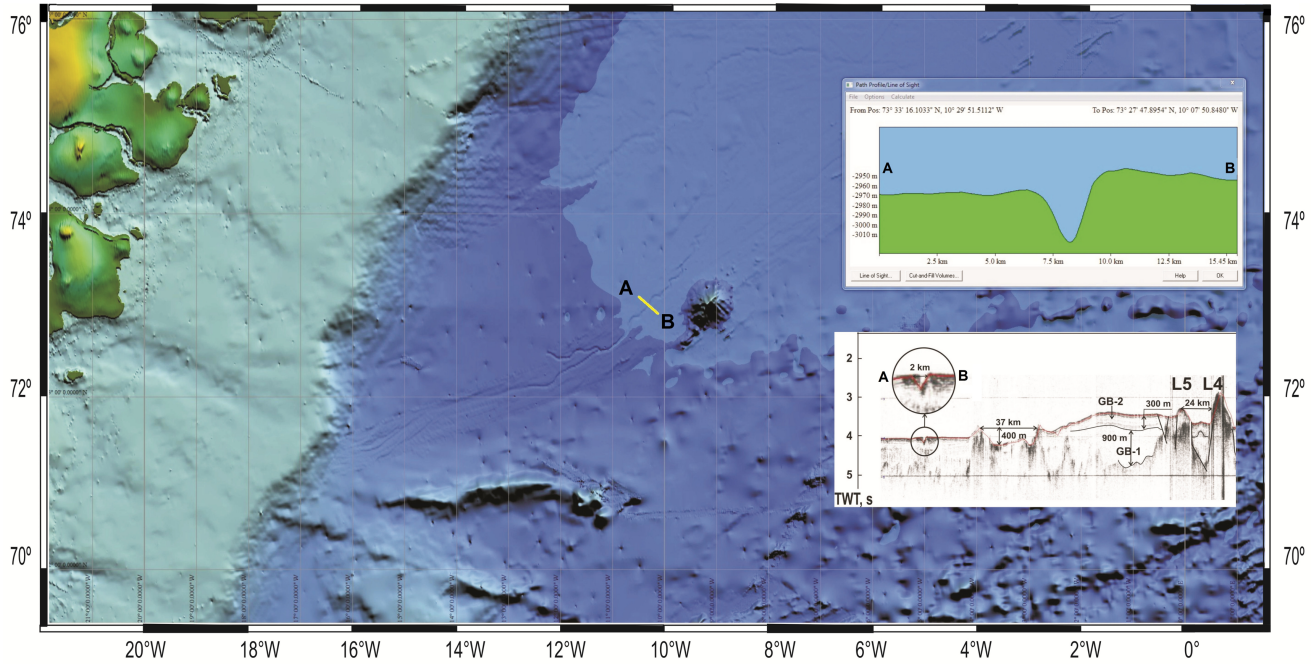


Figure 20. The location and origin of a depression in seafloor relief highlighted in Figure 19 (for explanations see text). The topographic base is SRTM 15.

- The MSs that we have tentatively identified in seafloor relief are features of the acoustic basement that underlies the Cenozoic sedimentary cover, they were formed after the origination of the GB-2 sedimentary unit;
- The young post-Quaternary tectonic movements within the Greenland continental slope were normal displacements whose amplitudes reached 800 m.
- The interface of unconformity between the GB-1 and GB-2, LB-1 and LB-2 seismic units is regional in extent, is quasi-synchronous, and corresponds to the Middle Miocene change in the character and conditions of sedimentation;

There are also reverse movements (rising seafloor patches) with amplitudes of 300–500 m along with block subsidences on normal faults in areas adjacent to the Western Jan Mayen transform fault zone and to the Mohns Ridge flanks, in the area of the MSs discussed in this paper.

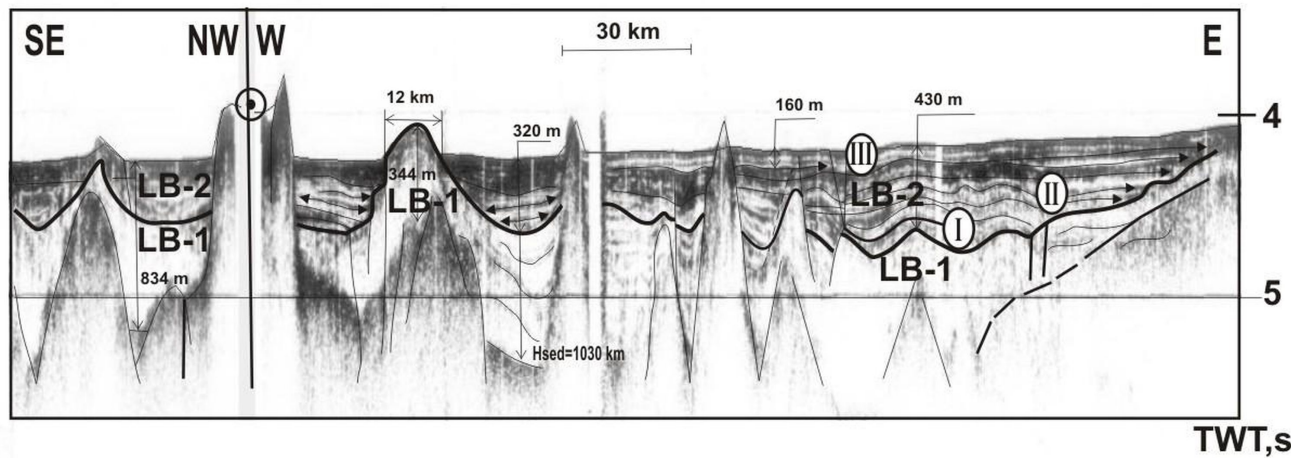


Figure 21. A seismostratigraphic interpretation of the time section for V2304.1 (the position is shown in Figure 1). LB-1 and LB-2 are seismic units of Cenozoic sediments in the Lofoten basin; I–III denote subunits of LB-2; H_{sed} is sediment thickness; the circle with a dot marks turn in the line. The arrows inside the seismic units fit the sedimentary layers (for explanations see text).

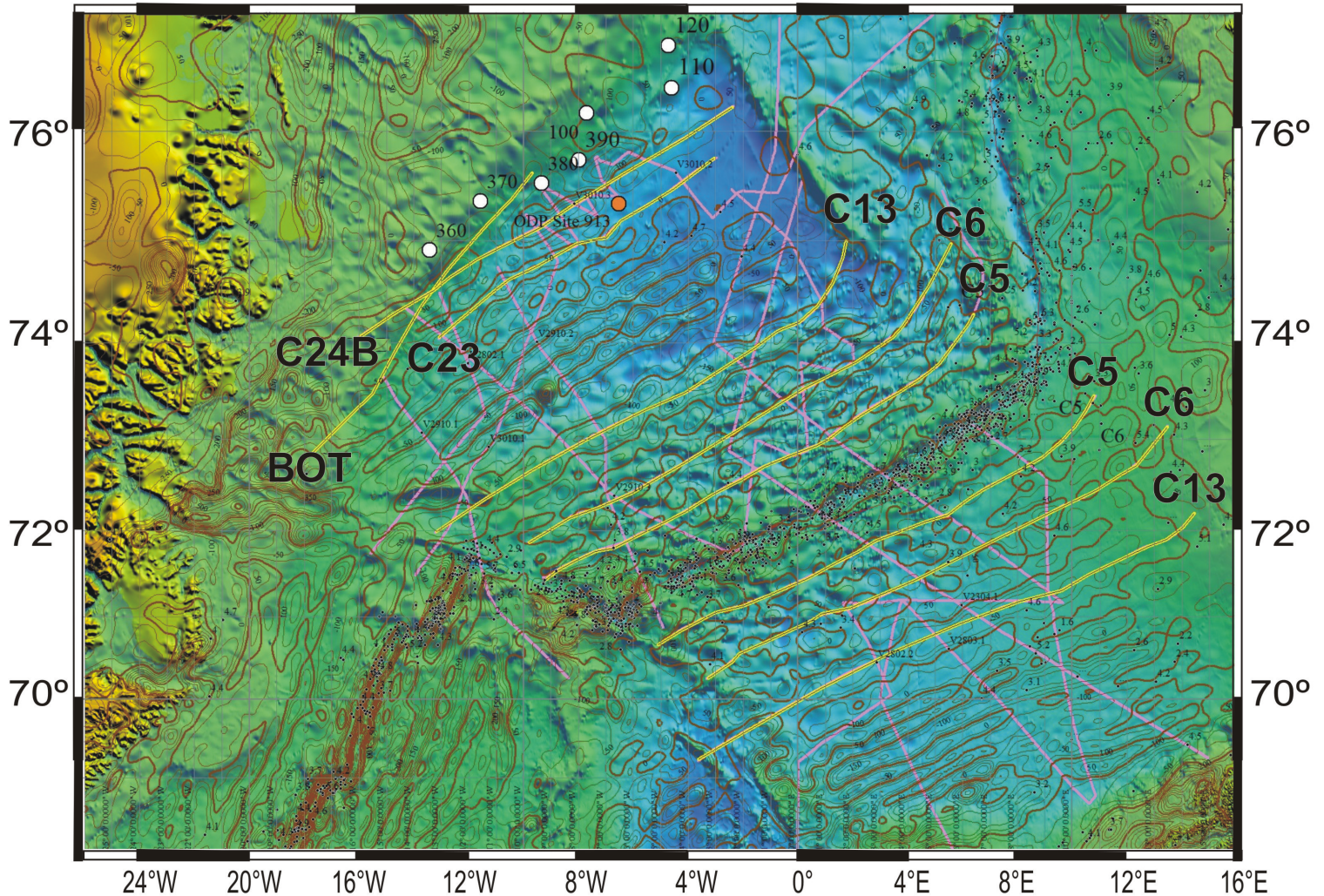


Figure 22. A map of magnetic anomalies in the Norwegian–Greenland region. The magnetic isolines are in nT; yellow lines with index C5–24B are axes of magnetic anomalies [EMAG-2: Earth Magnetic Anomaly Grid; <http://www.geomag.us/models/emag2.html>]; BOT denotes the line that marks the ocean-continent transition boundary [Voss and Jokat, 2007]; open circles are basement highs; the numeral is the identification number of the CDP line where these were identified (see Figure 1) [Berger and Jokat, 2008]. The red circle marks the ODP site 913.

Discussion

Above we discussed in comparatively great detail the structure of our MSs L1 through L6, their seafloor relief expression, and their aspect in time sections below the seafloor. There is an interesting feature, as we think, that consists of the spatial locations of these linearly elongate MSs relative to the major tectonic features of the region, the continental margins, the Mohns spreading ridge, and the Western Jan Mayen Fracture Zone. This feature is their east-west trend. Our seismostratigraphic analysis of seismic time sections showed that they are “young”, and that these MSs were formed after the origination of the Quaternary sedimentary deposits. From south to north, they make an echelon series of east-west striking horst ridges in the area

where they occur. The lateral distance between their crests from south to north is invariably close to 25 km (a kind of return period). Also, the depths to the crests increase northward, while the relative amplitude of the highs decreases in the same direction (Figure 3). This may be due to the decay of tectonic activity from south to north.

As no drilling data and seismic velocities are available for these features, it is difficult to assess their composition. By outward aspect they remind one of magmatic bodies whose composition is the same as in the acoustic basement, i.e., basalt, though they find no reflection in the magnetic field (Figure 22), even if the Upper Oligocene magnetic moment of the earth was approximately twice as low as the present-day one, based on G. M. Solodovkinov’s data [Gordin, 2001]. The area of the MSs in the Greenland Basin is bounded by the axial anomaly of the Mohns Ridge and by anomaly C13.

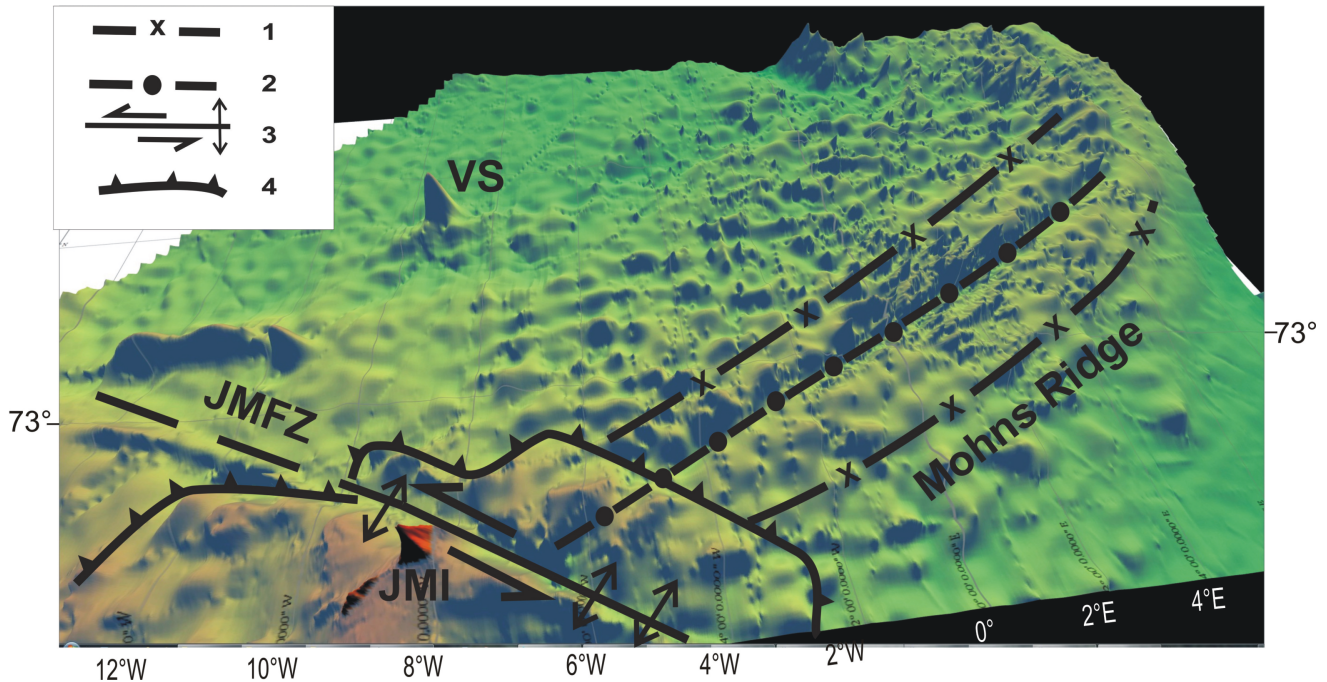


Figure 23. An illustration of the crustal block identified in the map of acoustic basement relief (3D) in the junction zone between the Mohns Ridge and the Jan Mayen transform fault: (1) boundary of the Mohns Ridge; (2) the axis of the MR rift valley; (3) transform fault; (4) boundary of the block. The map of the acoustic basement is based on bathymetry data (STRM 30.v.4) and sediment thickness (Figure 13).

The generation of these MSs provides evidence of intensive tectonic activity in the region of study during a recent geological past. The open circles with identification numbers in Figure 22 correspond to the location of the basement high that had been identified in the relevant CDP seismic section [Berger and Jokat, 2008]. These fragments of the basement highs are older than 15 Ma and probably have a basaltic composition, judging from compressional velocities (~ 4.3 km/s) and an absence of stratification in the highs as seen in the seismic sections.

Berger and Jokat [2008] noted that the lateral extension of this basement feature is not a lineament and is at present found at different depths. The lineated magnetic anomaly C24B (see Figure 22) is further southward, and the distance between the basement high and the axis of this anomaly increases from south to north. They therefore hypothesized that this basement high was formed in a diachronous manner.

Our seismostratigraphic analysis suggests that the basement highs that Berger and Jokat [2008] identified within the East Greenland continental margin (EGCM) have experienced two phases of vertical tectonic movements during the neotectonic geological epoch. The earlier phase was characterized by an insignificant rise, while the later involved subsidence on a normal fault in the eastern flank of the high. The amplitude of vertical displacement reached 800 m. These events coincided with the tectonic movements in the area of MSs L1 through L6 as can be inferred from the timing and character of the movements.

We think that the Jan Mayen Fracture Zone (JMFZ) was a kind of “epicenter” for these tectonic movements. The seismic time sections across the JMFZ (Figure 16 and Figure 17) show the latter as an uplifted basement block that is conjugate with the basin unfilled with sediments (Figure 16). It can be seen from inspection of the sections that the uplift occurred after the accumulation of the GB-2 unit, i.e., quasi-synchronously with normal-sense movements in the continental margin of Greenland and with the formation of the MSs L1–L6. The sediment thickness within the transform on the bottom of the basin (Figure 16) is equal to the GB-2 thickness, and the sediments seem to have collapsed down onto the bottom at the time the basin was opening.

There is a crustal block (part of the seafloor) toward the Mohns Ridge from the transform fault (WJMFZ) that is bounded to the northeast by fault F2 (Figure 11) and that was previously, in our opinion, part of the crustal block that comprised the Jan Mayen Ridge (Figure 23) and the entire Iceland Plateau.

The area of the linear MSs L1 through L6 (northwest of the Mohns Ridge) shows as a separate zone of the gravity field with values of 5–15 mGals in the map of Bouguer gravity anomalies [Olesen et al., 2007]. Further north is an area of negative anomalies (the Greenland Basin). One notes positive anomalies ranging from 25 to 50 mGals or still greater farther south and southeast. These higher Bouguer anomalies occur in a flank of the Mohns Ridge and the separate crustal block, with the highest gravity values (more than 50 mGals) being over that block.

The study of the mid-oceanic Mohns Ridge relief shows that it has a blocky character. The transverse depressions that we have tentatively identified within the rift valley (Figure 19 and Figure 11) also persist into the flanks of the ridge. These transverse depressions are substantially deeper than the rift valley and are generally typical of transform fault zones [Grachev, 1987]. This is also indicated by the focal earthquake mechanism data (Figure 12), suggesting a strike slip component on faults that are confined to the transverse depressions in the rift valley.

The morphologic features of the Mohns Ridge structure, its spatial location in a zone smaller than that bounded by magnetic anomalies C5 (9.6 Ma), some peculiarities of the sediments, all combine to suggest its origin to date back to 4–10 Ma. This is also indirectly indicated by the transgressive character of sediments in the GB-2 unit in the Greenland Basin and of the LB-2 unit in the Lofoten Basin (rising sea level). The sediment section acquired from well 345 does not contain Late and Middle Miocene deposits (4–13 Ma). Considering that well 345 was drilled at the foot of the Mohns Ridge, it well may be that this sedimentation gap could have been due to the sedimentary deposits sliding down from the ridge slope during Middle and Late Miocene time [Kharin and Emelianov, 1987].

Conclusions

Our studies of linear horst features (MSs L1 through L6) revealed their phenomenal nature. Their positions as seen in map view from south to north show an echelon arrangement. The following patterns are observed: (1) the depths of highs increase northward; (2) the relative amplitudes of the highs decrease from south to north; (3) the distances between the ridges of the highs remain comparable, with the average being 25 km.

The study of lateral peculiarities in seafloor relief along regional lines of measurement showed that the relief has a blocky structure. The relief has a staircase character along Leg R2. The steps successively become lower from the Jan Mayen transform fault toward the Greenland Fracture Zone.

The rift valley contains deep transverse depressions that divide the ridge into blocks. The focal mechanisms of earthquakes occurring in these depressions suggest a normal-oblique character of tectonic movements.

Our seismostratigraphic analysis of seismic time sections for the region showed the following:

1. The linear MSs L1 through L6 as identified in seafloor relief are features of the acoustic basement that underlies the Cenozoic sedimentary cover; their formation occurred after the origination of the GB-2 sedimentary unit;
2. the young (post-Quaternary) tectonic movements within the Greenland continental slope experienced normal-sense movements reaching 800 m;
3. the interface of unconformity between GB-1 and GB-2, LB-1 and LB-2 is regional, quasi-synchronous, and

was formed during the Middle Miocene tectonic rearrangement of the region, when a change in the character and conditions of sedimentation occurred.

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