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GEOLOGY

Sedimentary Cover and Bouguer Anomalies in the Northern Part of the Knipovich Ridge

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The sea floor Knipovich ridge is the northern termination of the Mid-Atlantic Ridge (MAR). It stretches in the submeridional direction from 73°30′ to 78°0′ northern latitude (see inset in Fig. 1) and is located between the Mohns Ridge in the south and the Molloy fault in the north. It has been suggested that the current location of the ridge is determined by migration of the spreading axis. Accretion of this spreading segment of the MAR started in the Late Eocene–Early Oligocene (34 million years ago) [1], while rifting at the present location of the ridge may have started in the Quaternary period [2]. The Knipovich ridge is an ultraslow spreading ridge according to [3], and the rate of spreading varies from 0.1 cm/year on the eastern side to 0.7 cm/year on the western side. Most researchers believe that the direction of spreading is not perpendicular, but at some angle to the modern ridge axis. The side edges of the rift valley developed asymmetrically. Linear anomalies typical of other segments of the MAR are not recognized near the Knipovich ridge. It is a structure crossing narrow magnetic anomalies under an angle of about 40°. All the described peculiarities of the ridge show it as an interesting tectonic body. Description of the development and formation of the ridge allows one to extend considerably knowledge of the geological structure and evolution of the Norway–Greenland basin.

This work is based on the results of studies carried out by the Institute of Geology, Russian Academy of Sciences, and the Norway Petroleum Directorate during the 24th cruise of the R/V *Akademik Nikolaj Strakhov* [4] (supervisor of the expedition A.V. Zaionchek). In the course of the expedition, a detailed bathymetric survey was carried out over the northern part of the Knipovich ridge and 56 seismic lines were surveyed by the method of continuous seismic profiling (CSP) and high frequency profiling (HFP) (Fig. 1). Earlier in [5], the results of processing these data were described. In the present paper, these results are considerably supplemented.

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The CSP method implemented in R/V *Akademik Nikolaj Strakhov* (chief geophysicist V.N. Efimov) was used to obtain reconnaissance data on the structure of the upper part of the sedimentary cover with resolution from 20 m to 40 m at a frequency range from 20 to 200 Hz and sedimentary penetration of about 1000 ms, on average, under forward motion of the vessels at speed of 7–12 knots. At practically every seismic survey line, the acoustic basement was detected; in the area of MAR, it was the top of the basalt layer. Based on the results CSP data interpretation of the 24th cruise of R/V *Akademik Nikolaj Strakhov,* a detailed map of the acoustic basement of the northern part of the Knipovich ridge (Fig. 2a) and a map of thicknesses of the sedimentary cover of this region (Fig. 2b) [5] were calculated. The latter is a result of subtracting of structural surface value of the acoustic basement from the level of the bottom topography derived from the data of the multiple-beam sounder by K.O. Dobrolyubova, A.S. Abramova, Yu.A. Zaraiskaya, Yu.E. Baramykov, and A.S. Ponomarev.

The obtained values for topography and the sedimentary cover allowed us to calculate the Bouguer anomalies for this region taking into consideration the results of extra bathymetric terrain survey relative to free air gravity anomalies [6]. The Bouguer anomaly is the main primary gravimetrical material used in geological interpretation of the Earth's gravitation field, and it mainly reflects the influence of density heterogeneities in the lithosphere including anomalies of deep density boundaries [7]. Adjustments for the water layer and sedimentary layer were calculated based on the topography [6] and according to thicknesses of the sedimentary cover with a linear velocity model. With the adjustments applied to the values of the free air gravity anomalies, the map of Bouguer anomalies was calculated for the northern part of the Knipovich ridge (Fig. 2c).

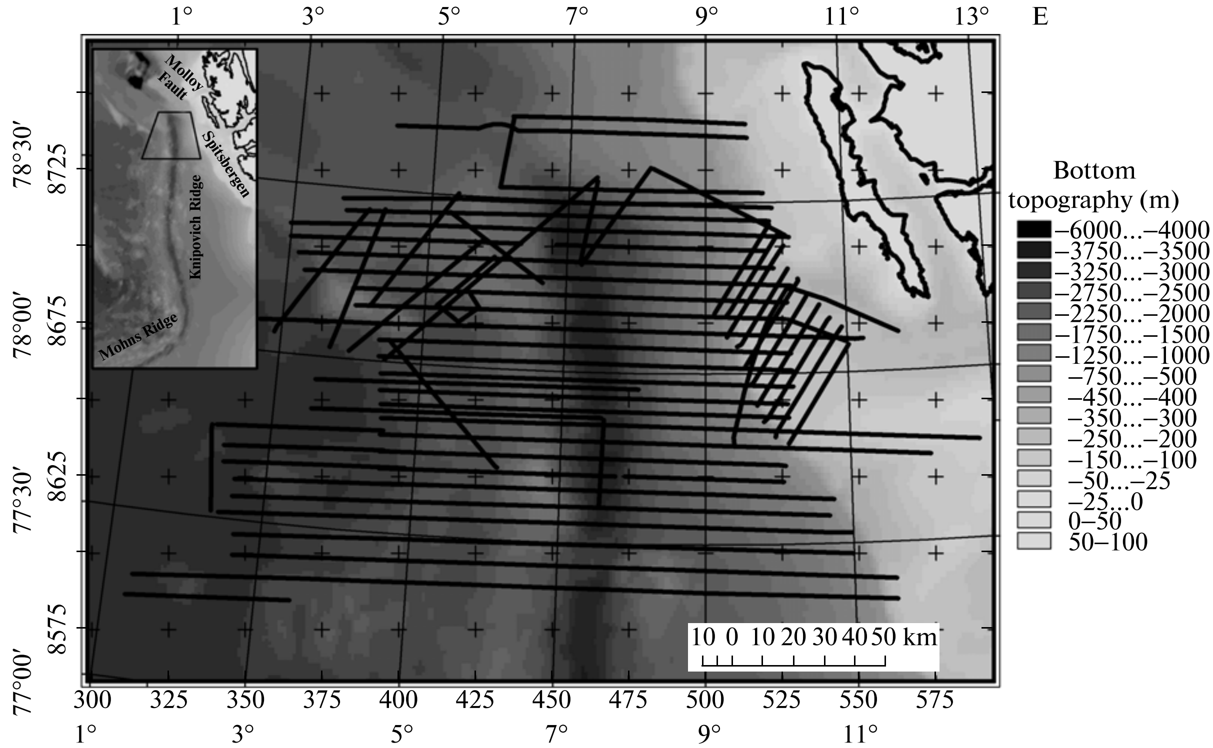

Fig. 1. Area surveyed in the 24th cruise of R/V *Akademik Nikolaj Strakhov* and the location of seismic survey lines. Geographic coordinates WGS84, projection coordinates UTM32 (thousands of meters).

The results obtained based on the actual data and calculations can be divided into two groups: results of analyzing maps of the acoustic basement and thicknesses of the sedimentary cover and the result of analyzing the map of Bouguer anomalies. The peculiarities revealed are outlined in the map of the bottom topography (Fig. 3).

The elongated zones of sedimentary occurrences with a thickness of 600 m parallel to the axis of the ridge are outlined on the map of sedimentary cover thicknesses. The sizes of these zones in the longitudinal direction are ~20–25 km, and in the latitudinal direction, they are ~5 km. They are outlined in pairs symmetrical relative to the axis of the ridge. In total, 3 pairs are outlined along the studied area of the Knipovich ridge. These zones occurred from an avalanche-like filling of the basin with sediments under ultra slow spreading. Compartmentalization of these sedimentary areas can be explained by transform faulted zones of the northwestern strike across the axis of the ridge.

Usually at the distance from axis of the MAR, an increased thickness of sediments is observed; for the Knipovich ridge, this relation is absent. Eastwards of the axis of the ridge, the thickness increases in the direction of the shelf, and westwards it remains constant. This can be explained by the fact that the studied spreading segment is located entirely in the discharge zone of sediments coming from the east. In the modern trough of the Knipovich ridge rift valley on the western and eastern borders, normal faults that shift units covered with sedimentary material with a thickness of up to 500 m (see Fig. 3) are recognized. Based on this and the configuration of the magnetic field [2], we made a conclusion that the modern stretching zone on the Knipovich ridge was formed over the spreading basalt substrate covered with a weakly consolidated [4] sedimentary cover.

In the map of the acoustic basement (Fig. 2a), a trough in the southern part of the surveyed area (Fig. 3) is outlined located to the west of the ridge. Its length is 40 km, and the width is about 20 km. The trough is entirely filled with sediments and is practically not manifested in the bottom topography. The thickness of the sedimentary cover reaches 1000 m. In [8] it is assumed that here a paleorift zone of submeridianal orientation was located. In [2] based on the orientation of linear segments of the anomalous magnetic field and its intensity, the conclusion is made that the paleorift had an azimuth of 40°. The fact that the orientation of the submeridional swell at its margins, recognized by the acoustic basement (Fig. 2a), has an azimuth similar to the Knipovich ridge but not with linear magnetic anomalies, is an interesting peculiarity of the western border.

In the western part of the survey area, over the basement a strike-slip deformation in the southwestern direction is observed. It starts near the Molloy fault

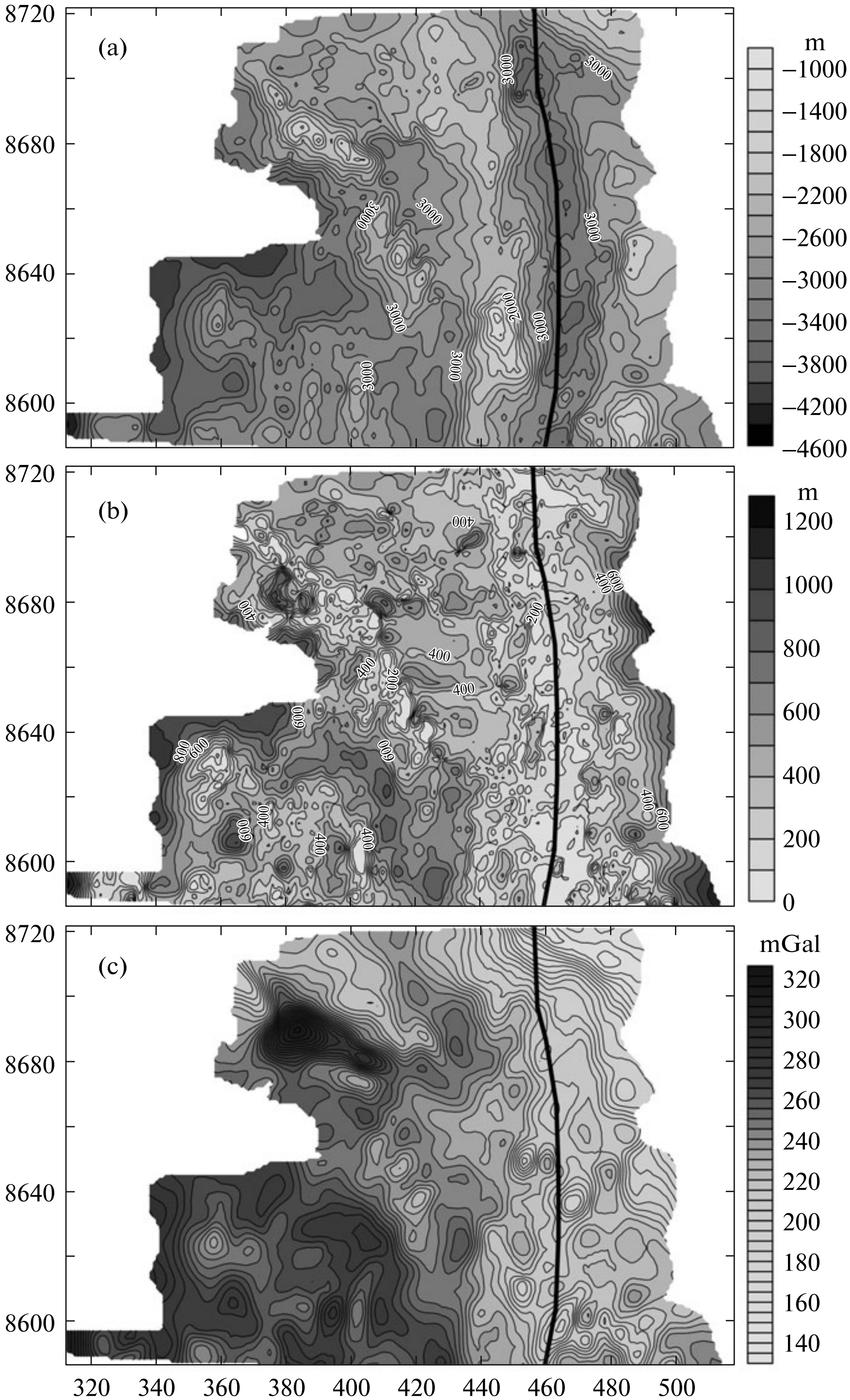

Fig. 2. Acoustic basement map (a), thickness of the sedimentary cover (b) and Bouguer anomalies with sedimentary cover additional reduction (c). The line shows the axis of the Knipovich Ridge. Coordinates UTM32 (thousands of meters).

zone with the basin at the end in the southwestern part of the survey area, which is probably a nodal paleodeep. The length of the deformation is ~90 km, and the amplitude is ~15 km. Along the deformation a swell of southwestern strike with an amplitude of 300–400 m is outlined. The basin at the end of the deformation is clearly outlines in the acoustic basement. In the topography of the bottom, it is not observed practically. Sediments in the trough are about 1000 m thick.

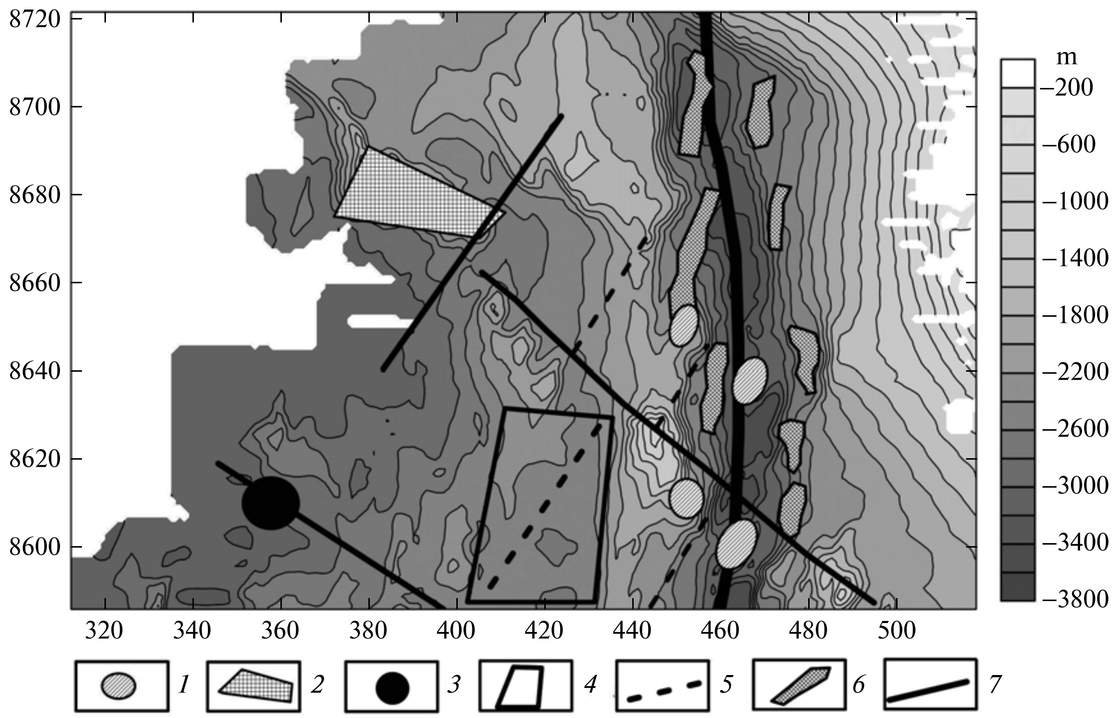

Fig. 3. Map of the topography of the area surveyed during the 24th cruise of R/V *Akademik Nikolaj Strakhov* (coordinates UTM32, thousands of meters) with features drawn schematically: (*1*) is a strong negative Bouguer anomaly, (*2*) is strong positive Bouguer anomaly, (*3*) is nodal paleodeep, (*4*) the trough outlined in the acoustic basement, (*5*) is expected location of the paleospreading axis, (*6*) are zones of near-side normal faults with sediments, (*7*) is expected transform faults and strike-slip deformation.

In the map of Bouguer anomalies in the area of the Knipovich ridge (Fig. 2c), there are paired negative anomalies of the gravity field (here and further, anomalies are values that differ strongly from the background value, to the greater side are positive anomalies, to the smaller side are negative anomalies). These anomalies are nonsymmetrical relative to the ridge axis. Based on their location and the orientation of linear segments of the anomalous magnetic field after processing [2], the axis of the paleospreading must have deviated from the submeridional position of the ridge by 45° in the northwestern direction and is adjacent to pair anomalies in the center between them. This is one of the ways of interpreting the location of the axis of the paleospreading shown in Fig. 3 by two dashed lines, adjacent to the Knipovich ridge between pair anomalies. In these segments, spreading occurs perpendicular to their center and under an angle of 45° to the fixed axis of the ridge. Transform faults must be located between segments, and they are also shown in Fig. 3. These faults are traced along the sequence of positive and negative Bouguer anomalies of the northwestern orientation. Another way of interpreting the position of the paleospreading axes is shown by two segments located further to the west in Fig. 3. This location is in accordance with the intensity of the anomalous magnetic field. In this case, segments of the paleoaxis are located in the center between other pair groups of anomalies along the expected transform fault. In any variant of the interpretation, spreading under an angle of 45° is excluded.

The field of Bouguer anomalies in the southwestern part of the survey area has a complex structure. Formation of the field configuration can be connected to the influence of the modern rift of the Knipovich ridge and paleo-tectonic processes. As was described above, spreading could occur here with the geometry of MAR structures tied to the nodal paleodeep (Fig. 3) until axis migration.

A strong positive anomaly is outlined around Hovgaard mountain. The anomaly has the form of a triangle in the layout. This high value of the Bouguer anomaly is typical of a thick oceanic crust formed as result of intensive extrusion of the magmatic substance and increased thickness of lower structural elements. Based on values of anomaly gravity field here, the area of the oceanic crust with a very thick basalt layer is located. These anomalies are found at the borders of the continental shelf and are formed during the beginning of ocean opening. If this anomaly was formed at the moment of beginning of activation of the MAR segment near the Knipovich ridge, then it may have a pair symmetrical relative to the ridge axis. On the available maps of anomalies of the gravity field and anomalous magnetic field, the pair analogue is traced.

Thus, we can make the following conclusions:

(1) We outlined lowered normal faults symmetrical relative to the ridge axis with sedimentary bodies with a thickness of up to 500 m, which shows that stretching along the Knipovich ridge occurred over the basalt spreading substrate covered with a weakly consolidated sedimentary cover that was formed earlier. Compartmentalization of these sedimentary areas can be explained by presence of faulted zones across the ridge axis.

(2) A trend of increased thickness of the sedimentary cover westwards toward the Knipovich ridge is absent.

(3) In the western part of the survey area, a strike-slip deformation of southwestern orientation is recognized, which is observed in the acoustic basement. To the southwest the disturbance ended with the nodal basin.

(4) A trough in the acoustic basement filled with sediments with a thickness of up to 1000 m is outlined, and it is not observed in the bottom topography where the axis of the paleo-spreading might be located.

(5) The Bouguer pair negative anomalies in the area of the ridge axis are outlined. They are nonsymmetrical relative to the axis. Their location is explained by stretching in these segments in a direction of about 45° to the fixed orientation of pairs.

(6) The field of the Bouguer anomaly in the southwestern part of the survey area has a complex structure reflecting paleo-tectonic processes in this region that took place before the jump of the spreading axis.

(7) The strong, positive Bouguer anomaly that is outlined around Hovgaard shows that here are located an area of the oceanic crust with a thick basalt layer and more, deeper layers of the oceanic crust.

The results of the studies carried out give new data on the structure of the Knipovich ridge and its sides. The maps of the surface of the acoustic basement, thicknesses of sediments, and the map of the Bouguer anomalies give extended grounds for production of further historical and tectonic and geodynamic maps relative to the Knipovich ridge.

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REFERENCES

1. V. V. Verba, G. P. Avetisov, L. E. Sholpo, and T. V. Stepanova, Ros. Zhurn. Nauk O Zemle **2** (4), 3–13 (2000).
2. S. Yu. Sokolov, Dokl. Akad. Nauk **437** (3), 378–383 (2011).
3. K. Crane, S. Doss, P. Vogt, et al., Mar. Geophys. Res. **22**, 153–205 (2001).
4. A. V. Zaionchek, Kh. Brekke, S. Yu. Sokolov, et al., *The Structure and History of Lithosphere Evolution. Contribution of Russia to the International Polar Year* (Paulsen, Moscow, 2010), Vol. 4 [in Russian].
5. K. P. Yampol'skiy, Geotektonika, No. 2, 17–31 (2011).
6. D. T. Sandwell and W. H. F. Smith, J. Geophys. Res. **114**, B01411 (2009).
7. Geophysical Research Technique, Ed. by N.I. Seliverstova (KPGU, Petropavlovsk-Kamchatskii, 2004), pp. 61–86 [in Russian].
8. A. A. Peive and N. P. Chamov, Geotektonika, No. 1, 38–57 (2008).