ISSN 1028-334X, Doklady Earth Sciences, 2018, Vol. 482, Part 2, pp. 1288–1292. © Pleiades Publishing, Ltd., 2018.
Original Russian Text © E.V. Shipilov, S.I. Shkarubo, L.I. Lobkovskiy, 2018, published in Doklady Akademii Nauk, 2018, Vol. 482, No. 5.

GEOLOGY

Middle–Late Paleozoic Duplex Rifting of the Barents Continental Margin and the Role Played in Formation of the East Barents Megabasin

E. V. Shipilov[a,*], S. I. Shkarubo[b], and Corresponding Member of the RAS L. I. Lobkovskiy[c]

Received January 25, 2018

Abstract—Based on analysis and interpretation of seismic and other geological-geophysical data, duplex rifting is identified in the Paleozoic evolution of the South Barents Basin. Its first, pre–Late Devonian, phase was manifested on the southeastern side zone that limited the Pechora Plate structures. After a certain pause, a second, pre–Late Carboniferous phase involved the western Barents Sea region, including the slope of the Central Barents Rise and the western South Barents Basin. Thus, Late Paleozoic riftogenic structures in the western and southeastern South Barents Basin formed at different times. All this caused an asymmetric structure profile and asynchronicity of evolution of the rift system sides. In the Mesozoic, under the effect of formation of the Novaya Zemlya fold-and-thrust structure, the asymmetry of the riftogenic trough became even more contrasting.

DOI: 10.1134/S1028334X18100173

One of the problems of tectonics and geodynamics is the development and validation by modern geological and geophysical data of the formation and evolution models of superdeep sedimentary basins; in the Arctic these basins are represented by, first of all, the East Barents Megabasin with its large and even giant hydrocarbon reserves [5, 10].

Within the limits of the continental margins framing the deep part of the Arctic, three deepest riftogenic sedimentary megabasins evolved: Sverdrup (Canada Arctic Archipelago), North Chukchi, and East Barents. The thickness of the sedimentary cover in the Sverdrup Megabasin is 12–14 km; in the other two, it is up to 18–22 km. In the general plan view, depocenters of these megabasins are subparallel to each other. They are located either within the Caledonian–Ellesmerian belts (their branches) or in the zones of their influence.

In the East Barents Megabasin, comprehensive geological–geophysical studies have revealed the contours of the paleorift (trough) system consisting of depressions (basins and troughs) of 14–20 km deep in the basement surface [5, 10, 11, 15]—South Barents, North Barents, North Novaya Zemlya, and St. Anna—divided by saddles (Figs. 1, 2). In the cross sections, the western sides of these depressions are gentler than the eastern ones. Remarkably, most of the sedimentary–volcanogenic filling (up to 10–14 km thick) of these basins, with the paleorift sequence at the base, is composed of Late Permian–Mesozoic terrigenous deposits. Among the rocks underlying this terrigenous sequence, Permian–Carboniferous and Late Devonian complexes can be more or less reliably identified. However, the age and origin of this quite thick and extensive sequence in the megabasin remain debatable even now (see [4–6, 10] and others). The ambiguity of the age and origin interpretations is caused by the fact that stratigraphic constraints of reflectors in older complexes are problematic due to their deeper occurrence and absence of continuous correlation of seismic data.

Note that the Middle–Late Paleozoic riftogenic structures, as is shown by the investigations, are quite widespread in the Barents continental margin. On Svalbard, the large West Svalbard graben was formed from the Devonian until the Middle Carboniferous. The main extension and graben-formation phase after the Svalbard folding corresponded to the Bashkirian stage. The largest Late Paleozoic unconformity on Bear Island, western Barents Sea, refers to the Serpukhovian–Bashkirian time (324 Ma BP) and is explained by rift activation in the adjacent areas [13, 14].

The stages of rifting evolution of almost all large troughs and basins in the western Barents Sea, includ-

[a] *Polar Geophysical Institute, Kola Science Center, Russian Academy of Sciences, Murmansk, 183010 Russia*
[b] *Marine Arctic Geological Expedition, Murmansk, 183038 Russia*
[c] *Shirshov Institute of Oceanology, Russian Academy of Sciences, Moscow, 117218 Russia*
**e-mail: shipilov@pgi.ru*

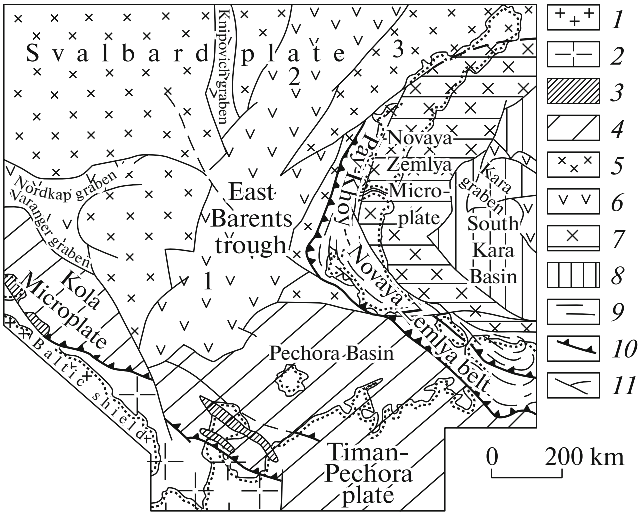

Fig. 1. Tectonic scheme of the southeastern Barents continental margin and adjacent area, after [5] with modifications. Numerals: 1, South Barents Basin; 2, North Barents Basin; 3, Admiralty Arch. Arbitrary notes: (*1*) basement of the Baltic Shield; (*2*) Proterozoic basement of the East European Craton; (*3*) Riphean–Vendian folded complexes; (*4*) epi-Baikalian plates; (*5*) epi-Grenville plate; (*6*) troughs and grabens of various ages; (*7*) epi-Grenville plate involved in Kimmeridgian dislocations; (*8*) epi-Herzynian plate; (*9*) Early Kimmeridgian folded structures; (*10*) thrusts; (*11*) normal faults and strike-slip faults.

ing such salt-bearing ones as Nordkap, Tiddli (Varanger) (Fig. 1), and others, occurred in the Late Devonian and Early–Middle Carboniferous. After them, in the period from the Late Carboniferous to the Late Permian, the platform regime took place in the western Barents Sea, with formation of a vast carbonate shelf.

In the eastern part of the region, on Novaya Zemlya, a riftogenic trough formed in the Middle–Late Devonian; it was most likely part of the East Barents paleotrough system, but was inverted at the turn of the Triassic and Jurassic resulting from fold-and-thrust processes [5, 11].

In the Pechora Plate and its subaerial continuation, rift activation ended in the Late Devonian [5].

At present, the most common opinion is that the rifting time in the eastern Barents Sea took place in the pre–Late Frasnian. Evidence for this view is traditionally based on seismostratigraphic extrapolation of the Pechora Plate reference seismic horizons into the limits of the South Barents Basin, with the respective correlations of tectonic events. However, the manifestation time is expanded to the entire region without any changes, despite the uncertain correlation of Paleozoic horizons in the axial zone of the East Barents Megabasin, especially below the horizon Ia (Lower Permian carbonates), which is the oldest among the drilling-proven ones and only in the Admiralty Arch

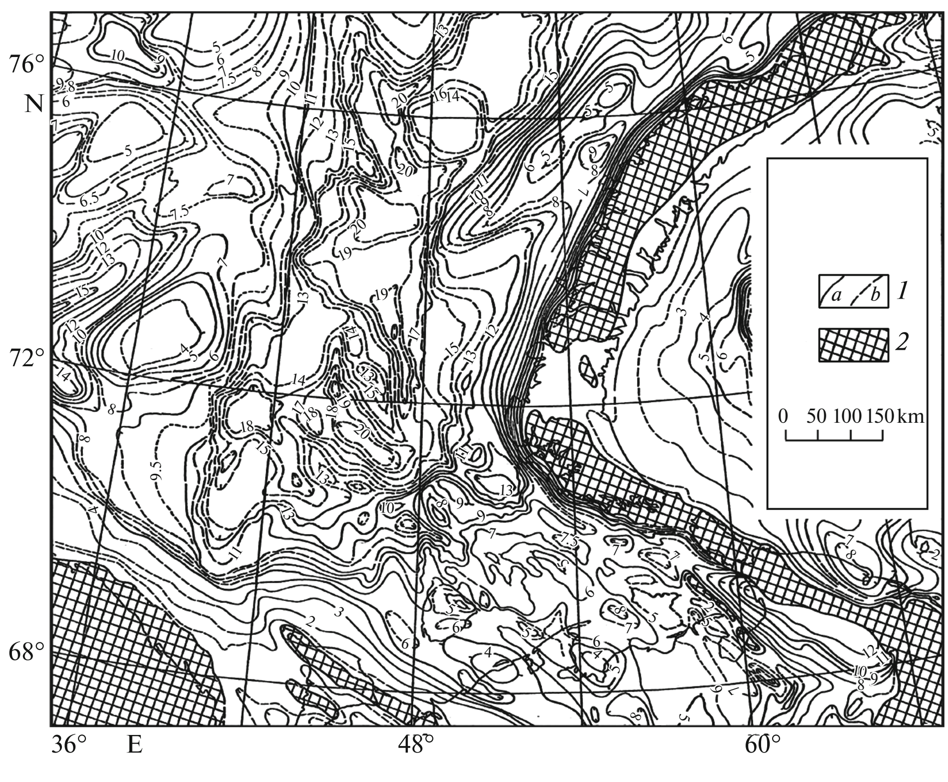

Fig. 2. Scheme of isohypses of the sedimentary cover base; (*1*) isohypses (km): (*a*) principal, (*b*) additional; (*2*) outcrops of the folded and crystalline basements.

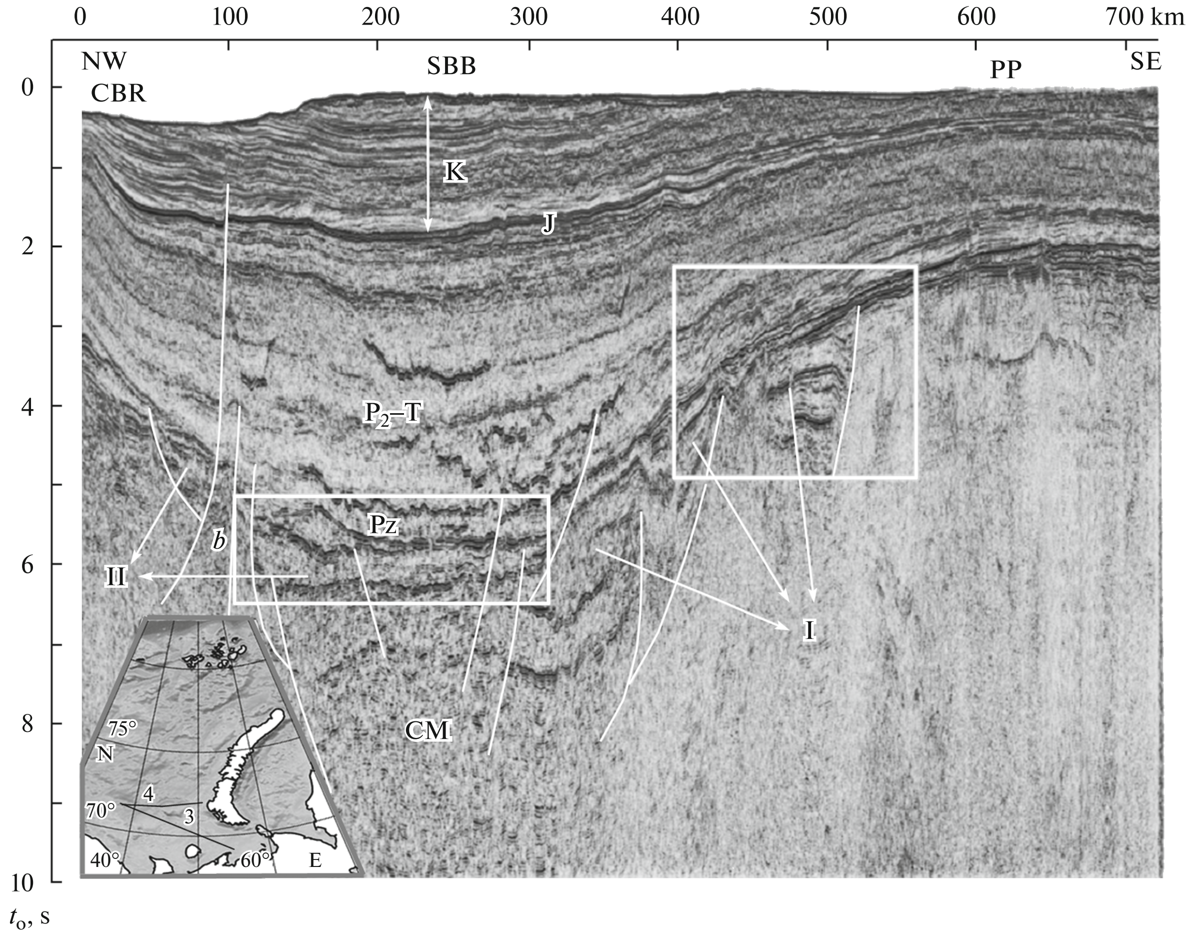

Fig. 3. Deep seismic section along the RB4190 profile (by the Marine Arctic Geological Expedition, Murmansk), illustrating the structure of the South Barents Basin (SBB) and the character of its junction with the Pechora Plate (PP) and Central Barents Rise (CBR). In the inset, the locations of sections are shown (numerals near lines denote figure numbers where these profiles are shown). Rectangles mark the most typical extension structures on sides of the SBB: semigrabens of (I) pre–Late Devonian and (II) pre–Late Carboniferous rifting phase; b means an intrusive body. In the Permian–Triassic complex and below it, in the Paleozoic complexes, multiple chaotic anomalous reflectors caused by basaltoid sills can be seen. The consolidated crust in the axial zone is represented by the crustal–mantle mixture (CM).

[10]. This is related to the screening of the seismic signal by basaltoid sills which are quite abundant in the Permian–Triassic and underlying parts of the sequence.

In this respect, proceeding from the general regional geological knowledge and visual assessment, in the seismic section of the South Barents Basin, we can distinguish three groups of anomalous seismic reflectors related to the remains of basaltoid magmatism (Figs. 3, 4).

The first group of anomalous reflectors is related to Late Devonian effusives, which occur mostly subhorizontally and in the lowermost parts of the section. Note that the Devonian magmatic province covers quite a large area, from the Kola Peninsula in the west to Novaya Zemlya inclusively in the east. Additionally, different geological–geophysical data indicate that magmatism of the East Barents trough system can be traced into the land (Kola Peninsula) along the so-called Kovdor–Khibiny–Ivanovskaya riftogenic zone [12], the magmatic activation of which refers to the Middle–Late Devonian [1], but might also include the Carboniferous time [12, 15].

The second group of chaotically arranged igneous bodies is distinguished in the middle part of the sequence filling the South Barents Basin and, judging from all the data, corresponds to the age of the Korotaikha trough basaltoids (Permian–Triassic boundary). This is also supported by the presence of tufogenic interbeds and horizons in terrigenous deposits of the Upper Permian and Lower Triassic in rock outcrops of peninsulas at the western end of Novaya Zemlya (Shadrovskaya Formation) and in the Admiralteiskaya hole (Admiralteiskaya Formation).

The second group of chaotic sills (uppermost Triassic complex) and dikes correlates in terms of abso-

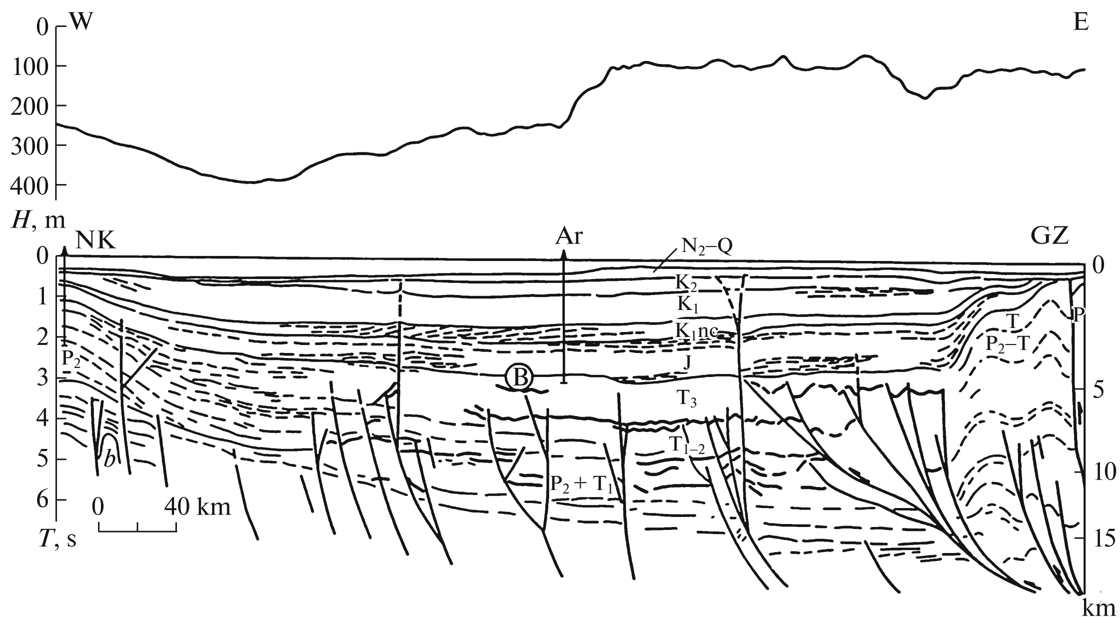

Fig. 4. Sublatitudinal seismogeological section along the 038702 profile, illustrating the asymmetry of sides of the South Barents Basin. The curve above the section is the bottom topography; solid thick lines, igneous intrusions (sills). Boreholes: NK, North Kil'din; Ar, Arkticheskaya. GZ means Gusinozemel'skaya zone of the Fore-Novaya Zemlya dislocation system; *b*, intrusive body.

lute dates to the Jurassic–Cretaceous stage of magmatism, which is manifested in the most widespread manner and most clearly in the Barents Sea region that formed the basaltoid province of the same name [3].

The junction zone between the Pechora Plate and thte South Barents Basin (southeastern side of the paleorift) is the only place where the most typical seismic sections were obtained [5, 10, 15]; these sections contain high-amplitude listric normal faults and rotational blocks verifying the rifting nature of the East Barents system and characterizing the rifting time as pre–Late Frasnian. There were no fault-block structures identified on the western side of the paleorift.

Stratification of the reference reflectors in seismic sections characterizing the western side of the rift system is based on comparison with the seismic data on the adjacent, Norwegian sector of the Barents Sea supported by drilling data from the Finnmark Platform [10, 13, 14]. Taking into account the data on the Norwegian offshore zone, the age of reflectors in the lower part of the western South Barents Basin sedimentary cover has been revised and become younger [10, 13]. This, in turn, caused changes in the chronological dating of tectonic events, in particular, the age of Paleozoic rifting. As a result, within the limits of the western side zone of the basin considered (including the slope of the Central Barents Rise), the age of riftogenic graben formation was estimated at the Early Carboniferous–Bashkirian. In the most active near-fault zones, this process probably continued up until the Permian. A similar pattern is characteristic of the deepest part of the South Barents trough system. These events are synchronous with the extension and graben-formation stages in the Norwegian offshore zone, the North Sea, southern England, and in the Sverdrup Megabasin, Canada (Dinantian and Stephanian phases corresponding to the Early Carboniferous and Kasimovian–Gzhelian time, respectively).

The above information is reflected in the deep seismic section shown (Fig. 3) depicting the system of listric faults in the junction zone between the Pechora Plate and South Barents Basin, where a series of large semigrabens had formed in the pre–Late Devonian phase of rifting. On the western side of the basin, we also identified the superimposed combination of semigrabens of different sizes: the largest of them includes the depocenter of the South Barents Basin and its syn-rift complex of Early Carboniferous–Bashkirian age superimposed on the structures of the earlier phase of crustal extension.

Thus, Late Paleozoic riftogenic structures in the western and southeastern South Barents Basin are not coeval in terms of the time of formation: they are mainly pre–Late Carboniferous and pre–Late Devonian, respectively. It is obvious that the pre–Late Devonian rifting initiated the formation of the South Barents Basin, and its manifestation intensity was emphasized by the extent of the accompanying magmatism. All this caused the asymmetric profile and asynchronicity of evolution of the side zones of the rift system. In the Mesozoic, under the effect of formation of the Novaya Zemlya fold-and-thrust structure (Fig. 4) [5], and also in the Cenozoic, due to the foundation of oceanic spreading basins [7–9], the asymmetry of the riftogenic trough had become even more contrasting.

ACKNOWLEDGMENTS

This work was conducted within the framework of fulfilling the program ("Arctic") of the Russian Foundation for Basic Reaserach, project no. 18-05-70012.

REFERENCES

1. A. A. Arzamastsev, R. V. Veselovskiy, A. V. Travin, et al., Petrology **25** (1), 42–65 (2017).
2. G. S. Kazanin, S. I. Shkarubo, and V. A. Zhuravlev, in *Proc. Int. Workshop "State and Trends for Developing State Geological Mapping of the Russian Federation Territory and Its Continental Shelf* (Karpinsky Russ. Geol. Res. Inst., St. Petersburg, 2015) [in Russian].
3. Yu. V. Karyakin and E. V. Shipilov, Dokl. Earth Sci. **425** (2), 260–263 (2009).
4. M. V. Korotaev, A. M. Nikishin, E. V. Shipilov, et al., Dokl. Earth Sci. A **359** (3), 364–367 (1998).
5. V. I. Bogatskii, N. A. Bogdanov, S. L. Kostyuchenko, B. V. Senin, S. F. Sobolev, E. V. Shipilov, and V. E. Khain, *Explanatory Note for Tectonic Map of Barents Sea and Northern Part of European Russia 1 : 2 500 000* (Inst. Lithosphere Russ. Acad. Sci., Moscow, 1996).
6. V. I. Ustritskii, in *Proc. 42nd Tecton. Conf.* (Geos, Moscow, 2009), Vol. 2, pp. 253–256 [in Russian].
7. E. V. Shipilov, Dokl. Earth Sci. **402** (4), 529–533 (2005).
8. E. V. Shipilov, V. A. Tyuremnov, V. N. Glaznev, and V. A. Golubev, Dokl. Earth Sci. A **407** (2), 366–371 (2006).
9. E. V. Shipilov, S. I. Shkarubo, and Yu. N. Raznitsin, Dokl. Earth Sci. **410** (7), 1056–1061 (2006).
10. E. V. Shipilov and S. I. Shkarubo, *Current Issues of Geology and Tectonics of Sedimentary Basins of Eurasian-Arctic Continental Margin. Vol. 1. Lithologic- and Seismostratigraphic Complexes of Sedimentary Basins of the Barents-Kara Shelf* (Kola Sci. Center Russ. Acad. Sci., Apatity, 2010) [in Russian].
11. S. I. Shkarubo and E. V. Shipilov, Razved. Okhr. Nedr, No. 9, 32–47 (2007).
12. A. D. Shcheglov, V. N. Moskaleva, B. A. Markovskii, L. R. Kolbantsev, M. P. Orlova, and V. F. Smol'kin, *Magmatism and Metallogeny of Rift Systems of Eastern Part of Baltic Craton* (Nedra, St. Petersburg, 1993) [in Russian].
13. A. K. Bogolepov and E. V. Shipilov, in *Proc. EAGE 58th Conf. Techn. Exhibition* (Amsterdam, 1996), Vol. 2, A017.
14. R. H. Gabrielsen, R. B. Faerseth, L. N. Jensen, et al., *NPD-Bulletin* (*Oliedirektoratet, 1990*), Iss. 6.
15. *Lithospheric Structure of the Russian Barents Region,* Ed. by N. V. Sharov, F. P. Mitrofanov, M. L. Verba, and K. Gillen (Karelian Res. Center Russ. Acad. Sci., Petrozavodsk, 2005) [in Russian].

Translated by N. Astafiev