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GEOLOGY

Tectonic Setting and Geodynamic Nature of the Saint Anna Trough (Northern Barents–Kara Continental Margin)

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In terms of geographic position, the Saint Anna trough located east of Franz Josef Land serves as a boundary between the Barents and Kara seas. Its bottom topography represents a meridional graben-shaped depression extending over nearly 600 km from the northern end of Novaya Zemlya to the continental slope of the Nansen depression of the Eurasian oceanic basin (Fig. 1). The bottom of this structure is located at a depth of 300–600 m, and its width varies from 100 to 150 km. Thus, the Saint Anna trough is among the largest continental-margin troughs in the Arctic and can be compared with the Medvezhii trough in the western Barents Sea. Geophysical data indicate that the Saint Anna trough is underlain by a sedimentary basin composed of Paleozoic–Mesozoic sediments with a total thickness of more than 12 km (Fig. 2).

Although the Saint Anna trough has long ago attracted the attention of researchers, its genesis remains ambiguous. According to one concept, the trough has an exclusively exogenous origin related to the exaration activity of glaciers. According to the second (tectonic) concept, this trough is an element of the Barents–Kara platform related to the following processes: (a) the inheritance of ancient (almost Riphean) structures; (b) the development of the West Siberian rift system; (c) the evolution of a single system of the East Barents trough with a transformed continental or suboceanic crust; or (d) the opening of the Eurasian oceanic basin and, in particular, the influence of a transform fault of the Gakkel Ridge on the continental margin. However, none of these concepts can satisfy the available database. They can at best only reflect one of the episodes of complex evolution of the trough.

The present paper is based on the geotectonic interpretation of marine geological–geographical data with consideration of publications devoted to paleomagnetic investigations and isotope datings of rocks from the adjacent land and islands. We assume that the Saint Anna trough is a boundary structure located between the Svalbard and Kara plates. The consequent geodynamic implications of its origin are also discussed.

The northern part of the Barents–Kara Platform is a belt of marginal shelf rises. Their domes incorporate islands of the Spitsbergen Archipelago, Franz Josef Land, and Severnaya Zemlya, which are separated by prominent graben-shaped trenches (Franz-Victoria, Saint Anna, and Voronin). Structures of the platform are truncated in the west and north by flexure-shaped normal fault belts of continental slopes of the Norwegian–Greenland and Eurasian oceanic basins, respectively.

We believe that elucidation of the complex tectonic junction shown in Fig. 3 can provide insights into the evolution of tectonic and dynamic interrelations between continental cratons and microplates in the Arctic. Their collision promoted the accretion of lithospheric blocks into a new supercontinent (Pangea II) [6, 13], which included the Barents–Kara segment of the continental-margin platform, at the terminal Paleozoic–initial Mesozoic [6, 13]. The Saint Anna trough played a crucial role in the structure and evolution of this platform.

Let us discuss the main structural features of the Saint Anna trough and the arguments in favor of its interpretation as a boundary structure between the Svalbard and Kara plates.

The basement surface within the Kara plate has a complicated rugged topography with the deepest and highest zones located at 12–14 and 1–2 km, respectively. Analysis of the geological setting of the continental and insular framing, coupled with data on potential geophysical fields, makes it possible to extrapolate the basement structure of the Severnaya Zemlya and northern Taimyr regions into a significant area of the North Kara shelf. Thus, the study region can be considered a common plate with the pre-Riphean basement [3–5].

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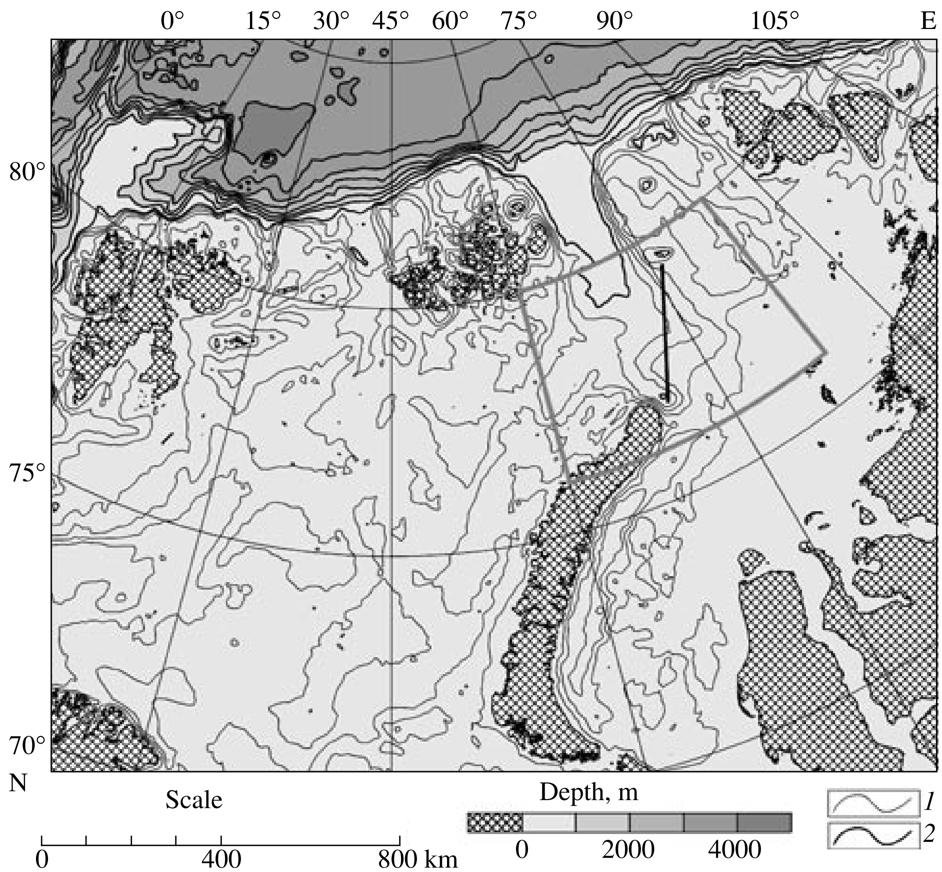

Fig. 1. Bathymetry of the Barents–Kara continental margin, location of the study region, and seismogeological profile across the southeastern Saint Anna trough. (*1*) Isobaths with a spacing of 100 m (up to the 500-m isobath); (*2*) isobaths with a spacing of 1000 m.

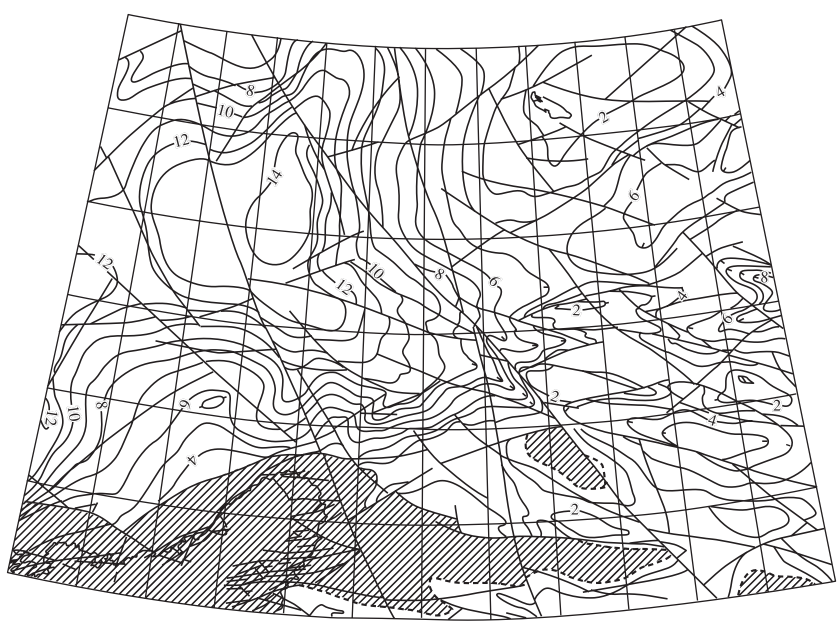

Fig. 2. Isohypses (km) of the bottom relief of the sedimentary cover of the Saint Anna trough and adjacent areas of the Svalbard and Kara plates (see Fig. 1 for the location). Sectors with Paleozoic folded complexes of Novaya Zemlya Archipelago and North Siberian sill are hatched.

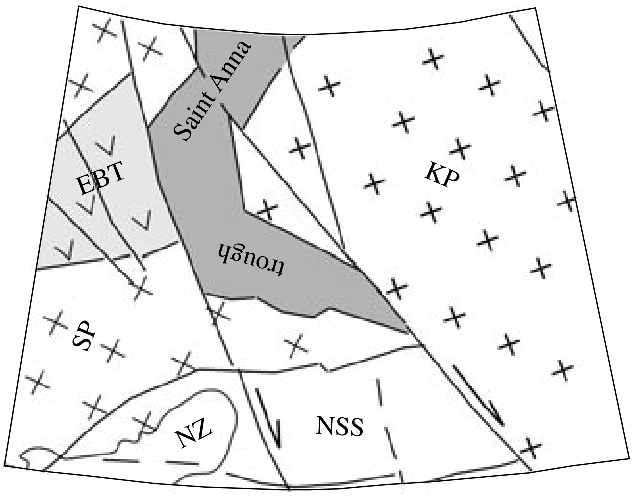

Fig. 3. Tectonic sketch of the Saint Anna trough (see Fig. 1 for location). (SP) Svalbard plate; (EBT) northeastern part of the North Barents trough; (NZ) Novaya Zemlya; (NSS) North Siberian sill; (KP) Kara plate.

Orientation of the main structural elements of the Kara plate is consistent with the strike of collisional belts and the major dextral strike-slip fault zones of the arcuate framing of the plate. The western extension of these elements is distinctly truncated by the meridional Saint Anna trough. The southeastern extension is marked by dextral strike-slip faults bounding the Kara plate in the south.

It should be emphasized that the Kara plate differs significantly from the adjacent regions in the map of geophysical fields. Therefore, this plate appears as an independent block with specific features of the internal structure. In the anomalous magnetic and gravity fields, the Kara plate is defined as an oval structure (~800 km across) with concentric-type zonality.

The sedimentary sequence of the Kara plate can be divided into two structural stages. The lower (probably, Riphean–Paleozoic) stage is composed of carbonate, evaporite, and terrigenous sediments. The upper (Mesozoic) sequence of the Kara plate consists of Triassic–Cretaceous sediments (no more than 2 km). These sediments unconformably overlie eroded rocks of various ages at the lower stage. However, if Triassic–Jurassic rocks are eroded on uplifts, they are covered only with a Cretaceous–Cenozoic sequence approximately 1 km thick.

The gravity field of the Kara plate is characterized by a lack of distinct confinement of positive or negative anomalies to a certain positive or negative structural element. This fact can probably indicate significant tectonic transformations of the regional lithosphere in the course of Phanerozoic evolution and, in particular, the presence of detachment surfaces in the consolidated crust.

The northeastern zone of the Svalbard plate and the adjacent North Barents basin are characterized by calm (generally, positive) low-gradient gravity fields similar to the anomaly field of the South Barents basin. The North Barents basin is bounded in the west and southeast by high-gradient zones. The walls of the basin have an asymmetric structure. The eastern wall is steeper and complicated by deep faults. In the northeast, the basin adjoins the Northern Novaya Zemlya basin via the Gorbov dam, which is expressed as an arcuate band of positive gravity anomalies extending from the northern end of Novaya Zemlya to Franz Josef Land. With respect to structure and thickness of the sedimentary sequence (15–18 km), the North Barents basin resembles the South Barents structure. However, the former basin is marked by a slightly reduced stratigraphic range of the sedimentary cover and a higher position of the anomalous reflector horizons due to the manifestation of the Jurassic–Cretaceous basic magmatism [7, 9, 10].

The Saint Anna trough, sandwiched between the Svalbard and Kara plates, is mainly characterized by a low-gradient positive gravity field with some patches of submeridional weak isometric negative anomalies.

Thus, the group of negative structures of various ages (the northeastern segment of the East Barents trough and the Saint Anna trough) make up a T-shaped junction in the plan view (Fig. 3). This interpretation of the tectonic setting makes it possible to outline new approaches for the reconstruction of the geological evolution of the study region.

The North Siberian sill represents a boundary tectonic element, which separates the Svalbard and Kara plates from the South Kara depression of the West Siberian basin [1]. The sill has an intricate morphology of the folded complex located beneath Quaternary sediments. In the south, the folded complex is overlain by Jurassic–Cretaceous and Cenozoic sediments of the South Kara basin. A narrow arcuate band of positive and negative anomalies of the gravity field indicates the sill that connects the northwestern part of Taimyr with Cape Zhelaniya and further extends to Franz Josef Land. Therefore, we can assume the development of a long fault zone of similar orientation and dextral strike-slip kinematics. Based on the CRWM data, the Earth's crust is 39–42 km thick in the sill region. Seismic profiles across the sill suggest the presence of Paleozoic rocks subjected to Cimmerian deformations. The sill is complicated by large dextral strike-slip and oblique thrust faults. The sedimentary cover of the Kara plate encounters folded complexes of the sill.

The total thickness of Paleozoic rocks of the Kara plate is much more than that of the overlying Mesozoic rocks. Such a relationship between the Paleozoic and Mesozoic rocks is also observed in the Timan–Pechora plate. However, the relationship is reverse in the eastern Svalbard plate (East Barents sill). It is interesting that the sedimentary cover is more than 12 km and that the volumes of the Paleozoic and Mesozoic rocks are approximately equal in the Saint Anna trough (Fig. 4).

Thus, the Saint Anna trough evolved in specific tectonogeodynamic settings according to the following scenario.

At the Middle–Late Paleozoic boundary, the Kara plate (probably together with certain blocks of the present-day uplifts in the central Arctic) encountered the Siberian Craton due to counterclockwise rotation. The initial phase of this process can be qualified not as collision but as sliding convergence of the Kara microcontinent with the Siberian Craton [12]. This geodynamic setting gave way to subduction marked by two (Late Carboniferous and Early Permian) generations of the collisional granitoid magmatism in northern Taimyr [2]. Thus, the subsequent dislocation of the Kara plate was virtually blocked and a relatively stable boundary of the Saint Anna basin was outlined in this time interval.

According to the existing concepts, the East Barents trough is supposed to have been formed at the Late Devonian–Carboniferous stage. (Versions of the geodynamic nature of this trough are not considered in the present paper.) Therefore, this trough already existed during the collision of the Kara plate with the Siberian Craton. Hence, the marginal northeastern segment of the East Barents trough was connected for some time with the narrow marine basin (prototype of the Saint Anna trough) via a continental-margin transform or strike-slip fault zone. The Saint Anna trough was located at that time between the Svalbard plate and the Kara plate moving relative to the former plate. This geodynamic setting was responsible for the T-shaped junction of the East Barents trough system and the Saint Anna trough. If this interpretation is correct, fragments of the oceanic crust can be retained beneath the Saint Anna basin.

The thickness of Upper Permian–Triassic rocks varies from 10–11 km in the East Barents megadepression [3, 7, 8] to approximately 3–4 km in the Saint Anna basin and <1 km in the Kara plate. Hence, precisely the Saint Anna trough converged and overlapped the East Barents trough system in the north at the Late Permian–Triassic stage. This interpretation also suggests a dramatic difference in the evolution style of the Kara plate relative to the Svalbard and West Siberian (South Kara basin) plates at the Late Permian–Triassic stage [1, 4, 8].

In the Jurassic–Cretaceous, the development of northern regions of the Barents–Kara margin was governed by the young (Amerasian) stage of ocean formation [9]. A very thick terrigenous sequence was accumulated in the Saint Anna basin and the depocenter of sedimentation was shifted to the west. In contrast, a thin sequence of Jurassic–Cretaceous sediments (no more than 1 km) was accumulated in the eastern (Kara plate) area. The Svalbard plate was occupied by large-scale bimodal basaltic magmatism at the Jurassic–Cretaceous stage. In the western area, this magmatism was manifested in Spitsbergen, Franz Josef Land, and the adjacent shelf. The available seismic profiles show that basaltic magmatism was also developed in the eastern Saint Anna basin area, but it was absent in the Kara plate region. The fact mentioned above is an additional specific feature of the Saint Anna basin.

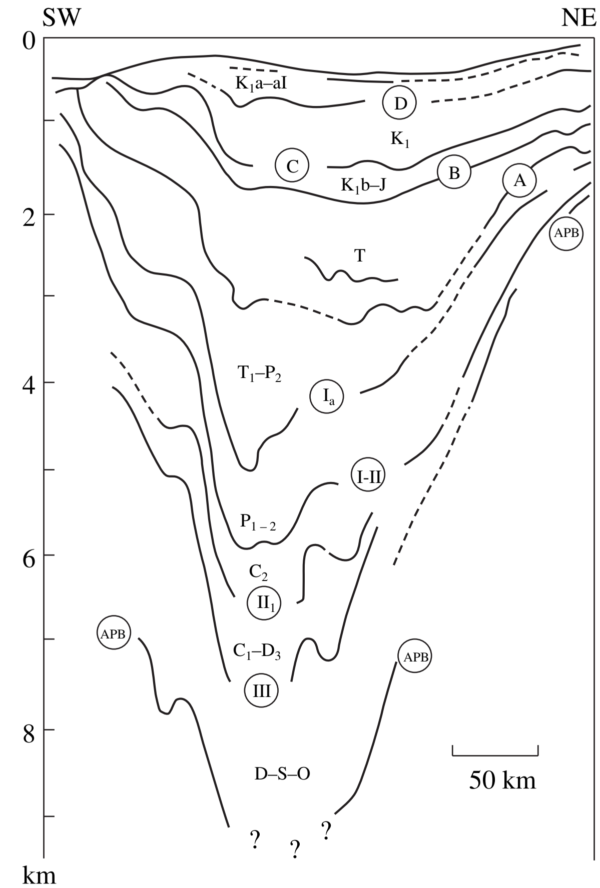

Fig. 4. Schematic seismogeological section across the southeastern Saint Anna trough (see Fig. 1 for location). Indices of the main seismic reflectors are given in circles. (APB) Archean–Proterozoic basement.

In the Cenozoic, the Saint Anna basin subsided, although the continental margin was uplifted and the Norwegian–Greenland and Eurasian oceanic basins of the spreading type were open [7, 11]. Only beginning with the Pliocene did the margin begin to subside gradually, and a transgressive environment prevailed in the region. The Saint Anna trough began to acquire the present-day configuration due to the reactivation of tectonic motions along strike-slip faults and fracture zones. Coupled with the subsided topography, these zones promoted the selective evolution of the bottom surface and the exaration activity of glaciers. The latter process was responsible for the present-day morphostructure of the Saint Anna trough. Seismoacoustic profiling data indicate that the eroded surface of Cretaceous rocks in this area is covered with a thin Quaternary sequence.

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