Influence of neotectonic processes on the transformation of geosystems of the Lena-Angara plateau

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Abstract. Addressing the issues of assessing and predicting environmental changes in regions is the basis of modern geographical research. It is based on identifying the direction of geosystem transformation consisting of a large number of variable components and their interconnections. The task is compounded by the need to study geosystems developing under climatic and geodynamic changes. The paper presents the research results of the transformation of geosystems of the Lena-Angara plateau, which is located on the southeastern outskirts of the Siberian Platform and is a pre-rift structure of the Baikal rift zone. The specificity of the spatiotemporal transformations of geosystems associated with the manifestation of neotectonic processes and climatic changes in the Late Cenozoic is revealed. It was determined that within the plateau there were four periods of irreversible transformations of geosystems caused by the synchronous manifestation of climatic and neotectonic processes. Changes resulted from neotectonic processes led to the formation of landscape boundaries coinciding with deep faults and blocks of the earth's crust.

1. Introduction
Addressing the issues of assessing and predicting environmental changes in regions is the basis of modern geographical research. It is based on identifying the direction of geosystem transformation developing under climatic and geodynamic changes. The generally accepted view is, that within the platforms, climate change and vegetation cover during the Cenozoic era were more significant than relief transformations. In this regard, climatic and geobotanical factors are leading in identifying the features of the transformation of geosystems. But research based on these factors is controversial, i.e. it is necessary to study the transformation of geosystem platforms located near centers of tectonic activity.

The study of the transformation of geosystems is of particular relevance for the Lena-Angara plateau region. It is widely viewed that its formation is the result of the influence of the Baikal Rift Zone (BRZ) on the outskirts of the Siberian Platform. Within the Lena-Angara plateau, previously mainly local or small-scale paleogeographic, neotectonic, geomorphological, geobotanical, and landscape studies were carried out. At the same time, the issue of influence of neotectonic processes on the transformation of geosystems received little attention.

2. Objects, data and methods
The object of study is the geosystems of the Lena-Angara plateau. The goal of the study is to identify the features of the geosystem transformation of the Lena-Angara plateau under the influence of BRZ. The research of the geosystems in the region is carried out using the informational synthesis of data.
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and knowledge about the territory, based on the results of perennial ground-based route research, methods of complex physical and geographical research, interpretation of satellite images, cartographic, and comparative geographical methods.

The Lena-Angara plateau is about 500 km long and about 300 km wide, located on the crystalline basement of the Siberian platform (figure 1).

![Figure 1. Location map of the Lena-Angara Plateau.](image)

3. Results and discussion

Long denudation against the background of stable elevations led to the development of a peculiar table-and-stepped relief within the plateau. The plateau is separated from the Prebaikalian depression by a steep ledge of up to 500 m high. The plateau is located within the Angarsk and Verkholenskii blocks of the Siberian platform foundation, which differ in age, rock composition, nature of the relief, manifestation activity of neotectonic processes, and the history of the geosystem development.

The Verkholenskii foundation block with an age of 3.3 billion years is located in the north of the research area. And the Angarsk block with an age of 1.7 billion years is located in the south of the territory. A tectonically active Zhigalovskii fault is on their border. Orographically, the plateau is divided into two almost equal parts, coinciding with the foundation blocks: the more elevated northern and the lower southern. The northern part of the plateau is characterized of development of mid-mountain ridge forms of relief and Ordovician rocks. The submeridian direction of the ridges coincides with the compression forces associated with the development of the BRZ. The relief is complicated by the uplift in the northeast of the plateau in the region of the upper reaches of the Orlinga river (1509 m). The depth of the erosion cut also increases in the northeast direction up to 1000 m in the Orlinga and Lena basins, which is associated with the uneven elevation of the plateau sections. The region is characterized by numerous rocky outcrops and steep slopes. Gravitational processes such as scree and landslides are widely developed. The southern part of the plateau is characterized mainly by a combination of flat table-shaped hills and ridges with heights from 400 to
1000 m and the development of Cambrian rocks. The relative excesses of summits over the bottoms of the valleys are 250-300 m (figure 2).

**Figure 2.** Structural elements of the foundation of the Siberian platform. Foundation blocks: I – Angarskii, II – Verkholenskii, III – Tungusskii. Faults: A – Sayano-Taimyrskii transregional; B – Baikal-Lenskii; C – Zhigalovskii; a – the BRZ extension axis based on [1-3].

**Figure 3.** Scheme of physical-geographical zoning of the plateau. I-III – provinces; 1-6 – countries. Black lines indicate faults. Detailed description is in the text.

The Sayan-Taimyrskii fault zone is weakly manifested in the spatial boundaries of geosystems due to its antiquity and inertness. At the same time, in the area of its intersection with the Zhigalovskii fault, a mass overthrust was formed, i.e. paraclase of rocks, which developed due to intense compression arising under the influence of the BRZ. This contributed to the formation of the most elevated part of the Lena-Angara plateau. The expansion of the BRZ in the north-west direction determines the increase in neotectonic activity within the northern Verkholenskii block of the earth's crust. Here, in faults we recorded thermal anomalies and groundwater, with the temperature 55°C at a depth of 90 m [4]. The intensive growth of the absolute altitudes in the northern part of the plateau in recent times is confirmed by the morphological features of the narrow erosion valleys of the Lena, Angara and their tributaries.

The Lena has a narrow valley here, reaching a depth of 700 m in the area of the mouth of the Orlinga river. In contrast, in the south, plateau valleys differ in considerable width, gentle slopes, wide development of boggy floodplains and low floodplain terraces. At present, the formation and development of the Lena-Angara plateau is considered as a result of the influence of the Baikal rift on the outskirts of the Siberian platform. It is argued that the impact of riftogenic processes affects the entire territory of the Lena-Angara plateau [1]. The plateau is characterized by a transitional regime of neotectonic development from platform to orogenic. The amplitudes of the differentiated latest tectonic movements reach 1000 m. The Lena-Angara plateau is assigned to the Baikal pre-rift transition zone.

In the Late Cenozoic, during the formation of modern geosystems, tectonic transformations occurred simultaneously with climatic changes and caused resonance phenomena and the
transformation of geosystems. Three stages of evolutionary changes in geosystems are clearly revealed.

In the analysis of subsequent transformations of geosystems consideration is given to the Paleogene stage as the initial one. The tectonic conditions of that stage were stable. Planation surface and weathering crust were formed on a relatively low denudation plateau in subtropical climate. At present, they are preserved in the region at absolute altitude of 400 to 1500 m. Current locations of Artemisia nitrosa, Nitraria sibirica, and others in the south of the plateau are relics of the ancient Mediterranean flora that prevailed at that stage.

Stage 1 - Neogene. During this period, a long planation is completed and the activation of tectonic movements associated with the initial stage of the formation of the BRZ begins. Hydrographic network have entrenched deeply up to 200 m. It is transformed, and as a result of this, the rivers form a single runoff of Baikal waters through the Great Manzurka to the Great Lena. In the south of the plateau, on the contrary, wide depressions are formed during this stage (Kyrminskaya, Murinskaya, Khogotskaya, etc.), which are currently drained by small rivers, the sizes of which do not correspond to the volume of the depressions [5]. The sedimentation nature changes from acidic to alkaline. Toward the end of the era, a temperate climate with seasonal differentiation is forming [6]. Orographic barriers exacerbate the climate change. Formations of pine forests with steppe vegetation are spread in the south; and in the north, the areas of coniferous forests (hemlock, fir and spruce) increase.

Stage 2 – is dedicated to the Eo-pleistocene–Pleistocene. It is marked by the activation of tectonic processes associated with the late rift (neo-Baikal) stage, which was accompanied by intensive uplift of the mountains surrounding the Baikal basin. The highland of the platform rose more slowly, therefore, its edge part was skewed. The territory of the plateau along the periphery was elevated 100 m and higher and is divided by a fault into northern and southern elevations. This stage is associated with the discontinuation of discharge from Baikal to the Lena. The formation of the mountains influenced the air circulation: the Siberian anticyclone became aggravated, the western and eastern transport of air masses weakened. The appearance and long-term preservation of snow cover is characteristic. During this period, in the north of the plateau, the transformation of nemoral dark coniferous forests into taiga dark coniferous forests was completed. In the south, the Altai-Baikal forest-steppe was formed. During the Sartan ice age, permafrost formed and the development of yerniks, which are now considered its relics, occurred [7-10].

Stage 3 – Holocene. This is the era of formation of modern geosystems. The Holocene was marked by the activation of tectonic processes. In the South of the territory dominated by pine-birch grass forests with fragments of steppes. Steppes spread to the North of the territory, which is associated with the deepening of river valleys and the formation of terraces. In the North of the plateau, a high-altitude belt is formed, loaches are formed and the area of cedar forests is expanding. In the conditions of barrier shade the area of larch-taiga forests is expanding. Modern landscape boundaries largely coincide with the blocks of the earth's crust and the direction of the main faults (figure 3).

The Figure 3 shows follows types of geosystems. Baikal-dzhugzhur mountain taiga area. I. Northren dark-coniferous taiga: 1 – Kuta-Lenskii with a gently rugged, wavy relief of cool and humid habitats, southern taiga fir-Siberian stone pine with larch and pine, blueberry-green-grass-green moss on red-colored rocks of Ordovician with island permafrost; 2 – Angara-Lenskii plateau strongly dissected contrasting habitats mountain taiga fir- Siberian stone pine subshrub-small grass-green moss on red-colored rocks of Ordovician with island permafrost; 3 – Orlingan most elevated, deeply dissected of humid and cold conditions, mountain-taiga Siberian stone pine with spruce subshrub-small grass-green moss at the summits of the watersheds in combination with mountain-taiga larch with an admixture of spruce and Siberian stone pine, subshrub-moss facies on the red-colored rocks of Ordovician with permafrost. II. Southern subtaiga: 4 – Tuturo-Anginskii low-mountainous of cool and humid conditions, subtaiga larch mixed with Siberian stone pine and spruce yernik on Cambrian terrigenous rocks with sparse islands of permafrost; 5 – Angara-Manzurskii of elevated plains of cool and humid conditions subtaiga pine-larch grass-shrub on Cambrian rocks with seasonally freezing
soils. III. Angarian forest-steppe: 6 – Angara upland-plain of humid and cool conditions south-taiga fir–Siberian stone pine grass-green moss on the rocks of Ordovician with island permafrost.

4. Conclusion
Currently, due to the development of the Baikal rift and the strengthening of the climate continentality, the process of differentiation of geosystems is undergoing further development: the replacement of dark coniferous-taiga types with light coniferous in the southern and western regions, the shift of Siberian stone pine’s stands to higher orographic levels, and the further development of subgoletz geosystems.

Thus, the spatiotemporal transformation of the geosystems of the research area is largely determined by the location at the junction of the Baikal rift zone and the Siberian platform. The northeastern part of the Lena-Angara plateau from the Pliocene experiences a significant uplift, which occurs simultaneously with the formation of the ridges bordering Lake Baikal. The faults formed in the ancient crystalline basement of the platform, recent intensive elevations of the territory determined the boundaries and modern transformations of geosystems.

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