

The organization of geosystems in southern East Siberia (research and mapping)

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Abstract. Knowledge of modern geosystems properties, regularities of their formation, and changes under the influence of natural and anthropogenic factors is the basis for the timely prediction of adverse events occurring during the change of environment. Abstract review of the individual components and static geosystems cannot bring substantive results in solving these problems. The situation is compounded by the need to study and mapping of regions geosystems, which are characterized by tectonic activity and intensive dynamic processes. Currently, when a significant of geophysical, geological data and landscapes virtually no development, dedicated to solving the problem of study geosystems such regions. Specificity of study is complex mapping geosystems, which are characteristic diverse genesis, different stages of development, in the synthesis of space and time into a single whole, the comparison of the current state of geosystems with the natural rhythms and patterns of development of the natural environment. These studies are a theoretical model of reality, synthesized information on the functioning, dynamics and evolution of geosystems, the direction of their transformation, as in changing natural and anthropogenic conditions. In development analysis of the future state of geosystems these studies have high scientific and practical value.

1. Introduction

One of the major targets of modern geographic research is to find a solution to regional environmental changes evaluating and prognosis and thus to accumulate scientific data background for regional management. That is why research is based on the studies of geosystems composition, functioning, dynamics and evolution. Such studies are vital due to the lack of information about the structure of the regional geosystems. The knowledge of geosystems development regularities, their dynamics and transformation changes that occur due to the influence of natural and anthropogenic factors is the base for prediction of negative phenomena that may occur as a result of both natural and anthropogenic environmental transformation.

2. The object for study and methods

The object of this research is the geosystems of the Central Ecological Zone (CEZ) of Lake Baikal and of the extensive territory of the Vitim river basin. The CEZ includes the lake itself, its islands, adjoining water protection zone and specially protected natural reservations. The CEZ matches the World Natural Heritage site "Lake Baikal". The total area of CEZ is 89165 km², including the water area of the lake – 31500 km² and 24 950 km² of specially protected natural reservations. The area, occupied by water protection zone outside the natural reservations within the borders of CEZ equals to



20500 km². Lake Baikal is visited by a huge number of tourists from China and Mongolia and other countries. Based on this study, the most unfavorable areas for recreation and other anthropogenic activities.

The Vitim flows across the Stanovoi and Vitim Uplands and the margin of the Patom Upland. The study area refers to the Sayan-Baikal Stanovoi high mountains whose territory is encompassed by intense modern orogenesis and rifting. The region is characterized by an active reconfiguration of the river network, incessant mountain glaciations since the Pleistocene, and by a high pace and diversity of relief forming processes [1]. The area is a promising source for extraction of gold, uranium, copper and other resources. Also, the landscape structure is experiencing transformation. In addition to natural geosystems, their anthropogenic modifications are of widespread occurrence here. In this area there is a single transport system of Siberia. This is the area where the Transsib and Baikal-Amur railway pass. The Power of Siberia gas pipeline will pass through this territory. Knowledge of the landscape features of the territory will enable the safe development of natural resources of the territory.

Landscape research is based on the results of long-term studies of Siberian geosystems, terrestrial and aerial itinerary studies, interpretation of satellite images and literature data analyses. The work was supported by the Russian Fundamental Research Fund. Methodology geosystem study associated with the implementation of synergetic approach and the further development of the theory of geosystems V.B. Sochava.

3. Results and discussion

Most of the region's geosystems are situated within the boundaries of the Vitim, Baikal-Patom and Stanovoi Uplands. The mountain relief of the Vitim basin was transformed by the recent rifting characteristic for Baikal Rift Zone (BRZ). On the other hand, its development influenced the formation of geosystems in the areas adjacent to BRZ. It is thought [2] that the manifestations of deep-seated rifting processes in the modern structure and relief of the study region are not limited to the territory of the rift zone but are spreading from its lateral boundaries westward by 450 and eastward by 300 km. To put it otherwise these structures- and relief-forming processes in an attenuated form continue to be pronounced within the study territory in the Cisbaikalian pre-rift transition zone. The development of the relief, predetermined by the formation of BRZ, led to isolation of the Vitim and Baikal-Patom Uplands which differ in landscape characteristics from the other areas of Transbaikalia. According to the structure of relief and to isolation, they, like the Okinskoe Uplands, may be called Tibet in miniature where the territory with uniform topography is surrounded by high mountains.

3.1. The development of geosystems the study area

The cycle of development of the study area distinctly shows two stages: the pre-rift and rift stages [3]. The early stage is time-coincident with the Oligocene and Neocene when the aftermaths of the rifting manifested themselves for the first time in the region. The locally occurring volcanic activity did not have any substantial influence upon the dominant (in the region) low-mountain deciduous-coniferous (spruce, Tsuga, pine and birch with broad-leaved species) geosystems functioning in conditions similar to subtropical climate.

The end of the Miocene – beginning of the Pliocene was marked by intense volcanism characterizing the second development stage of the southwestern part of the region, which terminated in a relative tectonic calm. The Quaternary tectonic processes had the most dramatic influence upon the areas, which were involved in the uplift and were adjacent to BRZ. On the other hand, most of the Vitim Upland was also evolving subsequently as an autonomous geosystem. The northern part of the tableland in the Eopleistocene, with the rifting encroaching upon the territory of the Stanovoi Upland, had similar features of development with those of the rifting structures of the North-Baikal and Stanovoi sections of the rift zone. At that time, the mountain ranges (Yuzhno-Muiskii, Kalar, and Yankan) were rising slowly along the northern and northeastern margins of the tableland.

The uplift was time-coincident with the glaciation of the highest mountain ranges. The continental sandy layer (lacustrine, fluvial, aeolian, and water-glacial) was forming in almost all hollows of the region. These deposits absorbed the persisting patches of Miocene landscapes. At that time, the differentiated tectonic movements were accompanied by volcanism. They were most active within the basins of the Bol'shoi Amalat and Dzhilinda rivers to the north-east of the area of Neogene volcanism. The fissuring mechanism operated at the zone of faults. In the Mid- Eopleistocene there emerged an extensive Neogene-Quaternary lava plateau with the area measuring about 4000 km². However, the southern areas of the Vitim Upland, namely the Uda-Vitim interfluvies, and the Konda basin, were only slightly affected by these movements as before.

To date, the upper reaches of the Vitim as well as the area of the Ingur river mouth have retained evidence of volcanic activity of both Miocene (20-2.5 mil. years) and Holocene (10 thou years) age, with covers of basalts and cones of the extinct volcanoes: the Mushketov, Obruchev, Lopatin, Dombrovskii and other volcanoes. The largest basalt cover, Meister Plateau, is situated in the west of the region. It is thought that the basalts of the Vitim Upland are age analogs of the basalts of Eastern Sayan, Khamar-Daban and the Dzhida river basin [4]. Continuous basalt covers introduce some diversity into the region's landscape structure.

In the Mid-Neogene, Siberia saw the start of climate aridization implying a decrease in humidity of air masses caused by the regression of the sea basins in Western Siberia and the Far East [5, 6]. In the Mid-Pliocene, the climate was semihumid and moderately warm. Considerable spaces were occupied by steppes and forests growing on the tops of mountains and hills. Toward the Mid-Pleistocene the conditions of gradual humidification of climate [7] formed sparse pine-birch forests with fir, and with the inclusion of lime and oak. The grass cover was dominated by xerophytes: grasses, wormwoods, and Chenopodiaceae.

The final formation and spread of the taiga was taking place throughout the entire Quaternary; it was associated with three florogenetic centers: the Southern-Siberian, Angaridian and Okhotsk centers [8, 9]. The Southern-Siberian center developed forests of Siberian larch and Scots pine. Nowadays, the forests of this group occur in the south of the region. The middle and eastern areas are dominated by the communities of the Angaridian center which are younger than the Southern-Siberian communities. The main contribution comes from Arctic dwarf birch, Middendorff's birch, etc. Their development was influenced by the general worsening of the climate at the time of the Late Pleistocene cooling. The forests of this group are dominant in the middle part of the region. Boreal vegetation, with the species of the Beringian complex predominating in its composition, occurs in the north of the region. These include black birch, Erman's birch, and others.

3.2. The spatial structure of the region's geosystems

The spatial structure of the region's taiga geosystems bears evidence of the influence not as much from the latitudinal zonality as the history of BRZ formation. The geosystems are clearly differentiated according to the manifestation of tectonic processes and associated development stages of the region's geosystems. At present, they refer to the Baikal-Dzhugdzhur mountain-taiga region. The study area refers to two provinces: the Vitim taiga-flat-mountain province and the Western-Transbaikalian mountain-taiga-goletz province [10]. We subdivided the region's geosystem into five districts (figure 1).

The Uda-Kondinskii district occurs in the southern part of the territory, which has not experienced any substantial changes through its evolution. The region's oldest morphological relict, the pediplain, has persisted to date. The territory is the home for Lower-Cambrian sandy deposits and Pre-Cambrian granites. The same applies for the Pliocene-Pleistocene relicts, namely the subtaiga light-coniferous forests with patches of meadow steppes, tracts of stony steppes and limestone massifs with populations of relict species, such as *Allium altaicum*, *Hemerocallis minor*, and others.

The Dzhilinda-Amalatskii district territorially coincides with the ancient basalt plateau, with different-age effusive formations occurring on them. Of widespread occurrence, here are weakly dissected (by erosion) volcanic massifs with step relief and volcanic cones. It is dominated by *Betula*

pendula and *Larix gmelinii*, willow-Duschekia taiga-small-grass forests (*Purola incarnate*, and *Maianthemum bifolium*), as well as by tracts of mountain moss-yernik stony tundras.

The Konda-Tsipinskii district lies within the boundaries of the middle and northern parts of the Vitim Upland. It occurs at the denudational, weakly dissected tableland with massifs of farewell rocks and pediments dating back to the Neogene. The region is exemplified by flat or dome-shaped watershed surfaces with the Pliocene red weathering crust and Pleistocene alluvial and lacustrine deposits. The piedmont plains are along-valley pediments. They increase in height from south to north from 20 to 300 m. The oldest relief occupies the summit plane of the region. Its northern part is adjacent to the wing of the Baikal Arch which accelerates its growth and, as a result, was involved together with it in the uplift. At present the district refers to the region of decelerated weakly differentiated recent uplifts. The region's marginal parts are composed largely of solifluction and defluction Quaternary rubble and block-rubble loams. High flat, heavily swamped areas are dominated by *Ledum palustre* larch (*Larix gmelinii*) forests, the moss-lichen cover of which produces a continuous mantle that interrupts only on rocky benches of slopes. Green-moss and sedge larch forests occur in topographic lows in conditions of adequate humidification.

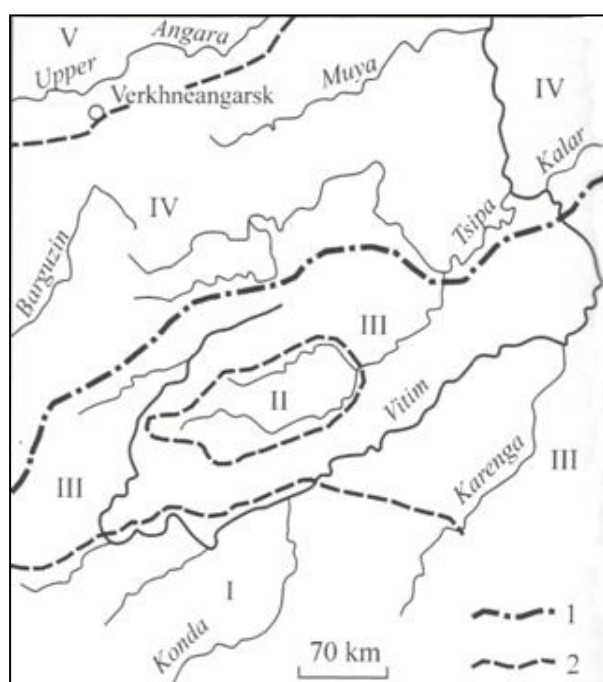


Figure 1. Physical-geographical regionalization of the Vitim river basin.

Physical-geographical districts: (I) Uda-Kondinskii, (II) Dzhilinda-Amalatskii, (III) Konda-Tsipinskii, (IV) Norh-Baikal-Stanovoi, (V) Vitimo-Patomskii.

Physical-geographical boundaries: (1) provinces, (2) districts.

The North-Baikal-Stanovoi district, like the next Vitim-Patom district, forms part of the Western-Transbaikalian mountain-taiga-goletz province. It is characterized by active neotectonic processes associated with the development of BRZ, and with the formation of alpine-type mountain topography and Cenozoic hollows of the Baikalian type. Everywhere there occur granites, basites and granodiorites, and the hollows show the presence of lacustrine-alluvial and glacial deposits. It is the area of formation and development of young progressive goletz and subgoletz geosystems. On the mountain slopes, there occur sedge-yernik larch sparse elvin woodlands, having a physiognomic resemblance with northern-taiga geosystems, Siberian mountain dwarf pine subgoletz geosystems, and Erman's birch sparse forests. The North-Baikal depressions are characterized by swampiness of floodplains of the main rivers. Powerful wintertime inversions are favorable for the development (in the lower parts of the intermontane depressions) of larch-taiga sparse yernik cryogenic groups of facies. The elevated trains, terraces and sand massifs in conditions of a different hydrothermal regime provide fragments of subtaiga geosystems on deep-freezing earth materials, alternating with tracts of barchans sands.

The geosystems of the Vitim-Patom district shaped themselves in conditions of the development of differentiated neotectonic movements. The district is characterized by a non-uniform, stepwise lowering of the surface northward thus exposing to the winds from the Arctic Ocean. This determines a dominance of lichen tundra's and oppressed sparse larch forests on its northern margins. On the whole, on the territory of the district there occur taiga sparse Siberian mountain dwarf pine and lichen larch forests with mixed undergrowth. They are genetically related to the development of mountain-tundra forests, at the same time exhibiting evolutionary-dynamical interrelations of the Beringian and Angaridian centers. Examples are provided by forests of Daurian larch with undergrowth of Siberian mountain dwarf pine.

3.3. Landscape structure of Lake Baikal and its protection

Lake Baikal and bordering area are regarded as unique objects of universal importance. The lake itself and surrounding mountain ranges belongs to the area of Baikal continental rift zone. The existence and development of this rift zone are associated with enhanced intensity of the heat flow rate and with the earths' crust warming due to the mantle afflux [11]. The Miocene epoch was marked by massive basalts discharge. Miocene period is associated with the formation of brown soils that nowadays underlay fir and cedar tall grass taiga geosystems of the Khamar-Daban northern macroslope. Intensive tectonic movements of the late Pliocene led to the raising of mountain systems around Lake Baikal and on the east of the Eurasian continent, forming the orographic barriers that influenced the atmospheric circulation [12]. Western air mass disturbance and Asiatic anticyclone greatly influenced the transformation of geosystems.

The growing aridization led to the expansion of the steppe geosystems on the south of the region. This time the precipitous mountain slopes on the shores of Lake Baikal were occupied by dry steppe geosystems with oxytrope, and selaginella. Pliocene –a time of Siberian taiga geosystems and Baikal-Altai forest-steppe complex formation [13]. At the beginning of the Quaternary period due to the Asian and Indian plate's collision new activation of tectonic processes in the region starts. This furthers the raising of the mountain chains and intensive erosional breakdown. The natural environment transformations, growing aridization and climatic cooling, contributed to the dark coniferous taiga geosystems expansion to the south of the region and to the alpine meadows evolvement in the highlands. The south of the region was occupied by mountainous steppe, which can now be found on the western shore of Lake Baikal. Late Pleistocene climatic cooling that coincided with the Baikal rift zone mountains raising led to the development of mountain-valley glaciation. So the mountain tundras and under-goltsy altitudinal belt of cedar and Silver fir woods were formed in the western highlands of the region, while the alpine meadows prevailed in the eastern highlands [14].

In the taiga forest belt was dominated by fir-cedar-ledum and rhododendron groups of slope facies. Stone birch (*Betula ermanii*) penetrated into the region through the mountain highlands during this time. Today this birch is considered to be the northern near-Pacific specie, therefore lake Baikal region the south-western border of its' natural area. The peculiar dark coniferous taiga forests with Siberian cedar and Siberian dwarf pine were formed along the periphery of the glacier at the nearest proximity to the lake. The spread of subsoil glaciation during the Sartan Ice Age, led to the dwarf birch thickets formation [15]. Between the Pleistocene and Holocene ages, the strengthening of climatic continentality and the permafrost development on the northern and eastern parts of the region determinated the formation of new progressive cryosolic taiga geosystems with Dahurian larch. Today the Dahurian larch and Siberian Dwarf pine are both referred as typical representatives of Baikal-Djugdjursky physical geographical subzone.

The historical evolution of Lake Baikal geosystems contributed a lot to the formation of their unicity and diversification. The peculiar features, created by interaction between the atmosphere, the surface area and the water mass of lake Baikal within its' protruded and surrounded by the mountains with highly dissected relief hollow led not only to the formation but also to the preservation of many unique geosystems. The regional factors of landscapes differentiation here are complexities by local geographical peculiarities such as thermal water exits, salination and marshes formation processes,

squall wind influence. Landscape contrasts within the Central Ecological Zone of Lake Baikal can be of a very large scale. The Selenga river delta and bordering area can be considered as one of the examples. Here due to the neotectonic movements and the foundering of the crust we can find the combination of marches and dry steppe types of geosystems, which is determined by the groundwater proximity and arid climate. The diversity of the CEZ natural conditions determined the formation of special altitudinal zonality types on the slopes that face the lake. As a result, the geosystems distribution within the CEZ does not directly correspond with the altitudinal and latitudinal zonality. Instead CEZ of lake Baikal has a peculiar unique combination of mountain taiga and steppe geosystems: the altitudinal zonality in this region is determined by the barrier humid and arid effects that form the continental climate on the western shore and the costal climate on the eastern shore.

Petrologic composition of the area had also influenced the formation of geosystems modifying the latitudinal regularities of their distribution. This influence can especially be observed in the conditions that are far from the ecological optimum. For example, the presence of Proterozoic carbonaceous rocks on the western “continental” shore strengthens the low humifying rate effect, furthering the formation of peculiar under taiga geosystems with combination of grass larch forests and meadow steppes. Landscape contrasts within the Central Ecological Zone of Lake Baikal can be of a very large scale. The Selenga river delta and bordering area can be considered as one of the examples. Here due to the neotectonic movements and the foundering of the crust we can find the combination of marches and dry steppe types of geosystems. This determined by the groundwater proximity and arid climate. Landscape contrasts within the CEZ of Lake Baikal can be of a very large scale. The Selenga river delta and bordering area can be considered as one of the examples. Here due to the neotectonic movements and the foundering of the crust we can find the combination of marches and dry steppe types of geosystems, which is determined by the groundwater proximity and arid climate.

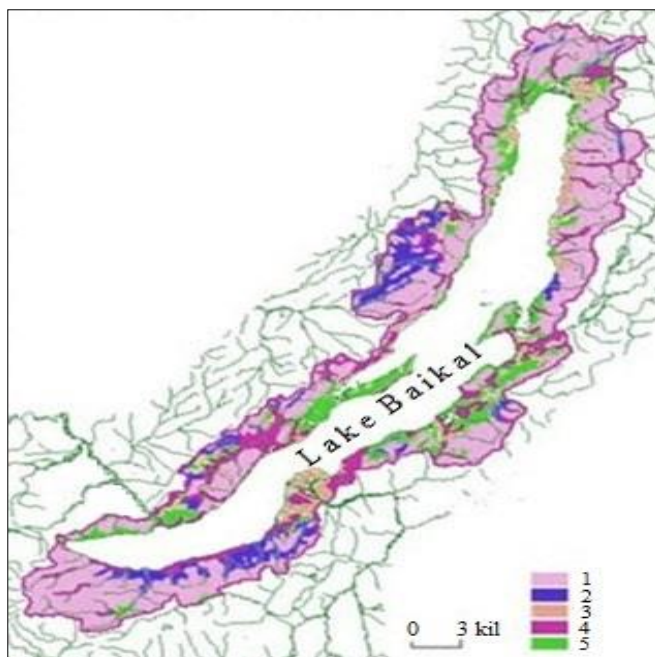


Figure 2. Environmentally oriented conservation functions of the geosystems (Explanations are in the text below)

The altitudinal zonality of Barguzinsky and Khamar-Daban mountain ranges differs from the Southern-Siberian mountain zonality type by the presence of Silver fir geosystems along the upper border of the forest belt. The existence of the stone birch steep slopes geosystems is another peculiar feature of Lake Baikal altitudinal zonality. These geosystems are considered as the elements of northern-pacific costal altitudinal zonality types. In the intermountain depressions, valleys of smaller rivers and mountain gorges we can observe the so-called closed depression effect that appears due to

the cold air stagnation and extensive permafrost development. These conditions favor the formation of larch-taiga types of geosystems that are genetically associated with ancient periglacial Siberian geosystems. Such landscapes combined with larch-peatmoss bog forests, forestless bogs and dwarf birch thickets, which explained by the Pacific monsoon action. As a result, these geosystems are referred as the fragments of the Far-Eastern nature. The mountain-valley larch and fir geosystems are also referred as the Amur-Sakhalin (Far-Eastern) ones. Another distinctive feature of the Central Ecological Zone of Lake Baikal landscapes is the presence of the so-called false under-goltsy vegetation belt with larch and dwarf-pine. Obviously the reasons for the formation of such geosystems are not only the cooling influences of the lake, but also the temperature inversions that contribute to the continentality of the climate and to the relict character of geosystems; during the glaciation these geosystems “migrated” from the highland to the lakes shore. Dark coniferous fir geosystems with a higher humidity level that are more related to the broadleaf forests are confined to the southern shore of Lake Baikal. Unicity and environmentally oriented conservation functions of the geosystems were classified through the expert assessment. The unique geosystems were classified at 5 categories according to their environmental, water balance and landscape diversity preservation capability (figure 2).

1. Water-control geosystems zone. The geosystems of this category are vital for the regions’ water-balance preservation. Changes in their structure will lead to the transformation of the whole regions ecosystem. This category includes goltsy and under goltsy sparse forests, mountain-taiga geosystems of reduced development.

2. Relict geosystems zone. These geosystems reflect the complexity of the regions geosystems formation and development. The examples of such geosystems are poplar and chosenia woods of intermountain depressions, humid fir geosystems that are close to the Pliocene nemoral forests. Due to the limited ecological potential, these relict geosystems are likely to become the subject to destruction.

3. The zone of High geosystems diversity. The existence of such geosystems depends on many local geographical environment processes and conditions such as petrographic composition of the surface, salinization processes, thermal waters discharging, etc. Such types of geosystems can also be found in small river valleys and troughs, where the heat-moisture rate differs from the background ones. Local processes and factors limit the functioning of such geosystems, so any environmental transformation will lead to their elimination.

4. The zone of environment-stabilizing geosystems. Such geosystems developed on the unconsolidated lacustrine-riverine Quaternary deposits of in-termountain lower slopes’ parts, valley bottoms and terraces. These pines and larch forests boundary with steppes and negative anthropogenic impact in this place will lead to the soils erosion, forests elimination and the dry out of smaller rivers.

5. The zone of typomorphic geosystems. They geosystems correspond with the contemporary environment conditions.

4. Conclusions and Recommendations

The conducted research has identified the low stability of the regions geosystems. It is recommending the implementation of limited industrial exploitation and governmental regulation of any land use in this region. This research may become the ground for the creation of a model for the regional sustainable development. Its’ key point lies in the preservation of self-regulated geosystems development by the accurate managing of anthropogenic impacts.

Acknowledgments

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