Landscape-geochemical specifics of steppe geosystems in Baikal basin

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Abstract. Landscape-geochemical studies of the steppe geosystems of the Lake Baikal catchment area revealed the spatial regularities of matter differentiation of the geosystem components and the landscape-geochemical features of geosystems at different levels of organization. The steppe geosystems occupy mainly the piedmont plain and the bottoms of the submontane and intermontane depressions. Dry steppe geosystems are confined to the lowest belt in the altitudinal zonality system. Regional and local features of landscape-geochemical differentiation of matter are diagnosed by the ratio of radial and lateral heterogeneity of the distribution of chemical elements. The steppe calcium and subtaiga sour-calcium geosystems are characterized by a weak radial contrast ratio in the content of different chemical elements in soils against the background of a well-pronounced lateral contrast, and at the contact of steppe and subtaiga geosystems. Lateral differentiation of the content of chemical elements is practically absent. Thus, at the contact of many low-mountain and piedmont landscape-geochemical systems (LGS) in the Preolkhon region, ecotones have been formed, which determine very weak differences between the soil parameters of forest and steppe geosystems. This has necessitated the display of types of conjugations (TC) on landscape-geochemical maps for a more correct reflection of the nature of the matter differentiation. In connection with the predominance of heterolithic conjugations in mountainous conditions, for a correct assessment of the lateral migration of matter, it is advisable to single out individual links of conjugated rows of facies formed on homogeneous bedrocks.

1. Introduction
Lake Baikal is a unique natural object that is a World Heritage Site and the largest reservoir of drinking water not only in the region, but also in the world. In the landscape-geochemical respect, the Baikal catchment area is an open geochemical contrasting arena with a final accumulation of matter [1, 2]. The geosystems of the mountain ranges and depressions surrounding Lake Baikal are distinguished by the complexity and contrast of the landscape structure, high vulnerability and different stability to natural and anthropogenic impacts [3-7]. Despite numerous publications devoted to water pollution and bottom sediments of Lake Baikal [8-19], the sources and ways of their entry into the lake still remain unclear. Thus, the study of the geochemical characteristics of the geosystems of the lake basin, the identification of sources and routes of introduction of pollutants into the lake, which largely determine the quality of the lake waters, is an urgent task of geography and geocology. The activities for pollutant reduction in the surface and ground waters of the Lake Baikal basin and for prevention of negative impact of pollutants on the health of the local population should be based on...
the research results of the spatiotemporal structure of the substance of geosystems, patterns of distribution and migration of pollutants. Experience in studying landscape-geochemical systems (LGS) in Lake Baikal basin showed their high diversity [20-28] and uneven scientific knowledge about them. And the least studied were LGS steppe areas.

2. Materials and Methods
The geosystems of the Lake Baikal catchment area belong to the Baikal-Dzhugdzhur and South Siberian physical-geographical regions [29-31].

In the first region, steppe geosystems are most often found at the contact with low-mountain and submontane steppe subtaiga. In the second one, they are more widespread, occupying mainly piedmont plains, bottoms of piedmonts and intermontane basins. And dry steppe geosystems are referenced to the lowest belt in the altitudinal zonality system (figure 1).

The steppe geosystems of the Daurian type in the region are found primarily due to the special natural conditions formed by the special interaction of the Pacific and Atlantic air masses [32]. North Asian meadow-steppe geosystems and geosystems of steppificated meadows are represented in the Huvsgul region, within the valleys of the Selenga river tributaries, on the northeastern and eastern shores of Lake Huvsgul, on the slopes of the valleys of several Mongolian rivers. At the confluence of the Orkhon and Selenga, forbs-gramineous and rich in species forbs-gramineous steppe geosystems with chernozems and dark chestnut soils are widely represented. In locations with a dryness index of more than 2.0, dry bunchgrass steppe geosystems of the Mongolian type are developed [33]. A wide strip of dry steppe geosystems with a predominance of bunchgrass steppe vegetation associated with chestnut soils and with an annual precipitation of 150–250 mm is located in Mongolia. To the south,
these geosystems are substituted by desertified variants, which are associated with light chestnut soils and insignificant annual precipitation (up to 130–160 mm) [34].

The twenty three LGS types identified within the Lake Baikal catchment area include the following ones as steppe types: low-mountain subtaiga steppificated meadows and mountain steppe sites (maryans) (Ca$^{2+}$, H$^+$); mountain depression steppe (Ca$^{2+}$); plain steppe and meadow-steppe with sites of light-coniferous steppe forests (Ca$^{2+}$, H$^+$); accumulative plains meadow-steppe with sites of light-coniferous steppe forests (Ca$^{2+}$, H$^+$); accumulative plains meadow-steppe alkalinated and slightly saline (Ca$^{2+}$, Na$^+$); lacustrine-alluvial steppe basins (Ca$^{2+}$, Fe$^{3+}$) [25, 26].

One of the main regional landscape-geochemical features is a weak radial differentiation of the content of chemical elements along the profile of soils of forest and steppe LGS with a well-pronounced lateral one [22, 23]. Thus, at the contact of many low-mountain and piedmont LGSs in the Preolkhon region, ecotones have been formed, which determine very weak differences between the soil parameters of forest and steppe geosystems. This has necessitated the display of types of conjugations (TC) on landscape-geochemical maps for a more correct reflection of the nature of the matter differentiation [26].

3. Results and Discussion

On Olkhon Island, the steppe LGSs are part of the middle and low mountain taiga-steppe TSs of selvedges of the ridges with pine-larch, pine grass forests and mountain steppes; mountain subtaiga-steppe ecotones of plateaus and slopes with light-coniferous steppificated forests and low-forb steppes; steppe mountain and piedmont-depression; steppe and dry steppe piedmont-submontane; piedmont subtaiga-steppe ecotones of plains, deltas, debris cones and deluvial trails with low grass steppe vegetation, meadows and areas of pine and larch herbaceous and steppificated forests [21, 26].

Each of them is characterized by a certain set of elementary geosystems, displaying the nature of the lateral and radial migration of matter. In doing so, along with monolithic junctions in mountains, heterolithic ones are often formed, which are most characteristic of the near Cisbaikalalia. We had to distinguish individual links of conjugated series of facies formed on homogeneous bedrocks [22, 23] with the objective to correctly assess the lateral migration of chemical elements on such profiles. Thus, the landscape-geochemical profile on the northwestern slope in the urochishche of Kurkut (Preolkhon region), where the soil-forming rocks are the weathering products of hastingsite amphibolites, calcite marbles and garnet-biotite gneisses, as well as lacustrine sediments, according to the content and character of clearly subdivided into two chains, each is represented by three facies (figure 2).

The content of Mn, Cr, Ni and Co is increased in soddy steppe and chestnut soils of the first link, on the weathering products of amphibolites, and the lateral distribution of their content in soils tends to increase downslope, as a result of mechanical migration, and to accumulate on the mechanical barrier in the transeluvial-accumulative facies of the concave section of the slope. The coefficients of local migration of other elements are close to 1, which indicates the predominance of mechanical migration of matter. Moreover, landscape-geochemical conditions (neutral reaction of the environment and low content of organic matter) are unfavorable for water migration processes. In the link, on the marble weathering products, an increase in the coefficients of lateral differentiation is observed only for Ba and Sr in the hydroaccumulative facies, which is associated with the evaporation concentration (the soil was formed on lacustrine sediments underlain by marbles).

The Mn, Cr, Ni and Co accumulation in soils of the transaccumulative facies of the lower flattened part of the slope, relative to the bedrock, is explained by the lateral input from soils located higher up the slope and fixation on the mechanical barrier, as evidenced by the presence of deluvial sandy-clay deposits on the soil surface. On the profile of the southeastern slope in the same urochishche, successively (downslope) presented are the plots of facies on the eluvium of garnet-biotite gneisses, eluvium-deluvium of feldspar amphibolites, deluvium of garnet-biotite gneisses, deluvium of feldspar amphibolites, as well as on deluvium underlain by calcite marbles.
Figure 2. Facies of the urochishche of Kurkut. LOW MOUNTAIN SUBTAIGA LIGHT-CONIFEROUS (H⁺). Eluvial: 1 - larch forbs-gramineous with soddy forest immature soils on eluvium of hastingsite amphibolites; 2 - larch forbs-gramineous with soddy forest immature soils on eluvium of amphibole-biotite gneisses. MOUNTAIN-DEPRESSION STEPPE (Ca²⁺). Eluvial: 3 - sparse-larch forbs-gramineous with soddy steppe immature soils on eluvium of hastingsite amphibolites; 4 - forbs-gramineous with mountain steppe soils on the eluvium of garnet-biotite gneisses. Transeluvial: 5 - sparse larch forbs-gramineous with sod steppe soils on deluvium of hastingsite amphibolites; 6 - sagebrush - gramineous-forbs with mountain-steppe carbonate-free soils on eluvial-deluvium of feldspar amphibolites; 7 - sparse larch gramineous-sedge-forbs with arenosols on deluvium of garnet-biotite gneisses. Transeluvial-accumulative: 8 - forbs-gramineous with chestnut-like soils on deluvium of hastingsite amphibolites. Transaccumulative: 9 - gramineous-tall herbaceous with chernozem-like soils on eluvial-deluvium of calcite marbles; 10 - feather grass-forbs with mountain steppe soils on deluvium of feldspar amphibolites; 11 - gramineous-forbs with meadow-chestnut soils on calcareous proluvial deposits. LACUSTRINE-ALLUVIAL STEPPE DEPRESSIONS (Ca²⁺, Fe²⁺). Transsuperaqual: 12 - forbs-barley with meadow soils on lacustrine sediments, underlain by deluvium of calcite marbles; 13 - bentgrass-sedge with meadow humus-gley soils on lacustrine sediments underlain by deluvium of calcite marbles. Superaqual: 14 - veinless-sedge with boggy peaty-humus soils on lacustrine sediments underlain by deluvium of calcite marbles.

4. Conclusion
The results of landscape-geochemical research of the steppe geosystems in the Lake Baikal catchment area revealed a number of spatial regularities in the matter differentiation of the components of geosystems, as well as landscape-geochemical features of geosystems, manifested at different levels of their organization. The ratio of the radial and lateral heterogeneity of the distribution of chemical elements reflects the regional and local features of the landscape-geochemical matter differentiation. The steppe calcium and associated subtaiga acid-calcium geosystems are characterized by a weak radial contrast in the content of chemical elements in soils against the background of a well-pronounced lateral one. At the same time, the latter is practically not found at the site of their contact. Detailed study of the spatial differentiation of matter in key areas has revealed significant differences due to location, differences in the composition of underlying bedrocks, and processes of lateral and radial migration. Moreover, various types of geochemical conjugations are characterized by certain
sets of elementary geosystems. Due to the predominance of heterolithic conjugations in mountainous conditions, it is advisable to single out individual links of conjugated rows of facies formed on homogeneous bedrocks for a correct assessment of the lateral migration of matter.

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