

Regional patterns of zoning hypergenic transformations of sedimentary rocks of the middle Permian age of the Eastern Zakamye

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Abstract. The article is devoted to the study of eluvial deposits in the territory of the Eastern Zakamye. Due to the activity of river erosion, a highly dissected and rugged terrain has formed in this area. Its characteristic elements are erosion-denudation watersheds spaces separated by narrow river valleys and terraced slopes. According to the results of the research, it was revealed that the difference in the structure of weathering profiles in carbonate and terrigenous soil massifs is due to the structural and mineralogical features of rocks acquired at the stage of sedimentation and subsequent diagenesis. In the central part, at the upper plateau site, the rocks underwent mainly physical weathering processes, at the middle plateau site – chemical weathering processes, at the lower plateau site – physical and chemical weathering processes. Such selectivity in the manifestation of hypergenic processes is due to the predominant lithotypes of sedimentary rocks composing the upper, middle and lower plateau surfaces of the plateau of the studied territory. Based on the completed study, the zoning of the territory of the Eastern Zakamye was carried out and an engineering and geological map was built. The results obtained make it possible to understand the mechanism of weathering in carbonate and terrigenous rocks, and, consequently, to assess the potential change in the physical and mechanical properties of rocks, both during construction and during the operation of buildings and structures.

Introduction

The study of geodynamic activity of the near-surface part of the Earth is one of the most important problems of engineering geology at the regional and local levels. Since the 70s of the XX century, the USSR began to develop a scientific and applied direction at the junction of neotectonics, geomorphology, hydrogeology and other scientific disciplines - the doctrine of geodynamic zones [1, 2]. One of these zones, where the processes of tectonic rearrangements of landscapes and related geodynamic phenomena are actively taking place, is the Eastern Zakamye [3, 4, 5].

The Eastern Zakamye is a large regional structural and geomorphological element of the Volga-Ural antecline [6]. In the modern relief on the territory of the Eastern Zakamye, two

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large morphological structures are distinguished: the Bugulma-Belebeevskaya upland, which occupies the main and western parts, and the Kamsko-Belskaya lowland, located in the northeast. In tectonic terms, the territory is confined to the South Tatar arch, which can be traced as a positive structure along the roof of all stratigraphic divisions starting from the surface of the crystalline basement. A feature of the vault is the presence of deep annular faults intersecting with numerous lineaments of the northeastern and northwestern strike. The intersections of multidirectional faults cause a high degree of fragmentation of the rocks of the crystalline basement and sedimentary cover into blocks of various dimensions [7]. Throughout the long geological history of the development of the South Tatar arch, rigid blocks experienced multidirectional vertical movements, now sinking, now rising along the fault dividing them. As a result, a complex surface relief was formed along the boundaries of the stratigraphic divisions of the Paleozoic era [6]. Since the Mesozoic, the territory of the South Tatar Arch has entered a phase of tectonic uplifts. From this period, the modern relief of the Bugulma-Belebeevskaya upland and the Kama-Belskaya lowland began to form.

Materials and Methods

The blocks of the crystalline foundation in the central part of the South Tatar arch were raised most intensively. Due to this, two domes were formed within the top of the tectonic structure starting from the end of the Mesozoic, which, during geomorphological zoning, were called the Bugulma plateau and the Belebey Plateau [8]. In relief, they represent flattened denudation plate-like surfaces, lined with isohypses of 300-360 m.

In the north-western and south-western directions from the top of the South Tatar arch, the Bugulma-Belebeevskaya upland gradually descends in steps, in the form of terraces, towards the left-bank slopes of the river valleys of the Kama and Volga rivers. The most distinct in the relief are the middle and lower terraces, contoured along the isohypses of 230-280 m and 160-200 m, respectively. As independent geomorphological structures, they became isolated in the Cenozoic era [9]. The surface of the middle terrace was formed in the Paleogene, the surface of the lower one – in the Upper Pliocene stage of lowering and leveling the relief of the Russian platform [8]. During this time, the terraces were subjected to denudation processes, which led to the formation of the middle and lower plateaus within them. Thus, in modern terms, the Bugulma-Belebeevskaya upland consists of three plateaus, gradually sinking towards the river valleys of the Kama and Volga. The Kama-Belskaya lowland, in turn, is characterized by smooth, subhorizontal, exceptionally smooth relief outlines, a characteristic feature of which are the bottoms of cirque-shaped closed depressions.

The boundary between these areas can be conditionally drawn where the heights of the watersheds decrease to 200-180m.

The main features of the elevation relief were acquired in the Neogene-Quaternary period. Tectonic uplifts of the territory contributed to the establishment in the Neogene of narrow extended river valleys of Sheshma, Zai, Menzel, Kuchma and others, flowing into the Kama River and crossing the upper, middle and lower plateau surfaces of the Bugulma-Belebeevskaya geomorphological structure along the way. Somewhat later, slope processes were activated aimed at leveling Neogene erosive landforms due to the demolition of remnants of proluvial-deluvial deposits from the peaks of denudation [10].

Results

In 2020-2023, the authors conducted a large-scale study of the territory of the Eastern Zakamye. The purpose of the study was the engineering and geological zoning of the territory with the allocation of various geomorphological structures and various types of rocks on each structure.

Figure 1 shows a geomorphological map of the territory of the Eastern Zakamye. The following engineering and geological areas have been identified in the study area: erosion-accumulative, erosion-denudation watershed and erosion-denudation watershed areas. At the same time, sections of the denudation relief were further divided into three plateaus.

The uneven resistance of sedimentary rocks to weathering contributed to their differentiation in composition on different terraces (plateau) Eastern Zakamye. The upper plateau is composed mainly of strong light gray dolomites with layers of red-brown and greenish-gray dolomite marls of the Biarmian department of the Permian system. Most of the peaks of the erosion-denudation hills located here are armored with dense carbonates. The surface of the middle plateau is composed mainly of marine sandstones with layers of clays and dolomite marls, the lower one is mainly clay. The areas of predominant distribution of certain lithological differences of sedimentary rocks have determined the peculiarities of regional zoning of the upland territory by types of hypergenic transformations.

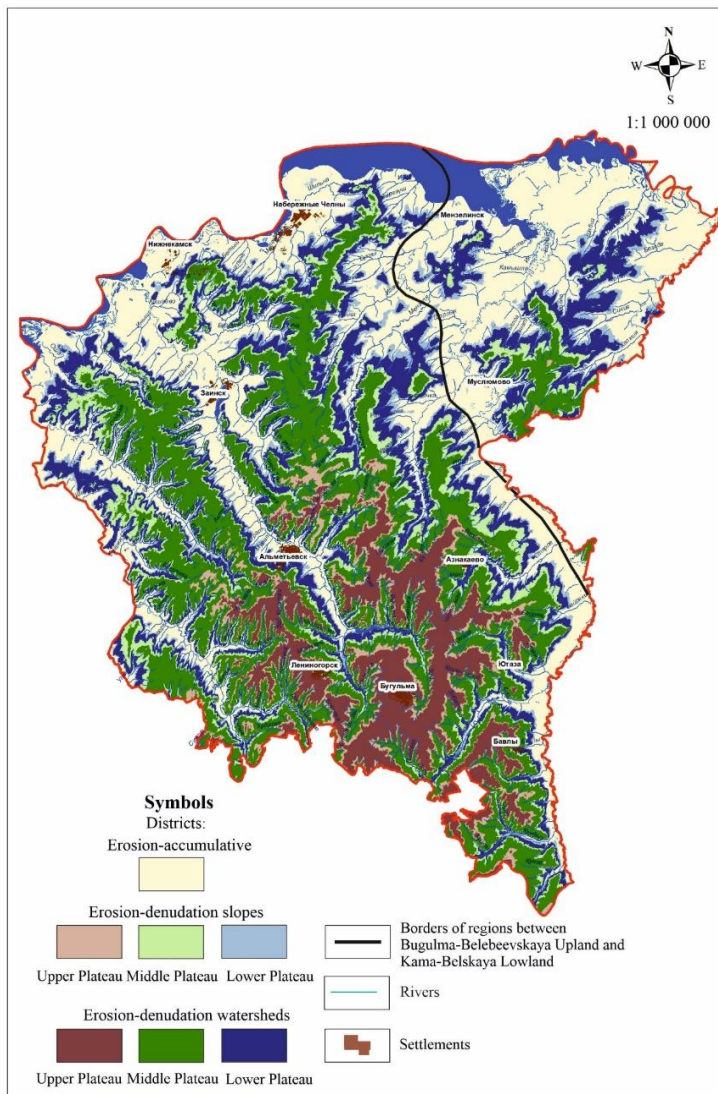


Fig. 1. Geomorphological map of the territory of Eastern Zakamye

Discussion

An analysis of the structure of weathering profiles for upper plateau carbonate rocks showed that three zones are clearly distinguished on all walls of natural and man-made outcrops: unchanged dense dolomites, dolomites of structural eluvium and dolomite flour of the zone of structureless eluvium. The last two zones represent a single area of disintegration with different intensity of change of the indigenous dolomites. In the zone of structural eluvium, the rocks are broken up by numerous systems of horizontal and vertical cracks into block and slab-like separations, which retain the original character of occurrence in the section.

From the bottom up along the weathering profile, the sizes of the separations decrease, turning into structureless eluvium. The latter is composed of rubble-gravel fragments cemented with loose white dolomite flour consisting of aggregates (0.05-2.0 mm) of firmly bonded rhombohedral dolomite grains. The good preservation of the habitus elements of rhombohedral crystals indicates mechanical breaks in the structural bonds between the grains during the disintegration of dolomites. Such a change in rocks is possible only during the physical processes of weathering, when the main factor of their destruction is temperature differences. Cyclic temperature changes causing uneven expansion and contraction of dolomite grains, as well as the effect of freezing water, led to the appearance of wedging cracks between the contacting crystals. Over time, the rocks crumbled into smaller aggregates with the preservation of the dolomite grains of smooth faces and edges without traces of dissolution.

Within the surface of the middle plateau, marine sandstones of the Kazan tier of the Middle Permian system are mainly subjected to hypergenic transformations. This is due to the better permeability of rocks to surface atmospheric waters and the presence of calcite cement in them that is not resistant to dissolution. In the weathering profile of calcareous sandstones, four zones are distinguished, characterized by different intensity of change: unchanged dense sandstones, a zone of chemical disintegration, zonaeluvated sandstones, and an eluvial sand zone. The unchanged terrigenous rocks lying in the lower part of the sections are sandstones in which the detrital component (fragments of effusive and siliceous rocks, quartz and feldspar grains, scales of muscovite and chlorite) of fine-grained dimension is cemented with calcite cement of basal-pore type with uneven recrystallization.

A feature of cement is the presence of a clay component, which is partially dispersed, partially concentrated in layers, causing a layered texture of the rock. The zone of disintegrated sandstone is located higher up the section. It is represented by large fragments of dense unchanged rock (from 10.0 to 30.0 cm) cemented with loose sandy material. This zone was formed due to the selective leaching of lime cement from sandstone by infiltration waters, which penetrated in the form of separate "tongues" - jams. Given the mechanism of hypergenic destruction of terrigenous rocks, this zone can be called a zone of chemical disintegration. Its thickness in sections does not exceed 0.5-0.6 m. The zone of eluted sandstones lies above. Calcite cement is almost completely leached out of sandstones within this zone. The clastic grains rest on each other with surfaces, forming point contacts of contact. Clay particles are concentrated on the contacts of fragments of minerals and rocks, forming a new cement. The loose structural packing of rocks and the predominance of water-colloidal and mechanical types of bonds in them determines the instability of eluvated sandstones to water saturation. At the same time, in sections of the zone of eluted sandstones in a dry state, all textural signs of primary unchanged rocks are noted (the layered texture is preserved).

The upper layer of hypergenically altered sandstones is represented by a zone of loose eluvium. Being in the zone of intensive aeration, clay cement is washed out, fragments of rocks and minerals are redistributed with the loss of initial textural features, and forms homogeneous loose sand.

On the surface of the lower plateau of the Eastern Zakamye, clay rocks of the Urzhum tier are subjected to hypergenic processes. In their initial state, the rocks are dense, dark brown, mudstone-like clays, broken up in soil massifs by numerous intersecting inclined cracks into fragmented individuals up to 10.0 cm in size. In most of the lower plateau, mudstone-like clays are overlain from above by quaternary deluvial-alluvial deposits, which makes it difficult to study the hypergenesis zone developing along them.

It is only in the walls of quarries and dug pits that it becomes possible to consider the peculiarities of changes in Middle Permian clay rocks under the influence of weathering processes. According to the data obtained, the hypergenesis profile consists of two zones: the zone of unchanged rocks and the zone of elution. Unchanged clays are polymineral in composition of the clay component, they are dominated by a mixed-layer mineral phase of illite-montmorillonite composition and illite, to a lesser extent contains chlorite. Calcite, dolomite and gypsum (15-20%) are present in unchanged clays together with clay minerals.

The allotigenic part, amounting to 40-55% in total, is represented by fragments of quartz, feldspar, siliceous and effusive rocks. The mineral components have a dense structural packing in the rock, which makes it impossible for infiltration waters to penetrate into them, except through cracks. In the eluvated zone, clay rocks have undergone disintegration. Under the influence of negative temperatures during the Valdai glaciation, clays from the surface were subjected to cracking. In some areas, traces of wedge-shaped frost-breaking cracks with a depth of more than 2.0 m filled with brown loess-like loam are recorded in the walls of the pits. Intensive fragmentation of clay rocks, complicated by exogenous folding, is confined to the Quaternary freezing zone.

Some of the separated fragments were subjected to dispersion processes. The loose clay material served as a kind of cement that binds the crushed-gravel fragments of the original clay rock. The decompression of clay in the elution zone contributed to a more intensive penetration of precipitation waters into them. This contributed to the activation of chemical weathering processes. Aggressive infiltration waters completely or partially leached dolomite, calcite and gypsum from disintegrated Permian clays, triggered the hydrolysis reaction of feldspars.

The latter manifested itself in the form of a decrease in the proportion of microcline and the appearance of kaolinite in the composition of clay minerals.

Conclusion

Thus, as follows from the above, regional areas with their own characteristics of the course of hypergenic processes of transformation of sedimentary rocks of the Middle Permian age have been clearly identified within the Eastern Zakamye. In the central part, at the upper plateau site, the rocks underwent mainly physical weathering processes, at the middle plateau site – chemical weathering processes, at the lower plateau site - physical and chemical weathering processes.

Such selectivity in the manifestation of hypergenic processes is due to the predominant lithotypes of sedimentary rocks composing the surfaces of the upper, middle and lower upland plateaus.

The results obtained as a result of the performed studies allow us to understand the mechanism of weathering in carbonate and terrigenous rocks, and, consequently, to assess the potential change in the physical and mechanical properties of rocks both during construction and during the operation of buildings and structures.

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