# Patterns of distribution of eluvia soils in the oil region of Tatarstan

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**Abstract.** The article is devoted to the study of eluvial deposits in the southeastern part of the Republic of Tatarstan. As a result of river erosion, a highly dissected and rugged terrain has formed here. Its characteristic elements are erosion-denudation watersheds separated by narrow river valleys and terraced slopes. According to the results of the research, it was revealed that the differences in the structure of weathering profiles in carbonate and terrigenous soil massifs are due to the structural and mineralogical features of rocks that were formed at the stage of sedimentation and subsequent diagenesis. In the central part, on the site of the upper plateau, the rocks underwent mainly physical weathering processes, on the site of the middle plateau – chemical weathering processes, on the site of the lower plateau – 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 plateaus of the studied territory. Based on the conducted research, the zoning of the studied territory was performed and an engineering and geological map was built. The results obtained made it possible to understand the mechanism of weathering of carbonate and terrigenous rocks, as well as to assess the potential change in their physical and mechanical properties during the construction and operation of buildings and structures.

## 1 Introduction

The Republic of Tatarstan is one of the leading economic centers of the Russian Federation. The oil industry plays an important role in its economy. The main deposits of Tatarstan are located on the territory of the Eastern Zakamye, located in the southeastern part of the Republic. Its area is about 20 thousand km2, the population is 1.5 million people.

When designing civil and industrial facilities in the studied area, builders often face serious difficulties associated with the ubiquity of eluvial soils.

The eluvial soils of the Eastern Zakamye are a product of weathering of the indigenous sedimentary rocks of the Kazan and Urzhumsky tiers of the Permian system and are not represented on any maps. This creates serious difficulties, because it is often extremely difficult to distinguish eluvial soil from non-mature parent rock both during field work and laboratory study.

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Also, eluvial soils are characterized by rapid variability of their physical and mechanical properties, often unstressed and therefore difficult to predict.

The most effective way to achieve sustainable development of territories is to conduct regional studies, including systematization of available information, preparation of regional tables of physical and mechanical properties of soils, as well as the construction of special engineering and geological maps [3].

The Eastern Zakamye is a well-studied region in tectonic, geomorphological and geodynamic terms. Research in this area has been conducted for more than 40 years [1, 4, 7-8]. At the same time, there is practically no engineering and geological study of the studied territory.

The Eastern Zakamye is the most important structural and geomorphological element of the Volga-Ural anteclise [6]. In the modern relief of the Eastern Zakamye, two main morphological structures can be distinguished: the Bugulminsko-Belebeevskaya upland, which occupies the main and western parts, and the Kamsko-Belsky lowland, located in the northeast. In tectonic terms, the territory is confined to the South Tatar arch, which is a positive structure on the roof of all stratigraphic units, 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 lead to a high degree of fragmentation of the rocks of the crystalline basement and sedimentary cover into blocks of various sizes [10]. Throughout the long geological history of the development of the South Tatar arch, solid blocks have experienced multidirectional vertical movements. They alternately descended and rose along the fault lines separating 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 Bugulminsko-Belebeevskaya upland and the Kamsko-Belsky lowland began to form.

## 2 Materials and Methods

The blocks of the crystalline foundation in the central part of the South Tatar arch rose most intensively. As a result, starting from the end of the Mesozoic, two domes were formed within the top of the tectonic structure, which, during geomorphological zoning, were named Bugulmin plateau and Belebeevsky plateau [2]. In relief, they are aligned denudation plateaued surfaces that are bounded by isohypses of 300-360 meters. In the north-western and south-western directions from the top of the South Tatar arch, the Bugulminsko -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 middle and lower terraces stand out most clearly in the relief, which are bounded by isohypses of 230-280 meters and 160-200 meters, 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 [2]. During this time, the terraces were subjected to denudation processes, resulting in the formation of the middle and lower plateaus. Thus, at present, the Bugulminsko-Belebeevskaya upland consists of three plateaus, which gradually sink towards the river valleys of the Kama and Volga rivers. The Kamsko-Belskaya lowland, in turn, is characterized by smooth and sub horizontal relief outlines, which are characterized by smoothness. Characteristic features of this relief are 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 formed in the Neogene-Quaternary period. Tectonic uplifts of the territory contributed to the formation in the Neogene of narrow extended river valleys of Sheshma, Zai, Menzel, Kuchma and others, which flow into the Kama River and along the way cross the surfaces of the upper, middle and lower plateaus of the Bugulminsko-Belebeevskaya geomorphologic structure. Later, slope processes aimed at smoothing Neogene erosive landforms intensified due to the demolition of material from the tops of denudation remnants by proluvial-deluvial deposits [5].

Based on the above, at the first stage, engineering and geological zoning was performed on the basis of the territories belonging to one or another geomorphological element.

At the second stage, field route work was carried out, which included 1106 observation points. The lithological composition of the rocks was recorded at each observation point and samples were taken for laboratory study.

The determination of the deformation and strength properties of soils was carried out using the devices of the ASIS NPP Geotech Company. To perform filtration and suffusion tests, an installation of the authors' own design was used, which has patent No. 2022110200 dated 04/15/2022 MPK-2022.01 G01N 3/10.

The mineral composition of the eluvial formations was determined by X-ray studies using a D2 Phaser diffractometer manufactured by the Brooker company (Germany). The microstructural characteristics of eluvial soils were studied using the FEI XL-30ESEM electron microscope.

The cartographic models were built using the software product "ArcGIS 10.8" (ESRI, USA).

## 3 Results

As a result of the study, the following engineering and geological areas were identified: 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 has led to some differentiation in their composition on different terraces (plateaus) 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 covered with dense carbonates. The surface of the middle plateau is composed mainly of marine sandstones with layers of clays and dolomite marls, and the lower one is mainly clays. 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 (Figure 1).

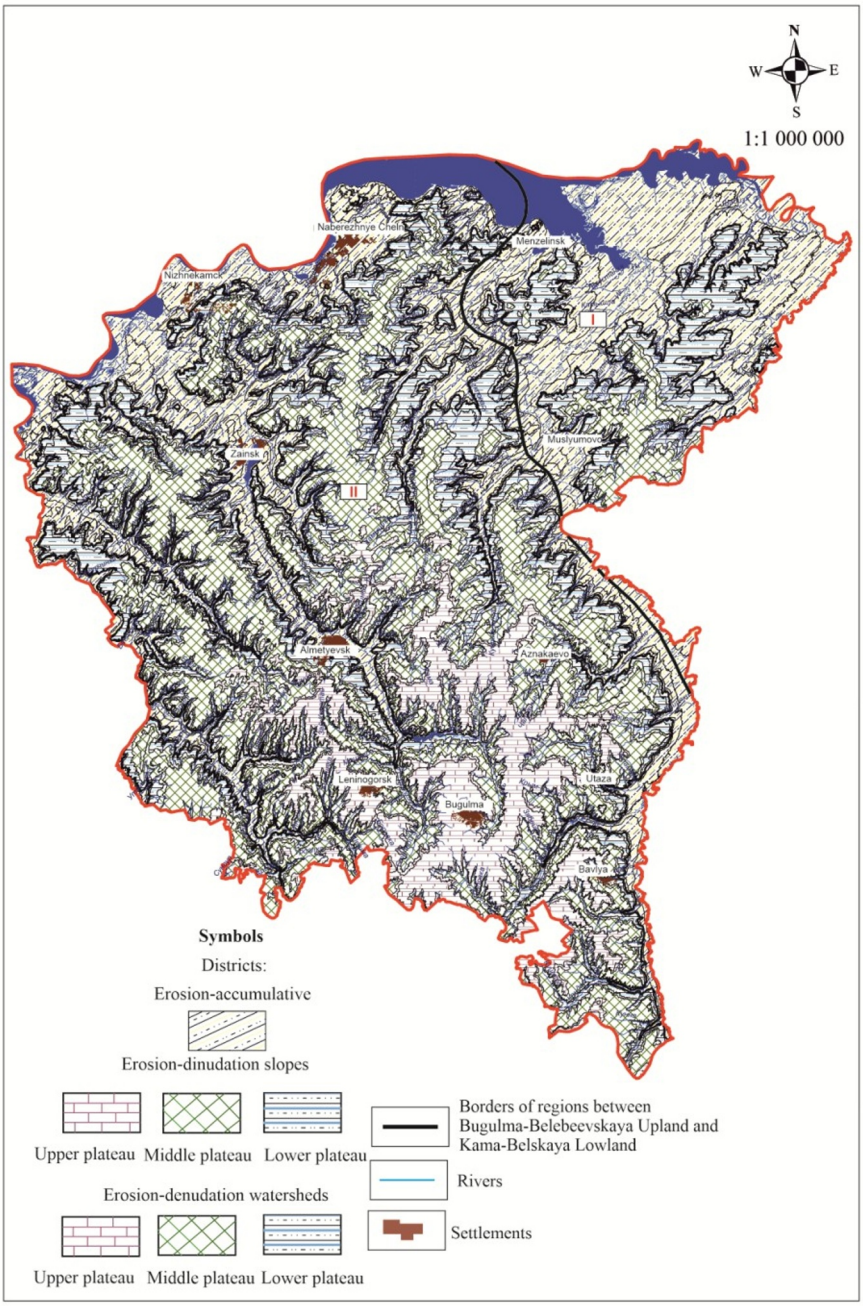


**Fig. 1.** Geomorphological map of the territory of Eastern Zakamye.

## 4 Discussion

The analysis of the structure of the weathering profiles of carbonate rocks of the upper plateau 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.

Last two zones show a single area of disintegration with varying degrees of alteration of the indigenous dolomites. In the zone of structural eluvium, the rocks are divided by numerous systems of horizontal and vertical cracks into block and slab-like sections, which preserve the original character of occurrence in the section. As we move up the weathering profile, the size of the separations decreases, 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 rhombohedra dolomite grains. The good preservation of the habitus elements of rhombohedra 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 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 atmospheric waters and the presence of calcite cement in them, which easily dissolves. In the weathering profile of calcareous sandstones, four zones can be distinguished, which are characterized by varying degrees of change: unchanged dense sandstones, a zone of chemical disintegration, a zone of eluvated sandstones and a zone of eluvial sands.

The unchanged terrigenous rocks lying in the lower part of the sections are grauvac 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. Zone of eluvated 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 cause the instability of eluvated sandstones to waterlogging. At the same time, in sections of the zone of eluvated 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 Urzhumsky tier are subjected to hypergenic processes. In their initial state, these rocks are dense, dark brown, mudstone-like clays, which are broken up in the soil massifs by numerous intersecting inclined cracks into fragmented individuals up to 10 cm in size.In

most of the lower plateau, mudstone-like clays are overlain by quaternary deluvial-alluvial deposits, which makes it difficult to study the hypergenesis zone developing along them. However, in the walls of quarries and excavated pits, 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 elution zone.

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 along with clay minerals. The allotigenic components, amounting to 40-55% in total, are 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 for cracks. In the eluvial 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 eluviation 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.

## 5 Conclusion

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