Clastocarst of the southern Cis-Urals

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Abstract. It has been established that along with the traditional types of sulfate and carbonate karst, its specific type, clastocarst, is developed in the Southern Cis-Urals. Its general characteristics are given, the regions and the intensity of distribution of clastocarst forms are determined. The main regularities of their distribution are established and the current activity of the development of clastocarst in the region is estimated.
Keywords: Southern Cis-Urals, Republic of Bashkortostan, Perm Krai, clastocarst, karst fields, karst sinkholes.

introduction

The southern Cis-Urals is characterized by the wide development of karst with the distribution of the most diverse forms of its manifestations, both surface and underground [9]. Along with the traditional types of karst in terms of the composition of karst rocks (salt, sulphate and carbonate), a specific type of karst is developed in the region, associated with the dissolution of inclusions of soluble components contained in rocks.

The term clastocarst was introduced into the scientific literature by G.A. Maksimovich to denote the phenomenon of chemical and mechanical impact (dissolution and suffusion) of groundwater on sedimentary rocks (clays, loams, loesses, sandstones, conglomerates with soluble cement) [5, 14]. Today this term has become firmly established in Russian karst studies and is used by many geologists to designate processes similar to karst in conglomerates, sandstones, breccias. The author, following G.A. Maksimovich, under klasokarst understands the dissolution and leaching of readily soluble inclusions (sulfates and carbonates) in sedimentary clays and silicate rocks.

Despite the presence of the long-known clastocarst in the region, its special studies have not been carried out until now, the available single publications on it are limited only to information on the forms of its manifestations in individual parts of the southern Urals. Moreover, despite the mention of him in the published [2, 3, 6, 7, 13, etc.] and numerous stock (Shevchenko, Sapozhnikov, 1969, Belyaev, Eremina, 1971, Eremina, Tabakov, 1972, Murtazin, Chaiko, 1973, Feschenko, Feshchenko, 1976, etc.) literature, as an independent type of karst, clastocarst received a cartographic display only in 2005 in the Atlas of the Republic of Bashkortostan [10]. It contains a small-scale karst map, which reflects the areas of clastocarst

distribution in the territory of the Republic of Bashkortostan (RB) and the extent to which it is affected by surface manifestations.

The purpose of the study is to analyze the development of clastocarst as a whole in the region under consideration, to establish patterns of distribution and to determine the current activity of its manifestation on the surface.

Исходные данные и методы исследований

The initial materials for the research were the data contained in the production reports of OJSC "Bashkirgeologia" of the author on the study of exogenous geological processes (EGP) and his own research in 2018-2020. [12, 13].

The research results are based on the materials for decoding large-scale (1-17 000-25 000 1957-1960 flights) aerial photographs, updated with modern satellite images using SASplanet and verified by field routes 2018-2021. (A. Smirnov and Yu Sokolov).

Results and discussion

The distribution of clastocarst on the modern map of the types of karst of the Southern Urals and the Cis-Urals [12] is shown in figure 1, from which it follows that clastocarst is developed exclusively in the karst country of the East European Plain and is relatively scarce in comparison with other types of karst in terms of the composition of karst rocks. Its largest continuous areas are typical for the northeast of the region (I-B) on the Priay plain. In the west (I-A), it is developed locally in some parts of the Belskaya plain, and in the rest of the territory, clastocarst is not found.

On the Priay plain, clastocarst is distributed in its western gently undulating part to the east of the Ufa plateau with a carbonate type of karst (along the Duvan-Krasnoufimsk meridian). It is developed here in terrigenous deposits of the Koshelevskaya suite (Irensky horizon) of the Kungurian stage of the lower section of the Permian system.

The Koshelevskaya Formation, 50 m thick in the south to 250 m in the north, is composed of carbonated and gypsum sandstones, siltstones and mudstones. Gypsum-bearing (with nests, lenses, and gypsum interlayers) polymictic, well-permeable sandstones occupy almost 50% of the total section of the formation.

The maximum distribution of surface karst manifestations in the area of the Koshelevskaya suite was recorded by us on the western edge of the Priay plain at the foot of the eastern slope of the Ufa plateau, 2-4 km southeast of the village Duvan (between the village of Ulkundy and the village of Pichugino). They are represented mainly by bowl-shaped and cone-shaped funnels, less often by dips. Their diameter is usually 5-30, less often 50 m, and their depth ranges from 2-5 to 15 m. Often there are funnels merged (with adjacent sides) and an accumulation of funnels, forming karst fields (fig. 2), on which the density of funnels reaches 100 pieces per 1 km^2 [13].

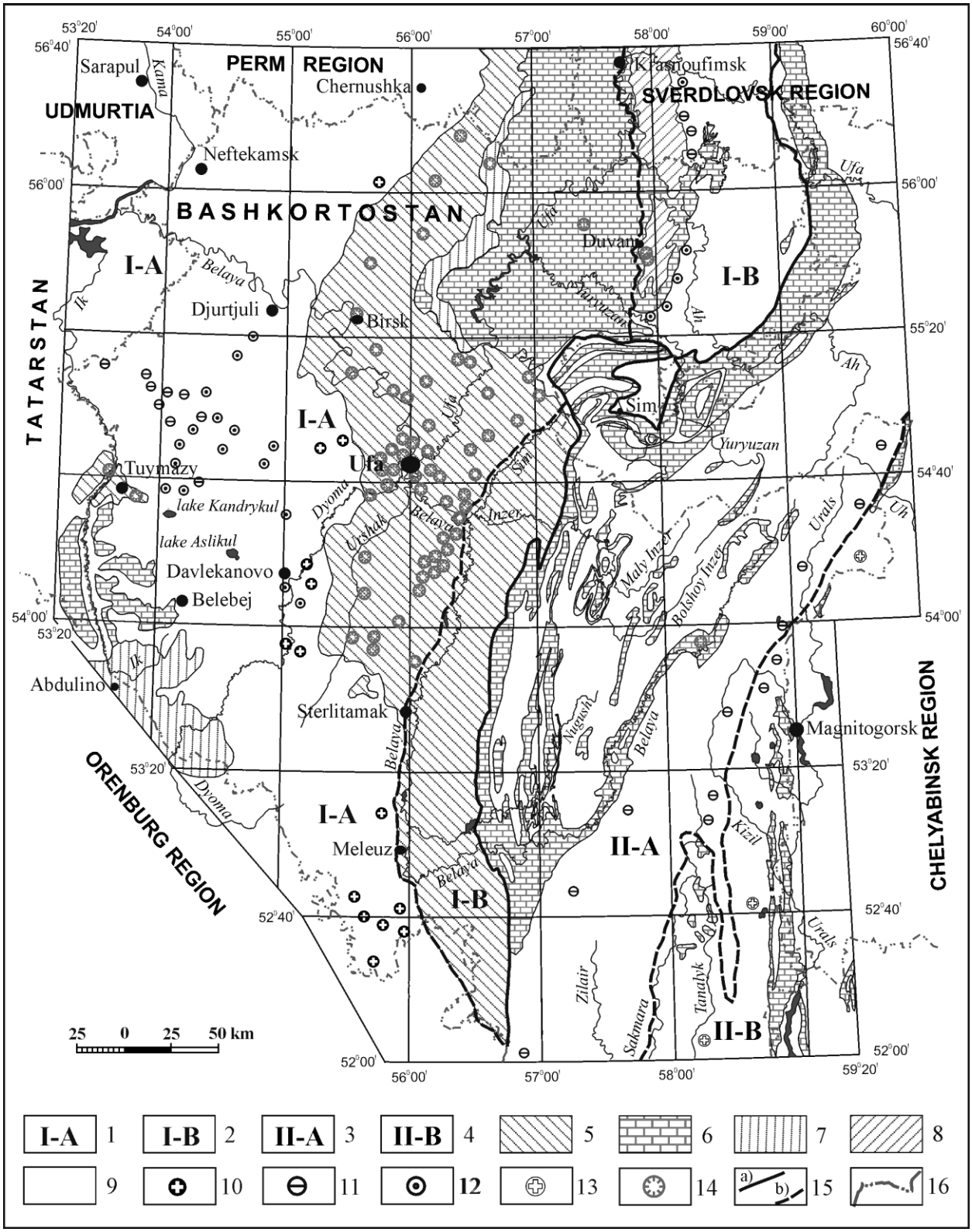

Fig. 1. Types of karst of the Southern Urals and Cis-Urals (Smirnov, 2020 [12 on 6, 7])

Karst country of the East European Plain (I): 1 — (I-A) plain kart in horizontally and gently lying rocks of the Cis-Urals; 2 — (I-B) plain and foothill kart of the Cis-Urals in gently sloping and weakly dislocated rocks.

Ural karst country (II): 3 — (II-A) mountain and foothill karst in dislocated and highly dislocated formations of the Urals; 4 — (II-B) flat karst in folded-block sediments of the Trans-Urals. Karst types: 5 — sulfate, 6 — carbonate, 7 — sulfate-carbonate, 8 — clastocard, 9 —

areas with no surface manifestations of karst. Local manifestations of karst: 10 — sulfate, 11 — carbonate, 12 — clastocard, 13 — sulfide. 14 — large karst sinkholes with a fixed formation time. Borders: 15 a) — karst countries, b) — types of karst by the nature of the relief and the conditions of bedding of rocks, 16 — subjects of the Russian Federation

Fig. 2. Field of clastocarst funnels on the southern outskirts of c. Ulkundy (Duvan district of the Republic of Bashkortostan). *Photo by Y. Sokolov, September 2021*

To the north and south of the village of Duvan, the occurrence of sinkholes decreases, following a decrease in the gypsum content of sandstones. Meanwhile, in the extreme north and south, in the area of development of the Koshelevskaya Formation, there are karst fields similar to the Ulkindinsky, associated with lenses and interlayers of gypsum. So, 10 km south-southeast of Krasnoufimsk, the density of craters with a diameter of 5-70 m and a depth of up to 15 m is 40-50 pieces per 1 km^2 [13. 30 km south of the village of Duvan (in the Yuryuzan-Atavsky interfluve), the density of craters is higher and amounts to 50-100 pieces per 1 km^2. Funnels here are mostly round, 5-50 m in diameter, 3-10 m deep, bowl-shaped and conical (fig. 3). Part of the funnels with ponors and plaster outcrops.

Fig. 3. Clastocarst funnels in the Yuryuzan-Atavsky interfluve. (Salavat region of the Republic of Bashkortostan). *Photo by Y. Sokolov, September 2021*

Outside the distribution of the Koshelevskaya Formation, clastocarst on the Priay Plain is developed along the left bank of the Ai River and is associated with the gypsum sandstones of the Sabanakovskaya Formation of the Kungurian Stage of the Lower Permian The gypsum content of the Formation is

extremely uneven; therefore, surface manifestations of clastocarst are formed only in some local areas. Funnels on them are small in size (up to 25 m in diameter) and usually occur singly. Karst fields are rare, but the density of craters on them per 1 km^2 can reach 110 pieces. *On the Pribelskaya Plain*, clastocarst is distributed locally in small areas in its western part, with their greatest occurrence in a strip about 70 km wide between the cities of Tuimazy and Dyurtyuli. V.I. Martin, according to engineering-geological surveys, notes its development also in certain areas in Ufa [7]. R.F. Abdrakhmanov et al. In the article of the Geological Bulletin of the Institute of Geology № 1 for 2021 give a map of the distribution of karst in the territory of the Southern Urals and the Cis-Urals [1, p. 107], which without explanations and justifications display the areal distribution of clastocarst along the left bank of the Dema and Belaya rivers at the latitudes of cities Davlekanovo-Dyurtyuli along the meridian of Belebey, and on the Priay plain, instead of clastocarst, a sulphate-carbonate type of karst is mapped. The authors of the article indicate a link to the map from the monograph "Karst of Bashkortostan" 2002 [2], but in the form as it is presented in the article, the map is absent in the monograph, and the overwhelming part of the contours of the main types of karst on it is identical to the map of karst types of the Southern Urals and the Urals 2020 [12, p. 44]. The monograph also contains a map of the karst of Bashkortostan by V.I. Martin without the contours of the areal distribution of clastocarst [7, p. 164].

Clastocarst on the Pribelskaya Plain is associated with sandy-clayey deposits of the Sheshminskiy horizon of the Ufa stage of the lower calving of the Permian system. Calcium sulphate and carbonate, together with clay cementitious material, is present in the rocks of the horizon in the form of cement. According to the state geological survey at a scale of 1:200,000, the amount of calcium sulfate in the cement of terrigenous rocks does not exceed 10%, and calcium carbonate reaches 40%. In addition, they contain thin (no more than 3 m) gypsum interlayers and lenses that are not sustained along strike.

V.I. Martin notes the development of clastocarst also in the rocks of the Lower Kazan substage of the upper section of the Permian system [7], but the author's studies of clastocarst did not record relief forms within the boundaries of development from the surface of this stratigraphic unit when decoding large-scale aerial photographs and during field routes.

Surface manifestations of clastocarst on the Belskaya Plain are monotonous and are represented exclusively by saucer, less often cup-shaped small (up to 30 m in diameter) and shallow (very rarely up to 3 m) funnels. They occur singly and do not form karst fields. A feature of their distribution is that they are often located in chains parallel to the nearest erosional incision from the west or south of it, and on the territory of Ufa clastocarst manifestations are represented by karst-suffusion subsidence.

Current development activity of clastocarst, the determining karst hazard of the territory is estimated by the frequency of karst sinkholes formation. Indeed, the frequency of the formation of karst sinkholes with a fixed formation time indirectly indicates not only the rate of dissolution and leaching of karst rocks, but also includes all the factors contributing to the formation of modern karst manifestations, and the sinkhole formation activity is the main indicator of the karst hazard of the territory [7, 11].

From published, stock and archival sources, the author has collected and systematized information about modern karst sinkholes in the Southern Urals and Cis-Urals within the boundaries of the RB over the past 100 years [12].

On the Priay Plain, in the gypsum sandstones of the Koschelevskaya Formation from 1952 to 2020, 8 large (up to 30 m in diameter and up to 32 m deep) and at least 10 small (up to 5 m in diameter and 3 m deep) sinkholes were reliably recorded. Most of them arose 2-10 km southeast of Duvan with a frequency of their formation of 0.01 pcs/km^2 per year. The largest sinkhole during this time occurred in April 1988, 2.3 km south-west of the village of Ulkundy (6 km south-east of the village of Duvan), which was recorded and examined by the author during the study of the EGP (Ulkundinsky depression). At the time of the first survey, the inlet of the sinkhole was round, 5 m in diameter. On its sides, eluvial-deluvial clays were exposed, under which fine-grained, thin-layered sandstones with leafy limestone interlayers lay. The depth of the sinkhole in the center was 22 m, and the diameter along the bottom was 10 m [8]. According to the re-examination of the hole in the fall of 1988, its dimensions with a bottle-like shape from the surface were 5.5x6.5 m, along the bottom - 11x14 m, and its total depth reached 32 (!) M [4]. 33 years later, at the site of the sinkhole, as a result of the collapse of its sides, a round cone-shaped crater 26 m in diameter and 13 m in diameter was formed (fig. 4).

On the Belskaya Plain, modern clastocarst in natural conditions are extremely rare; large karst sinkholes have not been recorded in the last 100 years [12].

R.F. Abdrakhmanov et al. [2] indicate that a sharp activation of the karst-suffusion process occurs during the construction of ponds and reservoirs. The creation of a reservoir with a pressure of 10 m on the Agarda River (the Karmasan River basin) caused the dissolution of layers of gypsum and gypsum cement in argillite-like clays.As a result, a chain of craters with a diameter of up to 2 m and a depth of up to 1 m arose in the upper reach of the left slope of the valley in the second year of operation of the pond, and then the reservoir with a capacity of 0.9 million m^3 was drained [2]. At present, the reservoir is being exploited, and in the last 30 years, no such phenomena have been recorded during the creation of small reservoirs on the Pribelskaya plain.

Fig. 4. Ulkunda ditch.
Left section by A. Smirnov, April 1988, right photo by Y. Sokolov, September 2021.

Thus, the current activity of the development of clastocarst both in the scale of its manifestation and in the frequency of the formation of its new surface forms on the Priay plain is several times higher than on the Pribelskaya.

Conclusions

According to the composition of karst rocks, Clastocarst is a peculiar, not traditional type of karst. In essence, it is a sulfate-carbonate (sulfate and carbonate) type of karst. A fundamental difference from it, clastocarst develops not in independently occurring sulfate and carbonate strata, as, for example, in the region under consideration along the western border of the Ufa plateau in the zone of their facies replacement with each other, but as inclusions in hardly soluble sedimentary sandy-clayey rocks in the form of cementing material or in the form of nests, interlayers and lenses of karst rocks. That is, clastocarst in the region fully corresponds to its definition by G.A. Maskimovich.

The most widespread and modern activity of development of clastocarst was received on the Priay plain than on the Pribelskaya, which is undoubtedly associated with the greater gypsum content of Permian terrigenous rocks in the first than in the second. At the same time, on the Pribelskaya Plain, the development of clastocarst is dominated by the carbonate component, which, as is well known, has a lower dissolving capacity than the sulfate one.

In conclusion, it should be noted that further research of clastocarst in the region is interesting to focus on monitoring the development of its manifestations, which does not require significant material costs, but the results of which can provide valuable material about the current activity of its development.

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