

GEODYNAMICS OF ARTYEMOVSKY UPLIFT SULPHATE KARST

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ABSTRACT

Karst characteristic properties of salt, sulphate and carbonate rocks have been studied in Artyemovsk district (Ukraine). Developments into three karst epochs have been established on the basis of structural, tectonic, paleogeographic, and lithologic and facial, geologic and hydrogeologic data. These epochs are closely connected with interruptions in sedimentation. Karst geodynamics and detailed investigations of karst activity nowadays made it possible to determine areas of its active development.

INTRODUCTION

The region where karst has been under detailed investigations is the south-west part of Artyemovsk Anticline Uplift located within Bakhmut Valley in the north-west of Donbass. The Uplift has been composed of Lower Permian (Nikitovsky and Slavonic suites) and Lower Triassic (Dronovsky suite) deposits overlaid with the cover of Paleogene, Neogene and Quaternary formations.

Connection of Artyemovsk Uplift with the contact zone of Dneprovsko-Donetsky Depression and Donetsky Ridge predetermined the depositional conditions in the Early Permian period when the Slavonic suite rocks were being formed. The movements of Donetsky Ridge in the Early Permian period caused movement of the pond borders in the region, their depth change, as well as introduction of friable material from Donetsky Ridge. All those factors led to instability of water salt concentration and complex lithologic composition of Slavonic suite rocks. At present karst is developing in Slavonic suite rocks.

GEOLOGY

The Slavonic suite is composed of sulphate rock strata 4m to 24m thick interstratified with layers of terrigenous formations 11 m to 19 m thick, salt strata and carbonate rock interlayers. The following strata are recognized (from the top to the bottom) in this rock massif: I, II, III, IV, V sulphate rock strata, Above-Bryantsevsky salt stratum (ABS), VI, VII sulphate rock strata, Bryantsevsky salt stratum (BS), unnumbered strata of sulphate rocks, Sub-Bryantsevsky salt stratum (SBS), Karfagensky salt stratum (KFS).

The thickness of salt strata exposed to karst processes varies from 22m to 24m, and thin salt interlayers occur throughout the suite. Interstratification of salt layers 2m to 12,5m thick, sulphate and clay rocks, and also thin interlayers of limestone and dolomites distinguish Karfagensky stratum. Salt strata are not homogeneous, and often contain clay and anhydrite inclusions.

Gypsum, anhydrite and gypsum-anhydrite represent the sulphate rocks. Gypsum rocks are composing the upper part of Slavonic suite, and from the depth of 55m to 90m anhydrite rocks replace them. Slavonic suite rocks are characterized by monoclinical folding with dip to the west and north-west. The salt-sulphate rock destruction within a long period of time substantially changed the Paleozoic rock surface (Figure 1).

1. The salt strata have been completely dissolved in the upper part and replaced by breccia composed of sulphate, carbonate and terrigenous rock fragments with clay.

2. The sulphate rock strata have been partially dissolved and do not always occur on the surface of Paleozoic rocks and have partially been replaced by breccia.

3. In the result of active dissolution of the salt strata the terrigenous and sulphate strata are bent and even folded.

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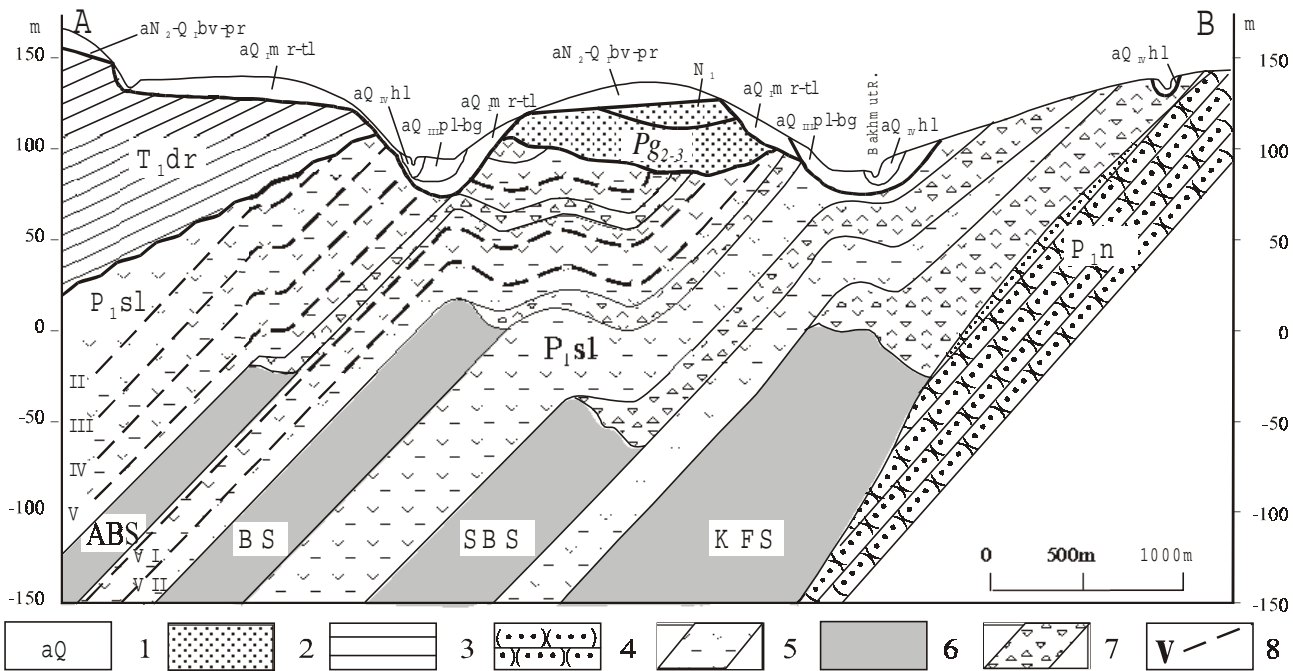


Figure 1 : Schematic geological cross-section A-B. 1- Quaternary and Late Neogene deposits; 2- Early Neogene and Paleogene deposits; 3- deposits of Dronovsky suite; 4- aleurolite of Nikitovsky suite; 5- terrigenous rocks of Slavonic suite; 6- salt stratum; 7- salt breccia; 8- gypsum stratum.

Therefore, the surface of the Paleozoic rocks has a complicated composition, significantly eroded, characterized by the remains of gypsum strata and buried karst forms of various sizes.

In the west and north of the region terrigenous deposits of Dronovsky suite overlay karstic rocks. Paleogene and Neogene deposits are not universally developed and occur in the watersheds, erosion and erosion-karst depressions in the Slavonic suite rocks. Sand and clay sediments of various genesis represent the Quaternary cover. Upper Neogene and Quaternary deposits compose the terraces of the Bakhmut-river, which is the main region drain. The additional geological characteristics and schematic geological map of the district are shown in Table 1 and Figure 2.

HYDROGEOLOGY

According to the region geology the following beds are recognized the water bearing bed of alluvial and alluvial-deluvial Quaternary deposits, the water bearing bed of Paleogene-Neogene deposits, the water bearing bed of Dronovsky deposits and the water bearing complex of Slavonic suite rocks.

The water bearing bed of Quaternary deposits (aQ_{I-III}) is slight abundant and low permeability. Holocene alluvial deposits (aQ_{IV}) are characterized by relatively higher hydraulic conductivity (up to 7.9m/day). The composition waters are sulphate and sulphate-chloride calcium and calcium-magnesium with total dissolved solids concentration from 0.7 to 7g/L. It should be noted that the concentration is reduced as far as moving away from the Bakhmut-river. In the places where Slavonic suite gypsum strata are covered with alluvial deposits crevice-karst waters intermix with alluvial waters. Alluvial waters are getting chloride-sulphate and more concentrated (up to 12.8g/L).

The waters of Paleogene-Neogene deposits (P_{Q2-3-N1}) connected with the sandstone and sands are characterized by varied composition with concentration from 0.9 to 7.0g/L. The hydraulic conductivity of Paleogene-Neogene deposits varies from 0.001 to 1.0m/day.

The waters of Dronovsky suite deposits (T_{1dr}) do not play a significant role. The waters are sulphate, sulphate-chloride sodium-calcium and sodium-calcium-magnesium with total concentration 1.0 to 5.3g/L.

The water-bearing complex of Slavonic suite rocks represents the system of water bearing beds. Waters are contained in crevice and karst gypsum, anhydrite, limestone, and dolomites. The clays of Dronovsky suite, Paleogene, Neogene and Quaternary deposits serve as a covering water-resistant bed. Slavonic monolith rocks serve as an underlying water-resistant bed.

Table 1: Formations, Complexes and Characteristics of Rocks

Formation Type, Genesis	Genesis of Geological Complexes	Lithologic Characteristics	Geological Index	Thickness, m
Quaternary non-glacial Continental	-Holocene Alluvial complex of river floodplains, ravine bottoms	Sands with loam lenses, gravel and pebble	aQ _{IV} hl	5 - 25
	-Late Pleistocene- Holocene Deluvial complex of river valley and ravine slopes	Dusty loam with sandy interlayers	dQ _{III-IV}	5-10
	-Early Pleistocene-Holocene Anemoclastic-Deluvial, Eluvial complex of plain deposits	Wood loam with inter-layers of buried soils	vd,eQ _{I-IV}	5-30
	-Later Pleistocene Alluvial Priluksko-Bugsky complex	Sand, loam	aQ _{III} pl-bg	3-17
	-Middle Pleistocene Alluvial Kaidaksko-Tyasminsky complex	Loam with interlayers of buried soils	aQ _{II} kd-ts	1-4
-Early Pleistocene Alluvial Martonoshsko-Tiligulsky complex	Sands, clays, silts, loam	aQ _I mr-tl	4-13	
Terrigenous Continental	-Late Pliocene-Early Pleistocene Alluvial-Lake Beregovsko-Priazovsky complex	Gravelly sands with interlayers and clay lenses	aN ₂ -Q _I bv-pr	3-10
	-Early-Middle Pliocene Alluvial-Lake Lyubimovsko-Oskolsky complex	Clays, silts, sands and gravelly sands at the bottom	aN ₂ lm-os	2-3
	-Early Pliocene Alluvial-Lake Belbeksko-Salgirsky complex	Sands, gravel, sandy clays	aN ₂ bl-sg	2-5
	-Miocene alluvial-lake complex Poltava suite	Sands, clay	N ₁ pt	up to 25
Carbonate-glaucinitic Marine	-Early-Middle Oligocene Marine complex Kharkov and Bereksky suites	Glaucinitic sandstone, sands with interlayers of clays and aleurolite	Pg ₃ hr-br	up to 24
	-Late Eocene Marine complex of Kiev suite	Glaucinitic sandstone, lime-like aleurolite	Pg ₂ kv	7-10
Parti-colored Continental	-Early Triassic Alluvial-Lake complex of Dronovsky suite	Clays, aleurolite with sandstone interlayers	T ₁ dr	up to 160
Salt-bearing Lagoon	-Early Permian Lagoon complex of Slavonic suite	Argillites, aleurolite, salt, sulphate, carbonate rocks, breccia	P ₁ sl	up to 450
Terrigenous-carbonate Lagoon	-Early Permian Coastal-Marine complex of Nikitovsky suite	Argillites, aleurolite with interlayers of sandstone, limestone, dolomites	P ₁ n	170-250

The waters are head type and crevice-karst type.

The hydraulic conductivity of the karstic massif varies from 0.001 to 47.5m/day. Highly karstified gypsum with large karst cavities has good filtration properties. The salt rock leaching breccia is characterized by low filtration properties.

The composition of the crevice-karst waters is unstable and closely connected with the type of the water-bearing rocks and distribution of the salt in the massif. The waters in the upper part of Slavonic rocks have the concentration of 1.8 - 5.6g/L and sulphate calcium composition. The waters in the lower part of Slavonic rocks have the concentration of 254.7g/L and chloride sodium composition.

Thus, the hydrogeological conditions of the region are:

1. Permian rocks contain some water bearing beds. Waters hydraulically connected in the areas where above-salt rocks are dislocated and also are significantly karstified.

2. There is a hydraulic connection between crevice-karst waters and waters of Quaternary alluvial and alluvial-deluvial deposits. In some areas of the Bakhmut-river valley with alluvial deposits directly bedding on gypsum strata crevice-karst waters are discharge into alluvial deposits.

3. The crevice-karst waters and waters of Paleogene-Neogene deposits are actively interchanging in erosion-karst depressions of Permian massif surface.

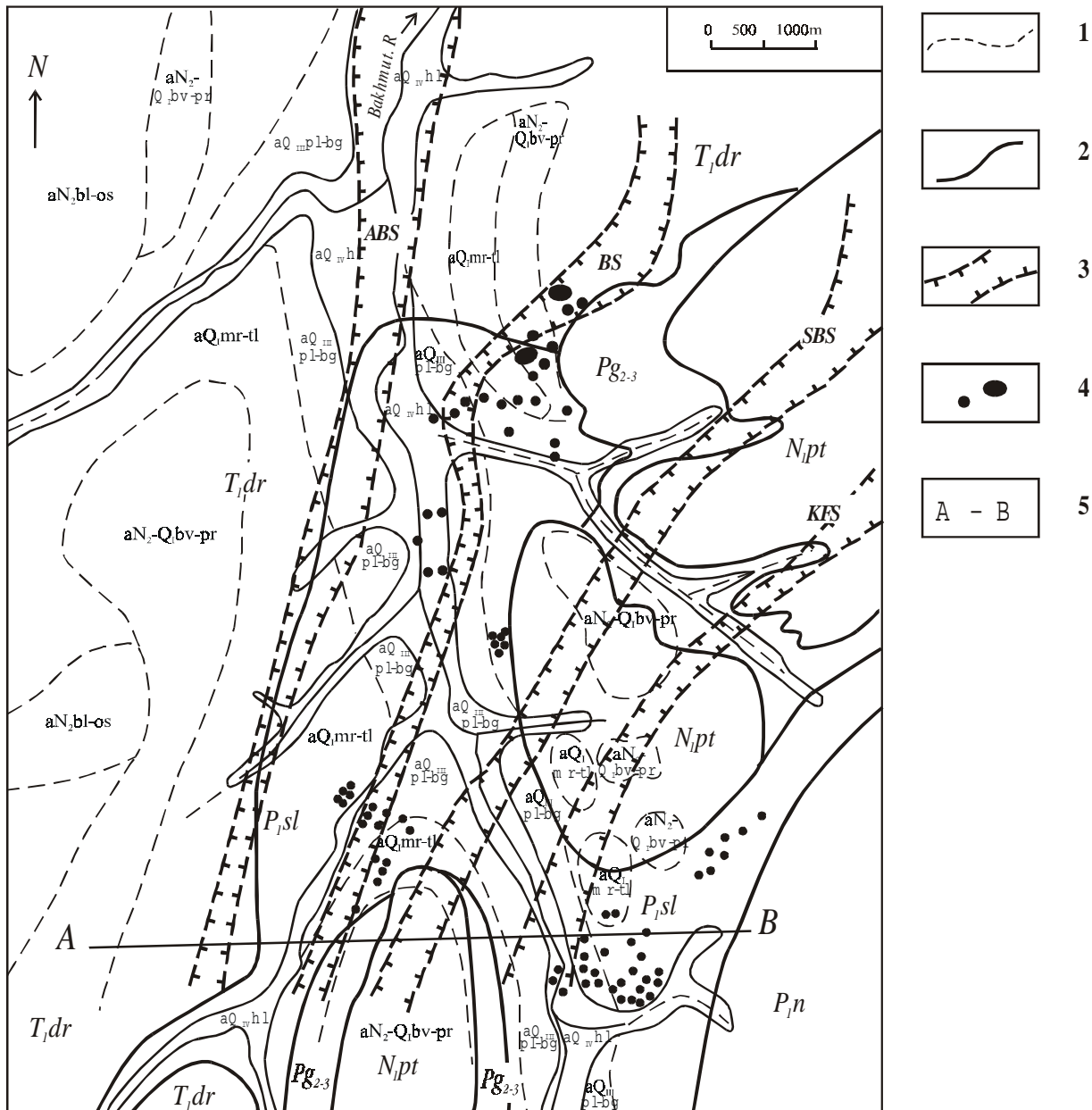


Figure 2 : Schematic geological map of the Artyemovskiy district (fragment). 1- boundary of terraces: aQ_{IV}hl - floodplain Holocene; aQ_{III}pl-bg - Late Quaternary; aQ_Imr-tl - Early Quaternary; aN₂-Q₁bv-pr - Late Pliocene-Early Quaternary; N₂bl-os - Early-Middle Pliocene; 2- geological boundary; 3- salt stratum projection; 4- sinkhole and depression; 5- cross-section line.

KARST PHENOMENA

Karst in the region has been developing, in our opinion, for a long period of time since the end of the Permian period. This long period of time has been characterized by leaching of salt rock strata and sulphate rocks. The development of both karst and erosion processes caused formation of rather complicated relief of the Slavonic suite surface. As a whole, the overall area of very strong karst development has turned into a depression complicated by smaller erosion, erosion-karst and karst forms.

The most typical underground manifestations of karst in the region are breccia of salt and sulphate rock leaching; ancient buried erosion-karst ravines, local depressions and karst cavities. The salt breccia is composed of the fragments of sulphate, carbonate rocks and the remains of the salt leaching by itself. The cement of breccia is a clay material. The salt breccia occurs in terms of layers, interlayers and lenses at

various depths from 25 to 197m. Fragments of gypsum and interlaying carbonate rocks bound with clay represent the gypsum breccia.

The ancient buried erosion-karst ravines take their origin from karst and erosion processes. On the surface of Slavonic suite rocks they are stretching in the north and east, but less often south-east and north-east directions. They are 30 to 130m wide and extending to 8000m and more. The ravines are filled with Paleogene or younger deposits. The buried karst local depressions are a specific feature of antiquity of karst process. They are filled with clay-gypsum breccia. The size of the local depressions varies from 200 to 650m and they reach 20m in depth.

Karst cavities and caverns are, mainly, related to gypsum, limestone and gypsum breccia. The cavities are 0.2 to 5.0m high, developed at the depth of 5.4 to 56m, occasionally up to 87m. There are two types of cavities: unfilled and filled cavities. In one case the cavities are filled with clay, in another cases – with sand and clay. Ancient karst cavities are filled with secondary gypsum (selenite) or some times with halite.

Current surface karst forms are widely met and represented by three main types: erosion-karst ravines and karst local depressions, local forms of problematical genesis and typical karst forms - sinkholes.

Current erosion-karst ravines and karst local depressions, as a rule, are connected with ancient erosion and erosion-karst forms. Erosion-karst ravines are not usually deep, extend from 500 to 700m and from 100 to 120m in width. Karst local depressions are ellipsoid with the size of 200-350m. Large karst cavities are connected with axis zones of erosion-karst ravines and zones of their intersections.

The mechanism of local problematic forms is not definitely established. They might be very old karst caves-in or local subsidence (Nechtchetkine 1999).

Sinkholes, both old and young, occur on the slopes of the Bakhmut-river valley, in the areas where gullies and erosion-karst ravines have been developed. Some individual areas contain 70 to 210 sinkholes per 1 square kilometer. The sinkholes are characterized by a cone-shaped and steep-sloped, 0.3 to 25m in diameter and 0.5 to 20m in depth. Doubled sinkholes often occur. Karren and ponors 0.3 to 1.0m in diameter are met in the places where sulphate rocks reach the ground surface (south-east part of the region).

KARST GEODYNAMICS

From the geological conditions 3 epochs of karst development are differentiated.

Late Permian Karsting Epoch (I)

Early Permian period is completed with general uplift and desiccation of Donetsky Ridge. A spacious flatland continent comes into life. Uplifting in Permian period is accompanied with folding and formation of Artyemovskiy anticline. Waters of continental origin drive out seawaters from the rock massif. Aggressive surface waters get free access to all soluble rocks (Sokolov 1962). Karst covers all lithologic types of soluble rocks. Salt strata are strongly dissolved and replaced by leaching breccia. Anhydrite is hydrated; sulphate and carbonate rocks are dissolved with formations of hollows and destroyed zones.

Sinkholes, karren, ponors, subsidence above salt strata are progressing; large erosion-karst ravines and local depressions are under formation. Karst deformations and erosion of the ground surface significantly influence the relief, surface drain and underground water discharge.

When the Triassic period with its hot and dry climate begins karst dies out. The terrigenous formations of Dronovskiy suite overlay karstic rocks, fill in the crevices and cavities, close to the surface, prevent infiltration of aggressive waters, and change the surface and underground drain. Secondary halite and gypsum in crevices, caverns and small cavities get crystallized.

Middle Triassic-Middle Eocene Karsting Epoch (II)

At the beginning of the Middle Triassic period sedimentation stops. Its typical hot and humid climate changes for the humid subtropical climate in the Early Paleogene period. A complicated 30-60m deep erosion system is formed. The water vertical circulation zone increases. Karst comes into active development. ABS stratum is gradually leached. Then karst processes step-by-step spread over to BS stratum (the edge parts of the salt strata that reach the surface were leached within karsting epoch I). The salt strata leaching reached the depth up to 138m for ABS, 117m for BS, 190m for SBS and 105m for KFS. Dissolution of salt strata is accompanied with warping and caving in overlaying rocks and salt breccia formation. Karst cavities in gypsum up to 3m high are developing at the depth as much as 87m.

By the end of karsting epoch II the relief of karstic massif was characterized by high ruggedness due to

karst and erosion. Erosion-karst ravines, karst local depressions and other surface karst holes of a smaller size appeared on the massif surface.

In the Late Eocene and during the whole Oligocene the sea enters the region, and the deposits of Kiev, Kharkov and Bereksky suites are formed. Karst cavities, erosion-karst ravines and local depressions are filled with clay and sands. Karst is dying out. In the Miocene the sea withdraws, the sediments of Poltava suite are accumulated under the continental conditions.

Early Pliocene - Holocene Karsting Epoch (III)

Karsting epoch III began in the Early Pliocene and is going now. 4 stages of karst development are differentiated in this Epoch. The first karsting stage is caused by neotectonics manifestation in the Early Pliocene that brought to life ruggedness of the territory. At the same time, the covering Lower Triassic, Paleogene and Miocene deposits were cut in. The conditions for karst development were created again.

The second karsting stage belongs to the Late Pliocene and Early Pleistocene and is marked by erosion of the Paleogene-Neogene deposits in the west part of the region. The surface drainage system existed before has been finally reformed and has been taking on its present pattern.

The present valley of the Bakhmut-river stretches over to the east of the buried valley. The washout of the covering deposits, outcrop of the karstic rocks and deep ruggedness of the relief by a new cutting in of the surface drainage system made it possible for precipitation and aggressive surface waters permeate into the sulphate massif, activated the circulation and discharge of the crevice-karst waters.

Many underground karst forms created in karst epochs II and I are rejuvenated, new cavities and holes develop. Sulphate rocks are dissolved and cavities develop most actively within fractured zones that correspond to erosion and erosion-karst ravines on the ground surface. Sinkholes, local depressions and ravines appear on the ground surface.

In general, the Early-Middle Quaternary period is characterized by relatively quiet conditions and predominating accumulative processes.

The third stage of karsting epoch III begins from the second half of the Middle Quaternary period and lasts till the Holocene. The pulsation positive movements in this time caused a repeated change of depth of the Bakhmut-river and its gullies that resulted in formation of a Middle Quaternary terrace and three Late Quaternary ones. The local erosion basis deepening produces favourable conditions for karst activation. Karst develops in the areas karstified earlier and is related to the Bakhmut-river valley and its gullies, erosion-karst ravines and zones where these elements are rugged (Nechtchetkine, Safronova 1996).

The fourth stage belongs to Holocene and develops under the condition of poor tectonic shoves. Karst, mainly, develops in sulphate rocks. Salt leaching does not occur or is in a very slow progress.

CONCLUSION

Thus, by the beginning of Holocene, non-homogenous geological settings have been created in the region. Erosion-accumulative processes have affected the west part of the Bakhmut-river valley, the Paleogene and Neogene deposits have been washed out, and the terraces are characterized by continuous development.

The salt and gypsum strata were substantially leached in the early karsting epochs up to complete disappearance in the cross-section. Karst is not developing now in the area with Triassic deposits

Paleogene and Neogene deposits are met in the east part of the Bakhmut-river valley. The Later Eocene-Early Quaternary terraces are remaining fragments. The gypsum is covered with a thin layer of terrigenous deposits or cropped out on the gully slopes.

Aggressive precipitation directly go to fractured karstic rocks. Karst is actively developing. New sinkholes, karren and ponors occur along with ancient karst forms.

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