

Chapter II.8

GYPSUM KARST OF THE EASTERN-EUROPEAN PLAIN

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1. General characteristics

The Eastern-European Plain (abbreviated EEP; also known as the Russian Plain) is one of the largest plains in the world. It extends north to south from the Arctic Ocean coast to the foothills of Caucasus Mountains for almost 3,000km, west to east from the Carpathians to Ural Mountains for more than 2,000km.

The geological foundation of the plain is the Precambrian East-European platform, complicated by numerous anticlines, synclines, fault steps and depressions in the crystalline basement. The thickness of sedimentary cover varies from zero, where the crystalline rocks crops out at the surface (the Ukrainian and Baltic shields), to 5-6km or more in grabens, basins and depressions (e.g. the Pre-Caspian, Dnieper and Pechorian depressions).

The sedimentary cover of the platform is composed of deposits of Cambrian to Quaternary age. Palaeozoic sediments are most common. Various stratigraphical units contain sulphate and sulphate-carbonate assemblages (gypsum and anhydrite interbedded with limestone and dolomite) (Fig. 1). Sulphate rocks underlie more than 80% of the entire region. Most extensive are the sulphate and sulphate-carbonate rocks of the Lower Permian (2.4 million km²), Upper Permian (1.5 million km²), Carboniferous (1.0 million km²) and Devonian (0.6 million km²). Sulphates are less common within the Jurassic (150,000 km²), Ordovician and Silurian (100,000km²) and Neogene (35,000km²). They are negligible within Cretaceous and lacking within Cambrian, Triassic and Palaeogene sequences. The above sequence areas are partially superimposed.

However, the areas where sulphate rocks crop out at the surface, or occur in relatively close proximity to it (within the upper 100-150m), are much smaller (Fig.2). Gypsum karst is most strongly developed and best manifested at the surface within these areas.

In almost all the areas where gypsum karst is manifested to the surface, it is developed within Palaeozoic rocks, particularly in the Devonian (in the Baltic republics and Timan ridge) and Permian successions (the northern, central and eastern parts of the EEP, pre-Caspian lowland and Donetsk Basin). Karst in Ordovician, Silurian, Jurassic and Cretaceous gypsum is documented only in deep-seated occurrences, without any surface expression. In the Western Ukraine (the Podol'sko-Bukovinsky region) gypsum karst has developed within Neogene rocks and displays distinctive characteristics in terms of both underground and surface forms.

As illustrated by Figure 1, gypsum karst within the EEP is associated predominantly with old, mainly Permian formations. Only the gypsum of the Western Ukraine is the product of relatively recent evaporite formation within the Para-Tethys zone. In the Palaeozoic successions sulphate rocks are represented commonly by quite thick (80-120m) sulphate-carbonate and sulphate-argil-

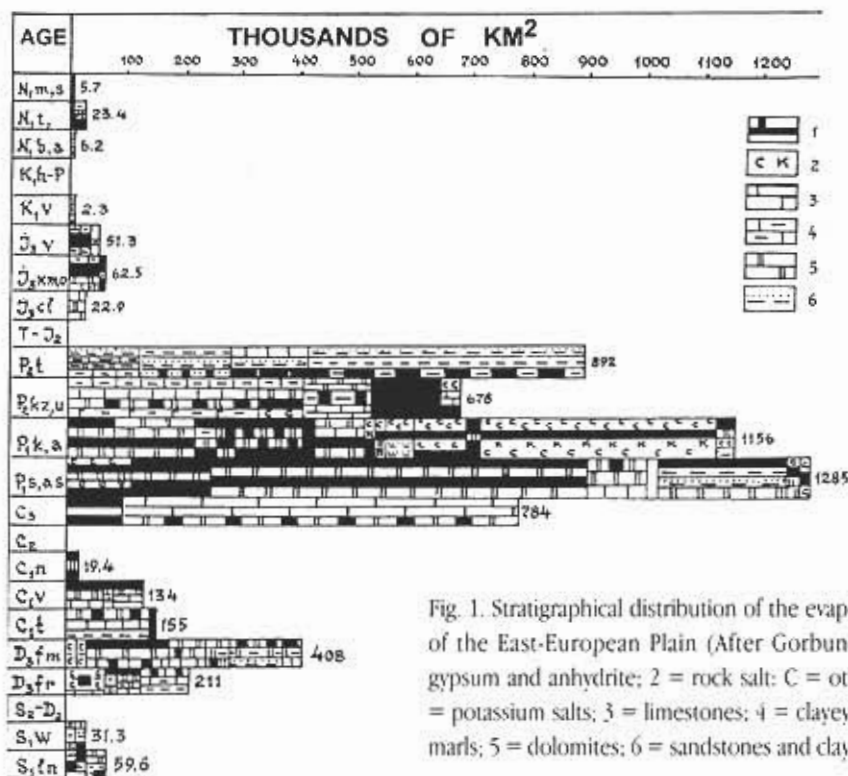


Fig. 1. Stratigraphical distribution of the evaporite formations of the East-European Plain (After Gorbunova, 1977): 1 = gypsum and anhydrite; 2 = rock salt; C = other chlorides, K = potassium salts; 3 = limestones; 4 = clayey limestones and marls; 5 = dolomites; 6 = sandstones and clays.

laceous units, comprising gypsum and anhydrite intercalated with dolomite, limestone, clay, marl and salt. The sulphate rocks normally have a cryptocrystalline or finely-crystalline structure. Because the rocks are well stratified and have experienced repeated cycles of tectonic activity and karstification, the sequences are heavily fractured and locally brecciated. In contrast, the Neogene gypsum in the Pre-Carpathian region is characterised by lithological homogeneity, occurring as a single bed (10-40m), surrounded by non-evaporitic sediments. This gypsum has a mainly coarsely-crystalline heteroblastic structure, which is the result of re-crystallisation and alteration of the rock in the vertical direction. Tectonic discontinuities are discrete and do not cause severe disruption of the gypsum, although they do separate the strata into large blocks.

Differences in the lithology, structure and age of the Palaeozoic and Neogene sulphate sequences, (along with other factors, such as depth of occurrence, presence of cover beds, relief etc.) largely determine locally important distinctive characteristics of the karst within corresponding regions of the EEP. The prolonged and complex history of tectonism, geomorphic development and karstification in gypsum karst regions upon the Palaeozoic sequences (such as the Pre-Urals) is responsible for the common occurrence of filled cavities and an abundance of other palaeokarst features, for the generation of regionally extensive 5-30m-thick sequence of karst breccia, capping or replacing the gypsiferous formation, and for the presence of large, polje-like,

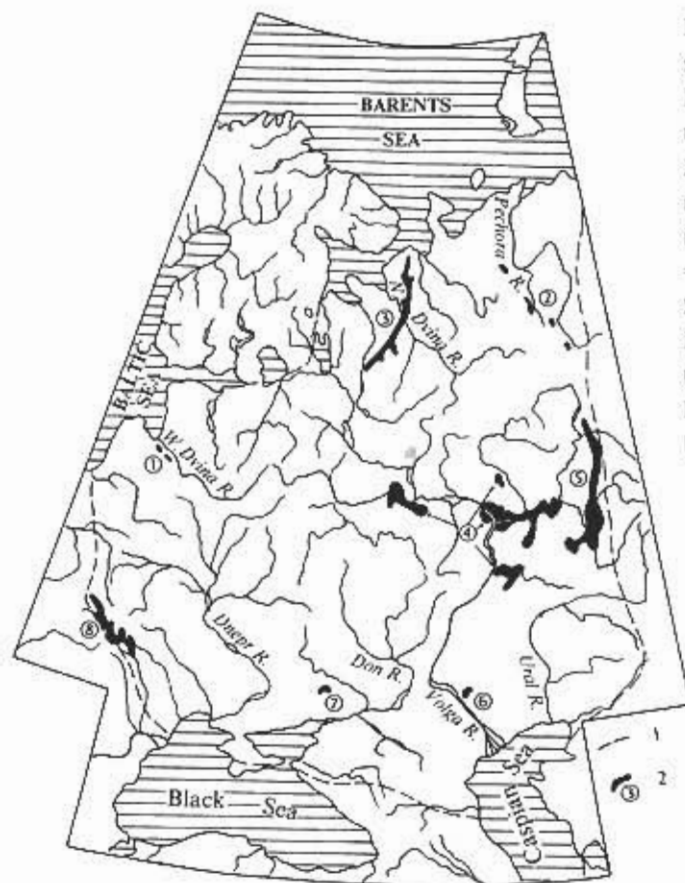


Fig. 2. Main regions of surface sulphate karst displays on the East-European Plain: 1 = contour of the East-European Plain; 2 = areas of intense development of gypsum karst. Numbers indicate the following regions: 1 = Baltic, 2 = Timan, 3 = Pinego-Severodvinsky, 4 = Volgo-Kamsky, 5 = Pre-Urals, 6 = Pre-Caspian, 7 = Donetsk, 8 = Podol'sko-Bukovinsky (Western Ukraine).

depressions and dissolution troughs filled with Neogene sediments.

In the Pre-Carpathian region (Western Ukraine) the karst is related to a single uplift cycle and is characterised by a relatively clear structural guidance, the presence of well-preserved and extensive maze cave systems, and a "simplicity" and uniform style of surface karst landforms.

The differences specified above are generally applicable throughout the EEP. However, when considered in detail, each gypsum karst region, even different karsts that have developed upon formations of the same-age, has many distinctive features, determined by local geological, geomorphological and hydrogeological settings.

There are many published works devoted to the gypsum karst of different regions of the EEP, but only two of them provide reviews of the whole plain (Rodionov, 1963; Gorbunova, 1977). Rodionov differentiated karst regions on the basis of their relationships to large tectonic structures, and considered both carbonate and sulphate karst within the specified regions. Gorbunova focused specifically on gypsum karst and made a regional division based upon the occurrence of evaporitic formations. Thus, the two schemes differ considerably. The regional division adopted in

*Table.***Geological settings of the main gypsum karst regions of the Eastern-European plain**

Karst region	Stratigraphical index of gypsiferous formations	Lithological associations	Typical thickness of main gypsum beds (total thickness of the formation), m	Tectonic setting, the type of gypsum occurrence	Lithology and thickness of the overburden, m
1. Baltic	D3 fm	Sulphate -carbonate -clayey	10-20 (40)	Latvian saddle, stratified, horizontal	Sands, clay, 10-50
2. Timansky	P1 k D3	sulphate -carbonate, sulphate -carbonate -clayey	5-20 (30)	Timan high, stratified, gently-inclined (2-6°)	Loams, alluvium, 5-30
3. Pinego-Severodvinsky	P1	sulphate -carbonate	20-30 (80-120)	Moscow syncline, stratified, horizontal	Loams, sands, aleurolites, 0-30 and more
4. Volgo-Kamsky	P1 k P2 a P3 s	sulphate, carbonate -sulphate	10-20 (60-65)	Moscow syncline, stratified, horizontal	Loams, sand, argillites, 0-100 and more
5. Pre-Ural	P1 k	Sulphate -carbonate	10-20 (100-120)	Highs and depressions of the east flank of the East-European Platform, stratified, monoclinical (3-5°) and brachy-folded	Loams, sandstones, argillaceous sediments, 0-60
6. Pre-Caspian	P1 k	Sulphate -clayey, sulphate -salt	40-50 (40-100)	Gypsum caprocks of salt domes	Loams, clays, pebbles, 0-10 and more
7. Donetsk	P1	Clayey -sulphate, sulphate -carbonate -clayey	15-20 (60-100)	Donetsk depression, stratified, horizontal	Sands, clays, limestones, 0-60 and more
8. Podol'sko-Bukovinsky	N1 bd	Sulphate	20-40	South-west flank of the East-European Platform, Carpathian fore-deep, stratified, horizontal to gently-dipping (2-4°)	Clays, marls, limestones overlying the gypsum 5-100

this paper attempts to combine elements of both approaches and is simplified to provide a convenient framework within which to compare the characteristics of the individual regions. Eight main karst regions (see Fig.2 and Table) are distinguished, within which gypsum karst is present at the surface and is characterised by specific karst type assemblages, not only by "hidden", deep-seated, intrastratal karst. Within each region it is possible to identify several (up to 5) karst areas where a gypsum karst of particular type predominates.

2. Regional overview

Some of the important gypsum karst areas within the EEP are described in detail in separate chapters of this volume. The overview below is intended to provide a brief comparative picture of the entire region, with special emphasis on those areas that are not covered by other chapters.

2.1. The Baltic region

The region is located in the northwest part of the EEP. An Upper Devonian gypsiferous formation occur in the shallow sub-surface or at outcrop within several small (7-113km²) areas. The formation comprises two 15-20m-thick beds of gypsum. Another, the Narva formation, consist of intercalated, relatively thin (0.3-3m) layers of gypsum, clays and dolomites and never crops out.

Gypsum karst settings represented in the region include subjacent intrastratal and entrenched karst types. Surface karst features (collapse and subsidence dolines, karst lakes) are best developed where the overburden thickness does not exceed 20-25m. In some localities the density of karst forms reaches 200 units per km². Karst forms in many places are related to upward discharge of confined or semi-confined aquifers. The presence of H₂S in water emerging from many springs and boreholes indicates that sulphate reduction processes are active in the source aquifers. Caves are uncommon. A detailed account of gypsum karst of the region is presented in Chapter II.10.

2.2. The Timansky region

The region encompasses numerous areas of subjacent intrastratal and denuded karst, with areas of deep-seated gypsum karst between, lying within the extensive Timansky ridge, a Riphean folded structure that stretches across the northeast part of the Eastern-European Platform from the northern Urals to the Arctic Ocean. Crystalline basement rocks crop out in the central parts of the ridge. Palaeozoic formations, which contain beds (up to 20-27m) of sulphates, occur on the slopes of the uplift, and are complicated by gentle linear and dome-like folds.

Gypsum karst is developed in Devonian (Frasnian; single gypsum beds) and Lower Permian (Kungurian; intercalated gypsum, dolomite and limestone beds) rocks. Where gypsum occurs at shallow depth dolines and blind valleys are common. In the Vym' river basin there are areas with a very high density of karst landforms, resembling badlands topography. Deep-seated and subjacent intrastratal gypsum karst is recorded in the gypsum mining area along the Izhma river, where the Devonian gypsiferous formation is up to 100m thick (Lysenin & Sosnovskaya, 1974). Boreholes and mines have intercepted numerous cavities yielding sulphate-rich water (TDS contents 2.1-2.4 g/l). The mine experienced karst water inflow that increased from 1,700 m³/day in 1959 to 20,000 m³/day in 1965. This inflow supposedly developed due to leakage from the nearby river, and eventually led to abandonment of the mine. The total water withdrawn in 1961-1965 was 8,820,000m³.

In general, the gypsum karst of this extensive taiga region is as yet poorly studied. The available data are derived from the works of Ljubimov (1959), Torsuev (1964, 1975), Rodionov (1963) and Lysenin & Sosnovskaya (1974).

2.3. The Pinego-Severodvinsky region

This is one of the largest integrated gypsum karst regions in Europe, located in the north of European Russia. It stretches more than 1,000km from south to north as a relatively narrow belt (10-50km wide), almost reaching the Barentz Sea coast. The Severnaja Dvina river dissects the middle of this belt. Sulphates are represented by Lower Permian gypsum and anhydrite. South of the Severnaja Dvina the sulphates are intercalated with dolomites and limestones, and to the north the gypsum and anhydrite form a relatively homogenous sequence 80-120m in thickness. Karst development is most prominent within the latter area, which is also known as the Belomorsko-Kulojsky Plateau.

Gypsum karst is represented by intrastratal entrenched and denuded sub-types. Surface karst morphology includes a great variety of forms, including different types of dolines, shafts, gorges, canyons, blind valleys and large depressions. The remarkable karst hydrology includes rivers and smaller streams with underground and surface course sections, karst lakes, springs, and so on. Locally, there are karst fields with an extremely high density of different landform types, some of which are 20-50m deep. As these are covered by taiga forest the area represents almost impassable terrain.

There are about 150 known caves in the region, with some 50km of mapped passages. 22 caves are longer than 1 km. The Kulogorskaja-1-2-Troja system is the longest gypsum cave in the world outside the Western Ukraine, with a length of 14,100m. Most of caves display linear or crudely dendritic patterns, although maze patterns are also common. Some caves have up to 4 storeys.

The gypsum karst of the region is described in detail in many published works, of which the more important include Torsuev (1964), Chikishev (1966), Saburov (1974), Caves... (1974) and Malkov et al (1986, 1988).

2.4. The Volgo-Kamsky region.

This region lies in the central part of the EEP, in the basins of the Middle Volga and Kama, and corresponds to the Volgo-Ural syncline. Within the region four relatively large gypsum karst areas are distinguished according to their major prominent tectonic structures: Gorkovskiy, Nizhnekamsky, Zhigulevsky and Vjatsky.

Karst is developed in a Lower Permian formation, in which 10-45m-thick gypsum beds are intercalated with limestones and dolomites. The formation is overlain by karstified limestones and dolomites, and sequences of terrigenous (poorly pervious) marls, argillites and sandstones, and/or glacio-fluvial (highly-pervious) sands. The prevailing karst development settings represent deep-seated and subjacent intrastratal karst.

Surface karst features develop in areas where the thickness of the terrigenous overburden is least (less than 40-50m), or where the overburden is represented by unconsolidated permeable sands, even if their thickness is great (up to 100m). In the former case, deep pit-like or pot-like collapse dolines predominate, while in the latter areas cone karst suffosional dolines are more common. The density of dolines recorded in some localities can be very high (93 or even 261

units per km²). There are also some large flat-floored karst depressions, dry valleys, karst lakes and springs, commonly discharging sulphate-rich water from deep-seated confined and semi-confined aquifers. Drilling data supply many recordings of cavities and brecciated zones within the gypsiferous formation.

The main works that deal with the gypsum karst of this region include: Iljin et al. (1960), Karst phenomena... (1960), Problems... (1962) and Stupishin (1965, 1967).

2.5. The Pre-Ural region

The region is located in the east of the plain. In the tectonic context it corresponds to the eastern flank of the platform and to the adjacent Ural foredeep. Sulphate rocks occur at relatively shallow depth (within the upper 100-150m of the preserved geological column) across an area of 37,000km² (Maximovich & Kostarev, 1973). The 100-120m-thick sequence of gypsum and anhydrite of the Lower Permian Kungurian Member includes some limestone and dolomite beds (commonly 2-5m thick). The outcrop of the gypsiferous formation stretches from north to south as a 10-20km-wide belt that widens in the southern (Bashkiria) part.

An erosional network is incised to different depths into the sulphate-carbonate sequence, locally cutting the full thickness and dividing the succession into isolated massifs. Consequently, the karst sub-types represented in the region range from deep-seated intrastratal karst through subjacent and entrenched, to denuded karst.

The most intense karst development is observed in the vicinity of river valleys, and within surface watersheds where the overburden thickness is reduced. Regionally, the most karstified areas correspond to the axis of the "sulphate belt", as westward and eastward the formation is buried by terrigenous sediments to considerable depths. Doline density reaches values of 500 units per km² locally. Other karst landforms include trenches, blind and/or dry valleys and large depressions. There are more than 200 known gypsum caves, the largest being the 5,600m-long Kungurskaya Ledjanaja (Kungur Ice Cave). Karst hydrology is represented by underground rivers and many karst springs, with discharges ranging up to 200 L/s.

Gypsum karst development in the region has a long and complex history dating back up to Mesozoic. Its earlier features include large depressions filled with Neogene sediments, whose floors lie 50-60m below the levels of modern valleys. Prolonged karst development has resulted in the formation of a 5-30m-thick cover of brecciated material overlying the remaining gypsum. Along the axes of structural uplifts, such as the Ufinsky dome, such breccia entirely replaces the gypsiferous formation. Karst breccia horizons are also recorded commonly within the formation.

The gypsum karst of the region has had considerable effect upon economic activity, and in turn, there has been a strong human impact upon the karst (see Chapter I.11).

Gypsum karst has been well-studied in the region; several hundred publications are devoted to it. Most important among these are: Gorbunova (1965, 1977), Gorbunova et al. (1992), Lukin (1964), Lukin & Ezhov (1975), Martin (1973), Maximovich & Gorbunova (1958) and Pechorkin (1969). A more detailed account of the gypsum karst of the region is presented in Chapter II.11.

2.6. Pre-Caspian region

This extensive region lies on the south-east side of the EEP, and is also known as the Pre-Caspian lowland. In the tectonic respect it represents a depression filled with thick (3 to 5km) sedimentary deposits. Some 1500 salt diapirs (domes) are known throughout the region. The dome arches normally lie at depths ranging from 200 to 1500m but locally their overlying gypsum rocks (the Lower Permian Kungurian Member) and underlying salts crop out at the surface. Some domes are topped by secondary gypsum caprocks, up to 100m thick. In fact, there are several tens of isolated gypsum karst "islands" throughout the region, ranging in area from 50 to 300km².

The characteristics of the karst are determined mainly by the depth of occurrence of the sulphate rocks. They are commonly karstified from the surface, although some deep-seated karst features are recorded that are associated with saline waters. In the Chelkarsky dome, karst cavities have been intercepted by boreholes at depths up to 350m. At the gypsum/salt contact some boreholes yielded up to 2.5 L/s of Cl-Na-Ca-SO₄ water.

Gypsum karst in the region is described in Gedeonov (1947), Gvozdetzky (1953), Korobov & Polenov (1964), and Sotnikov & Arkhidjakonskikh (1974).

2.7. The Donetsk region

This comparatively small region (about 2,000km²) is located on the south of the EEP, within the Donetsk depression, where salt and sulphate rocks of the Lower Permian evaporite formation are present. The following sequence types are distinguished: clayey-anhydrite, salt, gypsiferous with dolomites, and terrigenous. Gypsum karst is reported in areas where sulphate rocks lie at shallow depths or crop out at the surface. Dolines are associated mainly with gypsum karst, and large depressions are believed to have originated due to dissolution of salts. Within such depressions the gypsum beds are heavily broken and brecciated. In areas where gypsum beds up to 60m thick are intact, caves are reported to have been intercepted by gypsum mines. In the Pshenichny deposit, the average ratio of area of cavities in the workings to the area of intact original rocks is 17.5%. The largest known cave, which is 150m long, displays phreatic morphology.

The gypsum karst of the region is described in the works of Khod'kov (1955), Kozintzhev (1971) and Klimchouk & Rogozhnikov (1972).

2.8. The Podol'sko Bukovinsky region

The region is situated on the southwest side of the EEP, stretching along the junction between the platform and the Carpathian foredeep. The extensive 10 to 40m-thick gypsum bed of Miocene (the Upper Badenian Member) is intensely karstified. It is underlain by Lower Badenian sandy-carbonate sediments and overlain either by limestones and argillaceous limestones, or by thick (up to 100m or more) Sarmatian clayey sequences. The total area of the gypsum karst is about 20,000km².

Karst development began under deep-seated artesian conditions during the Late Pliocene. Owing to differential uplifts during the Late Pliocene to Pleistocene and a consequent deep incision of major valleys, the current karst development settings vary between three sub-parallel

zones, which represent deep-seated, subjacent and entrenched types of karst. Surface karst morphology and hydrogeological features differ considerably between these zones. In the entrenched zone and, to some extent, in the subjacent karst zone, giant relict maze caves have been explored. Five of these hold the highest ranks in the list of the world's longest gypsum caves. The longest cave, Optimisticheskaja, is now more than 200km long.

The gypsum karst of the region is well-studied, with several hundred published works. The most important of these are those of Ivanov (1956), Ivanov & Dubljansky (1966), Dubljansky & Ivanov (1970), Dubljansky & Smol'nikov (1969), Andrejchuk (1984, 1988), Klimchouk & Andrejchuk (1986, 1988), Klimchouk & Rogozhnikov (1982), Klimchouk et al. (1985, 1988, 1995), Klimchouk (1986, 1990, 1992). For more detailed discussion of this region see Chapter II.9.

References

- ANDREJCHUK, V.N. 1984. The regularities of karst development in the south-east of the zone of junction between the Russian platform and Carpathian foredeep. PhD Thesis, Chernovtzy University. (in Russian).
- ANDREJCHUK, V.N. 1988. The tectonic factor and peculiarities of the sulphate karst of Bukovina: geology, geomorphology and hydrogeology of karst. Sverdlovsk. 66 pp. (in Russian).
- DUBIJANSKY, V.N. & IVANOV, B.N. 1970. Karst of the Podol'sko-Bukovinsky karst region. In: Fisicheskaja geografija i geomorfologija, 4. Kiev: Kiev University. (in Russian).
- DUBIJANSKY, V.N. & SMOL'NIKOV, B.N. 1969. Karstological and geophysical investigations of karst cavities of the Pridnestrovskaja Podolija i Pokutje. Kiev: Naukova dumka. 151 pp. (in Ukrainian).
- Caves of the Pinego-Severodvinsky karst region. Leningrad: Geogr. ob-vo SSSR. (in Russian).
- CHIKISHEV, A.G. 1966. Karst of the Kulojsky plateau. In: Voprosy izuchenija karsta Russkoj rav-niny. Moscow. (in Russian).
- GEDEONOV, A.A. 1947. Karst in the vicinity of the Baskuntchak Lake. Tezisy dokladov karstovoj konferentsii. Perm. (in Russian).
- GORBUNOVA, K.A. 1965. Peculiarities of gypsum karst. Perm: Permskoe knizhnoje izdatel'stvo. (in Russian).
- GORBUNOVA, 1977. Karst of gypsum in the USSR. Perm: Perm university. 83 p. (in Russian).
- GORBUNOVA, K.A., ANDREJCHUK, V.N., KOSTAREV, V.P., MAXIMOVICH, N.G. 1992. Karst and caves of the Permsky region. Perm: Perm University Publ. 200 pp. (in Russian).
- GVOZDETSKY, N.A. 1953. Karst phenomena in the vicinity of the Baskuntchak Lake. In: Pamjati professora Masarovicha. Moscow: MOIP. (in Russian).
- IJJIN, A.N. et al. 1960. Karst phenomena in the area of Dzerzhynsky city. Moscow: AN SSSR. (in Russian).
- IVANOV, B.N. 1956. On typology of karst landscapes of planes, on the example of Podol'sko-Bulovinsky karst region. In: Voprosy izuchenija karsta na jube Evropejskoj chasti SSSR. Yalta. 131-156. (in Russian).
- IVANOV, B.N. & DUBIJANSKY, V.N. 1966. Superficial and underground karst of the south-west

- flank of the Russian Platform. In: Voprosy izuchenija karsta Russkoj ravniny. Moscow. (in Russian).
- Karst phenomena in the area of Dzerzhynsky city in Gorcovsky region. 1960. Moscow: AN SSSR Publ. (in Russian).
- KHOD'KOV, A.E. 1955. Processes of the underground leaching of salt and gypsum-anhydrite rocks on the Slavjansky deposit and their shows on the surface. In: Trudy VNIIG, vyp. 30. Leningrad: Goskhimizdat. (in Russian).
- KLIMCHOUK, A.B. 1990. Artesian genesis of the large maze caves in the Miocene gypsum of the Western Ukraine. Doklady Akademii Nauk Ukrainskoj SSR ser.B, 7. 28-32. (in Russian).
- KLIMCHOUK, A.B. 1992. Large gypsum caves in the Western Ukraine and their genesis. Cave Science 19 (1). 3-11.
- KLIMCHOUK, A.B. 1986. Genesis and development history of the large gypsum caves in the Western Ukraine. Le Grotte d'Italia, 4 (XIII). 51-71.
- KLIMCHOUK, A.B. & ANDREJCHUK, V.N. 1986. Geological and hydrogeological conditions of gypsum karst development in the Western Ukraine. Le Grotte d'Italia, 4(XII). 349-358.
- KLIMCHOUK, A.B. & ANDREJCHUK, V.N. 1988. Geological and hydrogeological conditions of development of large gypsum caves in the Western Ukraine and their genesis. In: Peshchery (Caves). Gypsum and Anhydrite Caves. Perm: Perm University Publ. 12-25. (in Russian).
- KLIMCHOUK, A.B. & ROGOZHNIKOV, V.Ja. 1972. Sulphate karst of the Bakhmutsky Depression. In: Peshchery (Caves), vol.12-13. Perm: Perm University. 41-48. (in Russian).
- KLIMCHOUK, A.B. & ROGOZHNIKOV, V.Ja. 1982. Conjugate analysis of the development history of a large cave system (on example of the Atlantida cave). Kiev: Inst. Geol. Nauk. 58 p. (in Russian).
- KLIMCHOUK, A.B. et al. 1985. Geological and hydrogeological conditions of karst development of the Pridnestrovsky Podolia. In: I.L.SOKOLOVSKIJ & A.B.KLIMCHOUK, eds.: Fizycheskaja Geographija i Geomorphologija, vol.32. Karst of the Ukraine. Kiev: Vyshcha shkola. 47-54. (in Russian).
- KLIMCHOUK, A.B., AKSEM, S.D., SHESTOPALOV, V.N. & RUD'KO, G.I. 1988. The regime study of gypsum karst activity in the Western Ukraine. Kiev: Inst. Geol. Nauk. 55 pp. (in Russian).
- KLIMCHOUK, A.B., ANDREJCHOUK, V.N. & TURCHINOV, I.I. 1995. Structural pre-requisites of speleogenesis in gypsum in the Western Ukraine. Kiev: Ukrainian Speleol. Assoc. 104 p.
- KOROBOW, S.S. & POLENOV, I.K. 1964. Karst of one salt dome uplift in the pre-Caspian depression. In: Hidrogeologija soljanykh mestorozhdenij i mineral'nye vody. Trudy VNIIG, vyp.46. Leningrad: Nedra. (in Russian).
- KOZINTZHEV, V.S. 1971. Types of subsidence depressions above salt diapirs of the Dnieper-Donetzk basin. Sovetskaja Geologia (Soviet Geology), 1. (in Russian).
- LJUBIMOV, B.N. 1959. Some peculiarities of karst phenomena on the territory of the Komi ASSR. In: Trudy VNIGRI, vyp. 131, geol. sb. 4. Leningrad: Gostopizdat. (in Russian).
- LUKIN, V.S. 1964. Collapse phenomena in the Urals and pre-Urals. In: Hidrogeologicheskij Shornik, 3. vyp. 69. Sverdlovsk. (in Russian).
- LUKIN, V.S. & EZHOV, JU.A. 1975. Karst and construction in the in the Kungur region. Perm. (in

Russian). 119 pp. (in Russian).

LYSENIN, G.P. & SOSNOVSKAYA, G.D. 1974. Flooding of the Izhemsky gypsum mine in the Komi ASSR. In: *Gidrogeologija i Karstovedeniye*, vyp. 5. Perm: Perm University Publ. (in Russian).

MALKOV, V.N., NIKOLAEV, JU.I., KUZNETSOVA, V.A. 1986. Regionalization of the Pinega and Kuloj basins according to settings and intensity of exogenous geological processes. In: *Geologija i poleznye iskopaemye Arkhangel'skoj oblasti*. Moscow, 154-174. (in Russian).

MALKOV, V.N., NIKOLAEV, JU.I. & LUSKAN', V.F. 1988. Types of karst caves of the Pinezhje. In: *Peshchery (Caves). Peshchery v gipsakh i angidritakh*. Perm: Perm University Publ. 46-50. (in Russian).

MARTIN, V.P. 1973. Karst in gypsum of the South pre-Urals. In: *Materialy 8-go Vseural'skogo soveshchaniya po voprosam ohrany prirody i prirodnopol'zovaniya*. Ufa. (in Russian).

MAXIMOVICH, G.A. & GORBUNOVA, K.A. 1958. Karst of the Perm region. Perm. (in Russian).

MAXIMOVICH, G.A. & KOSTAREV, V.P. 1973. Karst regions of the Urals and pre-Urals. In: *Voprosy fizicheskoy geografii Urala*, vyp. 1. Perm. (in Russian).

PECHORKIN, I.A. 1969. Geodynamics of coasts of the Kama reservoirs. Part II. Perm. Perm University Publ. (in Russian).

RODIONOV, I.V. 1963. Karst of the European part of the USSR, Urals and Caucasus. Moscow: Gosgeoltekhizdat. (in Russian).

Problems of study of karst phenomena in the area of Dzerzhynsky city. 1962. Moscow: AN SSSR.

SOTNIKOVA, V. & ARKHIDJAKONSKIKH JU.V. 1974. On karst waters of salt domes of the pre-Caspian depression. In: *Gidrogeologija i Karstovedeniye*, vyp.5. 150-153. (in Russian).

STUPISHIN, A.V. 1965. Karst of the Volga region. In: *Tipy karsta v SSSR*. Moscow: Nauka. (in Russian).

STUPISHIN, A.V. 1967. Karst of plains and regularities of its development, on the example of the Middle Volga region. (in Russian).

TORSUEV, N.P. 1964. Karst Onego-Severodvinsky watershed. Kasan. (in Russian).

TORSUEV, N.P. 1975. Distribution of gypsum karst on the Timansky ridge. In: *Gidrogeologija i Karstovedeniye*, vyp. 7. Perm: Perm University Publ. (in Russian).