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The Snezhnaya-Mezhennogo-Illyuziya cave system in the western Caucasus

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ABSTRACT

The Snezhnaya-Mezhennogo-Illyuziya cave system (SMI) is located within the Khipstinsky karstic massif, in the Western Caucasus. The cave is a branched, arborescent system of cave channels through which underground water streams flow and change in an upwards direction in sub-vertical shafts. Now 3 such shafts, which have a connection with the cave river, are being studied: the Snezhnaya (1970 m a.s.l.), the Mezhennogo (2015 m a.s.l.) and the Illyuziya (2389 m a.s.l.). The SMI cave system has been investigated since 1971 and the currently known depth of the system is 1760 m, the extent of the galleries - >32 km, the volume - >2.7 million m^3, the specific volume - 84 m^3/m. The size of the biggest cave chamber – the Thronnyj - is 309x109x40 m. The average discharge of the underground river is about 500 l/s. The temperature in the cavity changes from 0 to 6.5°C. Research on the SMI cave system continues.

Keywords: cave system, cave sediments, Caucasus, geology, geomorphology

El sistema de cuevas Snezhnaya-Mezhennogo-Illyuziya en el Cáucaso occidental

RESUMEN

El sistema de cuevas Snezhnaya-Mezhennogo-Illyuziya (SMI) se encuentra en el macizo kárstico Khipstinsky, en el Cáucaso occidental. La cueva representa un sistema arborescente y ramificado de canales de cuevas a través de los que fluyen corrientes de agua subterránea y cambian en una dirección ascendente en pozos subverticales. Se han estudiado tres de dichos pozos que tienen una conexión con un río subterráneo: Snezhnaya (1970 m s.n.m.), Mezhennogo (2015 m s.n.m.) y Illyuziya (2389 m s.n.m.). El sistema de cuevas SMI se investiga desde 1971 y la profundidad del sistema conocida hasta la fecha es de 1760 m, la longitud es de 32 km, el volumen es de 2.7 millones m^3 y el volumen específico es 84 m^3/m. La cámara más grande de la cueva, Thronnyj, tiene un tamaño de 309x109x40 m. La descarga media del río subterráneo es de 500 l/s. La temperatura en la cavidad varía de 0 a 6.5°C. La investigación del sistema de cuevas SMI continúa en la actualidad.

Palabras clave: Cáucaso, geología, geomorfología, sedimentos de cueva, sistema de cuevas.

VERSIÓN ABREVIADA EN CASTELLANO

Introducción

El sistema de cuevas Snezhyaya-Mezhennogo-Illuziya (SMI) está situado en el macizo kárstico de alta montaña de Khipstinsky en la ladera sur de un ramal del Ridge Razdel'nyj parte del Bzybsky Ridge en el Caucaso Occidental (Republica de Abkhazia). El macizo kárstico de Khipstinsky es una franja de carbonato que forma parte de la vertiente sur del Gran Cáucaso. Los límites del macizo son: desde el oeste el río Khipsta (río Belaya), desde el norte el río Reshevaya (el afluente izquierdo del río Bzib), desde el este el río Aapsta (Baklanovka) con los afluentes Shumnaya y Dzbazha. El límite meridional del macizo es una estructura tectónica - Kaldakhvarsky Fault (Tintilozov, 1976, Lyudkovsky et al., 1981) (Fig. 1). En la actualidad se conocen tres *entradas al sistema de cuevas SMI: pozo Illyuziya (2389 m s.n.m.), Mezhennogo (2015 m s.n.m.) y Snezhnaya (1970 m s.n.m.). La entrada al pozo Snezhnaya está localizada al fondo de un valle ciego de un cauce temporal en una zona de montaña y prado en la vertiente meridional de la cordillera de Razdel'ny. En la misma zona también hay entradas en los pozos Mezhennogo y Illyuziya en la vertiente sur de la montaña Khipsta (2495 m s.n.m). El pozo Snezhnaya fue descubierto en agosto de 1971 por los exploradores de la Universidad Estatal de Moscú T. Guzhva y V. Glebov (Galaktionov et al., 1974). En 1977 se encontró una vía descendente y en 1982 la cueva fue estudiada hasta los 1320 m de profundidad. En 1983 se había llevado a cabo la conexión del pozo Mezhennogo que se abrió por los espeleólogos de la Universidad Estatal de Moscú en agosto de 1979, con el pozo Snezhnaya y con profundidad del sistema alcanzando los 1370 m. En 2007 el sistema de cuevas fue conectado con el pozo Illyuziya (que fue descubierto en 1980) y la profundidad del sistema alcanzó los 1760 m. Las expediciones para el sistema SMI han conseguido explorar más de 32 km de nuevas galerías de la cueva, con 18 conjuntos de cámaras grandes y medianas, ocho de grandes dimensiones y un número de pequeños riachuelos y tres cascadas de gran alcance (alturas de 45, 25 y 32 m) (Fig. 2, 3).*

Metodología

El sistema de cuevas SMI fue investigado por métodos espeleológicos con el uso de las técnicas de escalada. La estancia media de los grupos de investigación en el subsuelo durante una expedición fue de 30 a 80 días, además de que se vieron obligados a transportar consigo mismos algunos materiales para los campamentos subterráneos y llevar a cabo la fase preliminar de carga de descenso. Una parte importante de la carga llevada a las entradas del sistema de cuevas fue realizada a pie o por helicóptero. Las investigaciones científicas en el sistema de cuevas se produjeron por miembros de grupos de investigación que llevan a cabo investigaciones científicas a medida que avanzaban en el camino de exploración.

Geología

El sistema de cuevas está formado en el flanco sur de un gran pliegue anticlinal de dolomías y calizas dolomitizadas (Fig. 7). La parte superior del sistema de cuevas hasta profundidades de 450-600 m está desarrollado en calizas masivas y dolomías del Cretácico superior (Barremiense). La parte inferior del sistema de cuevas tiene dos capas de conglomerados brechificados (cerca de 100 m de espesor cada uno) y está separado por dolomía y dolomía brechificada con unos 100 m de espesor. En diferentes lugares se aprecia la intercalación de brechas en paquetes de caliza y a veces hay contactos tectónicos. En base a dichos datos se asume que la brecha no es una capa sino que se sitúan en cavidades antiguas sobre las que se desarrolla el sistema de cuevas moderno (Mavlyudov y Morozov, 1984). Tosa la parte superior del río del sistema SMI está formado principalmente en la capa superior de conglomerados brechoides. En Bypass Gallery y en el Revushij (Roaring) Cascade el río corta un horizonte de dolomita y dolomita brechoide y después de IGAN Chamber el río corta en la capa inferior de conglomerado brechoide. Las investigaciones también han demostrado que excepto el conglomerado brechoide sedimentariamente estratificado en la cavidad es posible encontrar conglomerado brechoide tectónico y también conglomerado brechoide resedimentado que se ha probado por los hallazgos de fragmentos de estalactitas en ellos. Por desgracia, visualmente los tres tipos de conglomerados brechoides no se diferencian. La considerable cantidad de bloqueos del sistema de cuevas por bloques está conectado aparentemente al hecho de que el conglomerado brechoide tiene una menor resistencia mecánica que la caliza, son evacuados más fácilmente y son menos estables en los arcos del techo.

Hidrología

Por las estimaciones en la ladera sur de Razdel'nyj Ridge la precipitación es de 5000 mm (2500 mm en invierno y 2500 mm en verano) (Mavlyudov, 1996). La cantidad de grandes aguaceros durante la estación cálida fluctúa de entre 10 a 18. La descarga del río subterráneo tiene cerca de 300 l/s (por otros datos de 50 a 100 l/s), la media anual es de 500 l/s, la descarga en avenidas es mayor a 2000 l/s. En la parte sur del macizo kárstico de Khipstinsky algunos ensayos de trazadores permitieron identificar los lugares de descarga del agua de las cuevas. Se encontró que el agua del sistema de cuevas alimenta Khipsta River, Dokhurta River, Aapsta River y Spring Mchishta (Fig. 4). La dirección principal más probable para la dirección del agua en el karst en el sistema SMI es en una dirección «bottom of Snezhnaya → Estavella → Kaldahvarskyj fault»; a lo largo de la falla el movimiento básico del agua se mueve hacia el oeste en dirección de Spring Mchishta y *durante las avenidas se mueve también en la dirección opuesta hacia el este hacia Dokhurta River y probablemente a Aapsta River. Las aguas de parte del sistema de cuevas se mueve en Khipsta River por encima de Estavella. Aparentemente este canal funciona sólo durante las avenidas. Es imposible excluir también la posibilidad de la existencia de canales directos «bottom of Snezhnaya → upper reach of Dokhurta River » and «bottom of Snezhnaya → Estavella → spring Mchishta».*

Geomorfología

Se proporcionan datos básicos del sistema de cuevas en la Tabla 1. Las características morfométricas del sistema de cuevas SMI es a fecha de uno de enero de 2014: profundidad -1760 m, extensión de galerías mayor a 32 km, área de las cuevas - 100000 m^2, volumen de las cuevas – 2.7 millones de m^3, volumen específico - 84 m^3/m.

Sedimentos

En el sistema de cuevas SMI se han encontrado casi todos los tipos genéticos de sedimentos de cuevas: de colapso, autóctonos, productos de meteorización, por acción mecánica del agua y quimiogénicos, cuevas de nieve y hielo (Fig. 6), organogénicos.

Clima

En el sistema de cuevas SMI se aprecian los cambios estacionales en la dirección del aire que indudablemente alertan de la presencia de entradas bajas que todavía no se han encontrado. La temperatura de aire y agua en la cavidad crece con la profundidad desde 0-2ºC en la entrada de Snezhnaya hasta 6.2ºC a una profundiad de 1320 m (a unos 700 m s.n.m.) y alcanza 9.8ºC en el manantial de Mchishta (70 m s.n.m.). En el sistema de cuevas se llevaron a cabo investigaciones biológicas y médico-biológicas. La continuación del sistema de cuevas SMI puede incrementar su profundidad hasta alcancara los 600 m para nivelar el manantial Mchishta.

Introduction

The SMI cave system is located within the Khipstinsky high-mountain karstic massif on the southern slope of a branch ridge, the Razdel'nyj ridge of the Bzybsky ridge in the Western Caucasus (Republic Abkhazia). The Khipstinsky karstic massif is a component carbonate strip of the southern slope of the Greater Caucasus. The massif boundaries are: from the west - the Khipsta River (Belaya River), from the north - the Reshevaya River (the left tributary of the Bzyb River), from the east - the Aapsta River (Baklanovka River) with the Shumnaya and Dzbazha tributaries. The southern boundary of the massif is a tectonic structure – the Kaldakhvarsky Falt (Tintilozov, 1976, Lyudkovsky *et al.,* 1981) (Fig. 1).

The Snezhnaya shaft is located in a southern part of the Khipstinsky karstic massif, within the mountainous Kolhidsky province of the speleological area of the Greater Caucasus (Gvozdetsky, 1972, Tintilozov, 1976). Currently three entrances to the SMI cave system are known: the Illyuziya shaft (at a height of 2389 m a.s.l.), the Mezhennogo shaft (2015 m a.s.l.) and the Snezhnaya shaft (1970 m a.s.l.). The entrance to the Snezhnaya shaft is situated at the bottom of a blind valley of a temporary riverbed in a mountain-meadow zone on a southern slope of the Razdel'ny ridge. In the same zone there are also entrances to the Mezhennogo and Illyuziya shafts on the southern slopes of the Khipsta Mountain (2495 m a.s.l.).

The Snezhnaya shaft was found in August, 1971 by cave explorers of the Moscow state university, T. Guzhva and V. Glebov (Galaktionov *et al.,* 1974). During three expeditions in 1971-1972 it was surveyed by cave explorers of the Moscow State University speleology club to a depth of 700 m. The leader of all these expeditions was M.M. Zverev. About 2.5 km of the underground galleries, two large cave chambers (the Bolshoj or Big chamber and the Universitetskij or University Chamber at depths 200 and 460 m), were explored and mapped and a number of small cave chambers, the large rivulet the Vodopadnyj, the underground Guzhva River, a set of pits, including the Bolshoj (Big) pit, the largest in the cave system, with a depth of about 160 m, were opened up.

From a depth of 460 m the main obstacle to the further passages of the cave became boulder blockages. The especially complex "Fifth Blockage" served as a barrier to variety of the expeditions that were organised in the Snezhnaya shaft in 1972-1976. Only in 1977 was it possible for V. Fedotov, D. Usikov

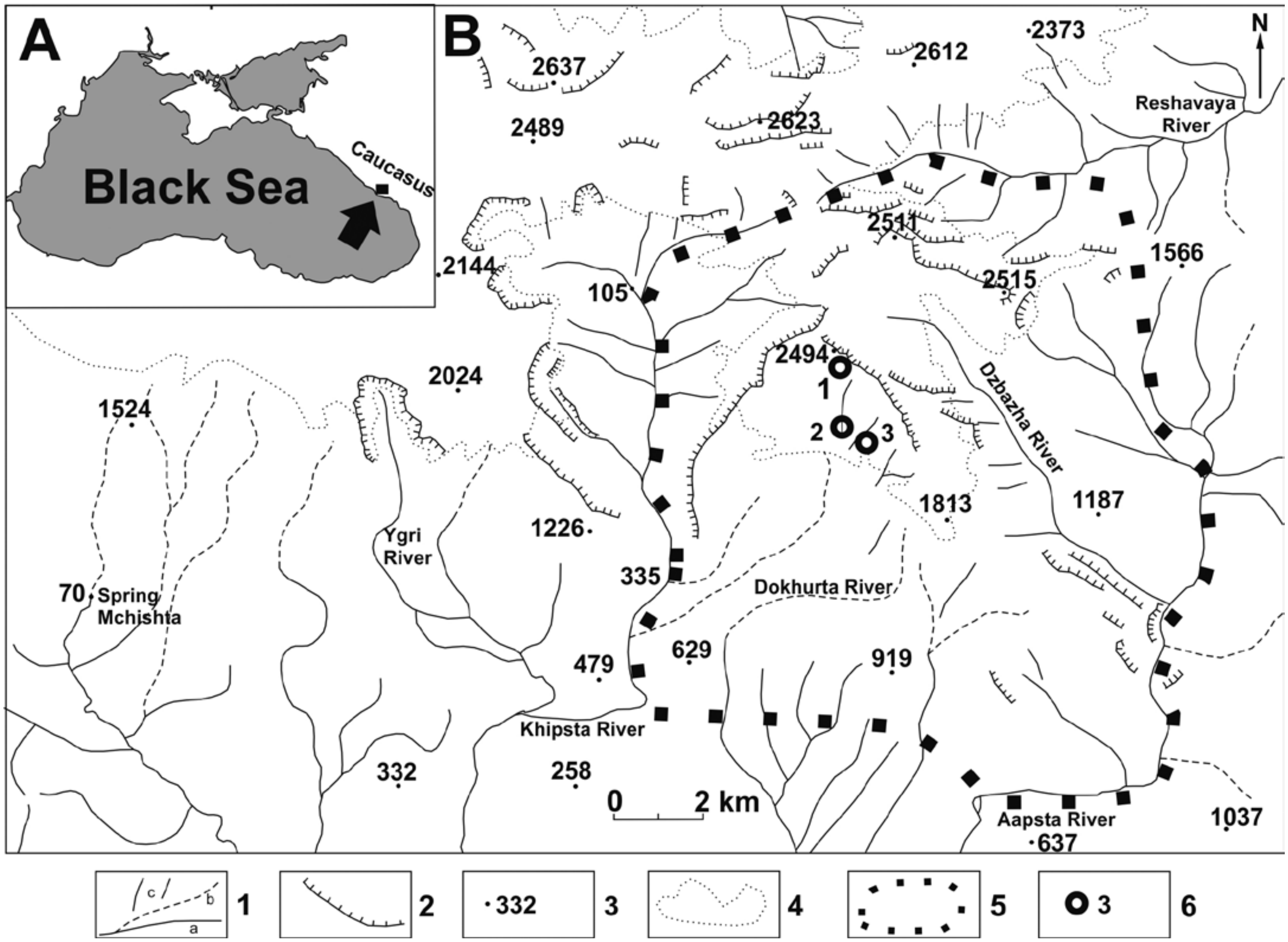

Figure 1: The Khipstinskij karst massif, Western Caucasus. A – Position of area. B - Khipstinskij karst massif and the Mchishta spring. 1 – water streams (a – permanent, b – drying up, c – dry valleys) , 2 – escarps, 3 – true altitude, m above sea level, 4 – forest boundary, 5 – boundary of the Khipstinskij karst massif, 6 – entrances to the cave system: 1 – Illuziya, 2 – Mezhennogo, 3 – Snezhyaya.

***Figura. 1**. Macizo kárstico Khipstinskij, Cáucaso occidental. A – posición del área. B - macizo kárstico Khipstinskij y surgencia Mchishta. Corrientes de agua - 1 (a - permanente, b - secándose, c - valles secos), 2 - escarpe, 3 - verdadera altitud, m sobre el nivel del mar, 4 - límite del bosque, 5 - frontera del macizo kárstico Khipstinskij, 6 - Entradas en sistema de cuevas: 1 - Illuziya, 2 - Mezhennogo, 3 - Snezhyaya.*

and A. Morozov to overcome this obstacle, and the following investigation phase of the shaft was begun. From 1977 to 1982 A. Morozov and D. Usikov carried out 7 expeditions and as a result of which the shaft was studied up to a depth about 1320 m. With the expedition leader, T. Nemchenko, it was possible to "deepen" the cave 15 m more in the summer of 1981 (Lyudkovsky *et al.,* 1981).

In November 1983 the group and the leader, V.Ya. Demchenko, made the connection between the Snezhnaya shaft and the *Mezhennogo* shaft, opened up by cave explorers of the Moscow State University in August, 1979, and the depth of the known cave system reached 1370 m. After numerous expeditions since 2005 it was finally possible for A. Shelepin's group to connect the *Illyuziya* shaft (found in 1980) with the Snezhnaya-Mezhennogo cave system in August, 2007 (Shelepin, 2007). As a result the depth of the known cave system has reached 1760 m. Now it is the third deepest cave system in the world (the first is the Krubera-Voron'ya – 2190 m, the second – the Sarma – 1850); all in the Western Caucasus. In recent years groups of the Moscow State University have continued to work and try to find cave extensions of the SMI cave system

As a result of expeditions to the SMI cave system more than 32 km of new galleries have been explored, 18 large and a set of small chambers have

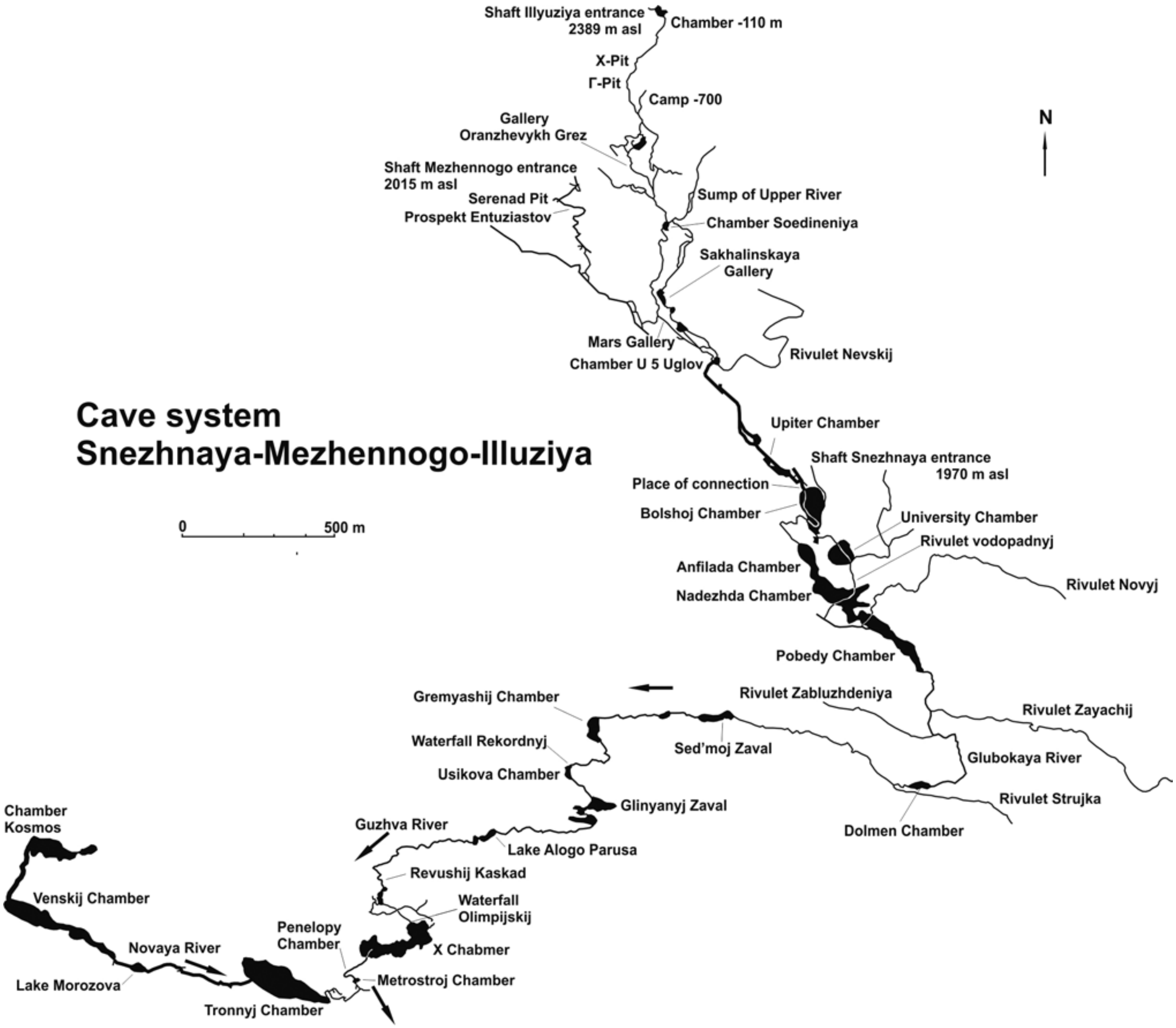

Figure 2: The Snezhyaya- Mezhennogo-Illuziya Cave system, plan (Shelepin, 2007 with additions).
***Figura 2.** Plano del sistema de cuevas Snezhyaya- Mezhennogo-Illuziya (Shelepin 2007).*

been opened up, and 8 large and a number of the small rivulets, and three powerful waterfalls have been discovered (with heights of 45, 25 and 32 m) (Figs. 2, 3).

Methods

The SMI cave system was investigated by speleological methods using climbing techniques. As stay of research groups under the earth surface during one expedition may last from 30 to 80 days, the explorers have been forced to transport the underground camps themselves and to carry out preliminary cargo drops. Cargo drops to the cave system entrances were carried out on foot or by helicopter.

Specific scientific research was practically not carried in the cave systems out but often research groups included various experts (geologists, geomorphologists, hydrologists, climatologists, chemists, biologists) who carried out scientific research with the support of the cavers.

Geology

The SMI cave system (Fig. 1) is formed in a southern flat wing of the Arabika anticline within the Abkhazian

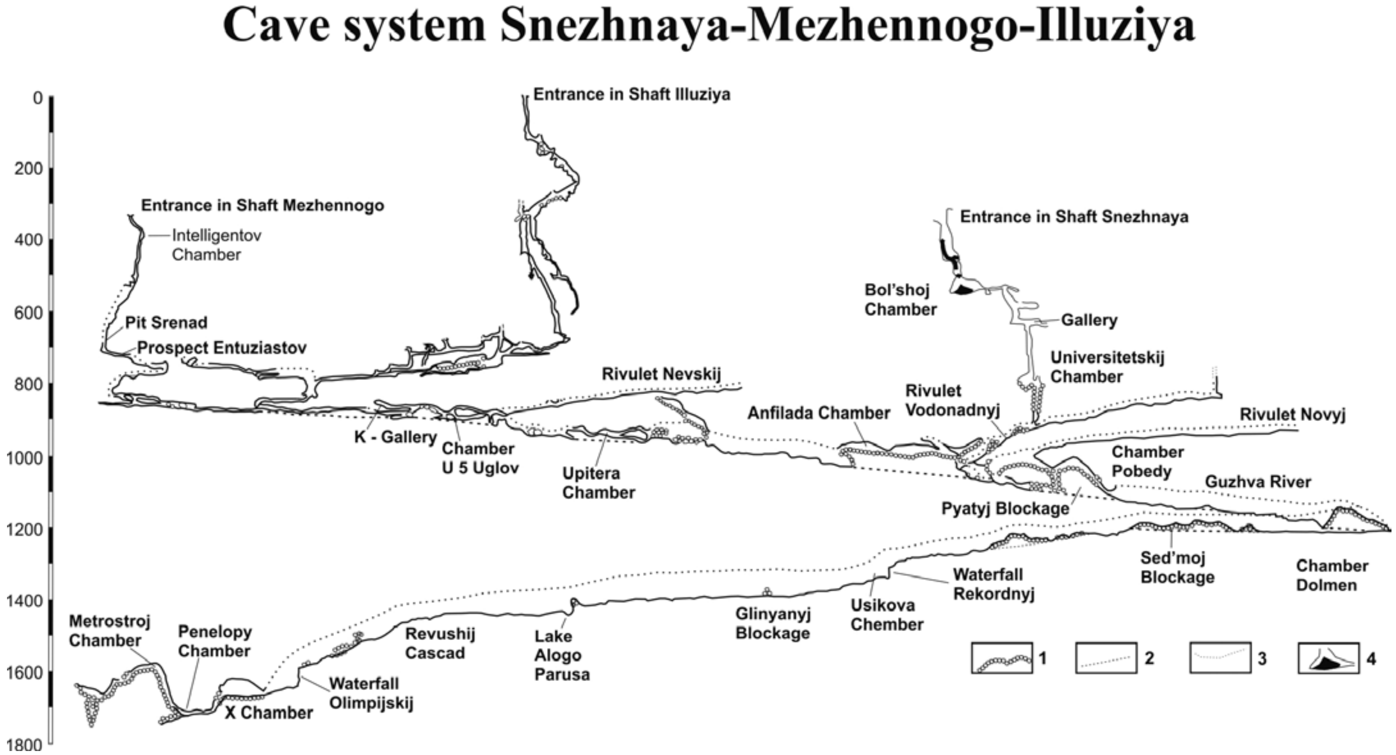

Figure 3: The Snezhyaya- Mezhennogo-Illuziya Cave system, cross section. 1 – boulder blockages, 2 – estimated water streams under blockages, 3 – invisible roof of cave channels, 4 – ice and snow (Shelepin, 2007). Novaya River and some chambers are not shown.
Figura 3*. Sistema de cuevas Snezhyaya- Mezhennogo-Illuziya, sección transversal. 1 – obstrucciones de bloques, 2 - arroyos de agua estimados por de bajo de las obstrucciones, 3 - techo invisible de canales de cuevas, 4 - hielo y nieve (Shelepin, 2007). Río Novaya, algunas cámaras no se observan.*

subzone of the Gagrsko-Dzhavsky zone of a southern slope of the Greater Caucasus. Complexes of upper Jurassic and lower Cretaceous carbonate rocks form part of the geological structure of the massif - limestone and dolomite (Gvozdetsky, 1972, Kipiani, 1965, Tintilozov, 1976). The common thickness of the carbonate rocks is 1100-1300 m. The rocks dip in a southern direction with inclination angles of 20-40°. The attitude of the rock beds is complicated by numerous faults, flexures and feather joints.

The cave system is formed in a southern wing of a large anticlinal fold in limestones, dolomitized limestones and dolomites. The upper part of the cave system up to a depth of 450-600 m is formed of massive limestones and dolomites of the Upper Cretaceuos (Barreme) and as we assumed earlier all the lower part of the SMI cave system is almost completely a layer of alluvial breccia of the Upper Cretaceuos (Neocomian) (Mavlyudov and Morozov, 1984). According to geologists (Bukiya *et al.,* 1971) the alluvial breccia is formed by angular fragments of dolomitized limestone and cemented by limy cement with a thickness of about 35-40 m. Our research in 1996 and 2013 has shown that the breccia (really more correctly conglobreccia) is most likely Upper Jurasic and has a greater thickness. It appears that the conglobreccia consists of two geological units each with a thickness of about 100 m which are divided by a layer of dolomite and brecciated dolomite with a thickness of about 100 m. Apart from fragments in the conglobreccia there are also limestones, dolomites, marls and sandstones which in some cases have a poorly rounded form. Apparently these are delta sediments of the Prakhipsty River which washed away the underlying lower Jurrasic rocks located in mountains territorially to the north. Good stratigraphic contacts of breccia in the SMI cave system were not observed. In separate sites layering of breccia in limestone pockets was noted and sometimes there are tectonic contacts. On this basis the assumption is made that the breccia is not a layer but is situated in ancient cavities on which the modern cave system has developed (Mavlyudov and Morozov, 1984). All the upper part of the river of the SMI cave system is mainly formed in the upper layer of the conglobreccia. At the Bypass Gallery and in the Revushij (Roaring) Cascade the cave river cuts into the horizon of the dolomite and brecciated dolomite and after the IGAN Chamber the river cuts into the lower conglobreccia layer. Therefore, the *X*, Penelopa and Thronnyj Chambers in the lower part of the SMI cave system are situated in this lower conglobreccia. Research has also shown that, apart from the sedimentary layered conglobreccia in the cavity, it is also possible to find tectonic conglobreccia and breccia and also resedimentary conglobreccia which is proved by finds of stalactite fragments within them (found in "Second Blockage" on the Vodopadnyj Rivulet). Unfortunately all the three kinds of conglobreccia do not differ visually.

The elements of a cavity located in limestone and dolomites usually have more abrupt inclination (pits, cascades) than corresponding elements in conglobreccia (galleries). The cavitated index is much higher in places where the underground river flows in conglobreccia than in sites in limestone. The majority of tributaries of the underground river are also situated in similar places.

The considerable quantity of boulder blockages in the cave system is apparently connected by the conglobreccia that has considerably lesser mechanical resistance than limestone, are more easily washed away and are less steady on the roof arches. Many blockages are controlled by large tectonic faults. Therefore, the largest boulder blockage under the Anfilada, Nadezhda and Pobeda Chambers is controlled by a vertical fault of a common Caucasus course with a zone of crushed rocks and melonitization exceeding 10 m thickness.

The galleries of the SMI cave system are developed basically on the base of vertical cracks with strikes of about 0°, 70-90°, 110-130°, and 150°. The rise of tectonic fissuring on surfaces and strikes of cave galleries confidently coincide only in the sub-latitudinal direction (about 113°). Discrepancy of other directions can be explained by the greater size and depth of the cavity which has originated in different tectonic blocks (Mavlyudov and Usikov, 1979).

Joint fissures in the cave system are various and are underlined by the morphology of the cave galleries, by slickensides and melanite zones. The largest faults have the common Caucasus course but the dip of the planes can be both northern and southern. The majority of the flexures found in a cavity have tectonic contact. The considerable quantity of faults means that when moving in the cave river gallery it is possible to see alternation of rocks: sometimes a gallery has developed in conglobreccia and sometimes in dolomite or limestone.

In the cave system the following secondary minerals are most common: Mg - and Sr-containing calcite, aragonite, gypsum, quartz, flint, clay minerals, sometimes hydromagnesite and celestite, very seldom strontianite, dolomite, goethite, rutile and zircon (Bazarova *et al.,* 2013). These minerals are formed on the destruction of parent rocks.

Hydrology

Unfortunately there are no meteorological stations at present in mountains nearby the Khipstinsky massif. The mid-annual estimated quantity of precipitation on the surface 2100-2300 mm, evaporation is estimated at~ 500-800 mm. The liquid precipitation which falls in the form of downpours form discharge peaks of underground rivers (floods) (Gigenejshvili, 1979).

By our estimations on a southern slope of the Razdel'nyj ridge precipitation is about 5000 mm (2500 mm in winter and 2500 mm in summer) (Mavlyudov, 1996). The quantity of large downpours during a warm season fluctuates from 10 to 18.

Melt water entering the hydrological system occurs all the year round, with a minimum in the autumn and in the winter. There is a melting from below of the snow thickness in winter as rocks under snow do not freeze. The part of condensation feeding the general water balance of a cavity is insignificant and will be coordinated with data from the Crimea Mountain (Dublyansky, 1977). Lower discharge of the underground river consists of about 300 l/s (by other data from 50 to 100 l/s), average annual is ~ 500 l/s, discharge at floods is > 2000 l/s. Unfortunately, this is all just estimations and very few measurements has been taken. Local meteorological observations on surfaces and hydrological observations in the cave allow the estimation of the catchment area of upper part of cavity (to a depth of 700 m from the Snezhnaya entrance) in 6.7 km^2 which is close to that calculated by other methods (Zverev *et al.,* 1975). From data (Vakhrushev *et al.,* 2001) the cave system has a catchment area of about 26 km^2, which in our opinion is an overestimated size. The module of drainage of the underground river is about 160 l/s per km^2. The annual drainage is about 0.03 km^3. Average current velocity of the underground river is about 0.2 m/s. Discharge of small underground streams (up to 1 l/s) during floods increase by hundreds of times, the underground river - 5-10 times. The water level before the blockages which serve as dams during floods rises by 5-20 m. With downpours with an intensity of more than 10 mm per hour flooding of the streams has shock character. The vertical component of current velocity of the water in the karst massif during floods (3-9 m per minute) in the upper part of the Snezhnaya shaft is established by the lag time of a flood wave front after the commencement of the rain (Mavlyudov and Usikov, 1979). At abrupt turns of the cave galleries in the river niches with depths of up to 10 m are formed by action of lateral erosion; at the bottom of the river galleries there is erosive copper of up to 1 m depth.

Water of the SMI cave system outflows from the Estavella spring which is situated in a gorge of the Khipsta River at an elevation about 330 m a.s.l. Average discharge at source is - 3 m^3/s but can reach ~ 5 m^3/s in periods of intensive of snow melting on ridge slopes.

The average inclination of the Guzhva River in the SMI cave system from the Pobeda (Victory) Chamber to the Penelopa Chamber consists of about 240 m/km, from the Penelopa Chamber to the Estavella spring- 85 m/km (Dyagteryov, 2009).

In the southern part of the Khipstinsky massif some dye tracing experiments were carried out to find of outflow sites of cave system water. The two first dye tracing experiments (July, 1973 and June, 1974) did not give significant results (Vakhrushev *et al.,* 2001). The single instance of dye exit has only been fixed in the Aapsta River below the confluence with its tributary the Dzbazha River in 1974 (Dublyansky and Kiknadze, 1984). In an experiment in August 1986 dye exit were repeatedly fixed in the Mchishta spring (in 6-14 days after the start from the Estavella spring and in 9-17 days after the start in the cave) and in the Estavella spring (in 5-6 days after the start in the cave) (Complex ..., 1987). Taking into account the factor of tortuosity of underground channels, water current velocity was about 1.3-4.5 km/day. The Mchishta spring is the largest in the Caucasus and in the former USSR (Fig. 1) and is situated on the southern slope of the Bzybsky karst massif at an elevation of 85 m a.s.l. 18 km to the WSW from the dye injection site. Its average discharge is about 9.5 m^3/s (from 3 to 120 m^3/s) (Tintilozov, 1976). The dye tracing experiments have shown that the southern parts of the Khipstinsky and Bzybsky massifs represent a uniform hydro-geological system with an intermediate discharge zone in the valley of the Khipsta River (Vakhrushev *et al.,* 2001).

A result of dye tracing experiments during the winter of 2009-2010 is the detection of dye exit in the Khipsta River above the Estavella spring and in the Dokhurta River left tributary of the Aapsta River (in the area of its crossing with the Kaldahvarskyj fault) (Gusev and Mazina, 2010) (Fig. 4). The data testifies the complicated character of underground water movement in the karst massif. The basic most probable direction of the karst water movement in the SMI cave system is the route «bottom of the Snezhnaya shaft → the Estavella spring → Kaldahvarskyj fault»; along the fault the basic water stream moves west in the direction of the Mchishta spring and during floods it also moves in the opposite direction, eastwards to the Dokhurta River and probably to the Aapsta River. Part of the cave system water moves along the Khipsta River above the Estavella spring. Apparently this channel works only during flood periods. It is impossible to also exclude the possibility of the existence of direct channels «the bottom of the Snezhnaya shaft → upper reach of the Dokhurta River » and «bottom of the Snezhnaya shaft → Estavella spring → Mchishta spring ». Probable routes of karst water movement are shown in Figure 4.

In an experiment on the high current velocity of karst water (7-11km/day) it has been fixed that it is 3-4 times above that for the dye tracing experiment in the summer of 1986 (Complex ..., 1987) and only in 2 times below the average velocity in the Guzhva River cave system (Lyudkovsky *et al.,* 1981).

The SMI hydrological system includes 2 large underground rivers, 8 large and more than 30 small rivulets. The catchment area of the SMI cave system covers the crest of the Razdel'nyj ridge, part of its

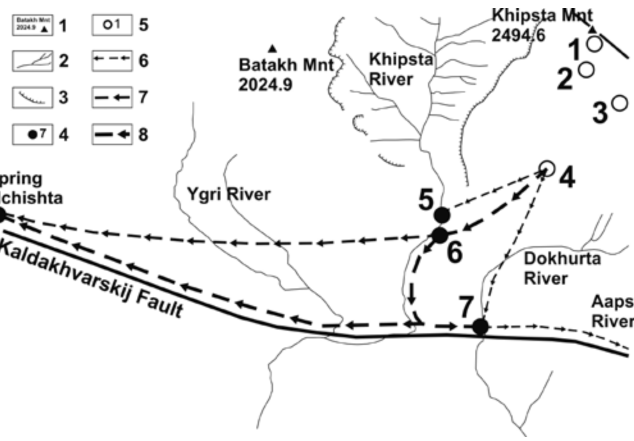

Figure 4: Dye tracing experiment of 2009/2010 (Gusev and Mazina, 2010). 1 – mountains and their elevation, m above sea level, 2 – rivers, 3 – escarps, 4 – springs and dye exit sites (5 – above the Estavella, 6 – the Estavella, 7 – the Dokhurta River, 8 –the Mchishta spring), 5 - entrances into cave system: 1 – Illuziya, 2 – Mezhennogo, 3 – Snezhyaya, 4 – place of dye entry inside the cave system, 6-8 – variants of water movement, 8 – water movement in flood periods.
Figura 4*. Experimento con trazadores de 2009/2010 (Gusev y Mazina, 2010). 1 - montañas y su elevación, m sobre el nivel del mar, 2 - ríos, 3 - escarpe, 4– manantiales y lugares de salida del trazador (5 - por encima de Estavella, 6 - Estavella, 7 - Río Dokhurta, 8 - manantial Mchishta), 5 - entradas al sistema de cuevas: 1 - Illuziya, 2 - Mezhennogo, 3 - Snezhyaya, 4 - lugar de entrada del trazador dentro del sistema de cuevas, 6-8 - variantes del movimiento del agua, 8 - el movimiento del agua en periodos de inundación.*

northern slope and part of its southern slope (Fig. 4). We estimate this catchment area of the SMI cave system to be10 km^2. Permanent waterways on the massif surface within the catchment area are absent.

Geomorphology

The SMI cave system is made up of the type of the underground cavities representing a combination of natural pits with horizontal and inclined galleries (Gvozdetsky, 1972) or the combined type of cavities (Tintilozov, 1976). The SMI cave system has well expressed vertical sections formed by the cascade of pits connected by rather short inclined galleries and the sub-horizontal sections having small angles of galleries with an inclination of about 9-20°.

The depth of the vertical sections of the system where the basic morphological elements are vertical pits is 670 m (in the Illyuziya shaft), 500 m (in the Mezhennogo shaft) and 550 m (in the Snezhnaya shaft). After the vertical section the cave streams and rivers begin. The entrance pit of the Snezhnaya shaft, with a depth of about 50 m leads into a system of high inclined narrow galleries (angle 50-70°) filled by snow at a height of about 25 m and ending at the upper part of the Bolshoj (Big) Chamber (140x90x60 m). Almost all area of the chamber is filled by a snow-ice cone at a height of 32 m. The only exit from the Bolshoj Chamber is a narrow tube which leads into another part of the system which does not have its own exit to the surface. Here, at a depth of about 230 m, there is first constantly flowing water. The gallery formed by the cascade of pits at a depth of about 300 m joins with several other galleries and ends in a pit with a depth of about 160 m. Ledges divide the pit into four parts. At the bottom it extends forming the large University Chamber. The chamber floor represents a surface of a boulder blockage inside where the route continues. At the end of the blockage the cavity is narrows, turning into a pit which comes to a place where two streams join forming the Vodopadnyj Rivulet.

The sub-horizontal part of the Mezhennogo shaft leads to a series of vertical pits, the largest of which are: the Dobryj Pit (76 m) and the Serenad Pit (80 m). In the Illyuziya shaft a small sub-horizontal part at a depth of about 280 m can be noted with the biggest pit - the Yadernyj (Nuclear) cascade with difference of about 110 m. The sub-horizontal part begins from a depth of about 550 m in Snezhnaya shaft which to the north-west adjoins sub-horizontal parts of the Mezhennogo and Illyuziya shafts. Here its basic morphological elements are canyon-like galleries interrupted by boulder blockages above which large collapsed chambers have been found. The width of the galleries corresponds to the water discharge. The main gallery of the cave through which the underground river flows has the greatest width (from 2 to 5 m). The ceiling height reaches 60 m or more. The list of the largest chambers is given in the Table.

The sub-horizontal part of the SMI cave system belongs to caves of the arborescent type (Tintilozov, 1976). Besides its main gallery, 8 tributary galleries are being investigated. In the upper part of each stream undoubtedly the vertical sections have not yet been reached. Thus the horizontal part of system unites the set of the vertical parts.

The lowermost part of the cave system is located by a powerful zone of tectonic faults after the Olympic waterfall. Here there are the largest collapsed chambers in the system. The *X* Chamber, with an arch of about 5 m in height is divided into two halves. The first half has a roof height of > 50 m, whilst in the second southern part the roof height does not exceed 43 m. Then the character of the cavity varies a little. If so far the height of the monolithic ceiling is at more than 30-60 m everywhere in the main gallery, over the river bed its height now decreases and in the Penelopa Chamber it does not exceed 10 m. The last blockage on the river Guzhva is the Metrostroj boulder blockage. It has height of about 127 m. It situated in the wide inclined crack going across a water stream. Crossing the blockage through its upper part leads at its foot to the Novaya (New) River which is the right-hand tributary of the Guzhva River and also becomes lost in the Metrostroj blockage as does the Guzhva River. We do not see the joining of these rivers occuring anywhere under the blockage. Upstream of the Novaya River the following chambers open up: the Thronnyj Chamber (the biggest in the system - 309x109x40 m) (Dyagteryov, 2009), the Venskij (Viennese) Chamber, the Kosmos (Space) Chamber, the Ural'skij (Ural) Chamber, the Dvukh brat'ev (Two Brothers) Chamber. On the Guzhva River it is possible to pass to the bottom part of the Metrostroj blockage about 250 m along the water stream (the Lebedinaya (Swan) River), whilst it is impossible to overcome the Metrostroj blockage.

The galleries of the tributaries of the underground river develop mainly in vertical cracks. They are considerably narrower than the main gallery (width about 1 m) and have about the same bottom inclination and also in many places are crossed by blockages which however nowhere reach such dimensions as on the Guzhva River. In the intermediate position is Zabluzhdenie rivulet - the right river tributary with a gallery almost similar to the main river gallery.

Chamber name	ΔH, m	L, m	W, m	h, m	S, m2	V, m3
Bolshoj (Big)	200	140	90	60	5 500	200 000
University	460	75	50	160	3 000	100 000
Nadezhdy	640	135	45	25	4 000	80 000
Pobedy	650	110	30	30	2 000	30 000
Anfilada 1	630	140	50	15	6 400	70 000
Anfilada 2	630	75	40	20	2 100	30 000
Upper River, lower	540	60	20	20	600	10 000
Upper River, upper	480	90	30	25	1 500	40 000
Dolmene	770	120		25		20 000
7th blockage N° 1	840	60	20	15		10 000
7th blockage N° 2	850					20 000
Gremyashij	900	60	40	15	2 000	20 000
Usukova	980	40	18	35	600	20 000
Glinyanyj	1 000	60	20			10 000
IGAN	1 150	45	20	25	550	15 000
X	1 300	220	70	50	11 000	250 000
Tronnyj	1 300	309	109	40	20 000	500 000
Venskij	1 300	160	40	25	6 000	90 000
Kosmos	1 300	130	50	15	5 000	50 000

Table 1: Morphometric indicators of the largest chambers of the SMI cave system (Ljudkovsky et al., 1981 with modifications).
Tabla. 1*. Indicadores morfométricos de las mayores cámaras del sistema de cuevas SMI (Ljudkovsky et. al., 1981 con modificaciones).*
Comments: ΔH = depth from the *Snezhnaya* entrance, L = chamber length, W = the maximum chamber width, h = the maximum chamber height, S = chamber area, V = chamber volume.

Independently there is the other right tributary - the Novaya River with galleries comparable to the Guzhva River galleries.

The morphometric characteristics of the SMI cave system are as recorded on 1 January 2014: depth – 1 760 m, extent of galleries > 32 km, cave area – 100 000 m^2, cave volume – 2.7 million m^3, specific volume - 84 m^3/m.

Sediments

In the SMI cave system almost all genetic types of cave sediments are found: collapse, autochthonous weathering products, water-mechanical and chemogenic, cave snow and ice and organogenic.

Collapse sediments in the SMI have a gravitational and seismo-gravitational origin and are located in the sites of the largest tectonic faults. Boulder blockages are formed by fragments of the most different sizes (to 1 000 m^3 and more). Fragments are not sorted; the density of their packing strongly varies. Cavities between blocks have fanciful forms and many of which have not been explored. The average height of boulder blockages is about 30-60 m, the last blockage at the bottom part of cave system has a thickness of about 127 m and a blockage upstream of the cave river – of about 140 m. By approximate calculations the volume of collapse accumulation in the SMI cave system exceeds 1.1 million m^3 and about half is concentrated in the range of depths from 460 to 700 m from the Snezhnaya shaft entrance. On the chamber ceilings over the blockages it is often possible to find gliding planes which “fortify” the roof, accordingly the collapsed blocks have levelled surfaces.

Thermo-gravitational sediments are formed in the entrance part of the Snezhnaya shaft in a zone where seasonally negative temperatures exist and which extends to a depth of 200 m. They are presented mainly by limestone detritus, they can be observed on wall shelves, on the floor of the Bolshoj Chamber, on the surface and in the thickness of the snow and ice.

Water-mechanical sediments in the cave have developed very widely, they are found in a kind of alluvium of the underground river and its tributaries, where lake sediments and clay sediments are partly introduced through cracks and entrance apertures. Riverbed sediments are presented by rounded and weak rounded boulders at more abrupt channel inclinations, gravel, small gravel material and pebbles and sand - on more flat sites with weaker water currents. The most finely-grained aleurite material is deposited during floods on the bottom parts of blockages (for example, in the Fourth and the Fifth blockages). Boulders basically are composed of limestone, dolomite and conglobreccia. Smaller pebble sediments are found out at the bottom of the lakes, in places they form friable bars. Even with a small rise of the water level in the river, these sediments are covered by water, therefore their wide distribution was only found during winter research. Large gravel and pebble consist of mainly limestone, dolomite, cement or fragments of conglobreccia, sometimes the surface of a pebble is covered by a film of oxides of manganese and iron. Small gravel and pebbles are often composed of flint (flint contractions are quite common in the Barreme limestone that lies above). These pebbles have a great impact as the agent of mechanical erosion in cave channels.

Lake sediments are seldom found. It is possible to find them in the Bolshoj Chamber where they are presented by particles of soil and humus brought from the surface (layer thickness up to 10 cm) and the remains of plants and to a lesser degree by detritus sediments. The lake sediment is sandy auleurite material deposited from temporary dammed lakes before the blockages and at their bases. Auleurite sediment at the bottom of the *X,* Penelopa, Peschanyj, Tronnyj chambers has such an origin at a depth of about 1,300 m from the Snezhnaya shaft entrance. The thickness of these sediments in some places exceeds 1-2 m. The composition of water-mechanical sediment corresponds to the composition of country rocks. Therefore, in different parts of the cave system these sediments have varied composition.

Ancient lake and alluvial sediments are noted on shelves along all the wall of the gallery from the floor to the roof (thickness about 15 m). Apparently there was a time when the gallery (depth about 280 m from the Snezhnaya entrance) was completely filled with friable sediments, later they have been washed away. It is possible to estimate the age of these sediments as flint detritus is weathered to such a degree that it can be crumbled by hand. Accumulations of ancient riverbed sand-gravel sediments are also found in the Nadezhda Chamber and in the first Anfilada Chamber.

Residual clay sediments are found in places where the influence of the smallest water drops on rocks in sprays zones in places of dripping. They are noted on the walls of the Pyatnistogo Olenya Gallery in small amounts. In the Anfilada Chambers residual clay reaches 1 cm thickness on the blocks of conglobreccia and the clay maintains the structure of the initial rock. On many sites in the cave system «cave weathering» has taken place which is shown where the external layer of the rocks (brecciated dolomite or dolomite) becomes friable at a depth of about 1 cm. The surface is composed of aleurite. The most intensive display of such processes has been noted in the University Chamber and in the Anfilada Chamber. Probably this destruction of these rocks is connected with the action of bacteria.

Water chemogenic sediments in the SMI cave system have not developed widely but are rather varied. Their insignificant distribution speaks of the presence of active water currents, frequent floods and a weak water mineralization. It is possible to find calcite coralloid speleothems and aragonite crystallictite growing from water films. With water drop reduction the first are replaced by the second and on the opposite occurs when with water drop increases. Coralloid speleothems are found mainly on a site in the Malyj Chamber of the gallery in the Snezhnaya, sometimes in the form of the big accumulations. Crystallictites in small quantities were found at a depth of about 50 m in the southern part of the entrance of the Snezhnaya shaft in an inclined crack. Further on they are widely developed in the Snezhnaya over the Malyj Chamber, in the Vertical Labyrinth, in the University Chamber, and also in the upper parts of many of the boulder blockages of the SMI. The largest such dendrite formations are found in the Tsvetochnoj Gallery at a depth of about 650 m from the Snezhnaya entrance, their height reaches 12-20 cm (width of a cone reaches 10 cm). Each aragonite "tree" is on leg with the thickness of ~ 2 mm or more. Above, it branches out in two or more parts. Here sediments of purely white hydromagnesite in quantities which till now were not found in the caves are being discovered. Hydromagnesite practically does not contain any impurities, which is proved by spectral and X-ray structure analysis data. Its scaly structure is confirmed by electronic microscope photos. Apart from the usual white curdled dry forms, unusual formations of the hydromagnesite are also fixed, representing ephemeral concretions with a form similar to cake meringues and have a nacreous shine. The sizes of these concretions, usually multilayered, reach 2-3 cm. The spectral analysis has shown that they contain magnesium oxide (up to 57%) in considerable quantity. They grow on the roof and walls of the Tsvetochnoj Gallery; their collapse from the roof has caused the formation of sediments of friable hydromagnesite on the floor. The reasons for the hydromagnesite accumulation are not clear. Apparently it may be due to special climatic conditions in this part of the cave and specific features of a rock substratum. In the Tsvetochnoj Gallery there are the stalactites which have been accreted by branchy coralloid speleothems focused on the side from which humid air comes. Similar coralloid speleothems have been noted on the descent route to the Guzhva River from the blockage in the Pobada Chamber. Here there are also collapsing stalactites, stalagmites and other speleothems.

Stalactites, stalagmites and flowstones are seldom found. The large variety of such speleothems is characteristic of the Gremyachij Chamber and for the Oranzhevykh Grez (Orange Dreams) Gallery. There are fixed helictites on the bases of the blockages and on the walls of the river galleries. Floating calcite crystals are found at a depth of 96 m in the *Snezhnaya* shaft and in small pools in the ice cascade of the Gvozdetsky Chamber.

There are many gypsum aggregates in the SMI cave system. In a kind of anthodite, gypsum flowers are noted on all the boulder blockages below 600 m from the surface, on the top of dry parts of the blockages, on blocks of rocks and on the walls of chambers over the blockages. Gypsum crusts with thicknesses of up to 2-3 mm are found in the Glinyanyj Blockage (depth 1000 m from the Snezhnaya entrance) and in the Gremyashij Chamber (depth 900 m). Gypsum flowers (Fig. 6) grow in the driest sites of the cave system, sometimes near to an intensive air current (in the Dolmen Chamber, the Gremyashij Chamber, the Almaznaya Gallery, the Crystallictitovaya Gallery, etc.). Gypsum flowers of the smallest sizes are noted in a considerable quantity on the walls of many tributaries of the underground river (*Novyj, Vodopadny,* and Illyuziya rivulets, etc.). Gypsum powder is noted in the Sakhalinskaya gallery. In all cases they form accurately outlined accumulations outside of which they are not present. Some researchers consider that the gypsum in the caves of the Caucasus has resulted from pyrite oxidation distributed in limestone close to fault zones and interactions with the limestone of sulphuric solutions (Dublyansky, 1977).

Cave snow and ice have developed in the Snezhnaya shaft up to a depth of about 200 m and remain there all the year round. We can divide this area into zones (from up to down) of feeding, transit and snow accumulation. From the area of superficial snow catchment the snow gets into an entrance pit, from there it goes along a system of vertical and inclined gallery cracks, transported by avalanches into the Bolshoj Chamber forming a snow-ice cone (Fig. 5). Snow, firn (compacted snow from the previous year) and ice of the cone have a distinct layered structure. In agreement with the quantity of the studied annual layers the age of the ice is more than 500 years. In 1980 the snow-ice cone degraded because of the small quantity of snow transported from the surface could not compensate the annual ablation of the snow and ice. In 2000 the snow-ice cone grew up to the roof (height about 60 m) and has blocked up a vertical part of the transit zone. In 2000 this led to the entrance pit of the Snezhnaya being full of snow and not melting out. In the following years the cone height began to decrease and in 2013 the cone had a height of about 45 m. We think that the cycle of the Bolshoj Chamber filling with snow is about 35-40 years (Mavlyudov, 2001). Ice in a cave has metamorphic, congelation, infiltration and sublimation origin and has a poorly positive mass balance (Mavlyudov, 2008). Congelation ice is developed in the forms that remind us of calcite speleothems: stalactites, stalagmites, flowspones, coralloids, helictites and anthodites (Fig.7). Segregation ice in considerable quantities is formed in the Bolshoj Chamber at the beginning of winter. The snow-ice volume in the cone varied from 50000 m^3 in 1980 to 90000 m^3 in 2000. In the upper zone up to 10000 m^3 of snow and ice collects. The total amount of permanent snow and ice in the shaft oscillates from 60000 to 100000 m^3.

The origin, conditions of accumulation and the regime of snow and ice melting of in the Snezhnaya shaft was in details considered in (Mavlyudov, 1980, 1981, Mavlyudov and Vturin, 1988). Organogenic sediments are presented by humus accumulation and the remains of plants in the Bolshoj Chamber in sediments of temporal lakes and in the thickness of the snow and ice. As birches, willow and juniper grow close to the cave entrance in the thickness of snow and ice occasionally it is possible to find their branches or fragments of trunks. The remains of leaves and branches of trees are noted in the X and Thronnyj Chambers.

The comparative chemical analysis of soil on a surface and clay on depths of 180 and 630 m has shown that they have a common origin: in all samples oxides of Al, Fe and Mn are in identical proportions. Clay from a depth of about 180 m has a structure

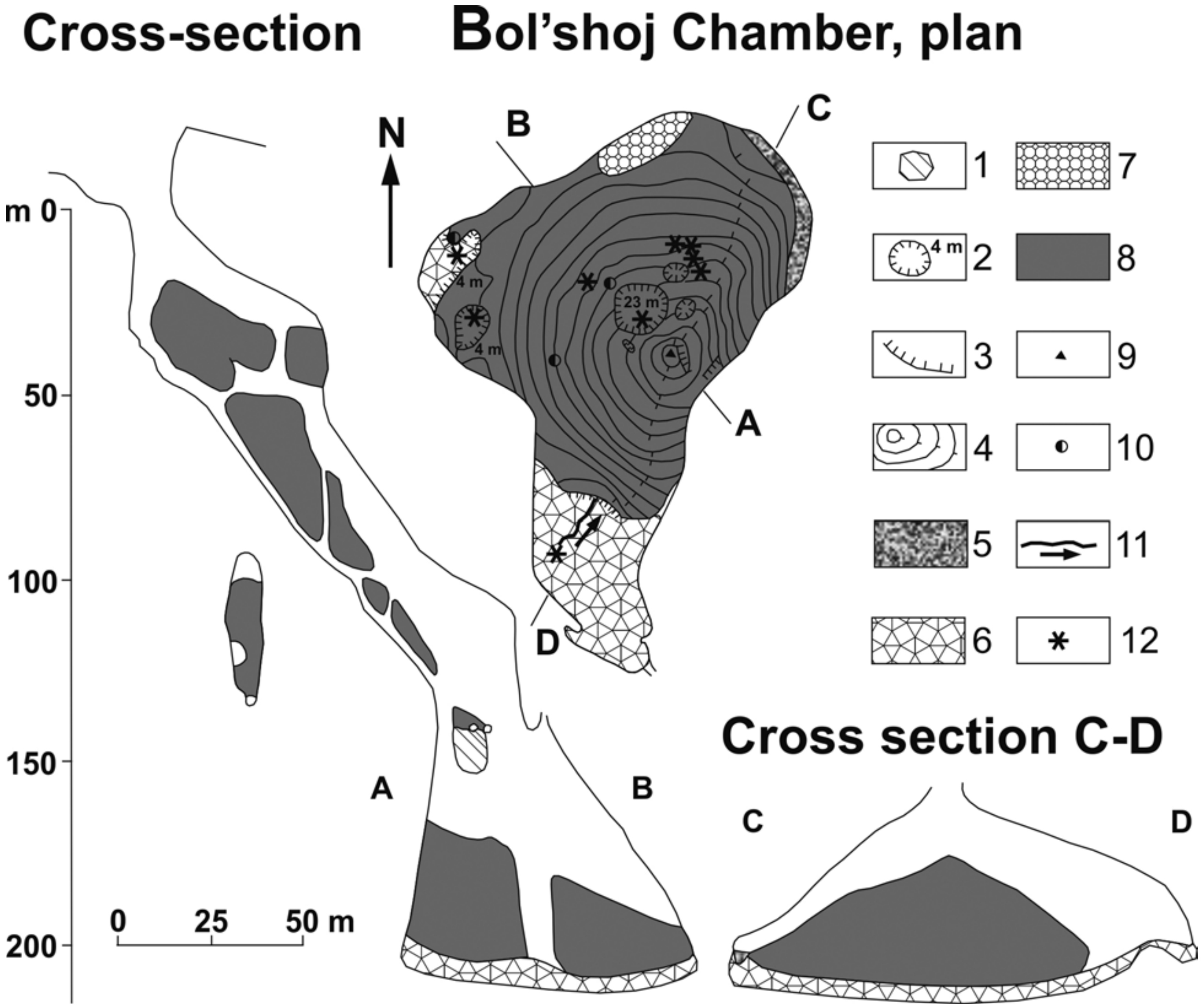

Figure 5: Cross section of the upper part of the *Snezhnaya* shaft and plan of the *Bolshoj* (Big) Chamber. 1 – rocks, 2 – pits in ice and their depth, m, 3 – escarps, 4 – contour lines of the snow ice-cone, distance – 2 m, 5 – alluvium of temporary water streams, 6 – collapse sediments, 7 – piled (collapse) moraine, 8 – snow and ice, 9 – upper point of snow-ice cone, 10 – ice stalagmites, 11 – water stream, 12 - dripping water (Lyudkovskij *et al.,* 1981).

Figura. 5*.* Sección transversal de la parte superior de Snezhnaya eje y el plano de Bolshoj (Big) Cámara. 1 - rocas, 2 - hoyos en el hielo y su profundidad, m, 3 - escarpe, 4 - Curvas de nivel de la nieve del cono de hielo, distancia - 2 m, 5 - aluvión de corrientes de agua temporales, 6 - sedimentos de colapso, 7 - morrena apiladss (colapso), 8 - la nieve y el hielo, 9 - punto superior del cono de nieve y hielo, 10 - estalagmitas de hielo, 11 - corriente de agua, 12 - goteo de agua (Lyudkovskij et al, 1981).

almost identical to the soil on the surface and from a depth of 630 m it is enriched by CaO and MgO but impoverished by SiO_2. (Mavlyudov and Morozov, 1984).

Speleogenesis

All the cavities of the SMI cave system initially had a corrosive-erosive origin. For erosion to occur two factors are favourable: 1) the presence of flint pebbles which cut the bottom of channels in enough soft limestone, dolomite and conglobreccia; 2) noted biological weathering of parent rocks which prepares the destruction of rocks by erosive processes. Above the largest cavities there are roof collapses and the formation of collapsed chambers.

The entrance section of the Snezhnaya shaft to a depth of about 200 m has undergone a nival-glacial process and frost weathering.

The Snezhnaya shaft consists of 2 parts: to a depth of 200 m and below a depth of 200 m. There are two different hydrological branches and the second has no exit on the surface and only has an exit by connecting with the first branch.

Figure 6: Ice stalagmites in the *Gvozdetsky* Chamber at a depth of about 100 m in the *Snezhnaya* branch of the SIM.
Figura 6*. Estalagmitas de hielo en la Cámara Gvozdetsky a una profundidad de alrededor de 100 m en Snezhnaya, una rama de la SIM.*

Climate

In the SMI cave system seasonal changes of the air circulation direction can be noticed, which undoubtedly influences the lower entrances not being discovered so far. Changes of seasonal draughts are noted in the entrances of the Illyuziya and Mezhennogo shafts but in the upper part of Snezhnaya entrance (up to a depth of 550 m) the descending direction of the air current, characteristic for a summer season, also remains in the winter.

The cavity climate influences the processes of denudation, the dynamics of snow and ice masses and the formation of speleothems. The profile of water temperatures of the underground river and air in the cavity is substantially defined by a gravitational warming up of the water which is 2.3° C at 1 km of depth. The air and water temperature in the cavity increases with depth from 0-2°C in entrance parts of the Snezhnaya shaft to 6.2 °C at the depth of about

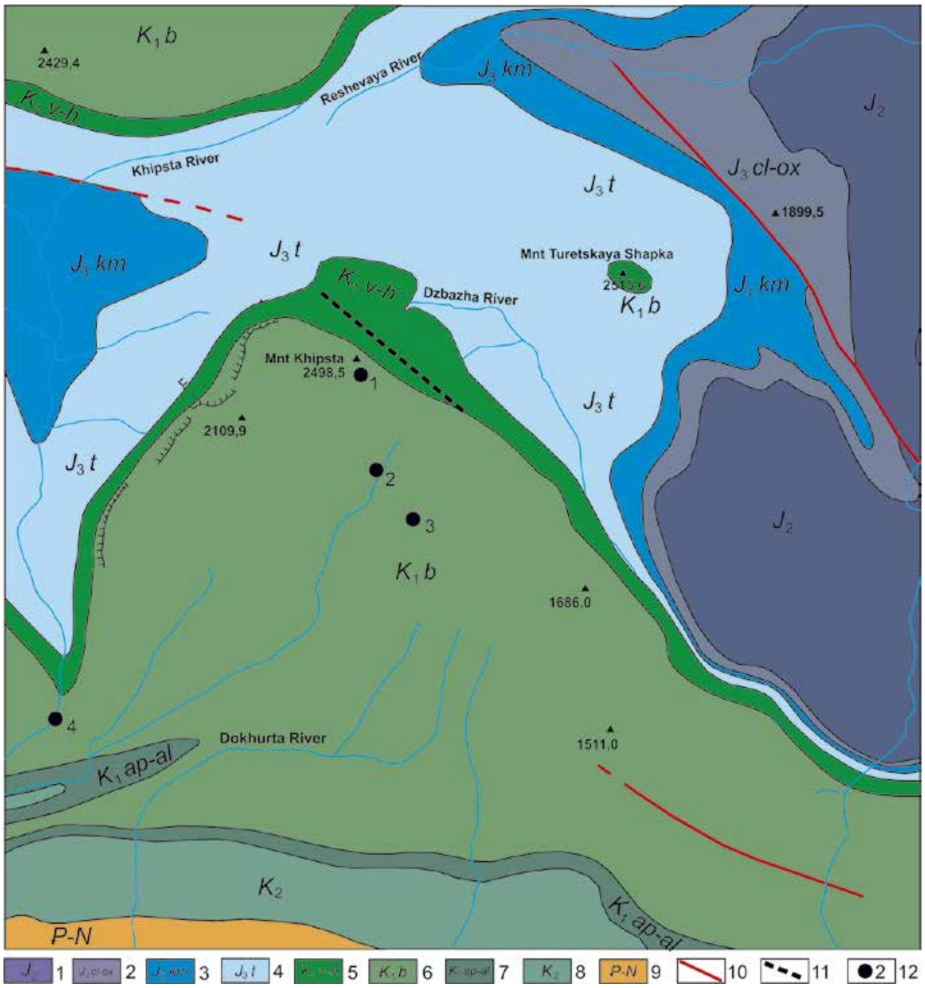

Figure 7: Geological map of the Khipstinskij karst massif. 1 – Porphyrite suite of Bajocian, 2 – sandstones and clay of Callovian-Oxfordian, 3 – sandstones, clays and limestones of Kimmeridgian, 4 – dolomitized limestones and marl of Tithonian, 4 – limestones, marls, dolomites and «alluvial breccia» of Neocomium, 5 – dolomitized limestones and limestones of Barremien, 6 – marl limestones and marls of Aptian, 7 – marls, clays and sandstones of Albian, 8 – limestones of upper Cretaceous, 9 – sandstones and clay of Paleogene and a Neogene, 10 – Faults, 11 – northern border of a watershed limiting catchment area of the SMI cave system, 12 – Entrances to the cave system: 1 – Illusiya, 2 – Mezhennogo, 3 – Snezhnaya, 4 – Estavella – water exit from the underground river of the SMI cave system.
Figura 7*. Mapa geológico del macizo kárstico Khipstinskij. 1 - porfirita de Bajociense, 2 - areniscas y arcillas de Calloviense-Oxfordiense, 3 - areniscas, arcillas y calizas de Kimmeridgian, 4 - calizas y margas dolomitizadas de Titoniense, 4 - calizas, margas, dolomías y «brecha» aluvial de Neocomiense, 5 - calizas dolomitizados y calizas de Barremien, 6 - calizas margosas y margas del Aptiense, 7 - margas, arcillas y areniscas de Albiense, 8 - calizas del Cretácico superior, 9 - areniscas y arcillas de Paleógeno y Neógeno, 10 - Fallas , 11 - frontera norte de una cuenca que limita la zona de captura del sistema de cuevas SMI, 12 - entradas en el sistema de cuevas: 1 - Illusiya, 2 - Mezhennogo, 3 - Snezhnaya, 4 - Estavella - salida de agua del río subterráneo del sistema de cuevas SMI.*

1320 m (about 700 m a.l.s.), reaching 9,8°C in spring in the Mchishta spring (70 m a.s.l.).

The velocity of the air movement is defined by the difference of temperature profiles in the cavity and on the surface and also by the resistance of cave channels and fluctuations of atmospheric pressure. At a depth of 1300 m in a narrow place in the Etshenko Point the wind velocity was about 5 m/s (January 2013). Similar wind velocity was recorded in January, 1980 in the NW sections of the Anfilada Chamber. Along the gallery of the underground river, both in summer and in winter, about 5-10 m^3/s of air moves downwards and upwards on average. A switch in the direction of air movement occurs in the winter at the end of December but in the summer the switch of the draught direction has not been recorded. Relative air humidity in different parts of the cave system is close to 100 %.

Biology and medicine

Troglobites and trogloxenes live in the SMI cave system. In 1980, at a depth of 700 m in an input the Snezhnaya shaft entrance a false scorpion was found by a senior lecturer (S.I. Levushkin) of Moscow State University and denominated as a new species of the genus Neobiisium Blothrus (Lyudkovsky *et al.,* 1981). The false scorpion is related to the troglobites and has a specific red colouring . Trogloxene earthworms have been found in the Mezhennogo shaft and in the Thronnyj Chamber near to the ascending Oreshkovyj Ruchei Pit. Ecological research was also carried out in the SMI cave system by (Mazina *et al.,* 2011).

In 1979-1983 some medical-biological research was carried out in the Snezhnaya shaft: in this most complicated exploration participants in the 1979-1980 expedition spent over 80 days under the earth, in 1981-1982 - 71 days, and in 1982-83 - 70 days. Sometimes underground "days" could be as long as 68 hours. The influence of difficult and unusual conditions on the human body during such a long period represents considerable interest for science.

It was found that overcoming especially difficult places there was a "consolidation" time from 2-4 times but in underground base camps extended or truncated days (54-20 hours) were formed. Despite the "imbalance" of physiological processes the mental condition of the cavers was not observed. At high mobilization of mentalities painful sensitivity became dulled and the time of blood coagulability and healing of damaged skin were shortened. The physiological departures slowed down on the way were restored in completely underground camps: the sleep was deep, almost without dreams. But on the surface a psychological discharge occurred: sleep was with disturbing dreams - falling in a stream, failure in a pit. Many of the participants were ill which is appreciably connected with a decrease in immunity to rich terrestrial bacterial microflora (Dublyansky, 2000).

In long expeditions research has shown that cavers lived on the "stretched" 50-hour days; "the state of health + activity + mood" varied as a sinusoid with maxima for the 4th, 12, 18, 26, 34 and 48 days and minima on the 6th, 15, 23, 26 and 38 days; in the first 23 days of expedition the test of the"subjective minute" showed a small acceleration (5-8 s), and for 24th day – a spasmodic delay (the real minute was estimated as 100-110 s). Readaptation to surface conditions proceeded for at least 3-4 weeks. All the participants of the expeditions had infringement of water and salt exchanges, loss of blood plasma, calcium salts; muscular strength decreased, work capacity fell (24 hours in a day was not enough); small wounds which had almost begun to live in the cave suppurated (Dubljansky, 2000).

Prospects

The Snezhnaya shaft found in 1971 (Galaktionov *at al.,* 1974) is a unique natural object and in many respects not yet studied. Its further research, no less than other cavities in the area, will allow regularities of a high-mountainous karst formation to be discovered. Study of the snow-ice cone will give additional data on glaciers development and the dynamics of climate change. The analysis of the thickness of friable sediments in the Snezhnaya Gallery at a depth of about 280 m will also give information on climate dynamics. Complex research of the cavity continues.

As to the search for the continuation of the SMI cave system, the increase in its depth by the discovery of its upper entrance is almost settled (the greatest possible height increment is only some tens of metres) but the prospect of the depth escalating is possible by at least 600 m to the level of the Mchishta spring. But so far all attempts to know the true depth of the SMI cave system have not been successful.

Conclusions

The SMI cave system has a known depth of about 1760 m and is the third deepest cave in the world and is probably the most difficult to explore amongst caves without sumps. For 43 summer periods of research in the cave there have been more than 40 expeditions, and the cave has been visited by more than 300 people. Many tributaries of the underground river have been opened up, one of which (the Novaya River) is located at the modern bottom of the cave system and is comparable with discharge of the Guzhva River. During research the extent of the investigated galleries in the cave system has exceeded 32 km, the cavity volume is estimated as 2.7 million m^3, the snow and ice volume can reach 100000 m^3, the catchment area of the known part of the cave system is not less than 10 km^2 and the annual drainage of the underground river is about 50 million m^3.

Three large underground waterfalls have been found on the Guzhva River and its tributaries: the Irkutskij (the Illyuziya shaft, the height of two steps of waterfall is 45 m), the Recordnyj (25 m) and the Olympijskij (32 m). There are large pits in the cave system: the 7 Seconds pit (270 m), the Oreshkovyj Ruchej pit (185 m) and the Bolshoj pit (165 m). The height of boulder blockages on the Guzhva River is about 60-100 m. The huge slot-hole boulder blockage in the lower part of the cave system – the Metrostroj blockage has height of about 127 m. Almost everywhere above the cave river there are upper floors which have scarcely been explored. Research on the cave system continues.

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