Divya cave - the longest cave in the Perm region (Russia)

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Abstract

The work is a review of contemporary research carried out in Divya Cave, the longest cave in the Perm region. This is one of the largest and most beautiful limestone caves in the Urals, the first mention of which dates back to the 70s of the 18th century. The cave provides the richest material for geologists, karstologists and speleologists, as it is a relic of an ancient aquifer and it is truly a natural museum, where almost all types of secondary calcite formations found in caves are collected.

The remoteness of the cave from roads and settlements has never stopped explorers. The first plan of Divya Cave was drawn up in 1949. Subsequently, many speleologists continued to explore the cave, but not all passages were marked on the latest maps. Hydrogeological and hydrochemical research was done for the first time in 1948, 1956, 1962 and 1967. Numerous springs between the village of Divya and Divya Cave were surveyed, water temperature and flow rates were measured and the hydrochemical indicators of water in the cave lakes were studied. Modern data on the composition of water from surface runoff and the sources flowing from the cave were required. Findings of cryogenic calcite in 1968 prompted further research related to the study of cave deposits, using isotopic analysis methods, taking into account their dating, to determine the migration of permafrost boundaries.

Our research was carried out between 2016 and 2020. Significant results obtained during this period include an instrumental and semi-instrumental topographical survey of the cave and surface, followed by the creation of a combined plan, studies of cryogenic mineralization, isotopic studies of water and speleothem and their dating.

1 Introduction

Divya Cave has been known for more than 250 years. The remoteness of Divya Cave from large settlements and roads has never stopped travelers. It has been explored by travelers, geologists and archaeologists since the end of the 18th century. The cave was first described in 1770 by N.P. Rychkov, who gave a detailed description of it (Rychkov 1772). Among numerous researchers, we should mention the works of V.N. Berkh (1821), V.N. Mamontov (1991), P.N. Kapterev (1913), V.S. Lukin (1949), E.V. Yastrebov (1958), G.A. Maksimovich (1960; Atlas of Specially 2017), V.D. Shcheglov (Shcheglov, Kolyasnikov 1964), Alekseeva (1964, 1965), V.J. Aleksinskii (Alekseeva, Aleksinskij 1965) et al. In 1976–1983 the cave was explored by speleologists from Berezniki municipal speleological expedition and later they made a 9,720m long plan of Divya Cave (Sivincev, Chuhlancev 1984). In 1999 E.I. Luzina drew a plan of the Divya Cave with a length of 10100 m.

The Divya Cave is currently the longest cave in Perm region (Russia). According to 2016 data, its length is 10100 m and its amplitude is 28 m (Internet resource). Divya cave is located on the right bank of the Kolva River, 7 km north of the village of Nyrob (Fig. 1).

The entrance to the cave is located in the upper part of the massif (absolute elevation height 232.5 m a.s.l.). The height of the entrance above the river level (absolute elevation height 119.4 m a.s.l.) is 113 m.
The entrance is trapezoidal with a width of 1.5 m and a height of 0.6 m and a low and narrow corridor of 80 m leads deep into the cave. The cave is a ramified system of halls, passages and galleries, stretching from west to east with an intensely meandering western part. It is divided into three parts: old, new and modern. The new part was uncovered and explored by speleologists from Moscow and Perm in 1963–1964, the modern part was discovered in 1979–1980 by the researchers of the Berezniki speleological expedition Karst. The largest halls (Titanic hall, Sun hall, Vetlan hall, etc.) are 50 m long, 15 m wide and 15 m high (Atlas of Specially 2017).

The cave and the study area are tectonically confined to the junction zone of the northern part of the Pre-Ural fore deep and the western margin of the West Ural folding zone. Within the limits of the Pre-Ural fore deep, there are distinguished major structures – the Kolvinskaya Saddle, where the Divya Cave was created. The Kolvinskaya Saddle is located at the end of the Ksenofontovsky-Kolvinsky arch that extends south-eastward and is part of the Timan. The area where the cave is located is a steep bank of the Kolva River, which slopes down to the river with steep cliffs up to 80 m high, and is formed by light grey laminated calcified limestones of Permian age (Lavrova 2009).

Since the discovery of the Divya Cave and up to the present there have been conducted numerous studies, a current review of which is presented in this article. The results obtained can be used for further research and monitoring of the cave, as well as for mineralogical and environmental specialists.

2 An overview of the research carried out in the cave

2.1. Topographical work

In 2017–2018, a topographic survey of the surface and the old part of the cave was carried out using a Sokkia FX-105 electronic total station and a Leica Disto x310 laser rangefinder (Krasikov, Kudymov 2018). The topographic survey produced an accurate map of the position of the Divya Cave. Absolute elevations of the earth's surface, the roof and the base of the cave, as well as the entrance were determined. They made it possible to determine the spatial position of the karst speleological system relative to the river valley and the thickness of the carbonate overlapping rocks, as well as to specify the morphometry of the halls and galleries in comparison with previous surveys. It is confirmed that the entrance to the cave is situated in the upper part of the massif (top elevation 232.5), the height of the entrance above the river (top elevation 119.4) is about 113 m.

2.2. Hydrological studies

The current study of the river flow is connected with the determination of chemical and isotopic parameters of the Kolva River, which is the main watercourse of the study area, as well as a major tributary of the Vishera River of the Kama River basin. River water was sampled 30 km from the cave near the village of Kamgort; one sample was taken directly from the cave in the autumn period. In terms of chemical composition, the river water near Kamgort belongs to the hydrocarbonate class and the calcium group. The river water has an increased content of iron compounds, copper, hard-to-oxidize organic
substances, phenols and lignosulphonates. Mineralization and chemical composition of the Kolva River water are subject to seasonal changes: the minimum values of mineralization (103 mg/l) and the simplest ionic composition (HCO$_3^-$-Ca) are observed in spring due to the increased role of melt water in the river feeding (70% and more) at this time; the highest values of mineralization (383 mg/l) and the most complex chemical composition (HCO$_3^-$-Cl-SO$_4^-$-Ca-Na) are observed in winter. The river is mainly fed by groundwater in winter, as there is practically no surface runoff at this time. However, according to the correlation analysis, it has been established that the feeding of the surface runoff water during this period comes from upstream sources, not the ones we sampled by us in the course of our research. Near the Kolva River cave, the water in autumn has HCO$_3^-$-Cl-Ca-Na-Mg with a mineralization of 319 mg/l.

Based on isotopic data, river waters have the heaviest composition ($\delta^{18}O = -12.9\%_o$, $\delta^2H = -96.6\%_o$) in summer (July) and the lightest ($\delta^{18}O = -17.3\%_o$, $\delta^2H = -127.4\%_o$) – in spring (April), which is normal for atmospheric feeding. Winter (December-March) "light" precipitation is delayed for a long time (about one month), as it falls out in solid form and reaches Kolva River only during the snowmelt period (April-May). During the warm season, because precipitation falls over a large catchment area, it also takes some time ("run-up time") for it to reach the river through surface and groundwater run-off.

2.3. Hydrogeological studies

Groundwater and fractured vein unconfined and confined to alluvial Quaternary sediments, terrigenous, terrigenous-carbonate complexes of Lower Permian rocks and Riphean-Lower Devonian terrigenous and metamorphic rocks are associated with the Kolva River valley. The main source of groundwater recharge is precipitation. Partial recharge comes from the absorption of river discharge and groundwater inflow from adjacent aquifers. The discharge areas are local erosion and hydrographic network (Kolva River) and underlying aquifer units.

At the foot of the cave, karst water can be found in the form of numerous descending springs with a discharge of up to 20 l/sec. We investigated three springs on the right bank of the river, discharging in the immediate vicinity of the cave: spring at the Divya cave entrance, Zakamenka spring and Alalai waterfall. They are confined to the water-bearing carbonate-sulphate-terrigenous series. Their chemical and isotope compositions are investigated, but the data is received only in summer and autumn periods that is connected with inaccessibility and natural conditions of the area. The received data showed the following: waters of mainly HCO$_3^-$-Ca-Mg and HCO$_3^-$-Ca composition with low mineralization (213.0-298.0 mg/l). Values of deuterium and oxygen-18 in groundwater are slightly lower than average weighted composition of atmospheric precipitation ($\delta^{18}O = -14.7\%_o$, $\delta^2H = -108.3\%_o$; Iskor village) of this region, which suggests that formation of groundwater occurs due to winter-spring precipitation, when it has the lowest isotopic values (Kazantseva 2019).

1 - source at the Divya cave entrance; 2 - Zakamenka spring; 3 - Alalai waterfall; aQ - locally low-water-bearing Quaternary alluvial aquifer; P$_1$slk - water-bearing Solikamsk terrigenous-carbonate formation; P$_1$k - water-bearing Kungurian carbonate-sulphate series; sP$_1$a-ar - water-bearing Asselian-Arthynian
terrigenous complex; c\textsubscript{P}\textsubscript{1} - water-bearing locally slightly water-bearing Lower Permian carbonate series; c\textsubscript{scC}\textsubscript{2-3} - aquiferous superzone of middle-upper Carboniferous and terrigenous-carbonate rocks; s.c.sc\textsubscript{D-C}\textsubscript{1} - aquiferous superzone of Devonian-Lower Carboniferous and terrigenous-carbonate rocks; s.gR-D\textsubscript{1} - locally low-water-bearing aquiferous superzone of Riphean-Lower Devonian terrigenous and metamorphic quartzite-like rocks.

There are no active watercourses in Divya Cave. The present-day aquifer is located 109–120 m below the cave galleries, as indicated by the numerous springs located 3 m above the river. The cave is of interest to geologists and hydrogeologists as a relic of an ancient aquifer. Nowadays the water in the cave is of infiltration and condensation origin. There are places with abundant dripping and there are several lakes. High lake levels are observed in summer, in winter the levels drop, and many small lakes disappear.

2.4. Cave deposits

The cave contains a variety of speleothems: stalactites, stalagmites, scallops, guras, columns and tiered pagodas, draperies from a few centimetres to 2–3 metres in size, as well as films on the surface of lakes.

Absolute dating of sintered crusts and stalagmites by U/Th plasma and thermionization mass spectrometry has long been used for palaeogeographic reconstructions of the past. The dating of stalagmites from Azhurny, Planetarium and Dalny halls showed that their last most active growth stage was relatively short and took place during the Mikulin interglacial, about 130 thousand years ago (Dublyansky, Kadebskaya 2014; Kadebskaya 2016; Dublyansky, Kadebskaya 2016).

The find of cryogenic calcite in the Divya Cave was made by E.P. Dorofeev in 1968 and went down in history as the first find of such deposits in Russia. Later cryogenic calcite of varying morphology and size was found in different halls of the cave (Azhurny, Dalny, Truschoba, Planetarium, Medvezhy, Kaban, Black Eyes, In-Idy, Vinogradny, Yastrebov, Torts, Sun, Zabludy-2 and the BIS and Intimate Galleries) (Kadebskaya 2016). The topographic survey data obtained made it possible to calculate the depth of occurrence of cryogenic formations in the cave, which ranges from 15.9 to 34.6 m from the earth's surface. Oxygen and carbon isotope composition of cryogenic crystals was studied and their age was determined; they are dated from 13 thousand years to 480 thousand years. The dating of cryogenic calcite complements the dating of speleothems and also provides new information about the periods when the area close to the cave was liberated from permafrost.

3 Conclusion

Over the past six years, a large amount of work has been done to study the cave, including a topographical survey of the surface and an underground survey of the cave, hydrological, hydrogeological and hydrochemical studies, and a detailed study of the cave's sediments.

As part of the 2017–2018 topographic survey, the absolute levels of the earth's surface, the cave roof, the cave base and the entrance were determined. They made it possible to accurately determine the spatial
position of the karst speleological system in relation to the river valley, the thickness of the overlying carbonate rocks and clarify the morphometry of halls, passages and galleries compared to previous surveys.

In the “old part” of the cave the data obtained allowed to delineate the zone of cave cryogenic formations distribution both in terms of plan and in terms of elevation. The depth of occurrence of cryogenic formations ranges from 15.9 to 34.6 m from ground surface elevations.

Hydrological and hydrogeological studies allowed us to obtain qualitative parameters and to clarify and confirm the genesis of water. The chemical and isotopic composition of water from the surface runoff - the main drain of the study area - the Kolva River near the village of Kamgort, 30 km from the cave, was studied in detail. Seasonal values of hydrochemical parameters confirmed that the river water supply is mixed: atmospheric and groundwater. One water sample was taken directly from the cave in autumn. In addition, three springs springing from the cave were analyzed, their chemical and isotope composition was determined for the first time. Due to the difficult accessibility of the location of the cave only partial testing was carried out. But even these data were enough to determine their meteogenic genesis.

Absolute dating of sintered crusts and stalagmites by U/Th methods was performed in the cave for the first time, which showed that the last, most active stage of their growth was relatively short and occurred during the Mikulin interglacial, about 130 thousand years ago. Cryogenic calcite of varying morphology and size was found in 13 halls of the cave. It has been dated from 13 to 480 thousand years ago. The dating of cryogenic calcite complements the dating of speleothems and also provides new information about the periods when the area close to the cave was free from permafrost.

References


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Figures
Figure 1

Location of the Divya Cave
Figure 2

Hydrogeological map of the study area
Figure 3

Findings of cryogenic calcite