CREATION OF THE SYSTEM OF MONITORING OF KUNGUR ICE CAVE

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Abstract: Kungur Ice cave has been described more, than 300 years ago. Since that time, more, than 500 scientific papers and near 100 popular ones had been written about it. Almost 100 years the cave is actively visiting by tourists, last 50 years - cave is a constant subject of exploration works, carried by scientific lab, placed next to it. In the Kungur Ice cave also is a basis for Perm State University student's practice. In 2001, according to the Federal law « About especially protected territories » and to the Law of the Perm region « About historic-cultural and nature heritage » nature sanctuaries «Ice mountain» and «Kungur Ice cave» has became part of the historic-natural complex «Ice mountain and Kungur Ice cave».
Among largest caves on territory of Russia, Kungur Ice cave, with its length 5.7 km, has unique characteristics, which are placed it into list of especially valuable objects of nature. The cave also is very sensitive to any anthropogenic influence. Thus, at present, it is impossible to exploit the cave further as touristic object without organization of complex monitoring. Specialists of Kungur lab of Mining institute of Ural branch of RAS is carrying observations of the cave from 1948 y. In 2005 there was created the new project of monitoring of the cave.
In the cave, in first time in Russia, is installed electronic system for performance of whole complex of monitoring, manufactured by Integrated Seismic System (South Africa).

Key words: cave, ice, monitoring, microclimate, hydrogeology

The Kungur Ice cave was described for the first time more than 300 years ago, in 1703, by S. U. Remezov. Since that time the cave always attracted the attention of many researchers. The first meteorological observations inside the Kungur cave were done by professor I. G. Gmelin in 1733. From 1948 the observations of various parameters of this unique natural object are carried out regularly by specialists of Kungur lab of Mining institute.

At present, the system of monitoring of the cave includes the following components:

- the structure, condition and properties of rock, natural geological processes, the relief;
- the microclimate of the cave;
- underground waters (aquifers);
- perennial icing (glaciological monitoring);
- anthropogenic influence onto environment.

The analysis of observations' data since 1948 allowed finding out much laws of existence of the cave as the anthropogenic & natural system. This work was described in a monograph "The Kungur Ice cave – experience of observations" issued in 2005 by the team of specialists, who has studied the cave for a long period. But already this monograph marked the necessity to improve the monitoring system because the old one didn't match many of the new requirements about safety of the visitors, saving of natural attraction and accuracy of measurements.

One of the parameters of the cave is the permanent danger of the collapse of rock from the roof of rooms. From 1926 just visually has been registered 150 such events. Regional seismic station "Kungur" installed in 2003 in Smelyh room, allowed to register not only earthquakes at south of Perm region, but the local events inside the Kungur Ice cave. From 2003 the station registered 25 crashes of the roof. The largest one was the fall of 40 tonnes rock from the roof in "Vishka II" room registered on 20 October 2003 year. It seems impossible to remove absolutely the danger of collapse from roof. The main task is to provide the reliable protection of excursion path. Therefore the new project of monitoring developed in 2005 by specialists of Mining institute, includes, as a part, the seismic monitoring of local events. Now it will be registered not only rocks collapses from ceiling, but the appearance of cracks in the walls and roof of the rooms. Technically all the system consists of 6 geophones installed into boreholes of diameter 80 mm and depth 80 – 100 cm in the roof, 2 digital modules of registration (QS), and a computer for collecting data (CS) with special software.

With the help of special sensors, which register the temperature of the air and water, humidity and pressure, the automatic system will provide not only the seismic monitoring, but microclimatic monitoring of the cave as well. Formerly all the microclimatic measurements have been done only in 13 points of the cave. New sensors will be installed onto the same places for getting successive data. Microclimatic part of the automatic monitoring system consists of 12 points of climate observation, equipped by sensors of air temperature (DS1624), humidity (HIH3610) and atmospheric pressure (24PCA) measurement. Three points are also equipped by sensors of water temperature (HEL777) measurement. All the points are connected with digital blocks of registration of non--seismic canals (NSIF), transmitting the data to the same computer through multiplexers of non-seismic canals (MUX).

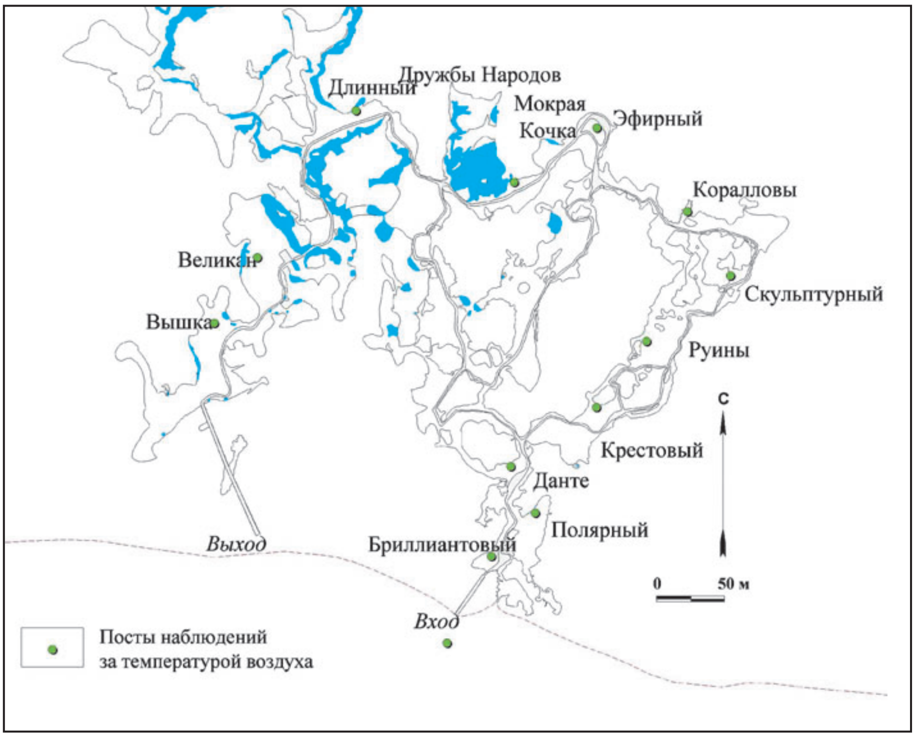

Fig. 1. Observation points (microclimate parameters) in the Kungur Ice cave, the big excursion path.

The main cable containing 20 pairs of wires is laid down along the big excursion path. Next to every point of measuring, the cable is connected by cross-box with sockets for devices of the system. The seismic sensors are distributed in regular intervals along the entire big excursion path, and QS- modules are situated in such a way that next to every module should be one sensor and the other two should be placed not further, than in 300 meters from it. Every geophone is connected to QS by its own cable, which is laid down parallelly to the main one. Also every QS is connected with one MUX by twisted pair. Every MUX is connected with 6 NSIF-modules by 4 wires (stand-alone wires or through main cable). NSIF -modules contain sensors for monitoring the microclimate, except the sensor for measurement of water temperature which is installed into wells or underground lakes and connected with NSIF by wires. QS-modules are connected with each other through the main cable and with serial computer port through the converter of interfaces. The system is supplied with electricity from 127 V electric circuit by means of 4 power units (one unit to every QS and MUX). Interruption of the connection between QS--modules and MUX does not result in loss of data because all the listed above modules have a buffer memory and may store data for a certain time. Restoration of the connection automatically renews transmitting of the data. Polarity of the line does not matter for interfaces between QS- modules and between QS and the computer.

To provide the proper work of the system the computer with OS SuSe Linux 9.3 connected with GPS-module is required for coordination of the time with Greenwich. Software ISS includes the system for collecting the data in real time:

1. programs for creation and configuration of seismic and microclimatic web;
2. programs of the management by parameters of registration;
3. programs for test of lines of connection, modules and geophones;
4. programs for viewing of seismograms;
5. programs for export of data to ASCII format;
6. programs for monitoring of the system operation.

At present this system of the cave's monitoring made by ISS International Ltd. is absolutely unique.

Besides, two autonomic observation points equipped by sensors with accumulators and data storage devices have been installed in a reserved part of the cave (Geograph and Biruzovoe ozero rooms).

For monitoring the temperature regime of the Ice cave it is possible to use the differentiated approach to measurements of the air temperature. The most optimal regime for such monitoring is to make one measurement in a minute. Then acquired data can be used for solving many problems of different class of accuracy and complexity level.

In the future the system will be supplied with some sensors for radon monitoring. Average concentration of radon in summer time (165 days a year with the outside air temperature of above 5 °C) is 3000 Bc/m^3. Such concentration is absolutely safe for visitors, but guides have not to work inside the cave more than 100 hours a year if average concentration of radon exceeds 10000 Bc/m^3 (or 1000 hours a year, if average concentration of radon is 1000 Bc/m^3). Also we need to take into account the absorption of radon on the clothes. After visits to the cave the radioactivity of the clothes lowers during some hours, so there is need to calculate the accumulated doze for every caveworker.

To make the data of microclimate monitoring more extended, in 2007 it is planned to carry out the observations of air streams movements and the air mass balance inside the cave.

Glaciological monitoring is based on the system of measuring points (20 pieces) which are installed into perennial ice and on observations of processes of growing, sublimation, ablation and melting of the ice inside the cave. Also twice a year the maximal and minimal icing (glaciation) is described and the photo of ice deposits is made.

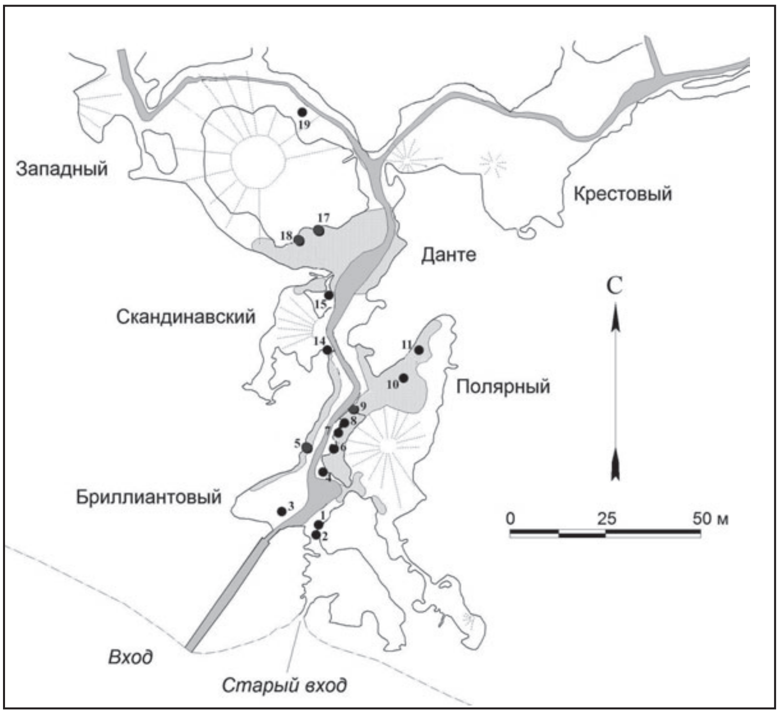

Fig. 2. System of observation points in perennial ice deposits of the Kungur Ice cave

Hydrological monitoring is carrying out to study perennial characteristics of main elements of hydrological regime of Sylva river. In spring, the water penetrates into the body of "Ledyanaya gora" mountain through the cracks in the rock, activates processes of dissolution and takes out dissolved material from the cave. Hydrological post is situated in 150 m to the south from the entrance in the cave. The river channel in the area of the hydrological post has rectilinear character during 1200 m, it is not deformed, without lateral inflows and water-intaking constructions. The width of river in summer is about 100 m, but in period of high water it grows till 170 meters.

The basic hydrological observations are:

1. observations of the level of water;
2. temperature of water and air;
3. thickness of ice and snow on the river;
4. visual observations (rain, snow, wind, water plants, changing of the stream and other).

In addition, in winter and in summer time the discharge of water is measured. Observations of river level are doing daily in 8:00 and 20:00 but in high water time the frequency of measurements increases. The temperature of water and air is also taken twice a day. The water level is measured with a portable ruler which is set onto closest to the river bank measuring point.

In time of high water, the level of lakes inside the cave increases too. A part of excursion path and some electrical equipment is flooded that may result in big financial losses. Forecasting of lakes level allows preventing it.

Hydrogeological monitoring includes monthly measuring of the water level inside the cave and in wells (inside and outside the cave). These points are placed in the following rooms:

1. Krestiviy (well)
2. Ruiny (well)
3. Koralloviy (well)
4. Druzhby narodov(lake)
5. Romantikov (lake)
6. Dlinniy (North lake)
7. Dlinniy (South lake)
8. Velikan (North lake)
9. Velikan (South lake)
10. Lukina (lake)

In July 2004 the hydrological points of measuring inside the cave was changed. The new points are made of aluminum and plastic and are mounted at the same places as the old ones. The altitudes above Baltic Sea level was measured for all the points. It allowed correlating changes of underground lakes level with Sylva river level.

During high water, the level of aquifer is measured daily. Also it is monitored the level of underground water in the wells situated near the cave. The first well is situated in 70 meters to the south-east from the cave's entrance, the second one-in 0.5 km, and the third one-in 1 km. Measurements are done monthly, and during the high water – daily.

Hydrochemical monitoring. Estimation of the state of aquifer is based on 2 parameters – quality and pollution of underground hydrosphere. The pollution level is estimated as follows: for the chemical pollution including phenols, chlorines-phenols and other chemical substances, heavy and other metals, nitrates, pesticides and mineral oil – in amount of maximum concentration limits or factor of total impurity, for bacteriological pollution – in koly-titres, for mechanical pollution – in amount of maximum concentration limits for suspensions.

Observations of lakes pollution in the Kungur Ice cave and Sylva river proved that the cause of maximal pollution of underground lakes is the atmospheric waters, penetrating from surface of Ledyanaya mountain. Visitors also influence on chemical state of water in lakes of the cave, because they frequently throw out coins, badges, buttons and wastes to the lakes. Results of analyses of water show that copper is present in all of the lakes, zinc – in Big underground lake. The supposed reason of zinc presence is the large amount of coins on the bottom of lakes. According to different estimations, in the lakes there are accumulated more than 1.5 tones of coins quickly corroding because of high chemical activity of the water.

Because of all above reasons, hydrochemical analyses of the water are made twice a year, in spring and in autumn, in 9 rooms of the cave (that is, 18 analyses per year).

This system of complex monitoring allows not only to model the natural processes but to manage them. With the help of this system it is possible to save such unique natural object as the Kungur Ice cave.