MODERN DYNAMICS OF ICE FORMATIONS IN PINEGA CAVES

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Abstract

Variety of cave ice and conditions of their existence are shown on an example of caves of Belomorsko-Kulojskoe plateau. Investigations of ice development dynamics in caves are an important component for estimation of changes of underground environment on the whole. Cave ice besides its aesthetic value indicates change of cave conditions, features of cave microclimate and hydrodynamics. The role of cave ice is great for increasing of karst stability especially in zones of rocks crushing on sides of karst ravines and river valleys. Ice-cements in conditions of strongly cracked rocks considerably enlarge the time of caves existence. Collapse phenomena on surface of karst massifs and in caves, opening or collapse of cave entrances are often connected with melting of perennial underground ice in rocks.

Современная динамика ледяных отложений Пинежских пещер

На примере пещер Беломорско-Кулойского плато показаны разновидности пещерных льдов и условия их существования. Наблюдения динамики развития льда в пещерах является важной составляющей для оценки динамики подземной среды в целом. Пещерные льды, помимо их эстетической ценности, являются индикаторами изменения состояния пещер, особенностей их микроклимата и гидродинамики. Велика их роль в повышении устойчивости карстового массива, особенно в зонах прибортового дробления пород карстовых логов и речных долин. Льды-цементы в условиях сильно трещиноватых пород значительно продляют время существования пещер. С таянием многолетних подземных льдов связаны обвальные явления в коренных породах на поверхности карстовых массивов и в самих пещерах, вскрытие или обрушение пещерных входов.

Investigations of development and degradation of underground ice was carried out during 15-20 years in different Pinega caves within the framework of monitoring dynamics of processes in underground component of karst. Monitoring of condition of underground environment in Pinezhskij natural reserve now is carried out in 3 regime caves (Pevcheskaya Estrada, Lednikovaya Volna, Bolshaya Golubinskaya) and 4-5 control caves of Golubinsky karst reserve. Research tasks include reception of data on condition of most dynamical parameters of underground environment: microclimate, hydrology and hydrochemistry, development of underground ice, activity of exodynamic processes. In another 3 originally regime caves the observations are stopped because of tourist activity and growth collapse danger. Investigations are carried out using standard techniques with author's additions.

There are specific features of cave microclimate in the region: low average annual air temperatures (0,2°C), its high humidity, insignificant air flows velocities. Maximum amplitudes of air temperature of regime caves in close-to-entrance parts make from 8-25 up to -40°C (at average year values from 4 up to -10°C), for zones of relative stabilization - from 8 up to -10°C (at average year values from 2 up to -2°C). For regime caves temperature amplitudes are determined (Table 1). Relative air humidity in caves changes from 85 up to 100 %. Air flows velocities consisted from some to tens centimeters per second. At small entrance aperture or in narrow passages local increase of air flow velocity is probable up to the some meters per second.

Cave ice is submitted by all genetic classes in a wide spectrum of their specific variety and morphometric displays. Congelation ice connected with freezing liquid and drop-liquid water prevail. This ice is formed due to the water inflow from zones of vertical descending and horizontal circulation. Metamorphic and sublimation ice develops in smaller volume.

Typical forms for northern caves are icings and residual icings, ice-cements, river and lake, stalactites, stalagmites and stalagnats, ice crystals. There are original icing forms in Pinega caves – «ice siphons» and icing walls (screens). The first develop on constants underground streams, the second in a zone of frontal splashing closely to waterfalls and places of dropping (Fig. 1,2).

The majority of Pinega caves are horizontal and subhorizontal. Usually caves have a descending, less often a collapse or a subhorizontal entrance. As a rule bag-like caves have only one entrance but high density of cracks in rocks and development of organ pipes (ceiling tubes) connected cavity and surface create good conditions for movement of air flows and a difference of temperatures between lower close-to-entrance zones and traps of warm air in sealing parts of cavity.

The basic volumes of underground ice of Pinega make large icings of various morphology and genesis. The majority of them are connected to dynamics of water streams in caves

Table 1
Amplitude of a temperature field of regime caves

Monitoring Caves	№ of points	Distance from entrance, m	Air temperature, °C		Amplitude, °C
			Max.	Min.	
Lednikovaya Volna Cave*	1	7,5	15,0	-42,5	57,5
	2	50	3,5	-34,5	38
	3	70	2,0	-31,5	33,5
Golubinskaya-1 Cave **	1	20	8,5	-37,2	45,7
	2	50	8,4	-19	27,4
	3	85	8,2	-24,5	32,7
	4	100	15	-12,5	27,5
	5	145	8,2	-9	17,2
Bolchaya Golubinskaya Cave***	1	2	24,5	-39,5	64
	2	25	5,0	-22,4	27,4
	3	45	11,5	-9,5	21

Investigation period: *1992-2000, **1988-2000,***1984-2000

Fig. 1. Vertical icing, Severnyj Siphon Cave

and inflow of snow melt and rain water from surface. Last kinds of icings develop in close-to-entrance and near-to-edge cave zones where there is an easy approach to open usually descending entrances. Such icings exist for long periods; their partial melting is determined by accessibility of cave entrances.The most significant volumes of perennial underground ice and ice that does not melt through the summer are formed in close-to-entrance areas of caves in zones of negative temperatures having usually extent up to 100-200 m. In far from entrance parts of cavities where positive air temperatures prevail development of ice formations occurs fragmentary and is caused by local cold air and water inflows that are connected with organ pipes or close cave position to edge zone of kast massif.

Development of seasonal ice occurs during all year however its main masses are formed in three cycles (Malkov et al, 2001):

The pre-winter cycle – in caves ice crystals and ice flowstones begin to develop: stalactites, stalagmites and stalagnats, different kinds of icings and ice covers on lakes and streams. At this time there is a formation of “ice siphons” in low caves passages due to development of icings on small streams or due to accretion of stalagnats. Dammed winter floods are connected to “ice siphons” on streams; as a result icings of significant length develop. Growth of ice formations volume may proceed during all winter period mainly due to infiltration water (Fig. 3).

The pre-spring cycle is connected with inflow of wet air during warm weather, thus large confused oriented crystals are formed. At high rising of water and small absorbing ability of ponors cover ice on flood reservoirs is formed.

Summer after-flood cycle is shown in freezing out of highly wet friable deposits in caves; thus segregation crystals are formed, which penetrate in deposits thickness or grow as anthodites. Growth of volume of the perennial icings that feeds mainly by snow melt water penetrating in caves through cracks in massif edge zone, is connected to floods spring waters. In the rest of the time of year metamorphic phenomena, ice melting and evaporation are typical.

Features of year dynamics of ice in caves of southeast part of Belomorsko-Kulojskoe plateau are determined by action of high-speed water streams during spring floods. Flood streams

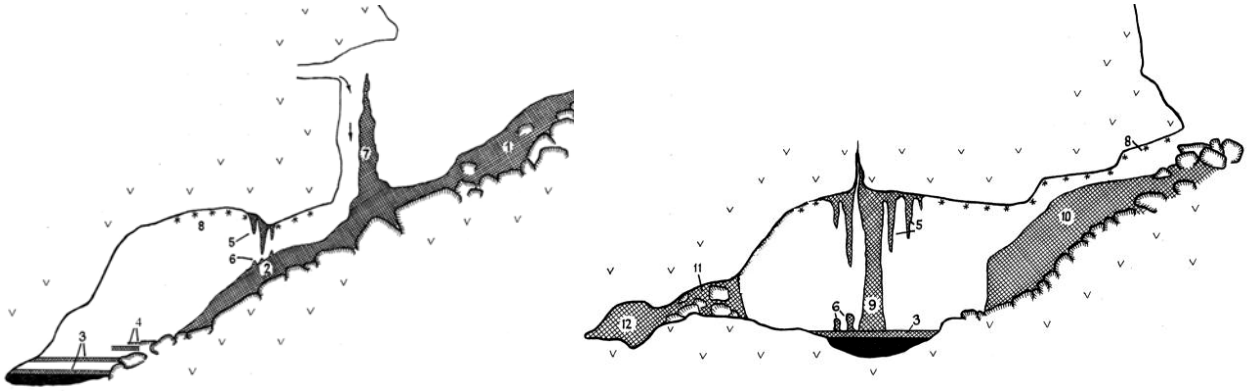

Fig. 2. Most typical ice formations of Pinega caves: 1 – icing in incline-descending cave entrance; 2 – moving slope icing; 3 – river and lake ice; 4 – residual shore ice; 5 – stalactites; 6 – stalagmites; 7 – vertical (wall) icing in a zone of stream splashing; 8 – ice crystals; 9 – stalagnats; 10 – residual icing; 11, 12 – «ice siphon»

almost completely destroy the ice of winter generation - up to level of the maximum rise of water. Freezing of dammed reservoirs of flooding water and freezing out of very wet deposits give «effect of cold-bag» and also influence on temperature regime of caves.

For caves in massifs with lower dynamism of processes influence of floodwater are less considerable. Kulogorskaya Cave system is smoothly flooded by river water. Because of specific catchment area for caves of Chugskyj karst massif more lower water velocities and short-term rise of flood streams are typical. Safety of ice crystals layer partly separated from the cave arch serves as proof in Krasnaya Raduzhka Cave, for example. Plastic deformation has obviously occurred prior to the beginning of flood, however low affected surface has kept traces of flood sediments.

There is certain cyclic in development and degradation of perennial ice in caves connected with climatic changes on surface. The probability of connection with rhythms of solar and space activity is high also. Thus growth of ice formations may be connected with these rhythms through dynamics of processes of floods and rain rhythms. So-called global warming has influenced the development of ice in a special way and mediated.

Fig. 3. A collapse of hanging ice of a winter flood, Golubinskaya-1 Cave

Icings in Pinega caves as a rule have small extent and develop in close-to-entrance and close-to-edge massif zones of caves on inclined gallery bottom that provides movement of ice masses - plastic current with deformation of a ice body. They have such important property of real glaciers as formation of «scatter» moraine contents due to gravitational

deposits freezing in ice and as sandy-argillaceous water sediments. Icings formed by inflow snow melt and rain water in frozen cavities. Ice growth occurs mainly in spring and summer period, in other time ice melting and evaporation, movement of ice body is observed. Icings length reaches first tens of meters.

Most brightly this mechanism is seen in the Ledyanaya Volna Cave where in 1970-ties ice fill cavity almost up to the ceiling. From the moment of repeated finding of the cave in 1992 there was a series of large collapses of the arch and blocking by an «ice siphon» of lower cave level, formation of new gallery from the upper to average cave level. Intensive ice growth is marked, and in the first 5 years of investigations movement of the upper ice layer on slope was measured. Ice increase their average thickness up to 1 meter to 1998 and ice movement has stopped. In October 2004 the top cave level was completely blocked by collapse of a fragment of organ pipe with volume above 85 m^3.

Residual icings are most various in formations time and duration of existence. In caves in side massif zones it is possible to find open ice strata bodies forming in open cracks. Their structure confirms a hypothesis of frontal ice growth with an increment on the top contact due to growth of congelation ice in a horizontal plane (Popov, 1967). Horizontal layers of sandy-argillaceous structure in some cases kept in fragments of such icings what testifies the perennial character of their development. Icings are stratified, have high level of recrystallization (*It is mistake, icings in caves never recrystallizate, editor comment*), contain as a rule opaque ice with inclusion of air bubbles. Opening of icings occurred with the help of flood streams, further melting of vertical surfaces take place by air movement (Fig. 4). From the beginning of active caves researches it is marked gradual degradation of residual icings.

Fig. 4. Residual icings in one of Pinega caves

Specific role in cavities plays the formation of icings (ice siphons) that lead to opening/closing of cave galleries or separation of internal parts of cavities. «Ice siphon» formation is connected with ice growth/melting in cavity cross sections. Both full filling of cavity volume by ice and local development of hanging icing are probable (Fig. 5). Besides icings on small streams and ice covers on lakes that have as a rule seasonal development these forms develop on inclined descending caves entrances limited by above cave sealing. Such icings are formed during spring snow-melting, filling channel cross-section completely by pure ice or ice mixed with colluvial and deluvial deposits. The similar mechanism is typical for the majority of caves in this area with small in height inclined descending entrances.

At the end of 1990-ties a number of caves entrances of Kulogorskaya Cave system reopened. These entrances were found at the end of 1960-ties and blocked by ice in the middle of 1970-ties (Franz, 2000). These phenomena are fixed and for several caves on the area of state reserve. In Malaya Golubinskaya Cave in 1986 top entrance was open which at the moment of cave topographical survey probably was closed by hanging «ice siphon». The same mechanism of development was observed for entrances in caves Delikatnaya, Kitez (top entrance), E-30 and for one of halls in Ledyanaya Volna Cave. In Ledyanoj Dvorets Cave opening and closing of an ice siphon was accompanied by large collapses in the entrance zone.

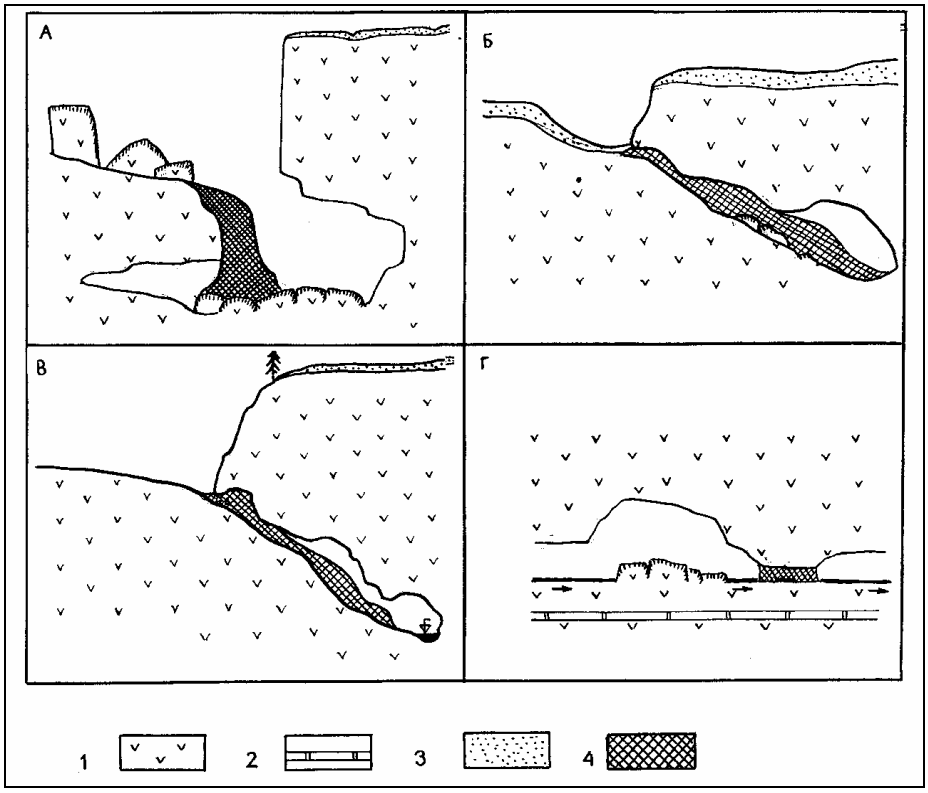

Fig. 5. Closing of inclined descending cave entrances and galleries as result of icing formation (Shavrina, 2002). А - partial blocking at wide entrance; Б - full cave closing with ice covered by diluvium and filling of a hall; В - with formation of an «ice siphon» and cutting of icing by streamlet; Г – icing in narrow part of cave. 1 – gypsum-anhydrite rocks; 2 - impervious dolomite layer; 3 - cave sediments (deluvium or colluvium); 4 – ice

Development and degradation of «ice siphons» is a reversible process; the periods between entrances opening and closing change for different caves from 9-13 up to 20-25 years. It is highly probable that these processes can be described as rhythmic. Now there is an intensive ice growth in descending caves entrances in which control investigations are carried out.It is necessary to note that the similar phenomena are finded not only for underground but also for superficial karst. Mass opening of «ice siphons» in ponors of dolins was marked at the end of 1990-ties in the most part of research area. Process was accompanied by landslides of doline slopes and trees falling.

Anthropogenous influence on dynamics of development of ice in northern caves is investigated poorly. However already now it is possible to note reduction of ice crystals and icing volume in the entrance area of Golubinskij Proval Cave in summer when the number of tourists reaches 200 persons a day.

Conclusions

Thus, investigations of ice development dynamics in caves is an important component for estimation of changes of underground environment on the whole. Cave ice besides its aesthetic value indicates change of cave conditions, features of cave microclimate and hydrodynamics. The role of cave ice is great for increasing of karst stability especially in zones of rocks crushing on sides of karst ravines and river valleys. Ice-cements in conditions of strongly cracked rocks considerably enlarge the time of caves existence. Collapse phenomena on surface of karst massifs and in caves, opening or collapse of cave entrances are often connected with melting of perennial underground ice in rocks.

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