CAVE ICE OF PRIOLHONIE (EASTERN SIBERIA, RUSSIA)

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Absract

Priolhonie is situated in the central part of the western shore of Lake Baikal. 8 caves with snow and ice formations are situated within the area considered. These caves are: Bolshaya Baidinskaya (the length /L/ is 45 m, the depth /H/ is 11 m), Malaya Baidinskaya (L = 55 m, H = 8 m), Mechta (L = 823 m, H = 52 m), Iya (L = 600 m, H = 32 m), Ryadovaya (L = 450 m, H = 57 m), Vologodskogo (L = 46 m, H = 17 m) and Skotomogilnik (this cave was not investigated completely). Ice cave observations in this region are carried out since 1976 to the present time. Three types of underground cavities are distinguished according to the origin of coldness and accumulation of snow and ice: cold caves with a bag-shaped morphology (both Baidinskaya Caves, Mechta, Ryadovaya, Oktyabrskaya), Cave Iay as a cave with two entrances, which is characterized of direction of air draught in cold and warm seasons and vertical cave Vologodskogo as a karstic pit. In the karstic cavities congelation, sublimation and deposited and metamorphosed ice is explored. From 1977 to 1997 the observations of dynamics of perennial ice were accomplished in cave Iya: in November 1977 the area of the icing-layer was 226 m^2 with depth from 1.5 to 2.5-2.8 m; in July 1993 its size have decreased to 6.9 m^2 with ice depth from 6 to 88 cm, in July 1996 – to 1.5 m^2 and maximum ice depth 7-8 cm. Complete melt of icing-layer was registered in July 1997. Observations of ice formations melting in both Baidinskaya and Mechta Caves were marked. During last ten years the average intensity of melting was reached 12 cm per year in Bolshaya Baidinskaya Cave, 1.7 cm per year in Malaya Baidinskaya Cave and 3.2 cm per year in Mechta Cave. A comparison of the dynamics of cave glaciation and trends of annual average temperatures by meteorological stations Irkutsk-observatory (1882-2003) and Sarma (1955-1989) allow to reveal the relation between the parameters researched and to consider the cave ice as an indicator of the climatic changes in Priolhonie.

Лед пещер Приольхонья (Восточная Сибирь, Россия)

Приольхонье расположено в центральной части западного берега Озера Байкал. В пределах рассматриваемой области расположены 8 пещер со снегом и ледяными образованиями. Пещеры называются: Большая Байдинская (длина/L/-45 м., глубина/H/-11 м), Малайя Байдинская (L = 55 м., H = 8 м), Мечта (L = 823 м., H = 52 м), Ия (L = 600 м., H = 32 м), Рядовая (L = 450 м., H = 57 м), Вологодского (L =, 46 м., H = 17 м) и Скотомогильник (эта пещера не исследована полностью). Наблюдения льда в пещерах района проводились с 1976 до настоящего времени. Три типа подземных полостей различают по происхождению холода и накопления снега и льда: холодные мешкообразные пещеры (обе Байдинские, Мечта, Рядовская, Октябрьская), пещера Ия как полость с двумя входами, в которой происходит изменение направления воздушного потока в холодный и теплый сезоны и вертикальный колодец – пещера Вологодского. В карстовых полостях исследовались конжеляционные, сублимационные, осадочные и метаморфические льды. С 1977 по 1997 гг. были выполнены наблюдения за динамикой многолетнего льда в пещере Ия: в ноябре 1977 площадь наледи была 226 m^2 и толщиной от 1,5 до 2,5-2,8 м; в июле 1993 г. размер наледи уменьшился до 6,9 m^2 с толщиной от 6 до 88 ст, в июле 1996 г. - до 1,5 m^2 и максимальной толщиной 7-8 ст. Полное исчезновение наледи было зарегистрировано в июле 1997 г. Были проведнны наблюдения за таянием ледяных образований и в пещерах Байдинская и Мечта. В течение последних десяти лет средняя интенсивность таяния достигала 12 см/год в Большой Байдинской пещере, 1,7 см/год в Малой Байдинской пещере и 3,2 см/год в пещере мечта. Сравнение динамики оледенения пещеры и трендов среднегодовых температур по метеостанциям г. Иркутска (1882-2003) и Сарма (1955-1989) позволило показать соотношение между исследуемыми параметрами и рассматривать лед пещер в Приольхонье как индикатор климатических изменений.

Introduction

Priolhonie is situated in the central part of the western shore of Lake Baikal (Fig. 1), geographical position is N 52°30´–53°30´ and E 106°20´–107°50´, the altitudes vary from 460 to over 600 m a.s.l. The region considered is confined by the Primorsky Range on the West and by the Lake Baikal in the East. The area is situated opposite the biggest island of Baikal – Island Olhon – and for that reason it is named Priolhonie.

The relief of Priolhonie is a typical hummocky topography: gently smoothed out forms of local watersheds (at 350-380 m above the level of Lake Baikal) divided by dry trough-shaped valleys which have low concave sides and flat bottoms with a width of 300-600 m. By geostructural signs the area belongs to the Sayano-Baikal fold belt. Metamorphic complexes from the Archaean-Lower Proterozoic consisting of gneisses, amphibolites, schists, marbles and calciphyres are folded in structures of NE direction. Karstic rocks represented Climatic peculiarities are defined by two main factors: huge water

volume of Lake Baikal and the Primorsky Range. Average annual air temperature is negative: -0,4°C, the duration of frost-free period is 124 days.

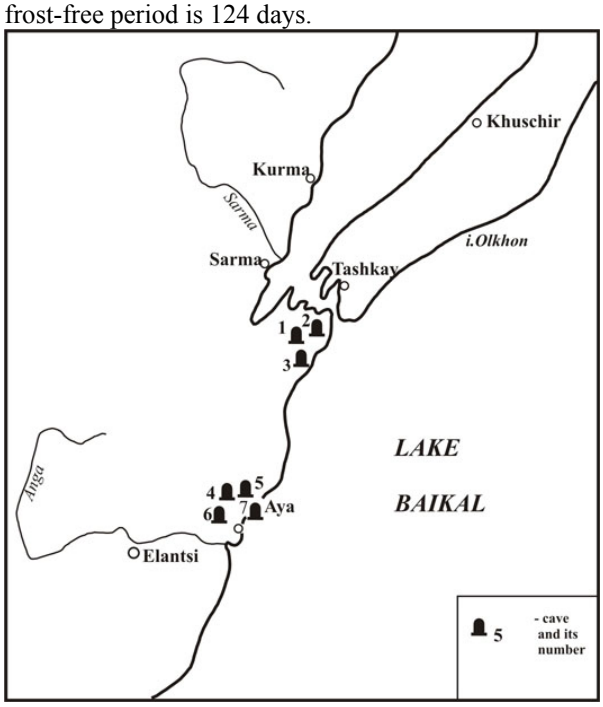

Fig. 1. Region of explorations. Caves and its number: 1 – Bolshaya Baidinskaya, 2 – Malaya Baidinskaya, 3 – Mechta, 4 – Ryadovaya, 5 – Oktyabrskaya, 6 – Iya, 7 – Vologodskogo, 8 – Skotomogilnik

predominantly by the marbles, have a thickness of strata from 1 to 200-250 m.

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Primorsky Range (maximum absolute altitudes are 1500-1600 m) blocks the predominant western and north-western winds and detains the moisture of air mass. Therefore least precipitation in the whole Lake Baikal basin falls in Priolhonie: 182 mm/year, 95 % - in warm season and 5 % - in cold part of year. Along the shore of Lake Baikal, approximately 3 km in land, snow cover is observed during a cold season only in negative forms of microrelief. Powerful winds with a velocity of up to 40 m/s in November and December are the reason of this phenomenon. Deep freezing of soil occurs due to the lack of snow.

8 caves with snow and ice formations are situated within area considered. The caves are called Bolshaya Baidinskaya, Malaya Baidinskaya, Mechta, Iya, Ryadovaya, Vologodskogo, Oktyabrskaya and Skotomogilnik (Fig. 1). All underground cavities are disposed near the coastal escarp of Lake Baikal, at the altitude of 300 m above lake level. Morphometric characters of the caves and volumes of its ice accumulations are represented in Table 1.

Table 1
Ice caves of Priolhonie

Cave name	Number (see Fig. 1)	Length	Depth	Volume, m^3	
		m		of cave	of ice
Bolshaya Baidinskaya	1	45	11	600	120
Malaya Baidinskaya	2	55	8	180	8
Mechta	3	823	52	8500	70
Ryadovaya	4	450	57	2500	3
Oktyabrskaya	5	80	20	290	2
Iay	6	578	32	1200	3
Vologodskogo	7	46	17	350	12

Cave Skotomogilnik wasn't investigated completely.

Genetic and morphological peculiarities of cave ice formations

Ice cave observations in Priolhonie are carried out since 1976. The caves taken are rich with snow and ice formations. Seasonal ice is formed in places where summer air temperatures rise above 0˚C. It is either near cave entrances or inside underground systems under fissures or under roofs situated near the surface. Perennial ice formations are developed in places where average annual temperatures are negative and summer ones are near to 0˚C. Underground cavities can be divided into 3 types, according to the origin of the coldness and accumulation of snow and ice in the caves.

Cold caves with a bag-shaped morphology, Bolshaya Baidinskaya, Malaya Baidinskaya, Mechta, Ryadovaya and Oktyabrskaya Caves belongs to the first type. These caves are characterizes by descending winter type of air circulation. Formation of ice is due to the freezing of water, which comes into cavity through fissures, as well as forming from the air through the process of sublimation. In origin it is congelation and sublimation ice. Snow-banks made as a result of accumulation of snow in underground cavities after snow-storms, as well as the falls of ice sublimated crystals are responsible for formation of deposited and metamorphosed ice near entrances, and in Bolshaya Baidinskaya Cave also between upper and lower halls. In its turn the snow-banks play an important role in supporting coldness in cavities.

Ice stalactites, stalagmites and stalagnates form as a result of supply of water-droplets in zone of negative temperatures, they are widespread in caves of this type (Fig. 2). Seasonal ice stalactites and stalagmites are seen every year near entrances in Bolshaya Baidinskaya (Fig. 4A), Malaya Baidinskaya, Mechta, Ryadovaya Caves, as well as in big halls inside both Baidinskaya Caves and in Throne Hall of Mechta Cave.

Forms and sizes of ice dripstones are variable. Conic, complicated, keel stalactites and complicated stalagmites appear (description of the forms of stalactites and stalagmites is given in accordance with (Gorbunova, Maksimovich, 1991).

Fig. 2. Gallery Metropolitan in Mechta Cave

Method used in (Dmitriev, 1980) was the base for the classification of cave ice. According to data of long-term observations the biggest stalactite was registered in May 1996 (length about 1 m, maximum diameter 0.55 m – in Khoroshikh Hall in Bolshaya Baidinskaya Cave). Usually the sizes of seasonal ice stalactites in Bolshaya Baidinskaya and Mechta Caves are not more than 0.5 m, and stalagmites are not more than 0.3-0.4 m, but in Malaya Baidinskaya and Ryadovaya Caves correspondingly 0.25-0.30 and 0.03-0.10 m. In Ryadovaya Cave ice dripstones melt by July, in both Baidinakaya and Mechta Caves - by August. The intensity of ice meltng was about 0.38-0.4 cm/day. Perennial ice stalactites, stalagmites and stalagnates have been seen in Mechta and Bolshaya Baidinskaya Caves. The following ice formations have been revealed: conic, complicated, keel stalactites, stalagmites-drum sticks, large ice-mass under stalactites. The following stalagnates (columns) have also been observed: conic from below, swollen in the middle part, with a large ice foundation and stalagmites. Ice stalactites reach a length of 1-1.5 m, stalagmites – 2-2.5 m. Special noted are the huge stalagnates in Mechta Cave, with a height of more than 3 m and diameter near the foundation of up to 1 m (Fig. 3). The position of seasonal and perennial ice dripstones indicates the direction of fissures along which underground water penetrate into cavity.

Icing-layers forming under supply of liquid water in frozen below 0˚C parts of cavities, are wide-spread on the horizontal and subhorizontal areas in Mechta Cave, both Baidinskaya Caves, Ryadovaya and Oktyabrskaya Caves. Seasonal icing-layers have been fixed near entrances in all caves researched. Areas of these icings not exceed 8-10 m^2, its melt completely in July. Perennial icing-layers are developed in Mechta, Bolshaya and Malaya Baidinskaya Caves. The area of icings body in Mechta Cave reaches 200 m^2, in Bolshaya Baidinskaya Cave 50 m^2, in Malaya Baidinskaya Cave 20 m^2, ice thickness varies from 0.1 to 0.4 m in all caves. Icings in Mechta Cave are characterized by hydro-carbonate-calcium composition with mineralization about 118 mg/l.

In cold period of a year in Bolshaya Baidinskaya, Malaya Baidinskaya, Mechta and Ryadovaya Caves condensed-congelation ice develops. Inverted distribution of air temperatures in underground systems conditions is typical for formation of this ice. For example vertical gradient in Bolshaya Baidinskaya Cave in winter is 0.8-1.4°C per 1 m.

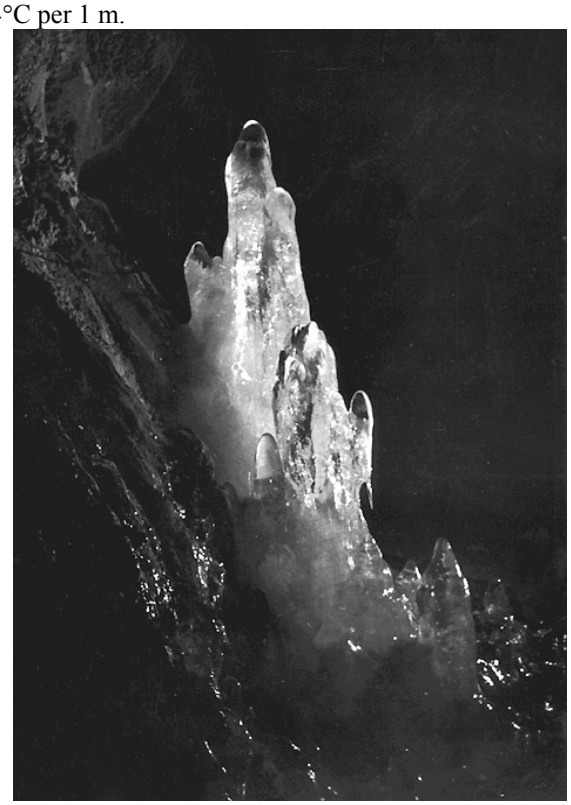

Fig. 3. Ice stalagmite in Mechta Cave

Condensed moisture forming in upper parts of walls and on roofs of underground cavities flows down and freezes in the zone of negative temperatures. The mantle of icing with thickness 5-15 cm, as well as ice conic stalactites with a length of 15-20 cm and foundation diameter of up to 5 cm are formed in the lower parts of passages in caves considered.

Small lakes of 15-20 cm deep are situated in Bolshaya and Malaya Baidinskaya and Mechta Caves, the sizes of these lakes are 4.5×2.2, 2×1.5 m and 5×1.5 m respectively. In winter they freeze. Seasonal segregation ice formed under slow chilling of ground has been found at the bottom of upper halls in both Baidinskaya Caves.

Seasonal and perennial crystals of underground hoarfrost are widely represented in Mechta, Bolshaya and Malaya Baidinskaya, Ryadovaya and Oktyabrskaya Caves. Crystals are formed as a result of the fall of atmospheric moisture on the surfaces with a temperature below 0˚C. Seasonal

formations have been noted near entrances in all the beginning of summer. Perennial crystals have been registered directly near perennial icing-layers in both Baidinskaya and Mechta Caves: on one hand, humidity is supported by sublimation of ice and, on the other hand, a zone of negative temperature is set up near perennial icing-layers. The latter defines the minimum melt of ice crystals. Sizes of crystals changes during the year, maximum ones are noted from March to June. Usually, ice crystals have a form of hexahedral plates, maximum sizes are 3-4 cm in diameter. Hoarfrost in the shape of needles with a height of 0.3-0.5 cm has been observed in Bolshaya Baidinskaya Caves only. Spring snow-banks with volume of snow-ice accumulation up to 5-15 m^3 have been fixed in Bolshaya and Malaya Baidinskaya, Mechta, Ryadovaya and Oktyabrskaya Caves. Snow melt by June. A perennial snow-bank made by snow, firn and ice was disposed in Bolshaya Baidinskaya Cave, ice thickness is 8.2 m, volume was 110 m^3. Remains of malacofauna were found in the lower part of snow-bank, they are dated as Pleistocene-Holocene (Trofimova, 2004). The question about origin of this snow-bank is being discussed.

Cave Iya belongs to the second type, a cave opens at both ends, which is distinguished by the change of direction of airflow in cold and warm seasons (Fig. 2 B). Congelation and sublimation ice has been observed here. Seasonal stalactites are noted in central parts of the underground system, with a length of no more than 12-15 cm, foundation underground cavities considered, they melt completely in diameters are 3-5 cm. Until 1997 the perennial icing-layer was disposed in the Ice Hall, the ice had hydro-carbonate-calcium composition, mineralization was about 189 mg/l. Seasonal hoarfrost has been registered near Entrance 1, it is hexahedrons with sizes 1-3 cm in diameter. During the whole year crystals of hoarfrost cover roofs and walls of the Ice Hall and the underground system adjoining it. In the Ice Hall there are ice needles with a height of up to 0.5 cm but in the adjoining system there are ice hexahedrons.

The sizes of hexahedral crystals increases in direction from the second (lower) entrance to inside parts of the cave – from 0.5 to 3-5 cm in diameter. Seasonal icing-layers and spring snow-banks have been fixed near the entrances to the cave.

Vertical cave Vologodskogo represents the third type (Fig. 2 C), a karst pit with snow and ice, ice is formed as a result of recrystallization of snow supplied to the cave through the entrance (its sizes are 3.5×2 m) in cold period of the year. Summer snow-banks with a volume of snow and ice of 10-12 m^3 (in accordance with the climatic conditions of the year) are developed here and are conserved until August. Seasonal hexahedral ice crystals have been noted near the entrance.

Types of ice in Priolhonie caves are represented in Table 2.

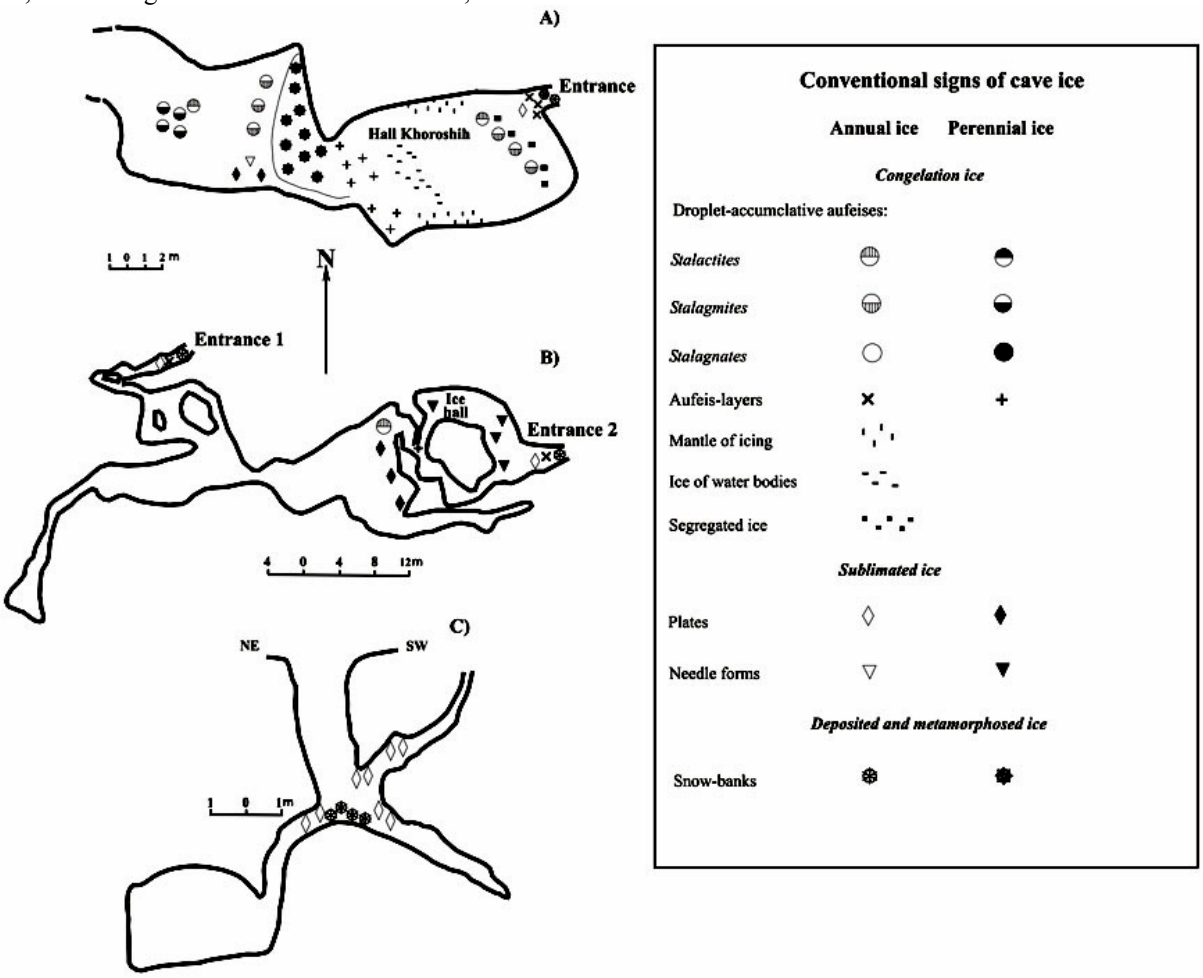

Fig. 3. Caves ice of Priolhonie: A – Bolshaya Baidinskaya, B – Iya, C – Vologodskogo

Table 2
Cave ice of Priolhonie

Caves	Congelation ice							Sublimation ice				Deposite and metamorphic ice		
	Dripstone-accumulative icings		Icings-layers		Icings mantle	Lake ice	Segregate ice	Hexahedral plates		Needle forms		Snow-banks		
	A*	P	A	P				A	P	A	P	Sp	S	P
Bolshaya Baidinskaya	+	+	+	+	+	+	+	+	+	+		+		+
Malaya Baidinskaya	+		+	+	+	+	+	+	+			+		
Mechta	+	+	+	+	+	+		+	+			+		
Ryadovaya	+		+		+			+				+		
Oktyabrskaya			+					+				+		
Iya	+		+					+	+		+	+		
Vologodskogo								+					+	

* - A – annual, P – perennial, Sp – spring, S - summer

Conclusions

• Three main types of cave ice are observed in 8 karstic caves of Priolhonie: congelation, sublimation and deposited-metamorphosed.

• According to origin of coldness and accumulation of snow and ice three types of cavities are distinguished here: cold bag-shaped caves, cold cavity characterizing by change of air direction flow in cold and warm seasons and vertical pit.

• The system of topographical signs for making cave ice formations on underground maps is proposed.

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