A CHARACTERISTIC OF THE ICE FROM THE KUNGUR CAVE

By G. A. MAXIMOVICH and G. G. KOBIAK

(Communicated, by A. E. Fersman, Member of the Academy, 27. II. 1941)

Among the various manifestations of the cryosphere a very interesting and comparatively little studied phenomenon is presented by the cave ice. Forming in caves where negative temperatures are prevalent, such ices differ as to their nature, origin and chemical composition.

At the present time there are more than a hundred ice caves known in literature ([9], [15]), and this number is still increasing. The best known abroad is the Dobshader ice cave in Hungary. Its ice-covered surface exceeds 7000 m^2, while the volume of the ice mass is 120000 m^3. The ice walls attain a height of 15 m. The Demanovo and Szilice caves are also in Hungary. In the latter the bottom is covered with ice only in spring. In Stiria there is known the Franzenmauer cave with a temperature of –2°. In the Salzburg region there is the Unterberger ice cave, and in Transylvania, the Skerisora cave. In France, near Besangon, there is known the La-Baume ice grotto, etc.

In this country there are also numerous ice caves. In Siberia the Abogy dje ([21]) and the Balagan ([20]) caves should be mentioned. In the European par we have the Iletzk and Inder caves, the Crimean caves in the Chatyrdag region, the caves of the Kungur region, and a number of others.

Below we give some data on the origin and chemical composition of the ice of the Kungur cave; these data were collected by first of the authors during his repeated visits to this cave in 1934–1940.

Some of the ices show salt varieties which have been so far unknown for caves (°). The chemical analyses have been made by G. G. Kobiak. The description of the cave and its glaciation is omitted since there exists a vast literature on the subject ([1–4], [7–8], [12–14], [22]) the Kungur ice cave there are several varieties of ice, differing as to their forms and origin.

A peculiar form of the cave ice are crystals. According to the physical-chemical conditions prevailing in the different sections of the anterior part of the cave, or in different years, they are mushroom-like, skeleted-II-shaped, rectangular-lamellar, trigonal-prismatic, hexagonal-lamellar, etc.

The analysis (Table 1, col. 1) has shown a certain degree of mineralization of the water of these crystals, 44.1 mg/1. The predominant components are $CaCO_3$, $CaSO_4$ and $CaCO_3$. $MgCO_3$, which fully corresponds to the geological conditions under which these crystals have been formed. The roof of the pass is composed of limestones, possibly dolomitized, lying amidst gypsums and anhydrites. Thus, the ice crystals, though atmogenous ([11]) and formed at the expense of sublimation ([5]), are to a certain degree mineralized.

Analyses of Ice from the Kungur Ice Cave

	Crystals of ice	Cover ice	Cover ice	Ice on the walls, height 1.2 m	Ice on the walls, height 0.85 m	Ice on the walls, height 0.50 m	Ice of stalagmites and stalactites	Water dropping from the organ pipe
	1	2	3	4	5	6	7	8
Sp. gravity at 20°C	1.00014	1.00079	1.00158	–	–	–	1.00191	–
Gs per liter:								
Dry residue at 110°C	0.0441	0.7966	1.4120	1 2832	1.2348	0.8440	2.0498	1.1734
Dry residue upon ignition	0.0333	0.7502	1.3300	1.1872	1.1386	0.7739	1.9396	1.0766
Loss on ignition .	0.0108	0.0464	0.0820	0.0960	0.0962	0.0701	0.1102	0.0968
Na	0.0002	0.0007	0.0016	0.0005	0.00024	0.0003	0.0023	0.0006
K	nil	nil	traces	traces	traces	traces	traces	traces
Ca	0.0099	0.2192	0.3959	0.3480	0.3238	0.2234	0.5102	0.2654
Mg	0.0009	0.0017	0.0022	0.0030	0.0015	0.00126	0.0404	0.0346
Cl	0.0003	0.0012	0.0027	0.0013	traces	traces	0.0036	traces
SO_4	0.0107	0.4985	0.8713	0.8160	0.7598	0.5280	1.3117	0.7220
HCO_3	0.0211	0.0430	0.1098	0.0360	0.0300	0.0246	0.0886	0.0546
SiO_2	0.0008	0,0002	0.0002	0.0019	0.0012	0.0012	0.0194	0.0078
Al_2O_3	0.00002	0.0007	0.0006	}0021	}10.0008	}0.0008	0.0008	}0.0017
Fe_2O_3	0.00008	0.0001	0.0002				0.0001	
Hardness of water								
in German degrees total	1.59	31.07	55.93	49.40	46.65	31.55	80.73	45.14
Removable .	0.97	1.98	5.15	1.65	1.38	1.13	4.07	2.51
Permanent	0.62	29.09	50.78	47.75	45.27	30.42	76.66	42.63
Date of sampling	April 6, 1940	March 29, 1940	April 6, 1940	Dec. 1934	Dec. 1934	Dec. 1934	March 29, 1940	Dec. 1934

1) Ice crystals from the roof of the old passage to the Diamond grotto.
2) Cover ice from the floor of the cave in the old passage to the Diamond grotto.
3) Cover ice (icefall) in the Diamond grotto.
4) Ice from the walls in the Diamond grotto at a height of 120 cm from the floor.
5) Same, at a height of 85 cm from the floor.
6) Ice from the walls in the Diamond grotto at a height of 50 cm from the floor.
7) Ice of stalactites and mainly stalagmites from the Krestovy grotto.
8) Water dropping from the organ pipe in the Ether grotto.

The second variety of ice developed in the cold part of the Kungur ice cave is the glaciation crust. It is formed in the anterior part likewise at the expense of sublimation of the water vapour on the walls of the grottoes and passages of the cave. The three analyses of the glaciation crust (Table 1, col. 4–6) show that this is already a salt ice [in the conception of Vernadsky ([6])]. The mineralization of the water obtained from this crust in two cases is over 1 g/1.

The origin of the glaciation crust varies for the different parts of the cave. In its anterior part, where it is atmogenous and forms exclusively by sublimation, the temperature is below 0°. In the depth of the cave, where the t° rises periodically above 0°, the crust is of a mixed origin, and the ice here is not only atmogenous (sublimation ice), but hydrogenic, too. The water penetrates here along fissures and solution cavities (organ pipes).

The next variety of the ices of the Kungur cave are the stalactites. These are effluxes of a typical icicle-like shape. Their annual varieties are mostly transparent. The perennial varietes are of a lustreless white colour with a bluish tinge. The ice of the stalactites and stalagmites is also a salt one. The investigation of the stalactites and stalagmites from the Krestovy grotto showed a dry residue of 2.0498 g/1. Here, too, the chief component is $CaSO_4$. It is followed by $CaCO_3$, $CaCO_3 \cdot MgCO_3$. The $Si0_3$ content is a considerable one. This is the most mineralized ice of all the cave ices studied. The reason of such a high mineralization is quite evident. The water penetrating from the surface down the fissures and solution cavities on its way dissolves anhydrites, limestones, dolomitized limestones, as well as the admixtures of SiO_2, $A1_2O_3$, Fe_2O_3 present in them.

An idea of the composition of this water is given by an analysis of the water dropping from an organ pipe in the Ether grotto (Table 1, col. 8). This water is also a mineral (salt) one with a dry residue of 1.1834 g/1. It resembles the water of a source in Chechnya in a gypsum-anhydrite series, studied by us ([17-19]). The predominant component is $CaSO_4$. A certain part is played by $MgCO_3$, $CaCO_3$. Magnesium, like in the case of stalactites and s talagmites, plays here a more considerable part than in the other ice varieties.

Although the ice crystals have different crystallographic habits and the forms of stalactites and stalagmites are diverse, the bulk of ice in the Kungur cave consists of cover ice, occupying the floors of grottoes and passages in the anterior part of the cave. The cover ice may be classed under mixed formations. It is both of atmogenous (sublimational) and hydrogen origin. The crystals dropping from the roof, the sublimation of the water vapour, on the one hand, and the water flowing along the fissures and solution cavities, on the other, form the cover ice. The analyses of cover ice show a different mineralization. The ice taken in the old passage in the Diamond grotto (behind the props) has dry residue of 0.7966 g/1. The ice taken at the wall of the Diamond grotto, near the passage to the Polar grotto, is more mineralized. It is already a salt ice. The dry residue here is 1.412 g/1.

The principal components are $CaSO_4$, and of lesser significance $CaCO_3$ and $CaCO_3 \cdot MgCO_3$. The presence of the mineral cover ice, where the chief component is $CaSO_4$, accounts for the formation of powdery gypsum, forming crystals. During the sublimation of ice, upon its surface gypsum is formed, which has been noticed by Fedorov ([22]) and by other investigators after him.

In the Kungur region ice is present in a number of other caves. The Mechkina cave contains 8 grottoes, in one of which the floor is covered with a layer of ice 20 cm thick. In the Iren cave, in the outskirts of the town of Kungur, the cover ice in the passage and one of the grottoes has a thickness from 1 to 25 cm. Of interest is the Turaev cave, where there is a lake covered with a thin ice crust. In the Andronov cave the thickness of the cover ice on the floor of the cave attains 50 cm. A similar phenomenon is observed in the nearlying Kladbitschensky cave, where the cover ice on the floor attains a thickness of 40 cm. The most diverse is the ice of the Kamensky cave. Here, like the Kungur cave, there are crystals of ice, stalactites and stalagmites up to 30 cm long. Near the entrance of the grotto the cover ice forms an icy slope. Out of the other caves, outside the Kungur region, the Abogydje ice cave ([21]) is of interest. Here have been established all the ite formations in the shape of stalactites, stalagmites, ice crystals, glaciation crust, cover ice, and hydrogenous ice on the lake.

Such are in brief the data available on the Kungur cave ices. Their principal varieties may be tabulated as follows (Table 2). In parentheses are given the varieties which have not been found in the Kungur region, but may possibly occur in ice caves.

Table 2

Classification of Cave Ices

Type of ice	Fresh ice; amount of dissolved substances up to 0.1 %	Salt ice, amount of dissolved substances 0.1–5%	
	Class of ice	Class of ice	Varieties (kinds)
I. Atmogenous (sublimational).	Diverse ice crystals Glaciation crust on the walls of the cave	(Ice crystals) Glaciation crust on the walls of the cave	
II. Hydrogenous	(Ice stalactites) (Ice stalagmites) (Ice columns) (Ice of underground lakes)	Ice stalactites Ice stalagmites Ice columns Ice of underground lakes (Turaev cave)	Ice curtains, ice cups, mush-room - shaped, ice columns, sugar heads, etc.
III. Heterogenous	Massive cover ice (Glaciation crust on the cave walls)	Massive cover ice Glaciation crust on the cave walls	

Thus, on the basis of the data on the Kungur ice cave in the classification of the minerals of the group of water, given by W. I. Vernadsky ([6]), the cave ices should be referred not only to the I class–of the fresh forms of water (family 7), but also to the II class – of the salt varieties of the solid phases of water. It is necessary to separate them as a family.

Departments for Dynamical Geology
and Analytical Chemistry.
Molotov (Perm) State University.

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MINERALOGY

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Classification of Cave Ices

Type of ice	Fresh ice; amount of dissolved substances up to 0.1%	Salt ice, amount of dissolved substances 0.1—5%	
	Class of ice	Class of ice	Varieties (kinds)
I. Atmogenous (sublimational).	Diverse ice crystals Glaciation crust on the walls of the cave	(Ice crystals) Glaciation crust on the walls of the cave	
II. Hydrogenous	(Ice stalactites) (Ice stalagmites) (Ice columns) (Ice of underground lakes)	Ice stalactites Ice stalagmites Ice columns Ice of underground lakes (Turaev cave)	Ice curtains, ice cups, mushroom-shaped, ice columns, sugar heads, etc.
III. Heterogenous	Massive cover ice (Glaciation crust on the cave walls)	Massive cover ice Glaciation crust on the cave walls	

Thus, on the basis of the data on the Kungur ice cave in the classification of the minerals of the group of water, given by W. I. Vernadsky (6), the cave ices should be referred not only to the I class—of the fresh forms of water (family 7), but also to the II class—of the salt varieties of the solid phases of water. It is necessary to separate them as a family.

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