The isotopic composition of hydrothermal waters and carbonate deposits in the adits of the Baksan Neutrino Observatory

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Abstract

The adit of the Baksan Neutrino Observatory explores the situation in the Baksan Gorge of the Kabardino-Balkarian Republic (Russia). There were opened several exits of thermal water in a fractured vein at the a distance of 3,700, 4,000 and 4,200 meters from the entrance. Various mineralization has formed from these thermal springs for more than 30 years. A qualitative set of minerals, isotopy of C and O carbonates, hydrotherms allow to suggest that carbon dioxide in the mine space has a deep nature, and salt composition of solutions was formed from the buried evaporite complexes.

Keywords: isotopic composition, hydrothermal waters, Caucasus

Introduction

The adit of the Baksan Neutrino Observatory (fig.1) explores the situation in the Baksan Gorge (Central Caucasus) of the Kabardino-Balkarian Republic (Russia). The tunnel of this adit has been drilling since the beginning of the 1970s in the muscovite-chlorite-quartz shales of Kurmotau mount. There were opened several exits of thermal water in a fractured vein at the a distance of 3,700, 4,000 and 4,200 meters from the entrance.

Various mineralization has formed from these thermal springs for more than 30 years. That is similar in morphology to the cave formations (fig. 2), which were formed from hot solutions (20-50 °C) and are mainly composed of calcite, as well as the constructed corallites of chlorine-sodium amphibole, magnesite, dolomite, magnesia calcite, tenardite, vanthgophyte, collectionjite, halite and sylvan. The authors selected water and rock material for research in June 2018.

Methods

The chemical composition of water. The water for analysis was taken in the adit from the unloading zone confined to cracks from 3 to 6 m long at a distance of 3800 m from the entrance. 2 hours after water sampling an abundant white crystalline carbonate precipitate fell from it. Chemical analysis of water was made at the State University of the Ural Branch of the Russian Academy of Sciences (analyst N.V. Bykova). The

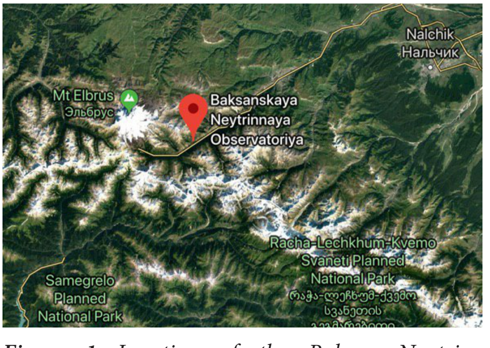

Figure 1 *Location of the Baksan Neutrino Observatory (Google Earth)*

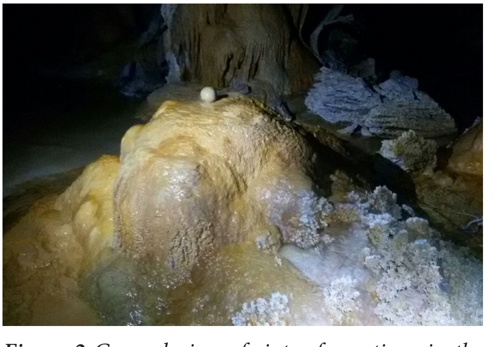

Figure 2 *General view of sinter formations in the Neutrino*

composition and morphology of the precipitated particles and other mineral formations were determined on a VEGA 3 LMH scanning electron microscope with an Oxford Instruments INCA Energy 250 / X-max 20 X-ray energy-dispersive microanalysis system for microanalysis (analysts E.P Chirkova, O.V Korotchenkova).

Analyzes showed (Table 1) that the water discharged in the Neutrino gallery is characterized by a hydrocarbonate-sodium chloride (chloride-soda) composition with a salinity of 8.2 g/L.

Mineral sediment that fell within two hours from the sampled water was represented by two generations of calcite (fig. 3). The early ones form rhombohedral crystals with a smooth-faceted and splintery surface, the later ones form a sheen-like crystals and spherulites. They differ in chemical composition too. The early ones are characterized by the admixture of magnesium (0.02-0.11 formula units), iron (0-0.02), Sr (0-0.01), and the latter - magnesium (0-0.01 feed units), iron (0-0.01) and strontium (0.01-0.02) Ba (0-0.01).

The isotopic composition ($\delta^{18}O$, δ^2H) of thermal waters was $\delta^{18}O$ -8.66 ‰, δD - -86.12, which is close to the isotopic composition of the brines of the Alberta oil basin in North America. Analyzes of the isotopic composition of water was made at the University of Innsbruck (Austria) using laser absorption IR spectrometry on Picarro's L-2130-i laser equipment, equipped with a WS-CRDS (Wavelength-Scanned Cavity Ring Down Spectroscopy) system, and carbonates on a mass spectrometer Delta PLUS XL (Fisher Scientific).

It is generally accepted that the mineral waters of the Greater Caucasus are formed mainly due to the infiltration of precipitation in the Glavny and Vredovoy Ridge. The enrichment of groundwater with carbon dioxide flowing through the faults from the basement during degassing of the mantle, thermometamorphism and magmatism. It is confirmed by the young age of the volcanic structure of Elbrus and the near-surface (5.8 km) position of the magma chamber (Bogatikov et al., 2002) which provoked the formation of numerous outcrops of sub-thermal carbonated mineral waters in the river valleys. A number of other reasons for determining the chemical specificity of the mineral waters of the Caucasus are indicated by Abayhanov (2010). On the one hand, it is an active carbon dioxide leaching, which leads to hydrolytic decomposition of feldspar and the formation of soluble carbonate salts (Na and Ca) and silica, and on the other, the involvement of normal and elevated salinity in the circulation of buried thalassogenic chloride waters of the Mesozoic sediments.

The isotopic composition of carbonates. Isotopic analyzes of carbon and oxygen was made at the Innsbruck Quaternary Group at the University of Innsbruck (headed by Academician of the Austrian Academy of Sciences, Professor C. Spötl) on a Delta V mass spectrometer (Thermo Fisher Scientific) equipped with an automatic line for analyzing carbonates based on the GASBENCH interface as described in Spötl & Vennemann (2003). For a detailed study of the isotopic composition of stalagmite, the material for analysis was selected every 3 mm from every layer. We made 20 analyzes of stalagmite and 1 analysis of corallite stalactite. This samples are presented in fig. 4

The C and O isotopic composition of carbonate sediments (Table 2) varies $\delta^{18}O$ from -8.47 ‰ to -10.31 ‰ V-PDB and $\delta^{13}C$ from + 1.22 to + 6.16 ‰ V-PDB (analytical error for both isotopes is 0.1 ‰ at the level of 1σ).

In Fig. 5 you can see comparison of the isotopic composition of C and O of stalagmites and corallite stalactites from the Neutrino tunnel with the isotopic composition of marine limestones, seamy formations from the caves of the Urals and Alps, as well as

***Table 1** The chemical composition of fissure-vein waters in the Neutrino gallery*

Mineralization, mg / dm³	pH	dry residue, mg / dm³	Anions			Cations		
			HCO^{3-}	Cl^-	SO_4^{2-}	Ca^{2+}	Mg^{2+}	K^++ Na^+
7878	7,75	7595	2892,7	2287,1	35,2	25,1	138,8	2499,4
8213*		7930	3034,4	2287,1	35,2	214,6	142,4	2499,4

* - taking into account precipitation

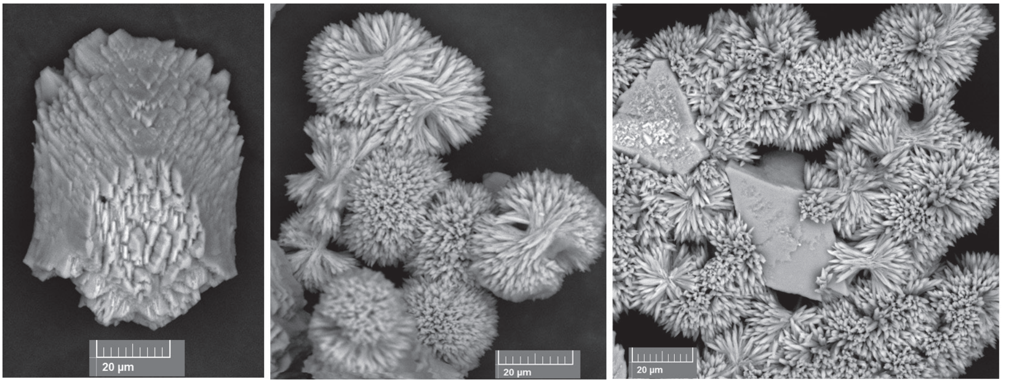

Figure 3 *The morphology of calcite particles from a water sample: early rhombohedrons and late spherulites*

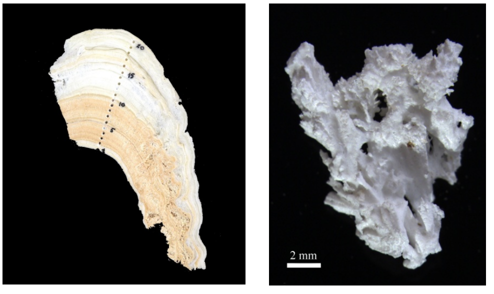

Figure 4 *Sampling sites for the C and O isotopic composition from stalagmite (a) and corallite stalactite (b) samples*

travertines formed from the hot springs of Pamukkale (Turkey) and travertines from cold carbonic waters of the Tokhan-Upper source (Elbrus)

The relatively close isotope compositions of oxygen and carbon have carbonate sediments of the Tokhan-Upper (Elbrus) source, which are formed from cold (7–9°C) carbon dioxide water (Bychkov et al., 2007). However, it was noted that in the process of heating water to atmospheric temperature (18 °C), the deposited carbonates are enriched with a heavy isotope of carbon. Also, the travertines from the world famous source Pamukkale (Turkey) have similar values of the isotopic composition.

The isotopic composition of C and O stalagmites and corallite stalactites which formed by thermal water in the Neutrino tunnel differs from the usual sinter formations from the caves of the Urals and the Alps.

Conclusions

A qualitative set of minerals, isotopy of C and O carbonates, as well as mineralization (8.2 g/L) and hydrocarbonate-sodium-chloride composition, hydrotherms allow to suggest that carbon dioxide in the mine space has a deep (magmatic, metamorphic) nature, and salt composition of solutions was formed from the buried evaporite complexes.

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Table 2 The isotopic composition of the newly formed carbonates from the Neutrino gallery

№	Sample description	Isotopic composition, ‰	
		δ^{13}CVPDB	$\delta^{18}O_{VPDB}$
1	Stalagmite selected at 4000 m from the entrance. Water temperature is 30 ° C.	6,16	-8,47
2		3,93	-9,46
3		1,82	-10,01
4		1,54	-10,03
5		2,16	-9,95
6		3,16	-9,79
7		2,32	-10,02
8		1,70	-10,13
9		1,22	-10,19
10		3,69	-9,81
11		2,32	-10,31
12		1,44	-10,04
13		1,75	-9,97
14		2,36	-9,93
15		2,23	-9,92
16		2,93	-9,84
17		1,71	-10,19
18		3,33	-9,60
19		2,50	-9,64
20		3,15	-9,61
21	Stalactite selected at 3700 m from the entrance. Water temperature is 20-25 ° C.	3,8	-8,5

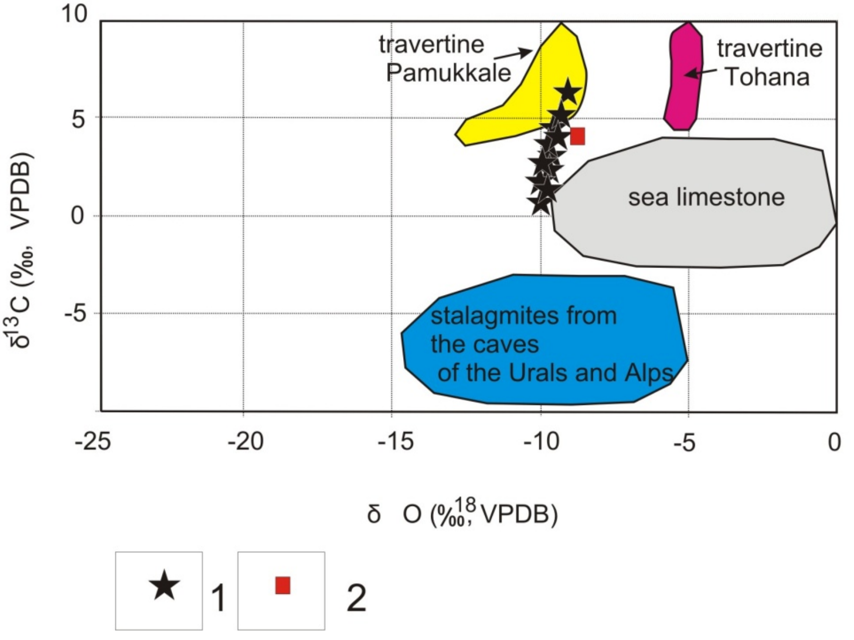

***Figure 5.** Variations of $\delta^{13}C$ and $\delta^{18}O$ of carbonates from the Neutrino gallery (1- stalagmite; 2 - corallite stalactite) and their comparison with the genetic associations according to Railsback, 2010 (with addition from authors): 1 - stalagmite; 2 - corallite stalactite*