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HYDROGEOLOGY
ENGINEERING GEOLOGY & GEOTECHNICS

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MINERALOGICAL AND CHEMICAL FEATURES OF BRINES AND MODERN EVAPORITES OF TALOE LAKE TRACT (REPUBLIC OF KHAKASSIYA)

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ABSTRACT

This work is dedicated to study of mineralogical and chemical features of modern evaporites and producing brines. The subject of inquiry is tract of Taloe lake (Republic of Khakassiya), which represents isolated basin. This basin consists of two temporary reservoirs with areas 3300×960 m and 1610×385 m, located at different hypsometric levels.

Mineral composition has been studied with use of X-ray diffraction analysis and raster electronic microscopy methods. As a result, it's found out that every hypsometric level has its certain complex of minerals. For the lower level there are halite, thenardite, astrahonite, gypsum, calcite, dolomite, plagioclase, quartz, mica and chlorite. For the reservoir at the upper level halite, calcite, gypsum, astrahonite, quartz, plagioclase, mica, chlorite are typical. Lateral zonality of minerals formation, which consists in regular change of minerals from bank to central part of the reservoir, has been stated at this level.

Chemical composition study is based on titrimetric analysis and inductively coupled plasma mass spectrometry (ICP-MS) results. Samples of surface and subterranean waters have been analyzed. Waters of the reservoirs are mainly of chloride type and are enriched with Li, B and Sr. But according to certain chemical parameters they differ significantly. Reservoir at the lower hypsometric level is notable for high degree of mineralization of surface waters (85,4 g/l) and low degree of mineralization of subterranean waters (4,7 g/l). According to pH value waters are alkaline, this is confirmed by large quantity of Na. Reservoir at the upper hypsometric level characterized by high degree of mineralization of surface (30,4-36,6 g/l) and subterranean (104,9-108,3 g/l) waters. Large quantities of Ca and Mg indicate that waters of this reservoir are hard. According to pH value waters are normal.

With the purpose of determination of brines, which produce evaporites, analysis of trace elements distribution in sediments has been carried out. Besides common level of accumulation, distribution of evaporite and terrigenous constituents has been studied. Enrichment with Li, Sr, V, Ba compounds has been stated.

Keywords: Evaporites, brines, mineral association, microelements.

INTRODUCTION

Study of mineral and chemical compositions of bottom sediments and surface waters and ground waters, which associate with the sediments, allows to solve a number of sedimentological, geochemical and ecological issues [2, 5, 13]. Direct observations of modern "brine – sediment" system enable modeling of chemogenic mineral formation and make extrapolation of the model to old lithologic associations possible [11, 13]. Variants of microelements redistribution between bottom sediments on the one hand and surface and ground waters on the other hand form the informative base of technogenic metals accumulation [7]. In cases when brines represent hydromineral resource, mineralogical and geochemical studying them bears technological meaning [7].

This investigation is focused on determination of degree of surface and ground waters influence on sediments composition in modern enclosed evaporite systems. As an object of research saline enclosed low-mountain sink "Taloe lake tract" (Eastern Siberia) has been considered.

GEOLOGIC AND GEOMORPHIC POSITION

Taloe lake is situated in Eastern Siberia (Republic of Khakassia, Russia) and located on divide of Bidja and Karasuk rivers basins. In the relief sense area of the lake represents hilly plain of denudation with positive landforms up to 540-560 meters high [8]. Climate here is temperately continental, subarctic. Maximal temperature in summer is about +36 °C. Minimal temperature in winter reaches -47 °C. Annual amount of atmospheric presipitaions – 266 mm.

Taloe lake tract is an enclosed sink surrounded by low hills. There are two intermittent reservoirs isolated from each other and allocated at different hypsometric levels. The reservoirs are located in parallel with each other. They both have elliptic shape and elongate in submeridional direction. "Lower" reservoir is located at 390-391 meters high, its' length is 1610 m, width – 385 m. "Upper" reservoir is located at 399-400 m high, its' length is 3300 m, width – 960 m.

Total catchment area of Taloe lake tract amounts about 25 km^2. Reservoirs recharge realize by means of atmospheric precipitations, snow melting and ground waters inflow. Seat rocks are represented by lower carboniferous samokhvalskaya suite deposits: sandstones, tuffs and tuffites of south-Minusinsk hollow. According to opinion of Rusanov A. V. [10] the source of salt for the lake is an anticlinal structure constituted by a salt dome. Rock salt is washing out and giving out brines, which rise via joints from subsurface to the western part of the lake and even to its' shore.

MATERIALS AND METHODS

As Taloe lake tract is an intermittent basin, it fills with water for a short terms, what is related to snow cover melting and abundant precipitation periods. Hence, only during these short periods it is possible to consider surface waters influence. Materials for this work are represented by samples, that had been collected at 10th of july 2015 nine hours after the rain. According to meteorological station "Abakan" 11.4 mm of atmospheric presipitations fell out during the preceding period.

samples of surface water, 7 samples of underwater sediments and 9 samples of salts, which crystallized during the materials collection period, have been collected. Sample of ground water of "Lower" reservoir has been collected from the wellspring. Two samples of ground water of "Upper" reservoir have been collected from technical well on 2 and 3 meters deep.

Mineral composition of sediments and salines were analyzed by means of X-ray diffraction analysis. Study of polymineral saline aggregates carried out by use of X'PERT PRO (PANalytical) diffractometer with X-ray tube with Cu-anode. Survey step was 0.02°, 2O angles range – 4-60°, rotation speed - 30 turns per minute, exposure time 0.1 second per point, operational radius - 141 mm. Results interpretation were carried out using PDF-4 [9] and HighScore software packages.

Microelement composition of the sediments was defined by means of inductively coupled plasma mass spectrometry (ICP-MS) using the Agilent 7500cx unit. Total-rock composition, soluble and insoluble in water parts of the sediment samples were analyzed. Analysis was carried out by original method. Quality of obtained results was estimated on the basis of BCR-2, OIB standards. Analytical work was performed at collective use center «Analytical center of natural systems geochemistry» of Tomsk State University.

Water samples were studied by means of titration and ICP-MS methods. Titrimetry analysis was carried out at PJSC "Tomskgeomonitoring" laboratory with the aim of macrocomponents identification in ground and surface waters composition. ICP-MS analysis was carried out at collective use center «Analytical center of natural systems geochemistry» of Tomsk State University.

RESULTS

Results of sediments mineral composition study confirm conclusions previously made [1] that there are two mineral associations: terrigenous and evaporite ones (table. 1). Terrigenous association is defined on the basis of mineral debris (quartz, plagioclase, hydromica, chlorite), which supposedly have been brought by means of eolian processes. Composition of this association depends on type of rocks disintegrating at nearby outcrops. Evaporite association of the "Lower" reservoir consist of tenardite, halite, gypsum, calcite, astrakhonite. Sediments of the "Upper" reservoir contain halite, gypsum, calcite, astrakhonite.

Table 1

Characteristics of minerals in samples according to X-ray diffraction analysis results

Mineral	Characteristic (d) spacing (A), intensity (I)	PDF-4 (# card) [9]
Terrigenous association		
Quartz	3,34(10); 4,25(5); 2,45(3)	[01-085-0794]
Plagioclase	3,19(10); 4,03(4),3,66(4)	[01-089-6426]

Hydromica	10,00(10); 4,49(9); 2,49(2)	[01-070-3754]
Chlorite	14,03(10); 7,05(8); 4,71(4)	[00-052-1044]
Evaporite association		
Halite	2,81(10); 1,99(6); 3,25(2)	[04-002-2489]
Calcite	3,06(10); 2,49(4); 3,84(2)	[01-086-1108]
Gypsum	4,25(10); 7,60(8); 2,89(6)	[01-074-1904]
Tenardite	4,66(7); 3,18(6); 3,84(2)	[00-037-1465]
Astrakhonite	4,50(10); 2,93(4); 2,59(2)	[01-077-1343]

Results of surface and ground waters study are given in table 2. It is shown that brines of "Upper" and "Lower" reservoirs differ on the basis of sulfate, hydrocarbonate and chloride ions content. Herewith, according to hydrogeochemical classification by Kurnakov-Valyashko [12] "Lower" reservoir water is alkaline (pH > 8) sulfate-chloride, while water of the "Upper" one are neutral (pH ~ 7) chloride (fig. 1).

Table 2

Macrocomponent composition (mg/dm^3) of Taloe lake waters (according to titration results)

Sample #	Water type	M, g/l	pH	Ca^{2+}	Mg^{2+}	HCO_3^-	K^+	Na^+	Cl^-	SO_4^{2-}
«Upper» reservoir										
1	s.w.	30,4	6,4	641,3	407,4	79,3	59,5	6486	13201	4200,0
2		36,4	6,2	741,5	571,5	91,5	67,5	9530	15372	6000,0
3		35,9	7,2	761,5	541,1	109,8	72,2	8967	15459	6833,3
4		36,6	7,0	761,5	541,1	109,8	70,2	10535	15459	5500,0
5		33,7	6,7	701,4	851,2	79,3	102,6	5880	14417	3600,0
6	g.w.	108,3	7,0	1142,3	2346,9	994,6	72,5	30527	51069	5700,0
6'		104,9	6,9	1122,2	2128,0	988,5	68,4	29155	51243	6900,0
«Lower» reservoir										
7	s.w.	85,3	8,5	10,0	188,5	2343,2	181,6	41650	43078	30000,0
8	g.w.	4,7	8,3	34,1	38,9	561,4	15,3	2450	1024	8250,0

Note: s.w. – surface waters, g.w – ground waters

elements do not amount considerable quantities in brines. Most high concentrations have been stated for Li, B and Sr (table 3). There is direct relation between concentration of these elements and total level of water mineralization (fig. 2), that is confirmed by contemporary works [3, 4, 6, 7]. Major difference between waters of two reservoirs in respect of microelements accumulation is determined by B and Rb in the "Lower" one and Sr in the "Upper" one concentrations increase.

Table 3

Microcomponent composition of Taloe lake waters (according to ICP-MS analysis data), ppm

№	Water type	Li	B	V	Cr	Fe	Sr	Ba	Rb
«Upper» reservoir									
1	s.w.	1,71	4,98	0,18	0,13	15,04	23,39	0,08	0,07
2		1,95	5,34	0,18	0,13	15,42	26,00	0,09	0,06
3		2,00	5,72	0,17	0,12	15,22	28,14	0,08	0,06
4		1,94	5,72	0,17	0,13	15,87	25,80	0,10	0,06
5		2,85	3,39	0,17	0,13	16,26	22,16	0,10	0,06
6	g.w.	5,82	3,33	0,38	0,31	36,81	44,22	0,09	0,16
9		5,97	3,13	0,38	0,31	37,70	44,60	0,08	0,12
«Lower» reservoir									
7	s.w.	3,24	29,64	2,30	2,29	346,67	1,47	0,59	4,17
8	g.w.	0,24	1,26	0,06	0,03	6,39	4,51	0,02	0,02

Note: s.w. – surface waters, g.w – ground waters

CONCLUSION

Stated differences of sediments mineral compositions of two intermittent reservoirs are determined by sodium sulfate (tenardite) presence in association with alkaline sulfate-chloride brines of "lower" level. This show sustainability of main evaporite minerals in waters of appropriate hydrochemical type. In addition, brines pH mostly determine the solubility of microelements [4]. Thus, higher concentrations of Rb, B, Fe, Zn, Cu and other chalcophile elements are typical for alkaline water (pH > 8) of "Lower" reservoir. Neutral brines of the "upper" one are enriched with such alkaline earth elements as Mg, Ca, Sr.

In all of studied water samples there are high concentrations of lithium (from 2 to 6 ppm). However, in contrast with other elements contents lithium does not show clear relation with hydrochemical type of water. The most distinctly Li concentration show

dependence on total brines mineralization (fig. 2). This finding confirms hypothesis of N. A. Makarenko and A. L. Arkhipov about possibility of discovery of lithium commercial content in ground waters of south-Minusinsk hollow in case when total mineralization level is higher than 150-200 g/l [7].

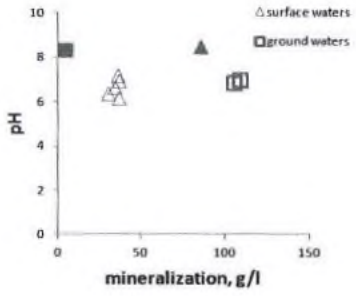

Fig. 1. Relation between pH and water mineralization

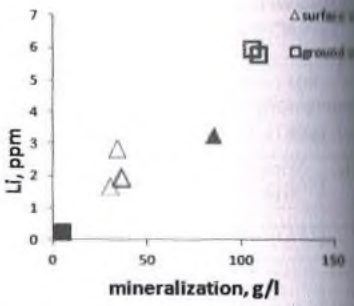

Fig. 2. Relation between Li content and water mineralization

With the purpose of definition of nature of brines which are responsible for evaporites formation microelements accumulation analysis has been carried out. Besides that trace elements distribution between soluble and dissoluble components of sediments has been revealed. Also it has been stated that soluble component enriches with Li, Sr, V and Ba the most. For estimation of different water types influence on soluble part composition Ba/Sr and Sr/Li diagrams have been built. There is single distribution trend for figurative points of sediments and ground water compositions observable at Ba/Sr diagram (fig. 3). This indicates alkaline earth elements input by ground waters. At the Sr/Li diagram (fig. 4) we see that sediments compositions are akin to ones of ground waters. On this basis we can assume that surface waters absorb alkaline elements out of sediments and consequently reduce their quantities there.

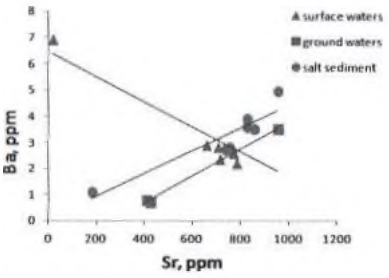

Fig. 3. Ba/Sr ratio

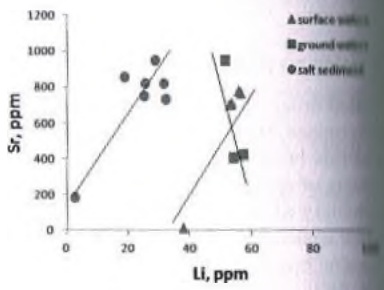

Fig. 4. Sr/Li ratio

In such a way, on the basis of investigation carried out it is stated that:

1) Hydrogeochemical type of brines determines microelements content and mineral composition features of precipitating salts;

2) Microelements content in sediments mainly is related to insoluble terrigenous component;

3) Soluble component of sediments mainly depends on ground waters composition;

4) Considerable surface waters enrichment with alkaline elements imply dissolution of solum sediment salts.

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