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PRECIOUS METALS IN SALT OF THE VERKHNEKAMSKOYE DEPOSIT AND TECHNOLOGY OF THEIR EXTRACTION*

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The results of studies of mineralogy and precious metal salts at Verkhnekamskoye deposit are presented. Fundamental and applied aspects of the research are identified. For the first time in the history of the research of salt deposits, the complex of precious metals (Au, Ag, Pt, Pd) and the form of their location and methods of analysis were revealed. Presence of precious metals in the salts of Verkhnekamskoye deposit shows the ability to detect them in other salt basins.

The features of mineral process are identified. Separation of the process of post-sedimentation epigenetic changes with radiogenic-chemical nature is substantiated. New type of deposit formation for Au, Ag and Pt-metals in evaporite deposits is introduced.

Complex information about the form of finding precious metals, features of mineralogy and chemical composition of rock salt was used to support the development of technological solutions for industrial sludge processing technology to extract precious metals. Technological solutions are implemented in the initial data for designing of pilot production facilities.

Key words: *sylvinites, carnallite rock,, stone salt, organic compounds, insoluble rest, precious metals, slimes, granulate, snuff.*

Verkhnekamsk potassium salt deposit (VKDPS) is presented by the thick (more than 500 meters) salt body that is divided (upwards) into the bedding rock-salt (thickness 320–400 meters), potassium body (70–100 meters) and overburden rock-salt (20 meters). Clayey-anhydride sediments (thickness 200–220 meters) lay under the salt body. Salt-marl, terrigenous-carbonate and particoloured rock, belong to Ufa stage, cover the salt deposit. Area of the salt deposit is 8.1 thousand m^2, area of potassium deposit is 3.75 thousand m^2.

Principal rocks for bedding rock-salt are rock-salt and marking clay (MC), for potassium deposit — silvinite and carnallite rock alternated with inter-layer rock-salt and dry-cakes. All above-mentioned rocks content residuum (I. R.) insoluble in water that is principal component only of the marking clay (table 1).

Mineral composition of I. R. of the salt rocks is approximately identical (table 2).

Minerals of I. R. (insoluble residuum) in the bedding rock-salt are localized in the inter-grains space of the aggregates of halite, in the clayey-anhydride inter-layers and in the seam of MC.

Minerals forming of I. R. of the salt rocks in potassium deposit are presented in two phases: mineral mass in the inter-grains space (inter-grains I. R.) in silvinite and carnallite rocks and mineral pigment of the salt minerals (table 3).

Pigment composition involves Au. Pt and Pd are absent. Inter-grains I. R. contents Au, Pt and Pd. Gold in the pigment composition is tied with hematite-goethite component. Au and Ag in the inter-grains I.R. are tied mostly with sulphate composition of I. R.

It has been found tie of sulphate composition of I. R. with organic substance [1–3].

Method of mass-spectrometric analysis with inductively tied plasma in I. R. of the salt rocks has demonstrated following content of precious and platinum-group metals, mcg/g: Rh<0.1; Pd — 3.3; Ag — 2.6; Ir<0.02; Pt — 0.79; Au — 0.17.

Discovery of tie of precious metals with organic substance has stipulated further examination of the last one. With that end in view the samples of I. R. of the salt rocks have been put to the test by chloroform and alcohol-benzol extracting — separately sedimentary and flotation parts. It has been found tie of the precious metals with

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Table 1. Mineral composition of the salt rocks of VKDPS, %

Mineral	Salt rocks					
	Rock-salt	Marking clay	Silvinite	Carnallite rock	Inter-layer rock-salt	Dry-cakes
Halite	97–99	7–13	45–95	to 45	to 92	60–85
Silvinite	–	–	5–45	1–3	–	–
Carnallite	–	–	0,5–3	До 55	–	–
I.R.	1–3	93–87	2,5–6	До 6	10–12	15–40

Table 2. Mineral composition of insoluble residuum of the salt rocks, %

Minerals	Rock salt	Marking clay	Silvinite	Carnallite rock
Anhydride	40	42	44	5
Gypsum	10	21	5	3
Jarosite	1,1	Evidence	–	–
Dolomite	24	11	20	18
Quartz	12	12	12	35
Feldspar	1,5	11	8	26
Chlorite	3,5	1,5	3	3
Hematite	0,6	0,6	Evidence	–
Goethite	–	–	1,5	–
C_{org}	0,9	1,35	1,1	1,54

Table 3. Composition of the silvinite pigment (in accordance with data of RKFA), %

Mineral	Pigment fraction	
	Flotation share	Sediment
Goethite	70	8
Hematite	7	3
Dolomite	10	80
Quartz	5	3

chloroform and alcohol-benzol bitumoides that are component of organic substance that involves sulphate component of I. R. Gold is exclusion since its main part is in the form of carbonil-halogenides and is tied with silvinite pigment.

Above-stated material demonstrates that gold, silver and platinum-group metals are localized in three groups of the minerals: in I. R. of bedding rock-salt, in silvinite pigment and in the inter-grains I. R. of the salt rocks of potassium deposit (silvinite and carnallite rock). So, they may be attributed to para-genetic mineral associations [4]. Products of the last ones are disunited in space and by the time of forming.

First association involves compounds of gold, silver, platinum group of the metals and minerals of I. R. of bedding rock-salt. In accordance with time of forming it is the following after halite that is attributed to the salt para-genetic mineral association. Two associations (salt and precious metals) constitute the stage of mineral forming that has formed bedding rock-salt.

Second association involves carbonil-halogenides of gold and is presented by the minerals of silvinite pigment, carnallite and, in small degree, halite. Silvinite, carnallite, halite and minerals of pigment of the salt minerals are presented by two (salt and precious metals) associations that have been formed simultaneously-consecutively and have formed potassium deposit.

Third association involves compounds of gold, silver, platinum-group metals and is the late one in accordance with time of forming. Its minerals form the inter-grains I. R. of the salt rocks of potassium deposit.

Comparison of conditions of localization of precious metals in salt sediments with conditions of localization of the deposits of above-mentioned metals, indicated in the ore-formation classifications (Konstantinov, 1991), shows that the first ones do not have analogues. It confirms possibility to separate new formation type of the deposits of precious metals.

Worked up technology of extraction of the gold and platinum-group metals from the waste after salt production is the basis of new geological-industrial type. It is impossible to consider geological-industrial type of the deposits without technology. In consideration of the new formation type of the deposit of precious metals it has to be taken into account that metals content, in evaluation in the rock salt, is not commercial. So, it is possible to speak about

Sample palladium salt

Table 4. Granulometric and mineral composition of I.R. of the sludge

Class of coarseness, mm	Yield, %	Mineral composition of the sample, % (mass)						Volume of metals, extracted from 1 ton of I.R. of the sludge, g		
		Quartz	Feldspar	Dolomite	Gypsum	Mica	Pyrites	Pd	Pt	Au
+1	16,71	7	11	4	75	2	1	2,23	0,03	0,20
–1+0,5	14,44	11	13	4	69	1	2	11,7	1,54	0,12
–0,5+0,25	17,49	13	18	5	61	1	2	0,67	0,03	0,06
–0,25+0,071	13,9	25	37	14	13	6	5	0,34	0,05	0,03
–0,071+0,044	27,77	35	30	15	5	10	5	0,39	0,08	0,03
–0,044	9,69	31	43	12	3	10	6	0,24	0,09	0,06

formation type of the deposit with low concentration of precious metals and about new geological-industrial (technogeneous) type of the deposits. Deposits of above mentioned type is tied with concentration of precious metals in waste after the ore processing.

Analysis of results of investigations has permitted to substantiate technical solutions for working out of industrial technology for processing of the sludge for extraction of precious metals:

All metals are concentrated in I. R. of the silvinite. After processing the metals are accumulated in the sludge. Metals concentration in the sludge is ten times more than their concentration in original rock. So, the sludge may be used for extraction of the metals.

Since the sludge is the pulp that contents I. R. (30 %), salt (30 %) and water (40 %) it has been recommended to use hydro-cyclone separation for concentration of I.R. [6].

Difference in distribution of precious metals by the classes of coarseness and their tie with sulphate component of I. R. have substantiated fulfillment of technological estimation of some classes of coarseness. It has been found possibility (table 4) to remove into the discharge not only water and some part of salt but additionally large share of I. R. of the sludge with low content of precious metals in course of hydro-cyclone separation. For all this up to 80 % of precious metals may be extracted into the sandy product (yield 25–40 %).

All precious metals, excluding some share of gold and silver, are in form of organic compounds and are tied with bitumoides with association with calcium sulphate. Assay analysis of original silvinite and its I. R. [1] shows that in course of assay melting of I. R. most of the metals removes into the sublimate. In course of assay melting of initial ore, when mass of the chloride matrix reaches 95 % and I. R. is 5 %, precious metals are kept, that is conditioned by presence of the chloride shield and high temperature. It has permitted to recommend chlorinating burning [7] for processing of I. R. with subsequent leaching of the burnt material with hydrochloric acid, sorption of precious metals from solution after leaching, desorption and precipitation of the collective metal-contenting concentrate.

It has been worked up principal scheme of affination of the collective concentrate with obtain of palladium salt (see the Fig.) $Pd_{1.094}(NH_3)_{1.8}Cl_{2.06}$ that contents 51 % of palladium.

Thus, recommended industrial technology of processing of the sludge, that contents precious metals, foresees:

hydro-cyclone separation with obtain of the sandy part (concentrate);

transformation of organic compounds of precious metals into the acid-soluble form (chlorinating burning);

hydro-metallurgical working of the products of burning.

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