REE in quartz fluid inclusions from gold deposits from North-East of Russia

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Fluid inclusions refer to the fluid entrapped during the formation of minerals. Rare earth elements (REE) are very useful tracers for a wide variety of geochemical processes. Inductively coupled plasma mass spectrometer (ICP-MS) was used to determine REE abundances in fluid inclusions. The samples analyzed in this study were fluid inclusion-bearing quartz concentrates. Object of this study are three major types of gold hydrothermal systems from North-East of Russia: polygenic (1) gold-quartz-sulphide (Au-Q, Nezhdaninsk) and (2) gold-antimony (Au-Sb, Sarylakh and Sentachan) and (3) intrusion-related gold-bismuth-siderite-polysulphide (Au-Bi-Sid, Arkachan) large deposits located in terrigeneous rocks of Verkhoyansk fold belt (Fig. 1). Quartz fluid inclusions from various types of ores have been studied: gold-quartz and Au-Mo-W-Bi veins and regenerated Ag-Pb ores from Nezhdaninsk deposit; Au-Q veins and regenerated quartz of Sb ores from Sarylakh and Sentachan deposit; metamorphic quartz and ore quartz from Arkachan deposit.

PT parameters and compositions of hydrothermal fluids of the deposits based on fluid inclusion studies are shown in Table 1. The data of inclusion types, phase compositions and microthermometry results have been adequately considered (Bortnikov et al., 2007; 2010; 2011).

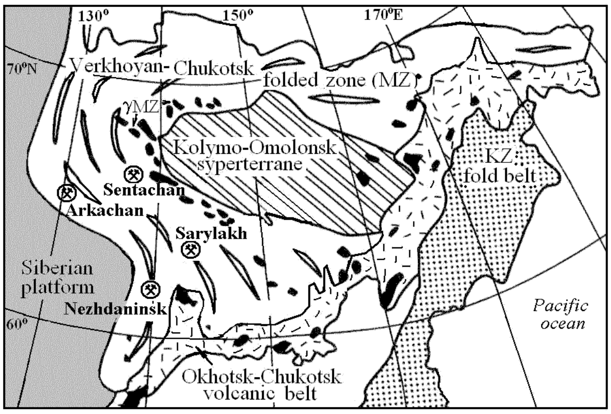

Fig. 1. The position of the studied deposit on the tectonic map of the North-Eastern Territory of Russia.

Our research is focused on the distribution of REE identified in aqueous solutions extracted from fluid inclusions. Analyses were performed by the uniform procedure published by Kryazhev et al. (2006). The procedure includes careful clearing of sample, breaking of inclusions in the quartz reactor by crushing or heating, gas chromatography of H_2O, CO_2, CH_4, preparation of aqueous extract (0,5 g of the sample + 7 ml of the cleansed water), ion chromatography of Cl^-, SO_4^{2-}, F^- and determination of other elements by ICP-MS. The sample washed out after the "working" extract is used for preparation of the "blank" extract.

Deposit	Stage	T_h, °C	P, kbar	w_{salt}, eq.%NaCl	CO_2/CH_4*	∑REE,* ppm	Au,* ppm	Cations*	Anions*
Au-Q	Au-Mo-W-Bi	374-199	1,4-0,4	31,1-1,9	0,1-0,5	5,5-52	0,8-1,3	K, Ca, Na	$Cl^->HCO_3^-$
	Au-Q	368-267	2,0-0,7	9,6-1,2	98-209	0,7-24,3	0,03-20	K, Na, Ca	$HCO_3^->>Cl^-$
	Ag-Pb	387-129	1,9-0,8	8,6-2,4	58-156	1,4-24,3	0,3	K, Ca	HCO_3^-
Au-Sb	Au-Q	340-232	3,4-1,2	8,3-1,6	47-54	0-0,8	0,05	Na, Ca	$HCO_3^->SO_4^{2-}$
	Sb	244-130	2,0-0,3	6,3-3,2	12-85	11,8-42	0,5-2,8	K, Ca	$SO_4^{2-}>HCO_3^-$
Au-Bi-Sid		385-261	1,7-1,3	26,3-3,7	20-137	0,2-4,0	0,5-2,2	Na	$HCO_3^->Cl^-$

*Table. 1. Parameters of hydrothermal fluids for the Nezhdaninsk (Au-Q), Sarylakh and Sentachan (Au-Sb) and Arkachan (Au-Bi-Sid) deposits. * - contents in fluid inclusions (TsNIGRI MNR, analyst Vasyuta Y.V.).*

REE are related to a group of elements-impurities, which arrive in the extract practically only from the matrix of the host mineral (quartz). Their concentration in the extract directly depends on the area of the surface of the sample and is identical in "blank" and "working" extracts. Between all elements of this group (Si, Al, Ga, Ti, Zr, Y, REE) strong positive correlations have been found (Kryazhev et al., 2008).

For samples of Nezdaninsk, Sarylakh and Sentachan deposits such correlation really exists, but for Arkachan deposit there is the opposite correlation. Comparison of total REE contents in the quartz and in the water extract shows enrichment of REE in the fluid inclusions compared to quartz.

The chondrite-normalized REE patterns of inclusion fluids for the Nezhdaninsk and Arkachan deposits are characterized by light rare earth elements (LREE) enrichment with a positive or negative Eu anomaly, whereas the patterns for the regenerated quartz from Sarylakh and Sentachan deposits are characterized by pronounced differentiation between both light and heavy lanthanides in fluid inclusions (La_n/Sm_n = 12 and 46, respectively). Only regenerated quartz contains HREE and has ratio La/Ce order higher than early milky quartz. The positive Eu anomalies in the fluid inclusions suggest that the hydrothermal fluids were relatively reduced. The total REE contents for studied deposits are shown on the Figure 2.

For Arkachan deposit the total REE contents are higher in the solutions having higher Na+K values. We interpret that REE concentrations increase, when the salinity the of inclusions becomes higher. Assuming that Cl^- content in the fluid inclusions increases together with the Na+K concentrations, our data suggest that REE could be transported as chlorine complexes in the Arkachan hydrothermal system. Values of Rb and Cs in fluid inclusions also show a positive correlation with the Na+K content.

The data presented here indicate that, indeed, markable amounts of rare earth elements may be transported in gold-bearing solutions.

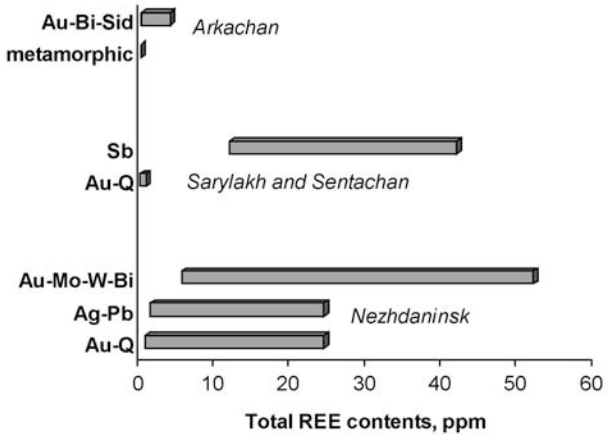

Fig. 2. The total REE contents in quartz fluid inclusions for varies types of deposits.

The authors thank V.Yu. Prokof'ev, S.G. Kryazhev and Y.V. Vasyuta for cooperation. This study was supported by Rus. Found. Basic Res. (09-05-00819a, 09-05-98536-r-east) and Min. Ed.Sci. (Gov.Contr. 16.515.11.5014).

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