CONDITIONS OF GOLD MINERALIZATION BY BORON-RICH FLUIDS

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Tourmaline often composes pre-ore mineral assemblages in hydrothermal gold deposits. Commonly boron concentration in mineralizing fluids not exceeds 1-2 g/kg of solution (Prokof'ev et al., 2002). Study of mineralizing fluids, which are responsible for the gold formation in the Teremkinskoye deposit, however indicates much higher boron concentration.

The Tetremkinskoye deposit located 5 km West of the Darasunskoye large gold deposit, Transbakalia, Russia is hosted in the Early Paleozoic gabbroide and the Middle Paleozoic granitoide to the Early Mesozoic granitoide. In this area gold mineralization is spatial related to the Mesozoic plagiogranite-porphyry bodies that are enriched in K. Altered wall-rocks are beresite (quartz+carbonate+serecite) and listvenite. Absolute age of the rocks is 145 Ma. Ore bodies are gently pitching quartz veins and mineralized zones. Quartz is the main gangue mineral crystallized during several stages. Tourmaline is one of the earliest minerals. Then sulfides (pyrite, arsenopyrite, chalcopyrite, sphalerite, and galena) deposited. After that native gold with a significant impurity of Ag, cosalite, tetradymite, aikinite, native bismuth, and Pb sulfoantimonides have crystallized. Carbonate-quartz assemblage with chalcedony, zeolites, and occasional fluorite is the latest.

Based on electron microprobe analysis and calculations tourmaline from Teremkinskoye can be classified as variety between the shorl-dravite end members with the Fe/(Fe+Mg) ratio ranging from 0.54 to 0.74. The tourmaline characterized by relatively high Ca content ranging from 0.18 to 0.30 apfu. This can indicates a relatively high temperature of the tourmaline crystallization (Zaraisky, 1989). In the Fe-Al-Mg ternary diagram tourmaline compositions are plotted below the shorl-dravite line (Fig. 1) suggesting tourmaline enrichment in Fe^{3+} (Slack, 1996). In turn this indicates a high f_{O2} during tourmaline crystallization. Thus, it could be concluded that mineralizing fluid at the earliest stage was oxidized.

Fluid inclusions in quartz from different assemblages have been studied by freezing and heating in the THMSG-600 Linkam camera, gas and ion chromatography, and atomic emission spectroscopy of individual fluid inclusions opened by a laser microprobe (Reyf, 1997). Salinity was estimated based on ice melting temperature (Bodnar, Vityk, 1994). Pressure was estimated based on vapor-rich and aqua-rich inclusions (Roedder, 1984). FLINCOR 1.21 (Brown, 1989) was used to calculate the pressure.

The study indicates that the aqua chloride-rich fluids were responsible for deposition of ore-bearing assemblages. Salinities and temperatures of the fluids range from 2.7 to 34 wt% NaCl eq. and from 118 to 466°C, respectively (Fig. 2). Syngenetic vapor-rich and vapor-liquid (T_h>260°C) inclusions often observed in quartz indicate a fluid boiling and immiscibility. Most of vapor-rich inclusions contain water vapor of low density. In some inclusions there is a dense CO_2 with the homogenization and melting temperatures ranging from –22.2 to 11.5°C and from –57.8 to –56.6°C, respectively. Pressure estimated for inclusions with the immiscible fluids ranges from 70 to 310 bars at 260 to 414°C. Gas chromatography indicates a presence of N_2 (6.0-19.9 mole %) and small amount of CH_4 (0.2-0.5 mole %) in addition to CO_2 (79.6-93.8 mole %). Based on the ion chromatography study Cl and F concentrations in aqua solution range from 2.8 to 15.8 g/kg of water and from 0.27 to 0.48 g/kg of water, respectively. Atomic emission spectroscopy of individual fluid inclusions opened by a laser microprobe indicates a presence of B (1.55-15.56 g/kg of solution), Cu (0.07-0.74 g/kg of solution), and Ag (2.45 g/kg of solution) (Table).

Types of the altered rocks (beresite and listvenite) and a presence of tourmaline in gold-bearing quartz veins indicate that the ore forming fluids were acid with boron in them as H_3BO_3 (Prokof'ev et al., 2002). Sometimes values of the boron concentration in the ore-forming fluids exceed those in a saturated solution of boric acid (about 6 g/kg of solution). Really during freezing experiments in some inclusions elongate crystals have arisen. These break down at temperature ranging from -6.1 to 15.2°C. Based on optical properties the crystals look like sassolite. Smirnov et al (1999) reported a diagnostics of sassolite in fluid inclusions.

Generally, boron concentrates in volatile phase of fluid-magmatic system. Therefore, a high boron concentration in the Teremkinskoye ore-forming fluid indicates probable magmatic nature of the fluid and magmatic source of ore substances.

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Table. B, Cu, and Ag concentrations in oreforming fluid estimated by the atomic emission spectroscopy of individual fluid inclusions opened by a laser microprobe.

№ incl.	Depth, mm	T_h, °C	C, wt%	d, g/cm^3	V, cm^3× ×10^{-5}	m, kg×10^{-8}	C_B, g/kg of solution	C_{Cu}, g/kg of solution	C_{Ag}, g/kg of solution
1	26	414	11.5	0.64	4.14	2.67	1.55	0.07	<0.28
2	4	382	7.2	0.63	4.33	2.72	3.37	0.24	2.45
3	21	345	13.1	0.80	0.71	0.57	15.56	0.74	<1.29
4	10	305	8.6	0.81	1.45	1.17	9.00	0.36	<0.63
5	12	298	16.8	0.90	1.55	1.40	3.10	0.09	<0.52
6	7	142	5.6	0.97	2.33	2.25	<0.54	<0.05	<1.45

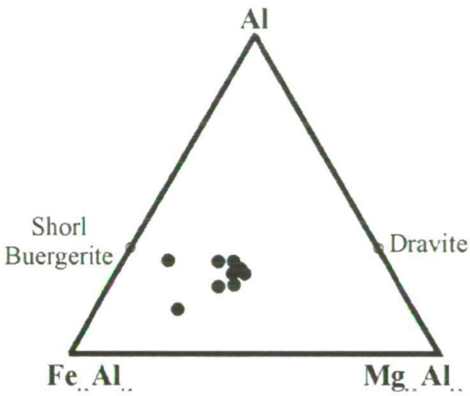

Fig. 1. Ternary Fe-Al-Mg plot for tourmaline from Teremkinskoye

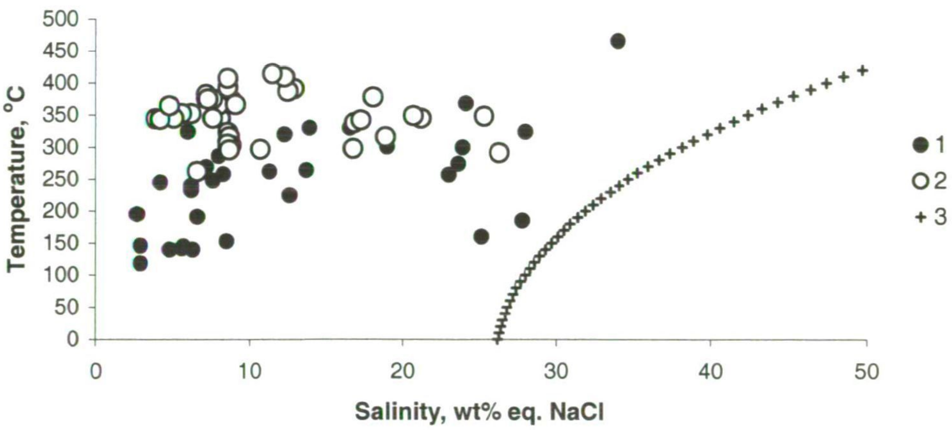

Fig. 2. Salinity, wt. % eq NaCl vs. Temperature, °C for ore-forming fluids in the Teremkinskoye deposit. 1 – homogeneous aqueous fluid, 2 – immiscible fluids (aqueous solution + vapor), 3 – saturation curve for the H_2O-NaCl system (Bodnar, Vityk, 1994).