Formation conditions and chemical compositions of ore-forming fluid of Butarnoye gold deposit (North-East of Russia)

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The Butarnoye gold deposit is situated on Chukotka, in the Hurchan-Ortukanskoy zone of tectonic-magmatic activation. The gold deposit is localized in granodiorite of the late-jurassic Butarninsky granitoid stock. Host rocks of the stock are presented by terrigenic sediments: argillites, alevrolites and sometimes by sandstone. The ore bodies are presented by gold bearing quartz veins and veinlets. Ore veins associated with metasomatites are presented by albite-sericite-quartz and sericite-quartz rocks developed on granodiorites and dikes of diorite porphyrites.
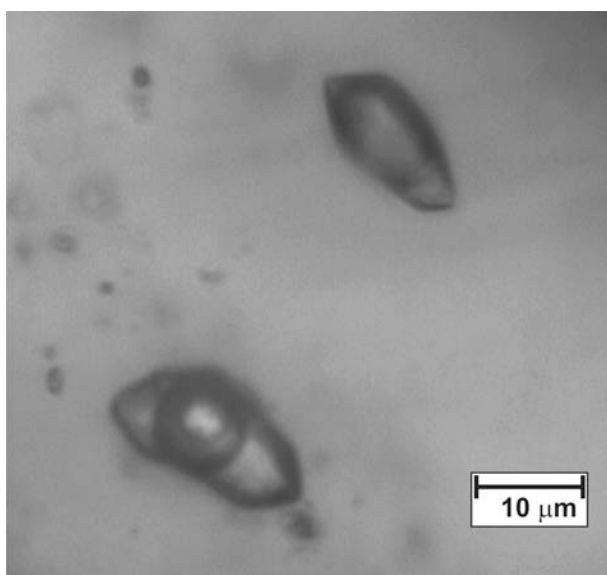

Fig. 1. Fluid inclusions in the ore vein quartz: type I three-phase fluid inclusions with H_2O liquid, CO_2 vapour and CO_2 liquid and type II is vapour-rich CO_2 fluid inclusions.

The ore was formed in two stages: arsenopyrite-pyritic and gold-bismuthic. Quartz is the main vein mineral in ore (more than 70%), whereas sericite, albite, K-feldspar, chlorite, epidote are the collaterally found. Arsenopyrite dominates among the ore minerals

Native gold, pyrite, native bismuth, stibnite, boulangerite, sphalerite and rare minerals like bismithinite, galena, chalkopyrite, pyrrotite are the secondary minerals.

The study of the chemical composition of the small mineral phases was conducted by scanning electronic microscope JSM5610LV with energy dispersion attachment Link ISIS in IGEM RAS. The presence of bismuthinite was confirmed and fineness of small gold particles was determined from 760 up to 908 ‰. In addition, two new minerals of bismuth: maldonite Au_2Bi and joseite A Bi_4TeS_2 was discovered in the ore deposit.

Fluid inclusions in quartz range from 1 to 30 μm in size and are in general irregular or have negative crystal shape forms. The primary and secondary inclusions are identified following the criteria outlined by Roedder (1984). Fluid inclusions are classified on the basis of phase compositions at room temperature (+21 °C). Type I are two-phase fluid inclusions consisting of H_2O liquid and CO_2 liquid and three-phase fluid inclusions with H_2O liquid, CO_2 vapour and CO_2 liquid. Type II is vapour-rich CO_2 fluid inclusions.

Fluid inclusion microthermometry was performed on a Linkam THMSG-600 heating-freezing stage attached to an Amplival microscope (Germany) and a monitoring video apparatus. The bulk salinity of the fluid was calculated from the combination of T_m(ice) and T_m(cla) (Distler et al., 2004). The identity of the species in the solutions was determined from eutectic temperatures (Borisenko, 1977). Quantitative chemical analyses of the inclusion fluid were carried out at the Central Institute of Geological Exploration for Base and Precious Metals of Moscow (analyst: Y.V. Vasyuta) using the technique reported by (Prokofiev et al., 2010).

Homogenization temperatures of Type I fluid inclusions in early quartz range from 334 to 245 °C. Clathrate melting temperatures at +15.1 to +9.0 °C were used to estimate a fluid salinity of 2.2 to 4.9 eq mass% NaCl. The estimated CO_2 content is 5.8 – 2.2 mole/kg in the solution. Eutectic temperatures of -24 to -35 °C infer that NaCl and $MgCl_2$ were the dominant soluble salts in the aqueous solution. The CO_2 melting temperatures of -57.1 to -59.7 °C indicate that the vapour phase contains CH_4. Vapour phase density in fluid inclusions of Type II, estimated from the CO_2 homogenization temperatures of 15.4 to 29.6 °C, ranges from 0.64 to 0.89 g/cm^3. Fluid pressures calculated by the intersection of the H_2O-CO_2 isotherms and the CO_2 isochors (Brown, 1989) varied from 80 to 140 MPa.

The chemical analysis fluid inclusions in quartz gave additional informations about ore-forming fluid composition. Carbonic acid (3.7 - 1.16 mol kg^{-1} water) and methane (0.18 - 0.05 mol kg^{-1} water) are detected in gas phase of fluid inclusions. Hydrocarbonate (0.03 - 0.02 mol kg^{-1} water) dominates among anions, whereas sulphate (0.01 mol kg^{-1} water) is discovered and chlorine is found in subordinated amount (0.004 - 0.003 mol kg^{-1} water) in the liquid phase of fluid inclusions. Na (0.06 - 0.02 mol kg^{-1} water) dominates among the cations, whereas K (0.004 - 0.0005 mol kg^{-1} water), Ca (0.002 – 0 mol kg^{-1} water) and Mg (0.0003 – 0 mol kg^{-1} water) are found in subordinated amount. In addition, following element concentrations are found in the inclusions (mmol kg^{-1} water): B: 28 – 12; As: 3.5 - 1.0; Br: 2.9 - 1.4; Li: 0.95 - 0.28; Fe: 0.7 - 0.009; Mn: 0.13 - 0.01; Zn: 0.12 – 0; Sb: 0.08 - 0.02; Ba: 0.05 - 0.0005; Co: 0.04 – 0; Cu: 0.03 - 0.0001; Sr: 0.02 - 0.004; Ni: 0.02 - 0.003; W: 0.01 – 0; Ge: 0.008 - 0.005; Rb: 0.008 - 0.003; Cs: 0.006 - 0.001; Bi: 0.005 – 0; Cr: 0.004 – 0; Sn: 0.003 – 0; Cd: 0.003 – 0; Ag: 0.003 – 0; Pb: 0.002 – 0; Mo: 0.002 - 0.0001; Au: 0.002 – 0; Hg: 0.001 – 0; Tl: 0.00005 – 0; and U: 0.00004 - 0. The value of K/Rb-relation changes from 62 up to 366, which indicate the participation of both, magmatic fluids and formation water in the ore-forming process.
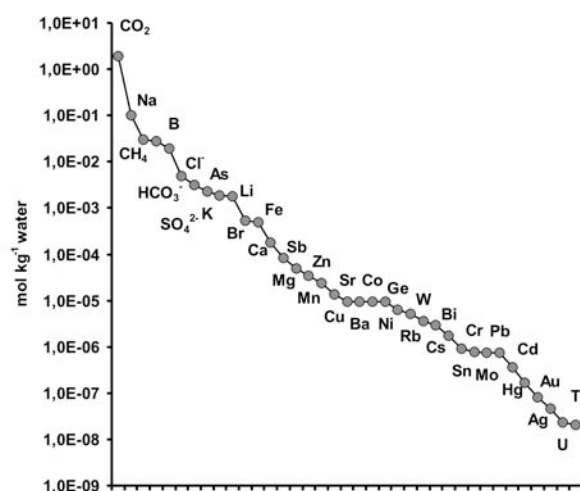

Fig. 2. The average chemical composition of fluid inclusions in the ore vein quartz.

The obtained data concerning the fluid inclusion particularities show the resemblance of ore-forming fluid of Butarnoye deposit with the fluids of orogenic gold deposits (Ridley, Diamond, 2000).

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