Formation conditions of the Bystrinskoe Cu-Au skarn-porphyry deposit (Eastern Transbaikalia, Russia): The first results of mineralogical and fluid inclusion studies

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The Bystrinskoe Cu-Au skarn-porphyry deposit is located in Gazimuro-Zavodsky ore district (Eastern Transbaikalia). It is confined to Bystrinsky structure of central type composed of terrigenous and carbonate formations of Paleoproterozoic to Mesoproterozoic and Mesomesozoic (limestones, sandstones, argillites, aleurolites, less often conglomerates) which are cut by diorites, diorite-granodiorites, granites and their porphyries, andesites and dacites of Bystrinsky stock. The dike suite is represented by granodiorite-porphyries, granite-porphyries, lamprophyres, and basalts. The large ore bodies are located along the contact of magmatic and terrigenous-carbonate sedimentary rocks in southern and eastern parts of the stock. The commercial mineralization is represented by disseminated (80 %) and streaky (20 %) ore types.

The history of hydrothermal mineralization is considered to include three phases.

I. The magmatic phase comprised the magnesium skarn formation synchronized with the injection of diorite porphyries.

II. The postmagmatic phase included retrograde alteration of Mg skarns, formation of Ca skarns and diaphtoric transformation of them. At this phase, there was a formation of potassium (K-feldspar and biotite) metasomatites (in magmatic rocks) synchronous with skarns formation.

III. In a hydrothermal (ore) phase, the following mineralization types were consecutively formed: the scheelite-molybdenite, ide (pyrrhotite-pyrite-arsenopyrite-chalcopyrite), base metal (galena-sphalerite), antimonite and quartz-carbonate mineralization which overprinted both skarns and magmatic rocks and were accompanied by zonally distributed quartz-sericite metasomatites, argillizites, and secondary quartzites.

Similar relations are typical of Cu-porphyry systems with various (porphyry, epithermal, skarn) mineralization (Sillitoe, 2010), however, though, within the limits of the Bystrinskoe deposit, the epithermal mineralization was not discovered yet (could have been destroyed by erosion), its ore-forming system can be qualified as skarn-porphyry-epithermal one.

The most widespread ore mineral in skarn is magnetite which is represented by monomineral cryptocrystalline accumulations. It is less widespread in ide assemblages of the ore-bearing phase where it develops at the expense of hematite and pyroxene. A ide mineralization is composed of pyrite, chalcopyrite, pyrrhotite and marcasite (result of pyrrhotite diidization), and also arsenopyrite and earlier not reported at the deposit cobaltite, which form inclusions in pyrite and chalcopyrite. This mineralization is productive on gold, presented here as native gold which is one of the latest minerals of this assemblage. It was observed in the form of fine inclusions in pyrite, on border between pyrite and chalcopyrite, magnetite and chalcopyrite. Share of Ag in native gold varies from 18.1 to 33.7 at%.

The first results of fluid inclusions (FI) study for the deposit (based on the THSMG-600, Linkam device), characterize mainly FI in amphibole, scheelite, quartz and calcite from skarn-ore mineralization. They are summarized on diagrams T_h - C and T_h - T_e. (Fig.1).

The *amphibole* contains three-phase (gas + solution + a solid isotropic phase) and two-phase (gas + solution) inclusions. Their major T_h range is from 421 to 382°C. Any detailed freezing studies were impossible because of too small FI sizes. Some indirect data (freezing temperature of solution near 90°C) testify that some bivalent cations were present in solutions of FI and the concentration of solutions was rather high (a gas phase essentially increases its size during cooling). A solid phase in three-phase FI was dissolved at 244°C, that corresponds to concentration of 34.5 % NaCl The pyroxene comprises mainly two-phase (gas + solution) FI with the solutions of NaCl composition and 8.4 5.0 concentration.

The *scheelite* has only two-phase FI (gas + solution), with T_h ranging in 335 - 277 and 195 -149°C intervals. All of them have NaCl composition and concentration from 22.4 to 6.5 %. Correlation between T_h and C is not observed (Fig. 1)

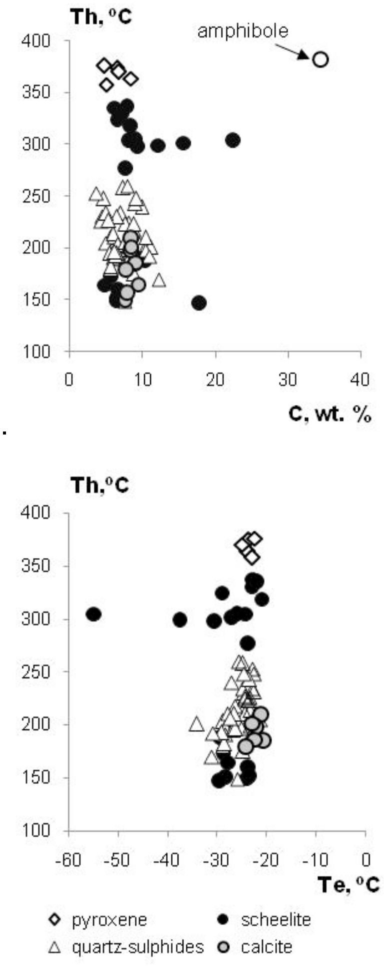

Fig. 1. The results of FI studies of skarn-ore mineralization of the Bystrinsky deposit.

In *quartz* there are two-phase FI of two types: 1 with the gas phase comprising up to 10 % of FI, and 2 essentially gaseous FI, usually with a film of solution at FI walls. The FI of the first type contain water-salt fluid of NaCl composition with concentration 11.2 - 6.2 % and T_h=248 -170°C.The inclusions of the second type are filled with practically pure liquid CO_2 (T_m = –-56.7 –57°C) or with the carbonic acid containing some other gases – impurity (T_m = –60.4 58.8°C). The CO_2 homogenizes into a liquid phase at the temperature range from 30.2 to 7.3°C. In calcite, all FI have two-phase composition (gas + solution) and NaCl solutions with concentration 9.17.7 % and T_h = 210 179°C (Fig.1).

The FI pressure was calculated using FLINCOR (Brown, 1989) code. For FI with CO_2 T_m from -60.4 to -58.8 which contain up to 0.5 1% of methane (samples 107-107), the CO_2 partial pressure at 200°C 310 - 320 bar. For FI with CO_2 T_m from –57 to –56.7°C, containing CH_4 less than 0.03 - 0.04%, pressure was calculated as pressure of pure CO_2. According to this estimate, the pressure during mineralization could vary from 1600 to 600 bars.

The obtained data show that a skarn-ore mineralization was formed in a wide range of temperature (420 170°C) and pressure (1600 - 310 bar). The fluids had mainly NaCl composition and moderate concentration (6 - 22 % NaCl). The CO_2 prevailed in the gas phase of fluids. Together with the data of mineralogical research considered above these parameters can testify that studied skarn-ore mineralization of the Bystrinskoe deposit is quite comparable by its features to mineralization formed as a result of activity of skarn-porphyry-epithermal ore-forming systems (Heinrich, 2005; Sillitoe, 2010), that essentially expands a potential ore capacity of the given deposit at the expense of porphyry and, probably, epithermal ore types.

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