The Bairendaba silver polymetallic deposit in Inner Mongolia, China: characteristics of ore-forming fluid and genetic type of ore deposit

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Abstract. Bairendaba silver-polymetallic deposit is located in the middle south of the Xing Meng orogenic belt, and in the silver-polymetallic metallogenic belt on the west slope of the southern section of Great Xing’an Range. Based on the study of fluid inclusions, we discuss the characteristics of ore-forming fluid and the metallic genesis of the Bairendaba silver-polymetallic deposit. By means of the analysis of the fluid inclusions, homogenization temperature, salinity and composition were studied in quartz and fluorite. The result is as follows: with homogenization temperatures of fluid inclusions in quartz veins being 196~312 °C, the average 244.52 °C, and fluid salinity 2.90~9.08 wt%NaCl; with homogenization temperatures of fluid inclusions in fluorite being 127~306 °C, the average 196.92 °C, and fluid salinity 2.90~9.34 wt% NaCl. The ore-forming fluid is mainly composed of water and the gas. The results of laser Raman analysis show that the gas phase is mainly CH₄. It shows that the ore-forming fluid is characterized by medium-low temperature and low-salinity system. The temperature of ore-forming fluid is from high to low, and the salinity from high to low, and the meteoric water or metamorphic water is added during deposit. According to the geological characteristics of the mining area, it is considered that the genetic type of the ore deposit should be the fault-controlled and the medium-low temperature hydrothermal deposit related to magmatic hydrothermal activities.

1. Introduction

Bairendaba silver-polymetallic deposit is located in the middle south of the Xing Meng orogenic belt, also, belongs to the silver-polymetallic metallogenic belt in the west slope of the southern section of Great Xing’an Range. Considering the tectonic position, it is located in eastern xing’an-mongolian orogenic belt of the Central Asian orogenic belt. Found in the beginning of this century, Bairendaba silver polymetallic deposit is one of the most important achievements for geological prospecting in China [1]. The silver polymetallic metallogenic zone in Bairendaba has become the largest silver polymetallic metallogenic area on the northern margin of North China Craton, which indicates the potential prospecting in this area. The evolution process of ore-forming fluid and the genesis of ore deposit haven't been discussed deeply. Therefore, based on the field geological work and combined with the study of fluid inclusion, the characteristics of ore-forming fluid and genesis of Bairendaba silver polymetallic deposit are discussed.
2. Geological setting
In tectonic framework, the Bairendaba silver-polymetallic deposit is located in the south central section of the Xing Meng orogenic belt, on the west slope silver polymetallic metallogenic belt of the southern section of Great Xing’an Range (figure 1). It is close to Hegenshan to the north, and Xilamulun fault to the south, and Nenjiang fault to the east, and it is located in accretionary orogenic belt in late Paleozoic in the south section of Da Hinggan Mountains between the North China plate and the Siberia plate, and in the east of micro continental blocks in Xilin Hot [2]. The metallogenic belt belongs to the west slope of nonferrous metal metallogenic belt in the South of Da Hinggan Mountains-mineralization sub-belt rich in lead, zinc, silver, and copper. The main stratum in the area include ancient Baoyintu group, Carboniferous, Permian, Jurassic, and quaternary. The regional intrusive rocks are mainly middle Hercynian quartz diorite, diorite vein and Yanshan granite. Fold structure is Mishengmiao anticline in this area, and fault is compressive fracture with NE, followed by NW extensional fractures, and the EW trending compresso shear faults are less developed, but the Bairendaba deposit is mainly controlled by the EW compression and torsion fault.

![Figure 1. Regional geological map of the Bairendaba deposit, Inner Mongolia (modified after [2]). 1-Quartary; 2-Upper Jurassic; 3-Lower Jurassic; 4-Upper Permian; 5-Lower Permian; 6-A Mu Mountain Group of Upper Carboniferous; 7-Bumbat Group of Upper Carboniferous; 8-Xilinguole Group; 9-Yanshan granite; 10-Quartz diorite; 11-Diorite vein; 12-Fault.](image-url)
3. Geological survey of mining area
The strata in the mining area are relatively simple. In addition to the Quaternary, only the biotite plagiogneiss, under the rock section of the Paleoproterozoic baoyintu group, mainly distributed in the south and north sides of west mining area and in the middle of east mining area. The exposed rock masses in the mining area are dominated by Hercynian quartz diorite and Yanshan granite. Besides, a small amount of granite veins and quartz veins can also be seen [2]. The structures are relatively developed, mainly in the NE trending faults, and then near East West and NW faults. Among them, nearly EW compressive torsion fracture is the main ore controlling and ore bearing structure. According to the field observation, hand specimens and microscopic minerals between each other through the cut, account, parcel and other relations, mineral production is divided into two phases: the first phase of arsenopyrite-pyrite-pyrrhotite, chalcopyrite, sphalerite, galena, and the second phase of pyrrhotite, galena, colloidal pyrite, sphalerite, quartz, fluorite, calcite, dolomite. At the first phase, metal mineralization is dominated by arsenopyrite and pyrite, and there are sparse light-colored iron-sphaled zinc mineralization and tinite mineralization, having weak mineralization, belonging to the early stage of mineralization; the gangue minerals are mainly quartz and fluorite. At the second phase, the mineralization is dominated by dark brown iron sphalerite, as well as silver minerals such as galena, pyrrhotite and chalcopyrite; the zinc ore is mainly formed in this phase, having higher mineralization temperature, while sphalerite often composed of the main vein, also, the gangue minerals are mainly quartz and fluorite.

4. Fluid inclusion

4.1. Petrographic characteristics of fluid inclusions
In the course of the study, the determination of minerals are mainly quartz and fluorite. The observation result shows that quartz and fluorite are extensive development of fluid inclusions, they are mostly distributed in directional distribution, clustered distribution, and there are also some groups like distribution of isolated inclusions [3], having size 1 to tens of micrometers, wrapped in elongated shape, round, negative crystal shape and irregular shape. According to the phase characteristics of fluid inclusions at room temperature, the types of fluid inclusions in Bairendaba silver polymetallic deposit are divided into two types: (1) AV. Liquid rich inclusions, at room temperature, composed of aqueous phase and gas phase (figure 2), and heated to liquid phase. The size is 1 to tens of microns, and the filling degree of the gas phase is 5~25 %, and the inclusion shape is round, lenticular and irregular. (2) CH₄. Pure CH₄ inclusions, at room temperature, consist of a single liquid phase, which forms bubbles at freezing temperatures up to -150 °C. However, there were no obvious signs of freezing until -190 °C.

4.2. Micro temperature measurement of fluid inclusions
Through microthermometry analysis of fluid inclusion, we can have some conclusion as follows: homogenization temperature of AV inclusion in quartz is 196~312 °C, more concentrated in 230~250 °C; and the average is 244.52 °C; homogenization temperature of AV inclusion in fluorite is 127~306 °C, more concentrated in 170~190 °C, and the average is 196.92 °C. Seeing from the test data, homogenization temperature in quartz was significantly higher than that of fluorite, which indicates that fluid changes from medium temperature to medium low temperature. AV inclusions in quartz have a freezing point range of -1.7~5.6 °C and are concentrated at -3.5 °C, with a salinity range of 2.90~9.08 wt%NaCl and an average of 6.49 wt%NaCl. AV inclusions in fluorite have a freezing point range of -0.8~6.1 °C and are concentrated at -2.5 °C, with a salinity range of 2.90~9.08 wt%NaCl and an average of 4.80 wt%NaCl. Based on the preliminary study of fluid inclusions, it can be concluded that the fluids in the ore-forming stages of the Bairendaba silver polymetallic deposit are characterized by medium low temperature, low salinity, and low density brine systems [4].
4.3. Laser Raman analysis of composition of fluid inclusions

Laser Raman microprobe analysis (LRM) of inclusions were carried out in quartz veins and fluorite of Bairendaba silver polymetallic deposit. The test results show that the AV analysis results show that the ore-forming fluid belong to H2O system with low salinity, and liquid composition is mainly water, and gas phase composition is mainly H2O, and CH4 gas phase is mainly CH4 and a little CO2 and N2 (figure 3). Tape of CH4 is pure liquid CH4 inclusions, and the characteristic peaks is 2915 cm⁻¹ [5]. Inferring from the homogenization temperature, the density of fluid is about 0.37-0.42 g/cm³.

**Figure 2.** Characteristics of fluid inclusions in various quartz veins and fluorite in the Bairendaba silver polymetallic deposit. a-AV inclusions in quartz vein, BR021; b-AV inclusions in fluorite, BR013D; c- AV inclusions in quartz vein, BR030E; d-Vapour inclusions, BR005.

**Figure 3.** Fluid inclusions in Laser Raman spectra. a-AV inclusions with CO2 and CH4 in fluorite, BR016; b-AV inclusions with CO2 in fluorite, BR012C; c-AV inclusions in quartz vein, BR025E; d-AV inclusions with CO2 and CH4 in quartz vein, BR033.
5. Conclusions

(1) The mineral formation sequence is divided into two phases: the first phase is arsenopyrite, pyrite, pyrrhotite, chalcopyrite, sphalerite and galena; the second phase is pyrrhotite, galena, quartz, sericite, calcite and dolomite.

(2) There are two types of fluid inclusions in Bairendaba silver polymetallic ore deposit, including rich liquid inclusions and CH₄ pure inclusions. The homogenization temperature range of quartz vein fluid inclusions is 196-312 °C, with the mean temperature 244.52 °C and the fluid salinity 2.90~9.08 wt%NaCl. The homogenization temperature range of fluorite inclusions is 127~306 °C, with the mean temperature 196.92 °C and the fluid salinity 2.90~9.34 wt%NaCl.

(3) The compositional characteristics of the ore-forming fluid are revealed that, by means of laser Raman microprobe analysis, the liquid component of the ore-forming fluid is dominated by water, and the gas phase is mainly CH₄ and a little CO₂ and N₂.

(4) According to the study on fluid inclusion, combined with the geological characteristics, it is preliminarily proven that Bairendaba silver-polymetallic deposit belongs to magmatic hydrothermal deposit controlled by faults.

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