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The Characteristics and Evolution of Ore-forming Fluids in A’erhada Pb-Zn-Ag Deposit, Inner Mongolia,China

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1 Introduction

The A’erhada Pb-Zn-Ag deposit, located in Dongwuqi, Inner Mongolia, is one of the largest Pb-Zn-Ag deposits in this region. The geology and geochemistry of this deposit have been reported by Tao (2006), Gao and Qian (2005) and Zhang et al., (2007), but not much research address the ore forming fluids and their evolution in this deposit. The ore genesis is still open to debate. Based on the field observation, ore-microscopic, petrographic, microthermometric, LRM (Laser Raman Microsprobe) and H-O isotopic results of fluid inclusions in quartz from various mineralization stages, this paper discusses the characteristics and the evolution of ore-forming fluid.

2 Geology

Tectonically, the A’erhada Pb-Zn-Ag deposit is situated at the Southern margin of the Siberian plate (Li, 1986) which was involved in the east Central Asian Orogenic Belt (CAOB). CAOB is the continent-continent collisional zone between North China Block and Siberian plate (Li, 1986).

Most area of the district is covered by Quaternary, with some outcrops of Devonian and Jurassic. Devonian comprises metamorphic sedimentary, pyroclastic and volcanic rock, including tuff-late, sandy slate, argillaceous slate and metamorphic volcanic rock. Jurassic is constituted of volcanic and pyroclastic rocks. The intrusive only outcrop in the west of the district. According to the intrusive relationships, petrographic and chronological results (unpublished data), the intrusive rocks, from early to late, are Hercynian K-feldspar granite (KG), granite porphyry (GP) and Yanshanian biotite monzontic granite (BMG), quartz monzonite porphyry (QMP), fine-grained granite (FFG). The mineralization in the deposit is dominated by vein style, stockwork and with minor massif style. According to the cross-cutting relationship of varied veins, ore texture, ore structure and mineral assemblage, the ore-forming process in the deposit can be divided into five stages, they are quartz – K-feldspar stage (stage 1), quartz – muscovite stage (stage 2), quartz – epidote - magnetite stage (stage 3), chlorite – carbonate - sulphide stage (stage 4) and quartz - clay mineral stage (stage 5). The third stage is the main Pb-Zn mineralization stage.

3 Fluid Inclusion Results

The samples used for fluid inclusion study are quartz from different ore-forming stages. According to the phase composition in fluid inclusions at room temperature, they can be grouped into five types and seven subtypes. They are:

AC type: AC type fluid inclusion contains a vapour (or liquid and vapour CO_2 phase) and an aqueous phase (Fig.1a). They have variable CO_2 volume percentage from 15 vol.% to 100 vol.%. Pure CO_2 fluid inclusions are referred to as C type.

ADV type: containing a vapour phase, aqueous phase and one or more daughter phase. The ADV-1 contains a halite daughter phase (Fig.1b), some with other small unknown solid phases. ADV-2 contains just non-halite daughter phase.

AV type: including a vapour bubble and an aqueous

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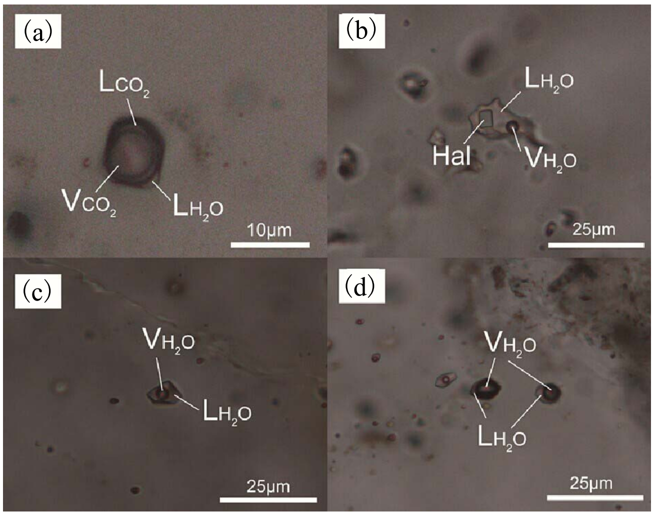

Fig. 1 Micrographs of fluid inclusions in quartz

L_{CO2} - liquid CO_2; V_{CO2} - vapor CO_2; L_{H2O} - liquid H_2O; V_{H2O} - vapor CO_2; Hal - halite;

a. AC type fluid inclusion; b. ADV-1 type fluid inclusions; c. AV-2 fluid inclusion; d. AV-2 fluid inclusions with varied vapor volume percentage

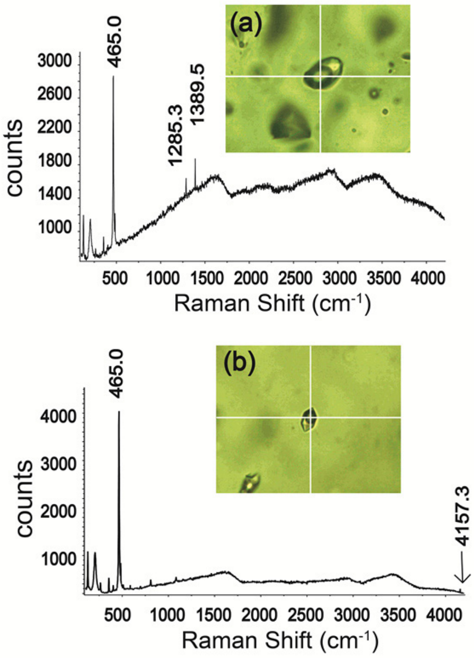

Fig. 2 Raman Spectrum of AC and AV-2 inclusions

a. vapor CO_2 in AC fluid inclusion; b. vapor phase in AV-2 fluid inclusion.

phase at room temperature. Based on their occurrence and vapour volume percentage, they can be further divided into AV-1 and AV-2 subtypes. AV-1 inclusions occur as secondary inclusion in quartz from stage 1 - 4, showing linear distribution along the healing fractures. AV-2 type represents primary inclusions in quartz from stage 3- 4 (Fig.1c) and in quartz from BMG.

V type: containing just vapour phase. V type inclusions coexist with different vapour volume percentage AV-2 inclusions (Fig.1d) and comprise a boiling inclusion assemblage in quartz from BMG.

The inclusion assemblages in quartz from different stage varied systematically. Stage 1 hosts boiling inclusion assemblage which comprise ADV, AV-2 and V type fluid inclusions. Stage 2 hosts a CO_2 - rich fluid inclusion assemblage including AC and C type inclusions. Stage 3 hosts non-halite daughter phase bearing inclusion assemblage comprises ADV-2 and AV-2 inclusions. Stage 4 host an aqueous fluid inclusion assemblages, comprise dominant AV-2 inclusion. Stage 5 are represented by low temperature, water - rich fluid inclusion assemblage. It comprise AV-1 and with some pure water inclusion because of necking down.

Microthermometric results show that AV-1 inclusions have homogenization temperature (T_h) of 162 - 177°C and salinity of 6.0 - 6.9wt%NaCl. AV-2 inclusions have a wide range of T_h (214 to 370°C) and salinity (0.53 - 12.28wt%NaCl). ADV-1 has a melt temperature of halite (Tm) of 231.4 - 312.5°C and $T_{h\ L\text{-}V}$ (liquid and vapour) of 171 - 209°C. The estimated salinities of ADV-1 inclusions are 33.4 - 38.7 wt%NaCleq. AC inclusion have T_h of 346 - 409°C and most of them homogenized to water phase, with minor homogenized to vapour phase. No available data for ADV-2 is acquired up to date.

LRM (Laser Raman Microscope Analysis) results show that C type fluid inclusions and the bubble phase in AC fluid inclusions are dominated by CO_2 (Fig.2a) and with minor N_2 and CH_4. H_2 is also detected by LRM in the bubble phase of AV-2 inclusions (Fig.2b) in quartz form BMG. The aqueous phases in AC, ADV and AV inclusion are dominated by H_2O.

4 Discussion and Conclusion

The CO_2 rich inclusion assemblage mainly occurs in greisenization quartz, with minor in quartz from BMG. The CO_2-rich fluid is responsible for greisenization, and occurs mainly in the north of the district. The solubility of CO_2 in silicate magma is much lower than water (Nixon, 1995) and largely depended on pressure. High CO_2 in primary magmatic fluid imply a pressure decrease control for fluid exsolution.

Together with this CO_2 - rich fluid exsolution, the crystallization of outer zone of the intrusion occurs and leads to the second boiling of the magma. The primary magmatic fluid exsoluted from magma is a supercritical fluid with low salinity (Bumham, 1979; Yang and Bodnar, 1994; Bodnar, 1995). The inclusion assemblage in quartz from porphyritic BMG including ADV-1, AV and V inclusions record the primary fluid form second boiling and imply a boiling process after fluid exsolution. Boiling of this fluid cause the high salinity fluid and low salinity vapor rich fluid. The vapor rich fluid was drainaged along the fracture zone, and reacted with the wall rock. The reaction between vapor rich fluid and argillaceous rock lead to the pH and Eh changes of the fluid and result in the Pb, Zn precipitation. The H-O isotopic results of inclusion water from stage IV imply a dominated magmatic origin with contamination from dehydration of clay mineral.

From early quartz - potassium feldspar stage, via quartz - muscovite stage, quartz - epidote stage to chlorite – carbonate - sulfide stage, the fluid evolved from high temperature CO_2 - rich fluid, via high salinity, moderate temperature fluid to low salinity, low temperature fluid. The main ore forming fluid are CO_2-bearing, low to moderate temperature fluid. The reaction between magmatic fluid and wall rock is the dominated mechanics for ore precipitation.

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