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FLUID INCLUSION CHARACTERIZATION OF TONGSHANKOU PORPHYRY COPPER (MOLYBDENUM) ORE DEPOSITE, DAYE, HUBEI PROVINCE, CHINA.

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Introduction

Tongshankou porphyry Cu (Mo) ore deposit is situated in the southeast of Wuhan, the provincial capital city in the east central China. The deposit which is mainly developed in and around a small porphyry granodiorite stock is located on the Middle-Lower reaches of the Yangzi River mineralization belt, one of the major copper mineralization region in China. The intrusive body has been created by the second activity of the early Yanshanian magmatism about 140 m.a. (Rui, 1984). The magmatism is responsible for various types of alteration and mineralization in the intrusive body, as well as carbonate host rocks. Hydrothermal alteration and mineralization is mainly centered on the stock and is intimately related to its emplacement. There is an evident alteration zoning in the area, with a core of early potassic alteration grading outward through late potassic, phyllic, skarn, skarnized marble, and serpentine-chlorite-carbonate alteration zones into unaltered carbonate country rock.

Tongshankou porphyry Cu (Mo) ore deposit contains a well-developed stockwork system concentrated on the porphyry granodiorite stock and the peripheral alteration country rocks. On the basis of the field observations, alteration mineral paragenesis, crosscutting relationships, and previous works (Yao et al., 1990), five major stages of mineralization were distinguished in the porphyry granodiorite stock and surrounding country rocks as follows: (1) Early potassic alteration stage characterized by pervasive potassic alteration accompanied by disseminated metal sulfidation, (2) late potassic alteration stage commonly occurred as k-feldspar-quartz veins and veinlets accompanied by minor pyrite and molybdenite, (3) molybdenite-quartz mineralization stage occurred as molybdenite-bearing quartz veins in both phyllic alteration and skarn zone, (4) chalcopyrite-pyrite-quartz mineralization stage mainly developed in phyllic alteration zone in the porphyry stock, as well as skarn zone, and (5) sulfide-carbonate mineralization stage occurred as veins and veinlets in serpentine-chlorite alteration zone.

Method of Study

The samples used for fluid inclusion study are from several localities on the surface of the stock. Every effort was made to sample different categories of veins across the entire Tongshankou porphyry granodiorite stock and its surrounding country rocks to obtain representatives of all stages of economic mineralization as well as accompanied alteration zones. The original intent was to study all the stages of mineralization all over the mining area, but fluid inclusion amenable to study were not found in all stages at all localities. Except for garnet/diopside skarn samples which microthermometric studies were carried out on garnet and diopside minerals, quartz was the only mineral amenable to further study. A total of about 365 fluid inclusions were examined on Linkam heating/freezing stage. The general method and procedure for heating/freezing experiments are reported elsewhere (e.g., Roedder, 1984; Shepherd et al., 1985).

The three main stages of economic mineralization, as well as two other uneconomic stages were used to categorize the fluid inclusion samples as follows: (1) Quartz metacrysts occurred in the potassic alteration zone and phyllic alteration zone in the porphyry granodiorite stock; (2) K feldspar-quartz veins (group I veins) occurred in the late potassic alteration zone in the main stock accompanied by sporadic pyrite and chalcopyrite, (3) Garnet- and diopside- skarn surrounding the main stock, (4) Molybdenite-quartz veins (group II veins) appeared in the late potassic alteration zone and phyllic alteration zone contained sporadic pyrite and chalcopyrite, and (5) chalcopyrite-pyrite-quartz veins (group III veins) occurred in both phyllic alteration and skarn zones.

Fluid Inclusion Classification

Fluid inclusions of the studied area were classified into four main types based on the number, nature, and proportion of phases observed at room temperature as follows: (1) Type I fluid inclusions (LV) which are two-phase, liquid and vapor inclusions with the liquid dominant phase, (2) Type II fluid inclusions (VL) which are two-phase inclusions containing vapor and liquid with the vapor dominant phase, (3) Type III fluid inclusions (LC) which are three-phase inclusions containing H_2O liquid, CO_2 liquid, and CO_2 vapor, and (4) Type IV fluid inclusions (LVH) which are three-phase inclusions consist of liquid, vapor and halite crystal. Presence of halite daughter minerals in LVH inclusions heve confimed by laser Raman spectroscopy. Primary and pseudosecondary inclusions were conducted to determine the temperature and apparent salinity of the ore forming fluids of the studied area.

Fluid Inclusion Microthermometry

Most of the LV fluid inclusions in group I quartz veins homogenized to liquid at temperatures between 130 and 190 °C, and temperatures between 340 and 400 °C, with two well-defined modes at about 160 and 400 °C, respectively. VL inclusions in group I quartz veins give a homogenization temperature range between 340 and 430 °C with a mode at about 400 °C, which is similar to the second mode in LV inclusions and may support boiling in this system. The inclusions in the group I quartz veins gave salinities between 5.0 and 21.9 NaCl equivalent wt%, with a clear mode at about 21 NaCl equivalent wt%.

LV inclusions from the group II quartz veins yield a homogenization temperature between 130 and 370 °C, with a mode at about 370 °C. Most of VL inclusions in the group II vein homogenize to vapor at about 400 °C. combined data on homogenization temperatures of all types of fluid inclusions in the group II vein represent a distinct mode at 370 °C. The salinity of inclusions in quartz from the group II veins ranged from 2.5 to 9.9 NaCl equivalent wt%, with a mode at about 9.0 NaCl equivalent wt%, although the mode is not so distinguished.

LV fluid inclusions in the group III quartz veins give homogenization temperatures of 280 to 400 °C with a mode at about 400 °C. homogenization temperature of VL inclusions are around 400 °C. LC type inclusions are relatively abundant in the group III quartz veins and their final homogenization temperature vary from 199 to 310 °C, with a mode at about 250 °C. Homogenization temperatures of liquid CO2 suggest that the density of CO2 in the LC type inclusions vary from 0.57 to 0.68 g/cm^3. Inclusions in the group III veins yielded salinities between 6.0 and 17.1 NaCl equivalent wt%, with an average of about 11.2 NaCl equivalent wt%. No mode was distinguished in the group III veins.

Homogenization temperature pattern of quartz metacrysts occurred in the potassic and phyllic alteration zones is slightly more complicated than those occurred in the quartz vein groups. LV inclusions homogenized to liquid at temperatures between 126 and 453 °C, with two modes at about 250 and 370 °C. Homogenization temperatures of VL inclusions varies from 340 to 430 °C, with a mode at about 400 °C. LC inclusions were relatively common and homogenized to liquid at about 310 °C.

Homogenization data on fluid inclusions in garnet and diopside minerals occurred in skarn zone are limited because of relative scarcity of inclusions. Some inclusions had not homogenized by 550 °C, the limit of the apparatus. Limited data show that homogenization temperatures of all types of inclusions in garnet vary between 350 and 430 °C, with a mode at about 430 °C. Fluid inclusions in diopside homogenize at temperatures between 370 and >550 °C, with a mode at about 550 °C or higher. Halite in LVH inclusions in garnet minerals dissolved at 285 to 463 °C, yielding salinities of about 37 to 52 NaCl equivalent wt%. Halite in inclusions from diopside grains in diopside skarn dissolved at 225 to 496 °C, yielding salinities of about 33 to 56 NaCl equivalent wt%. Diopside and garnet grains from the skarn zone contain numerous primary fluid inclusions; most are liquid rich with vapor ± halite, and about 10-20 percent are vapor rich with liquid. The latter finding indicates that hydrothermal fluid was boiling at least intermittently.

Composition of Fluid Inclusions

Major element chemistry of the fluids, as well as gas species and pH of the fluid inclusions in quartz minerals from the three major quartz veins were measured by bulk leachate method. The results show that H_2O (vapor) and CO_2 are the main components of the volatile phase. High K^+/Na^+ ratios, as well as positive anomaly of K^+ concentration in the group I veins represent the importance of K-rich fluids during the formation of group I veins. Ca^{2+}/Na^+ and Mg^{2+}/Na^+ ratios slightly increase during the group II and III quartz veins formation representing the importance of Ca-Mg-enriched fluids in their development.

Combined isotopic data (oxygen and hydrogen isotopes) on separated minerals from Tongshankou porphyry deposit consist with a dominant magmatic source for the group I vein forming fluids. Isotopic values suggest that both magmatic and meteoric fluids may have contributed in formation of the group II and III quartz veins.

Conclusion

Results of the study suggest that the earliest fluid circulated in Tongshankou porphyry Cu (Mo) deposit have been exsolved directly from crystallizing magma and resulted in early potassic alteration in the stock core. Along with magmatic crystallization and differentiation a high temperature (340 to 550 °C), high salinity (18 to 22 NaCl equivalent wt%) fluid was formed. This fluid was responsible for potassic alteration in the stock and skarn formation in the carbonate country rock. Cu-Mo sulfide minerals were not considerably associated with the potassic assemblage and the surrounding skarn rocks produced by this fluid. Oxygen isotope ratios of quartz minerals in K feldspar-quartz veins are relatively identical to quartz phenocrysts in the intrusion indicating potassic alteration zone forming fluid was mainly derived from magma. Potassic alteration was terminated upon introduction of lower salinity (about 6-10 NaCl equivalent wt%), lower temperature (310-400 C), Ca-Mg-enriched fluids of magmatic-meteoric (formational) origin in the peripheral parts of the system caused the development of hypogene metallization (molybdenite-quartz veins) in the system. Continuous inflow of meteoric water, and general temperature decrease in the system, produced progressively more oxidized and acidic fluids, which caused phyllic alteration and associated chalcopyrite-pyrite-quartz veins in the stock peripheral to the potassic alteration zone.

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