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Zoning of mineralization in hypogene porphyry copper deposits: Insight from comb microfractures within quartz–chalcopyrite veins in the Hongshan porphyry Cu deposit, western Yunnan, SW China

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ABSTRACT

The origin of zonal mineralization in porphyry copper deposit is important for understanding the mineralization processes. We propose a new, modified "orthomagmatic" genetic model for mineralization zoning in hypogene porphyry copper deposits. This new model is based on the features and formation mechanism of comb microfractures in quartz–chalcopyrite veins within pyrite vein from the Hongshan porphyry copper deposit in Zhongdian County, western Yunnan Province, SW-China. The main evidence for this model is volume expansion related to crystallization of chalcopyrite, magnetite and K-metasomatism in the deposit.

Comb microfractures are well developed in quartz–chalcopyrite veins and are present as comb-quartz veinlets consisting of a zone of central longitudinal quartz overprinted by laterally grown quartz combs. Chalcopyrite fragments lie perpendicular to the central quartz veinlet and were dismembered by the quartz combs. The combed microfractures are typical tensional hydrofractures. The formation of the comb microfractures is related to volume expansion that was induced by crystallization of chalcopyrite from a chalcopyrite melt that resulted in the subsequent increase of volumetric pressure in the confined residual silica melt. The formation mechanism of the comb microfractures, including volume expansion induced by crystallization, increases volumetric pressure, hydrofracturing and fluid expulsion, and was the most likely process for zoning of minerals in hypogene porphyry copper deposits.

Fabrics in the veins and veinlets are consistent with overpressuring and injection and are common structures that are directly related to volumetric pressure and crystallization of chalcopyrite and magnetite and K-metasomatism in hypogene porphyry copper deposits. The volume expansion ratio of chalcopyrite mineral to melt and that of magnetite mineral to melt are approximately 19 vol.% and 20 vol.%, respectively. The volume expansion rate of a monomolecular lattice is $\geqslant$8 vol.% for orthoclase replacing plagioclase.

We suggest that zoning of mineralization in hypogene porphyry copper deposits is mainly related to hydrofracturing, migration and distribution of ore-forming fluids, including (1) the enclosure and formation of a mush core, (2) concentration of ore-forming fluids in the orthoclase shell, (3) K-metasomatism and pressure building, (4) hydrofracturing and migration of ore-forming fluids, and (5) prior crystallization of magnetite and chalcopyrite that will expel residual fluids upwards and outwards due to the change in volumetric pressure.

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1. Introduction

Porphyry copper deposits supply nearly three-quarters of the world's copper (Sillitoe, 2010). These deposits are characterized by alteration and mineralization mineral zoning. This hypogene zoning typically manifests as quartz and pyrite in an outer phyllic zone, and K-feldspar and chalcopyrite in an inner alteration zone (e.g., Nielsen, 1968; Lowell and Guilbert, 1970; Corn, 1975; Cooke et al., 2005). The origin of mineral zoning in hypogene porphyry copper deposits has been related to a number of physical and chemical controls, such as: (1) temperature gradients, with near-magmatic temperatures at the center of the stock, grading to relatively cool temperatures in the wall rocks (Park, 1955, 1957; Nielsen, 1968); (2) chemical gradients and titration related to solubility of metallic compounds in the ore-forming solution (Barnes, 1962),

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related to temperature, pH, total chloride and pressure (Hemley et al., 1992a,b); (3) variation in the ratio of common metal cations to hydrogen ions in fluids (Hemley and Jones, 1964; Fournier, 1967b; Beane and Bodnar, 1995), which is probably related to mixing of magmatic fluid with meteoric water (Nielsen, 1968; Lowell and Guilbert, 1970); (4) magma oxidation state (oxygen fugacity) (Candela, 1992, 1997; Williams et al., 1995; Rowins, 2000); and (5) partitioning coefficient of metals among silicate melts, vapor-facies, chloride-bearing aqueous fluids, and crystalline phases during crystallization (Candela, 1997; Halter et al., 2002; Williams-Jones and Heinrich, 2005). In these systems copper may be efficiently concentrated in vapor and moderate to highly saline aqueous phases, which move upwards to form porphyry copper systems at shallower depths than porphyry-Mo systems (Burnham and Ohmoto, 1980; Williams et al., 1995; Williams-Jones and Heinrich, 2005). These genetic models and concepts, however, cannot precisely predict the spatial distribution of alteration and mineralization with respect to a cylindrical magmatic stock. An example is the common occurrence of abundant chalcopyrite and K-feldspar in the middle zones of porphyry copper deposits instead of at the center of the stock in the Lowell and Guilberrt's model; therefore it is important to search for further explore for general mechanisms of formation. In this paper, we propose that volume pressure that was induced by crystallization and K-metasomatism is the most important contributor to spatial alteration and mineralization zoning in porphyry-Cu deposits. Comb microfractures filled with comb-like quartz within confined quartz–chalcopyrite veins were identified in the course of this study in the Hongshan porphyry copper deposit, western Yunnan, SW-China. These textures provide evidence, which suggests that crystallization of chalcopyrite mineral from a chalcopyrite–silica melt—an important compound in ore-forming fluids from porphyry copper deposits—was caused by volume expansion. Volume expansion can potentially raise the pressure within the rock-fluid system enough to create fractures and drive hydrous silica melt outwards to produce theoretical and observed mineral zoning in most porphyry copper deposits. Examination and analysis of the porphyry magma and the volume varieties observed in many mineralization systems and specifically the Hongshan Cu-polymetallic deposit during alteration and solidification processes, allows the construction of a new genetic model for mineralization zoning in porphyry copper deposits.

2. Geological setting

The Hongshan Cu-polymetallic deposit is approximately 30 km NE of Zhongdian County in eastern Tibet (Fig. 1a). The deposit lies within the western part of the Yangtze tectonic Plate adjacent to the north northwest-striking Jinshajiang suture (Fig. 1a). The latter is a major shear zone containing a large number of both Triassic Cu–Mo porphyry deposits and Tertiary Cu–Mo–Au porphyry deposits. The Triassic porphyries and associated Cu–Mo porphyry deposits in the Zhongdian area have ages ranging from 240 to 210 Ma, and are attributed to subduction of the Paleo-Tethyan (Jinshajiang) oceanic plate (Zhao, 1995; Zeng et al., 2003, 2004, 2006). Tertiary porphyritic bodies and associated Cu–Mo–Au deposits lie in the northwest Yulong area (Rui et al., 1984; Zhang et al., 1998;

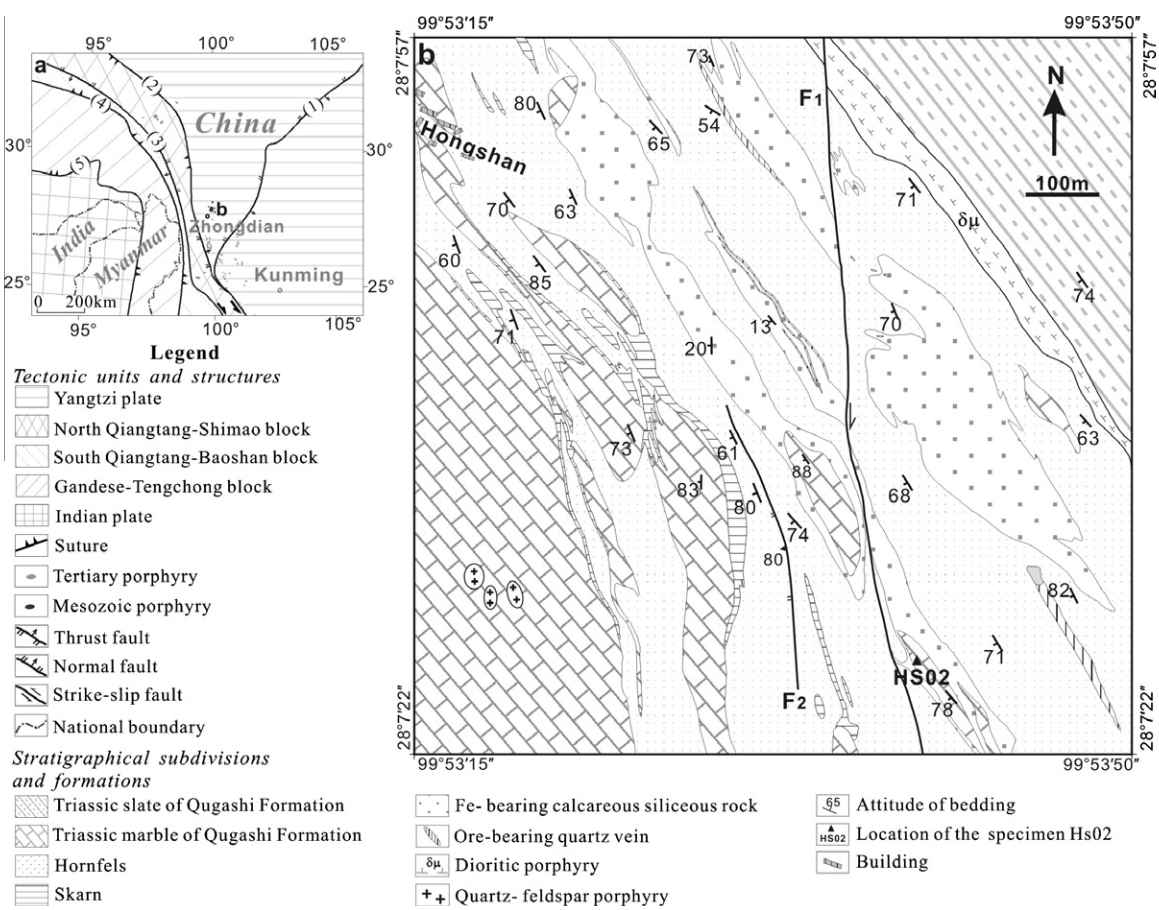

Fig. 1. (a) Regional tectonic location and (b) geological map of the Hongshan porphyry Cu deposit, western Yunnan, SW-China (revised after Xu et al.(2006a, 2007a)). (1) Rongmenshan thrust fault, (2) Jinshajiang suture, (3) Langchangjian thrust fault, (4) Nujiang suture, (5) Yarlungzangbojiang suture.

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