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Re–Os systematics of sulfides (chalcopyrite, bornite, pyrite and pyrrhotite) from the Jiama Cu–Mo deposit of Tibet, China

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ABSTRACT

The Jiama Cu–Mo deposit, one of the largest skarn-porphyry deposits in China currently being mined, is located in the eastern part of the Gangdese porphyry Cu belt, Tibet, China. Chalcopyrite and bornite concentrate in the Skarn Ore Zone at Jiama with molybdenite concentration, whereas molybdenite occurs in the Porphyry Ore Zone and Hornfels Ore Zone relatively by itself. Cu and Mo have different distributions in the Porphyry Ore Zone with Cu concentrating above the porphyry and with Mo inside of porphyry intrusion. The direct Re–Os dating on Cu sulfides will be helpful for us to understand the Cu and Mo mineralization at Jiama. This study is the first attempt to use the Re–Os isotope system to directly date chalcopyrite, bornite, pyrite and pyrrhotite at Jiama. The contents of Re, common Os and ^{187}Os in these four sulfides are 0.145–32.9 ppb, 0.0022–0.0669 ppb and 0.0003–0.0118 ppb, respectively. They have very low ratios of ^{187}Os to common Os (0.09–0.55), therefore, they are different from low-level highly radiogenic (LLHR) sulfides. The plot of ^{187}Re/^{188}Os and ^{187}Os/^{188}Os did not yield an isochron age based on the scatter points. Even if age of 15 Ma based on molybdenite Re–Os age is used to calculate the initial ^{187}Os/^{188}Os, the ratios show a wide range and low ratios of ^{187}Re/^{188}Os (<5000) is not suitable to calculate the model ages. The Re–Os results of these four types of sulfides indicate that Re–Os isotope system at Jiama has been affected by the disturbance. The black shale in the Cretaceous Linbuzong Formation is one possible source for Re–Os as we can see from the wide range of initial ^{187}Os/^{188}Os. The geology suggests the Cu and Mo mineralizations at Jiama are both related to porphyry intrusions, and the Cu mineralization should also have occurred in Miocene based on the molybdenite Re–Os age and porphyry zircon U–Pb ages.

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1. Introduction

The Jiama Cu–Mo ore deposit, one of the largest skarn-porphyry Cu deposits in China currently being mined, is located within the Gangdese metallogenic belt in South Tibet, about 60 km east of Lhasa City (Fig. 1) (Tang et al., 2011; Wang et al., 2011). Exploration and preliminary evaluation has increased the resources estimate compared to early 2000s, especially after extensive drilling programs since 2008. By April 2012, the measured and indicated resources at Jiama have been calculated as 4640 kt of Cu metal at an average grade of 0.44%, 380 kt Mo metal at 0.036% and indicated resources of Au 2.995 Moz at 0.21 ppm (http://www.china-goldintl.com/operations/jiama/; Tang et al., 2010, 2011). Re–Os isotope dating of molybdenite has been used to determine the Mo mineralization age of Jiama 15.3 ± 0.16 Ma to 14.67 ± 0.19 Ma (Li et al., 2005; She et al., 2006; Ying et al., 2009, 2010). But the direct dating of Cu sulfides has not been carried out at Jiama, and there also has no similar study yet in other Miocene porphyry Cu deposits of the Gangdese belt. High grades of Cu and Mo in Jiama both occur in the Skarn Ore Zone, but they have the different distributions in the Porphyry Ore Zone. Cu usually concentrates above the porphyry plug and very low grades in porphyry, whereas Mo concentrates inside of the porphyry itself with high grade. The age of Cu and Mo is one key to understand whether the separation is the result of only one event or two mineralization events. The direct dating of Cu sulfides will provide better information on the relationships between Cu, Mo and other metals. It will also help us to understand the metallogenic process of the skarn and porphyry system at Jiama.

Re–Os dating of chalcopyrite, bornite, pyrite, pyrrhotite, arsenopyrite, magnetite or even of massive sulfide ores has been used to determine the mineralization ages in some Cu, Cu–Ni, Cu–Au, Fe deposits (Lambert et al., 1999; Morgan et al., 2000; Stein et al., 2000; Mathur et al., 2002, 2005; Morelli et al., 2005; Sun et al., 2008; Zhang et al., 2008; Feng et al., 2009; Selby et al., 2009; Lü et al., 2011; Liu et al., 2012). This study of Cu sulfides (chalcopyrite,

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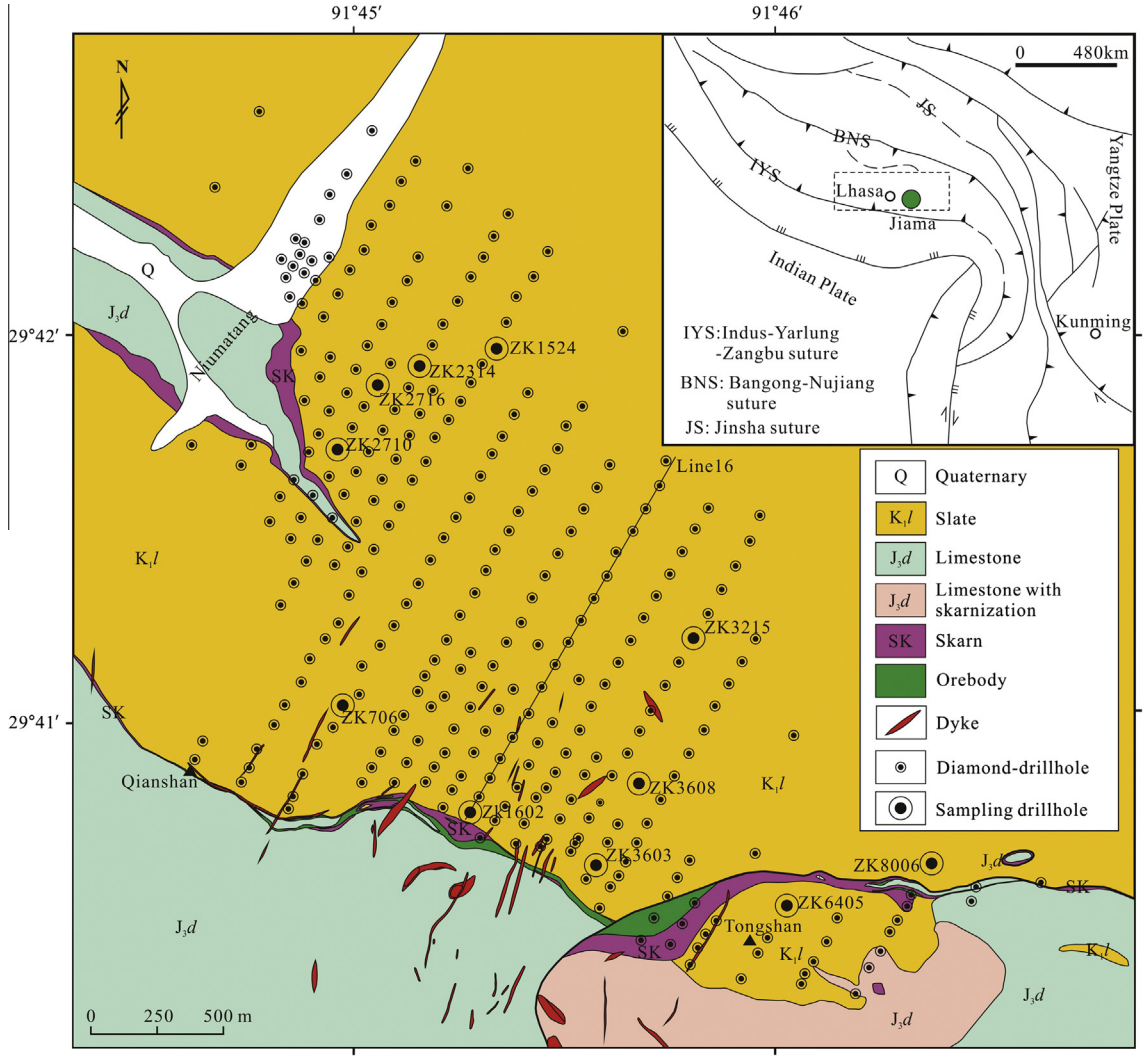

Fig. 1. Geological map of Jiama with sample locations.

bornite), pyrite and pyrrhotite at Jiama is the first attempt to directly date the Cu ore formation age by the use of Re–Os isotopes. Re–Os systems in chalcopyrite, bornite, pyrite and pyrrhotite are also compared.

2. Geological setting

The Gangdese porphyry Cu belt is located in the eastern segment of a 1000 km long tectonic–magmatic belt, resulting from the Cretaceous subduction of the Neo-Tethyan Ocean to Cenozoic collision of Indo-Asian plates since the Paleocene (the dash rectangle area in the corner figure of Fig. 1, Pan et al., 2006; Hou et al., 2011). The post-collisional mid-Miocene magmatic belt is characterized by small-volume, potassic and ultrapotassic intrusions, which intrude both pre- and syn-collisional granitoid batholiths and the earlier stratigraphic volcano-sedimentary sequences (Turner et al., 1993; Miller et al., 1999; Chung et al., 2003; Pan et al., 2006). Zircon U–Pb dating of porphyries in the Cu (–Mo) porphyry systems in the belt has shown that the timing of magmatism is from 18 Ma to 10 Ma, peaking at 16 ± 1 Ma (Turner et al., 1993; Miller et al., 1999; Chung et al., 2003; Hou et al., 2011; Qu et al., 2007). Re–Os dating of molybdenite samples of several porphyry Cu (–Mo) deposits (Qulong, Jiama, Zhibula, Chongjiang, Nanmu, Bangpu, Tinggong) yielded a range of ages from 13.5 ± 0.1 Ma to 16.9 ± 0.64 Ma (Rui et al., 2003; Meng et al., 2003; Li and Rui, 2004; Qu et al., 2006), suggesting a coeval, post-collisional Cu (–Mo) mineralization. The Jiama Cu–Mo ore deposit was formed during the post-collisional extension process similar to other porphyry Cu (–Mo) ore systems in the Gangdese belt (Hou et al., 2009; Tang et al., 2011).

3. Ore deposit geology

The stratigraphy in the Jiama Cu–Mo deposit includes the Upper Jurassic Duodigou Formation (J_3d) comprising limestone and the overlying Lower Cretaceous Linbuzong Formation (K_1l) comprising sandstone, siltstone and shale (Fig. 1). Skarn mostly occurred between these two layers, approximately 4200 m striking NWW and more than 2500 m in the NNE down dip direction, but on the surface, we only see skarn occurrences as narrow belt between the contact zone of two formations (Fig. 1). The shallow part of skarn is steep at the dip angles of 50–70°, but at deeper levels the skarn layer is flatter at an angle of <30° (Fig. 2). Skarn is comprised of coarse grain, or massive andradite and grossularite garnet and wollastonite with minor diopside, plagioclase, quartz, epidote, chlorite and actinolite. There are three major types of skarn in Jiama: garnet skarn, wollastonite skarn and skarn complex (skarn complex is comprised of both garnet and wollastonite and other

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