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Multiple mineralization events at the Jiru porphyry copper deposit, southern Tibet: Implications for Eocene and Miocene magma sources and resource potential

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ABSTRACT

The Jiru porphyry copper deposit in the Gangdese Porphyry Copper Belt (GPCB) is hosted by monzogranite and monzogranite porphyry with SHRIMP U–Pb ages of 48.6 ± 0.8 Ma and 16.0 ± 0.4 Ma, respectively. Rhenium–Os ages of molybdenite from the monzogranite and monzogranite porphyry are 44.9 ± 2.6 Ma and 15.2 ± 0.4 Ma, slightly younger than ages of the host rocks, respectively. These geochronological data indicate that there are two mineralization events at the Jiru deposit, in contrast to other porphyry deposits in the eastern part of the GPCB that are only Miocene in age. The Eocene monzogranite is characterized by high SiO_2 (63.0–71.4%) and K_2O (3.7–5.9%), enrichment in LILEs, depletion in Nb, Ta, and Ti, moderate negative Eu anomalies (δEu = 0.55–0.94), and relatively low Sr/Y (14–39) and $(La/Yb)_n$ (9–20) ratios. It also has young $\varepsilon_{Nd}(t)$ values (−0.43 to −0.25), low initial $^{87}Sr/^{86}Sr$ ratios (0.7044–0.7048), and young depleted-mantle model ages T_{DM} (742–821 Ma), compared to Eocene melts derived from mature continental crust in the central Lhasa subterrane. These geochemical features suggest that the Jiru monzogranite was most likely derived from the hydrated asthenospheric mantle wedge with involvement of subducted sediments related to the Neo-Tethyan oceanic slab breakoff. The Miocene monzogranite porphyry contains hydrous phenocryst phases (hornblende and biotite) and displays LREE-enrichment patterns, with high Sr/Y (131–183) and $(La/Yb)_n$ (22–72) ratios, and weak or absent Eu anomalies. The porphyry has slightly negative $\varepsilon_{Nd}(t)$ values (−3.8 to −3.5), low initial $^{87}Sr/^{86}Sr$ ratios (0.7057–0.7058), and young T_{DM} (952–974 Ma). The Miocene porphyry is likely the product of remelting of the stalled Neo-Tethyan oceanic slab, with input from the lower crust during the convective removal of thickened lithosphere below southern Tibet. Recognition of the Eocene magmatic-hydrothermal ore-forming event indicates a newly recognized potential for copper resources of that age in the eastern GPCB.

1. Introduction

Porphyry Cu deposits typically occur in subduction-related continental- and island-arc settings (Sillitoe, 1972; Richards, 2003; Cooke et al., 2005; Seedorff et al., 2005). Recently, a number of porphyry deposits in China (Chen et al., 2000, 2009; Deng et al., 2010a,b, 2012; Rui et al., 2003; Hou et al., 2004; Xiao et al., 2004; Zheng et al., 2004, 2007, 2012; Xue et al., 2010; Yang et al., 2012), central and eastern Iran, and western Pakistan (Richards et al., 2012) have been described as forming in collisional and post-collisional (or post-subduction) tectonic settings. The porphyry deposits are generated by subduction of oceanic lithosphere, collisional lithospheric thickening, post-collisional subcontinental lithospheric mantle delamination, or post-subduction lithospheric extension (Richards, 2009). Considering that magma generation beneath an arc may cease due to collision that terminates subduction (Richards et al., 1990; Cloos et al., 2005), it is necessary to distinguish the subduction-related from the collision- or post-collision-related porphyry deposits in an orogenic belt.

The Gangdese Porphyry Copper Belt (GPCB) is located in the southern Tibet, is one of the most important Cu belts in China, and contains the largest porphyry Cu deposit in China, at Qulong with >10 Mt (metal) Cu reserves, as well as many other large and

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medium sized deposits (Zheng et al., 2004). Most of these deposits were considered to form in a post-collisional tectonic setting in association with 18–12 Ma post-collisional intrusions (Rui et al., 2003). Recently, the Xiongcun porphyry Cu–Au deposit was discovered in the belt and shown to be associated with subduction of Neo-Tethyan Ocean at ca. 173–165 Ma (Tafti et al., 2009; Tang et al., 2010). Therefore, the possibility exists of other syn-collisional porphyry deposits in the GPCB, in addition to the well recognized Jurassic subduction- and Miocene post-collision-related porphyry deposits.

The aim of this paper is to describe a porphyry copper deposit that formed during two episodes, one syn-collisional and the other post-collisional, in the Jiru area of the GPCB. We provide geochronologic constraints on the two periods of mineralization, discuss the petrogenesis of the associated granitoids, and evaluate the potential of porphyry Cu mineralization associated with the Eocene and Miocene magmas. Our results provide an improved understanding of the metallogenic and tectonic evolution of the southern Tibet.

2. Geologic setting

2.1. Regional geology

The Himalayan Tibetan Plateau consists primarily of four continental blocks that are, from south to north, the Himalaya, Lhasa, Qiangtang, and Songpan-Ganzi terranes. The Lhasa terrane is bounded by the Bangong-Nujiang suture zone to the north and by the Indus-Yarlung Zangbo suture zone to the south. The Bangong-Nujiang suture zone is the result of the closure of the Bangong-Nujiang Ocean caused by the continental collision of the Lhasa and Qiangtang terranes during the Late Jurassic–Early Cretaceous. The Indus-Yarlung Zangbo suture zone marks the site where the Neo-Tethyan Ocean lithosphere was consumed at a subduction zone dipping northward beneath the Lhasa Terrane (Yin and Harrison, 2000). The Lhasa terrane is subdivided into the northern, central, and southern subterranes by the Shiquan River – Nam Tso Mélange Zone and Luobadui – Milashan Fault, respectively (Fig. 1). The GPCB discussed in the paper is located in the southern Lhasa subterrane and experienced a complex tectonic history from the Early Jurassic subduction of the Neo-Tethyan ocean to the Cenozoic India-Asian continental collision (Yin and Harrison, 2000; Chung et al., 2003; Chu et al., 2006). The strata occurring in the GPCB include the Lower Jurassic Yeba Formation, Upper Jurassic – Lower Cretaceous Sangri Group, and Paleocene-Eocene Linzizong Group. The Yeba Formation consists mainly of basalts and felsic lavas, as well as felsic volcaniclastic rocks, with a few andesites, and was formed during northward subduction of Neo-Tethyan oceanic crust during at ca. 190–174 Ma (Zhu et al., 2008). The Sangri Group consists of rocks of the underlying Mamuxia Formation and overlying Bima Formation. The Mamuxia Formation consists mainly of volcanic rocks, sandstones, siltstones, slates, and bioclastic crystalline limestones. The Mamuxia volcanic rocks vary compositionally from basaltic andesite to andesite and dacite, and were associated with the northward subduction of Neo-Tethyan oceanic crust beneath the southern Lhasa subterrane at a relatively steep angle at ca. 136 Ma (Zhu et al., 2009). The Linzizong Group, recognized in the Linzhou basin, consists of the andesitic lower Dianzhong Formation (64.4–60.6 Ma), dacitic middle Nianbo Formation (ca. 54 Ma), and rhyolitic upper Pana Formation (48.7–43.9 Ma) (Mo et al., 2003, 2008). The Dianzhong Formation includes rhyolitic tuff on the base, middle andesitic lava, and upper dacitic lava and tuff intercalated with red clastic rock. The Nianbo Formation consists of rhyolitic, dacitic, and basaltic trachy-andesitic rocks intercalated with beds of lacustrine limestones and tuffs. The Pana Formation consists of rhyolitic lava and tuff on the bottom and rhyolitic tuff and tuffaceous rocks on the top.

Four epochs of magmatism have been recognized in the southern Lhasa subterrane (Ji et al., 2009b; Zhu et al., 2011). Oldest bodies are 205–175 Ma granodiorite, syenogranite, and monzogranite that are associated with subduction of Neo-Tethyan oceanic slab, are silicic, metaluminous to peraluminous, have positive whole-rock $\varepsilon_{Nd}(t)$ values (−0.1 to +7.6; Chu et al., 2006; Qu et al., 2007; Yang et al., 2011), and slightly negative to very positive zircon εHf(t) values (−5.0 to +16.2; Chu et al., 2006; Zhang et al., 2007; Ji et al., 2009a; Yang et al., 2011; Zhu et al., 2011). Subsequently 100–80 Ma intrusions formed during the low-angle

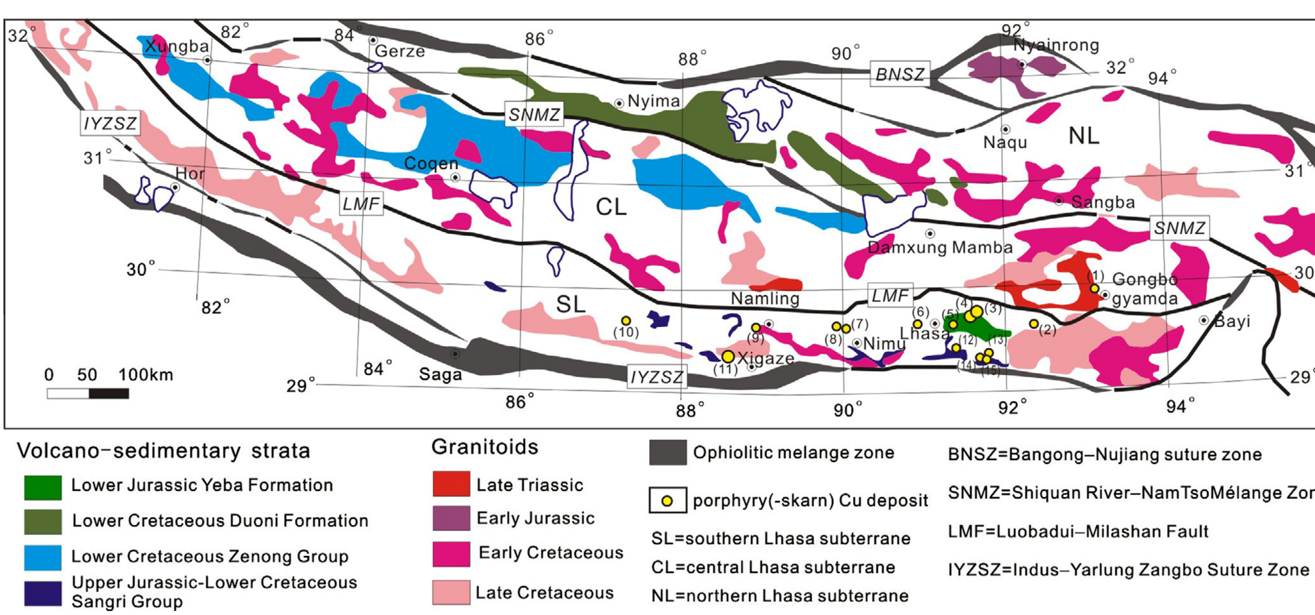

Fig. 1. Simplified geologic map of the Gangdese porphyry Cu belt showing major porphyry Cu deposits (modified after Zhu et al., 2011). The numbers denoting the deposits are as follows: (1) Tangbula, (2) Cuibaizi, (3) Jiama, (4) Qulong, (5) Lakange, (6) Dabu, (7) Tinggong, (8) Chongjiang, (9) Jiru, (10) Zhunuo, (11) Xiongcun, (12) Kelu, (13) Chongmuda, (14) Nuri, and (15) Mingze.