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Mesozoic multiple magmatism and porphyry–skarn Cu–polymetallic systems of the Yidun Terrane, Eastern Tethys: Implications for subduction- and transtension-related metallogeny

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ABSTRACT

Most mineralized porphyries associated with large to giant oxidized porphyry Cu deposits show an affinity with relatively high Sr/Y features. The Mesozoic porphyry–skarn Cu–polymetallic systems of the Yidun Terrane hosted by the Late Triassic and Late Cretaceous intrusions provide chances to investigate the spatial and genetic relationships between subduction- and transtension-related magmatism and mineralization, and determine the petrogenesis and fertility of magmatic rocks. Zircon U–Pb ages indicate that the Late Triassic pre-ore quartz diorite porphyries and syn-ore quartz monzonite porphyries were emplaced at ~225 and ~215 Ma, respectively. The Late Cretaceous syn-ore monzogranite porphyries were emplaced at 83–78 Ma. Our new data, combined with previously published geochronological data, show the spatially overlapping distribution of the multiple Mesozoic porphyry systems in the Yidun Terrane. Although all the Late Triassic intrusive rocks share similar geochemical characteristics, the pre-ore quartz diorite porphyries have normal arc-related chemical features with low Sr/Y and $(La/Yb)_N$ ratios, high Y and Yb abundances, while the syn-ore quartz monzonite porphyries exhibit high Sr/Y and $(La/Yb)_N$ ratios, low Y and Yb abundances. All samples show similar Sr–Nd–Hf isotopic compositions [$(^{87}Sr/^{86}Sr)_i = 0.7060–0.7117$, $\varepsilon Nd(t) = -6.7$ to 0.0, zircon $\varepsilon Hf(t) = -4.0$ to $+3.0$], suggesting that they were probably derived from partial melting of juvenile lower crust. Trace-element patterns and partial melt modeling indicate that the quartz diorite porphyries were likely formed by partial melting of normal thick lower crust, while the causative quartz monzonite porphyries were probably formed by partial melting of eclogitized, thickened lower crust. We propose that pre-ore quartz diorite porphyries were probably generated earlier via the subduction of Garze–Litang oceanic crust, and syn-ore quartz monzonite porphyries were formed later by partial melting of sulfide-enriched, thickened juvenile lower crust. Thus, these high Sr/Y quartz monzonite porphyries host several economically important porphyry Cu deposits, such as Pualng, Xuejiping and Songnuo. However, the Late Cretaceous syn-ore monzogranite porphyries have lower $\varepsilon Hf(t)$ values (-8.4 to -2.9) and $\varepsilon Nd(t)$ values (-7.5 to -3.8) than the Late Triassic porphyries, indicating that the former mainly originated from ancient crustal materials. New dataset and previous studies suggest that the Late Cretaceous post-collisional transtension triggered the asthenospheric upwelling and the underplating of mafic magmas, induced the partial melting of garnet-bearing amphibolite and thus caused the emplacement of monzogranite porphyries and associated porphyry–skarn Cu–Mo deposits.

1. Introduction

Porphyry Cu (–Mo–Au) deposits are widely considered to be products of calc-alkaline to high-K calc-alkaline silicic magmas under island- and continental-arc settings (Richards, 2003; Cooke et al., 2005; Sillitoe, 2010). However, recent studies have shown that porphyry deposits can form in collisional/orogenic belts, such as the Eastern Tethyan orogenic belt, including the Eocene Jinshajiang–Ailaoshan porphyry Cu–Mo–Au belt in Southwestern China (Hou et al., 2003; Liang et al., 2006; Lu et al., 2013; Deng et al., 2014a, 2014b, 2017; Deng and Wang, 2016), the Oligo-Miocene Gangdese porphyry Cu–Mo belt in Southern Tibet (Hou et al., 2004, 2013a, 2013b, 2015b; Yang et al., 2015; R. Wang et al., 2014a, 2014b, 2014c, 2015; Lu et al., 2015), and the Eocene to Miocene Urumieh Dokhtar porphyry Cu–Mo belt in Central Iran (Ahmadian et al., 2009; Haschke et al., 2010; Richards, 2013).

The relationship between subduction- and collision-related porphyry systems remains mysterious and has been under hot debate. Hou et al. (2015a) investigated the geological, geochemical and isotopic

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signatures of Jurassic subduction- and Miocene collision-related porphyry Cu deposits in southern Tibet and suggested that they have a genetic linkage. A summary of geochemical differences between subduction- and collision-related Cu-bearing porphyries from eastern Pacific Rim and southern Tibet was given in Chen et al. (2015). The subduction-related Cu porphyries show depleted Sr–Nd isotopic signatures, while the collision-related Cu porphyries show enriched isotopic features, suggesting that their source magmas probably generated by different melting processes (Chen et al., 2015; Hou et al., 2015a). For the subduction-related systems, the magmas are generated in a mantle wedge that has been metasomatized by fluids from a subducted slab, and then rise buoyantly to the bottom of the lower crust, where they undergo melting, assimilation, storage, and homogenization (a MASH process), resulting in evolved, volatile-rich, metalliferous intermediate to felsic magmas (Richards, 2003; Chen et al., 2015). For the collisional (referred to as "transtensional" in this study) systems, felsic porphyritic magmas are mostly derived from partial melting of lower crust contaminated by former arc magmas (Hou et al., 2015a) or enriched subcontinental lithospheric mantle (Richards, 2009; Wang et al., 2015; Lu et al., 2015).

The Yidun Terrane, which lies between the Qiangtang Terrane and Songpan–Garze Fold Belt (Fig. 1), has previously interpreted to be a Triassic volcanic arc in response to subduction of the Garze–Litang oceanic lithosphere. The Garze–Litang Ocean was generally considered as a

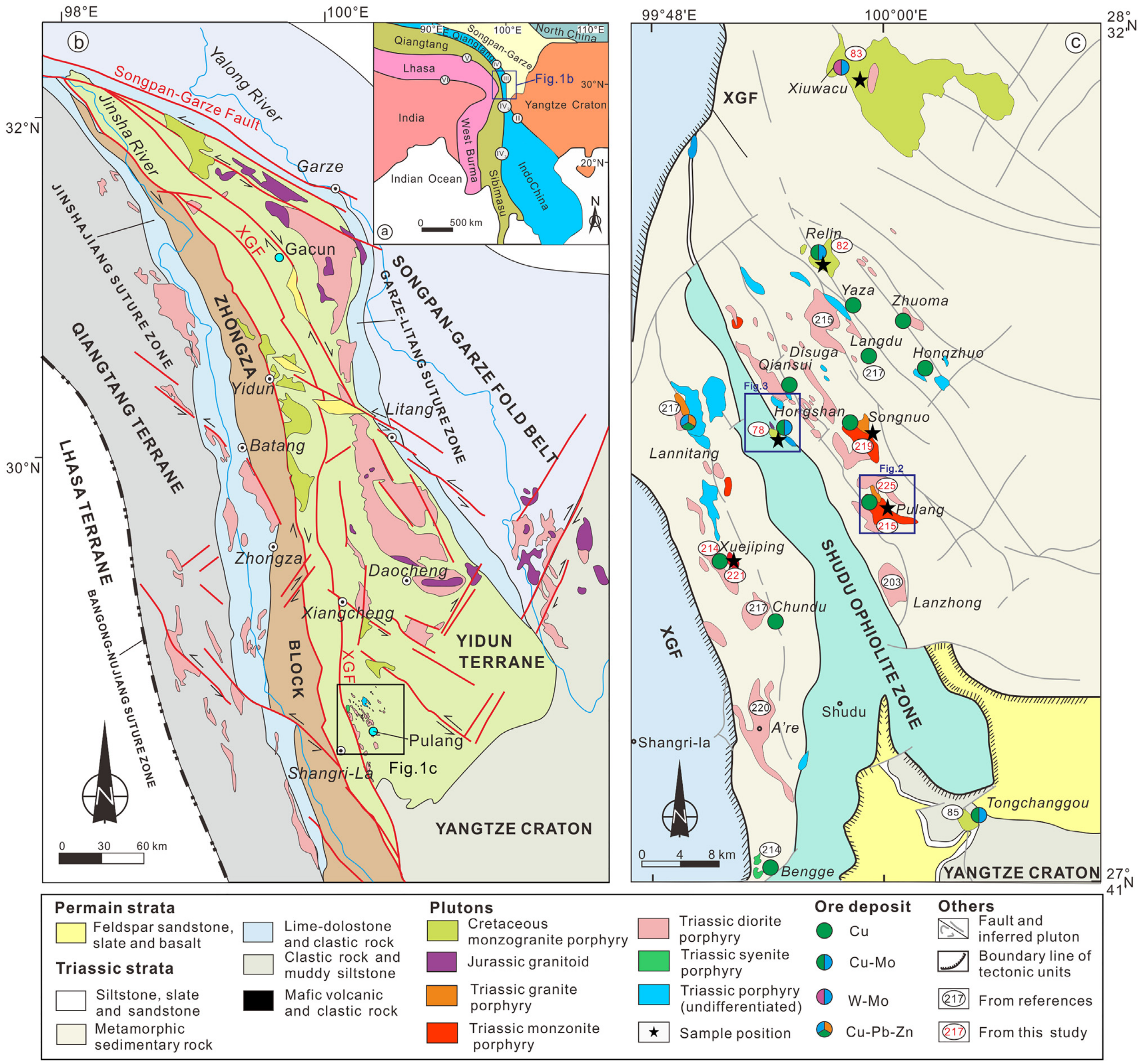

Fig. 1. (a) Tectonic outline of the India and Eurasia collision zone, showing the study area. Suture zones: I = Garze–Litang; II = Ailaoshan; III = Jinshajiang; IV_1 = Longmu Tso–Shuanghu; IV_2 = Changning–Menglian; IV_3 = Chiang Mai; V = Bangonghu–Nujiang; VI = Indus–Yarlung–Zangbo. (b) Simplified tectonic map of the SE part of the Tibetan Plateau, showing the Yidun Terrane, Yangtze Craton, Songpan–Garze Fold Belt, Qiangtang Terrane and Lhasa Terrane, and the major fault systems, suture zones, and different intrusions in the region. (c) Simplified geological map of the Shangri-La region, showing the southern portion of the Yidun Terrane (modified after Li et al., 2007), and highlighting the ages of magmatic rocks and related Cu–Mo mineralization. Sampling locations are also marked.
Data sources: Relin (Li et al., 2007; Yin et al., 2009; X.S. Wang et al., 2014a, 2014b); Yaza (Li et al., 2011a); Langdu (Zeng et al., 2003); Qiansui (Ren et al., 2011); Songnuo (Leng et al., 2008); Pulang (Zeng et al., 2004, 2006; Wang et al., 2008; Pang et al., 2009; Wang et al., 2011; Li et al., 2011b; Liu et al., 2013); Lanzhong (Yunnan Bureau of Geology and Mineral Resources, 1990); Tongchanggou (Li et al., 2012; Yang et al., 2017a); Lannitang (Leng et al., 2012; Chen et al., 2014); Hongshan (Xu et al., 2006; Huang et al., 2012; Peng et al., 2014; Yang et al., 2016); Xuejiping (Zeng et al., 2003; Cao et al., 2009; Ren et al., 2011; Leng et al., 2012); Chundu (Yunnan Bureau of Geology and Mineral Resources, 1990; Zhang et al., 2009; Yang et al., 2011); A're (Dong, 2013); Bengge (Cao et al., 2007).

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