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Petrogenesis and tectonic setting of the Devonian Xiqin A-type granite in the northeastern Cathaysia Block, SE China

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ABSTRACT

Most Silurian-Devonian granites in South China are S- or I-type granites, which are suggested to be petrogenetically related to the Wuyi-Yunkai orogeny. In this paper, we present the detailed LA-ICP-MS zircon U-Pb dating, major and trace element geochemical, and Nd-Hf isotopic data for Xiqin A-type granites in the northeastern Cathaysia Block, SE China. Zircon U-Pb dating results show that the Xiqin granites were emplaced at about 410 Ma, indicating that they were generated at the end of Wuyi-Yunkai orogeny. These granites are high in $K_2O + Na_2O$ (6.31–8.79 wt%), high field strength elements (Zr + Nb + Ce + Y = 427–699 ppm), rare earth elements (total REE = 221–361 ppm) as well as high Ga/Al ratios (10,000 Ga/Al = 2.50–3.10), and show characteristics typical of A-type granites. $\varepsilon_{Hf}(t)$ values of the Xiqin granites mainly vary from −0.4 to −3.1 and yield Mesoproterozoic $T_{2DM}(Hf)$ (mainly ranging from 1.29 to 1.45 Ga). The $\varepsilon_{Nd}(t)$ values are from −1.23 to −2.11 and $T_{2DM}(Nd)$ vary from 1.25 to 1.32 Ga. These isotopic data suggest that the Xiqin granites were generated by partial melting of metavolcanic rocks with minor metasedimentary rocks in the lower crust. Our data on the Xiqin granites, coupled with previous studies of Silurian-Devonian magmatism, suggest that the tectonic regime had changed to a strongly post-collisional extension environment in the Wuyi-Yunkai orogen at least since 410 Ma, and that delamination, which accounts for the change in stress from the compression to extension and asthenospheric upwelling during the early Paleozoic, plays a significant role in the generation of Xiqin A-type granites.

1. Introduction

The South China Block (SCB) consists of the Yangtze Block to the northwest and the Cathaysia Block to the southeast, amalgamated during the Neoproterozoic (Jahn et al., 1990; Chen et al., 1991; Charvet et al., 1996; Chen and Jahn, 1998; Li, 1998; Zhao and Cawood, 1999; Li et al., 2002; Wang et al., 2012; Zhang and Zheng, 2013; Charrvet, 2013). The boundary between the Yangtze Block and the Cathaysia Block is the northeasterly trending Shaoxing-Jiangshan-Chenzhou-Linwu Fault (Fig. 1, Zhao, 2015). The Yangtze Block is mainly built upon a stable Archean-Proterozoic basement with a maximum age of 3.3 Ga (Jiao et al., 2009; Gao et al., 2011) and an average age of 2.7–2.8 Ga (Gao et al., 1991; Qiu et al., 2000). Despite the identification of detrital and inherited zircons of Archean age at some locations, the Cathaysia Block seems to be much younger than the Yangtze Block and is predominantly constructed on Paleoproterozoic basement (Chen and Jahn, 1998; Xu et al., 2007; Yu et al., 2009). After the formation of the SCB, it subsequently underwent at least three major tectonothermal events in the early Paleozoic (traditionally named the "Caledonian"), the Triassic (Indosinian) and the Jurassic-Cretaceous (Yanshanian) (Faure et al., 2009; Charvet et al., 2010; Liu et al., 2010a; Li et al., 2010, 2011). In response to these events, an abundance of igneous rocks (especially granites) formed in the SCB (Wang and Zhou, 2005; Zhou et al., 2006; Li and Li, 2007; Wang et al., 2007, 2011; Li et al., 2007, 2010; Zhang et al., 2012).

The early Paleozoic granites are important components of and are widespread in the eastern SCB (Fig. 1). Studies on the early Paleozoic granites are fewer than the Mesozoic granites in the SCB, due to less economic mineralization. Reliable ages and geochemistry for these granites have only become available in recent years (Li et al., 2010; Wang et al., 2011; Wan et al., 2007, 2010; Xu et al., 2009; Zhang et al., 2012, 2015; Feng et al., 2014; Guan et al., 2014). Geochronological studies have defined an age-span of 390–467 Ma for these granites (Li et al., 2010; Wang et al., 2011, 2013a; Zhang et al., 2012 and references therein). According to previous studies, with the exception of a few I-type granites, most early

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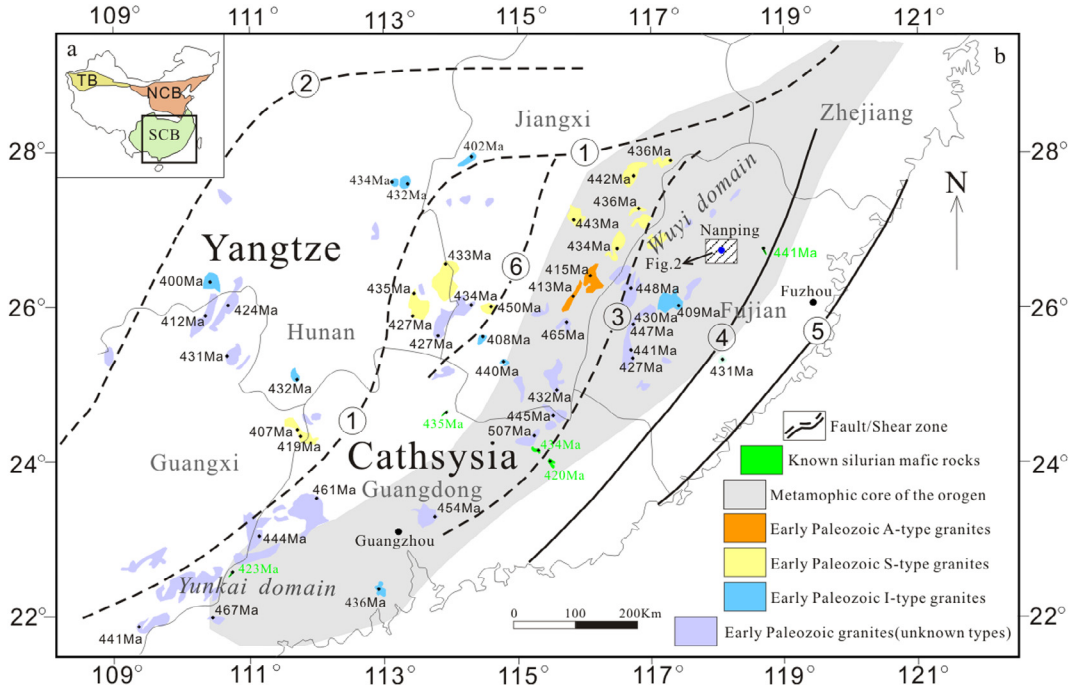

Fig. 1. Geological map showing the distribution of the Early Paleozoic granitic and mafic plutons in the South China Block (modified after Sun, 2006; Li et al., 2010; Wang et al., 2011, 2013a; Yao et al., 2012; Huang et al., 2013; Guan et al., 2014; Feng et al., 2014; Zhang et al., 2015). SCB, South China Block; NCB, North China Block; TB, Tarim Block. Faults: 1, Shaoxing-Jiangshan - Chenzhou-Linwu Fault; 2, Anhua-Luocheng Fault; 3, Heyuan-Guangfeng Fault; 4, Zhenghe-Dapu Fault; 5, Changle-Nan'ao Fault; 6, Ganjiang Fault.

Paleozoic granites in the SCB are peraluminous S-type granites that originated from crustal anatexis in the doubly crustal thickening environment (Wang et al., 2011).

Classification of S- and I-type granites essentially depends on the nature of the source rocks, thus they do not provide unambiguous tectonic constraints (e.g., Clemens, 2003; Förster et al., 1997) and the origin and the tectonic setting of these granites are still under debate. Feng et al. (2014) reported the presence of A-type granites (approximately 415 Ma) in Jiangxi that were derived from partial melting of Precambrian sedimentary rocks in an extensional environment. A-type granites may have important tectonic implications because they may be indicative of a regional extensional tectonic environment and thus could be used to constrain the end of the syn-collisional compressional environment of the orogeny (e.g., Bonin, 2007; Eby, 1992; Whalen et al., 1987). Recently, we identified an A-type granite in the northeastern Cathaysia Block, SE China. In this paper, we present zircon U-Pb ages, major and trace element geochemistry, and Nd-Hf isotopic compositions of this granite. The results will be used to constrain the age, petrogenesis and magma source of this granite and thus provide important insights into understanding the post-collisional extensional environment of the Early Paleozoic orogen of the SCB.

2. Geological setting

The study area is located in the northeastern part of the Cathaysia Block. The Cathaysia Block is separated from the Neoproterozoic Jiangnan orogen of the Yangtze Block to the northwest, and covered by the Southeastern China coastal complex to the southeast (Fig. 1). Four litho-tectonic units can be recognized, including: Mesozoic-Cenozoic volcanic and sedimentary strata, a sequence of Upper Paleozoic to Lower-Middle Triassic strata, Upper Neoproterozoic to Ordovician weakly metamorphosed sediments, and Proterozoic basement unit. Folds and faults are abundant in this area. The folds are mostly developed in the metamorphic basement, with a predominant N-NE strike, and there are several groups of faults that have destroyed the cover and the basement to different degrees.

The high grade regional metamorphic rocks were considered as representing the Proterozoic basement. In the study area, the metamorphic rocks are divided into Mayuan Group, Dikou Formation and Longbeixi Formation (Fig. 2a). The Mayuan Group consists predominantly of amphibolite to granulite facies graphite-bearing schist, fine-grained gneiss and small amounts of quartzite, marble and amphibolite. The metamorphic temperature and pressure conditions were 590–625 °C and 4.2–4.5 kbar (Zhao and Cawood, 1999). SHRIMP zircon U-Pb data reveal that some of these rocks have a protolith age not older than <807 Ma and were metamorphosed at 443–458 Ma (Wan et al., 2007; Li et al., 2010). The Dikou Formation mainly comprises of fine-grained amphibolite facies garnet- and sillimanite-bearing biotite gneiss, schist and quartzite. SHRIMP zircon U-Pb data imply that the Dikou formation formed later than 0.8 Ga and the metamorphic age should be younger than 604 Ma (Wan et al., 2007). The Longbeixi Formation, together with the Daling and Dongyan Formations, is belong to Mamianshan Group. The metamorphic grade of the Mamianshan Group rocks reaches upper greenschist- to amphibolite-facies, and estimates for the metamorphic temperatures and pressures are 459–612 °C and 5.6–7.7 kbar (Zhao and Cawood, 1999). Isotopic age data of the Longbeixi Formation are lacking. However, Wan et al. (2007) obtained a SHRIMP U-Pb age of 751 Ma on magmatic zircon from felsic metavolcanic rocks of the Daling Formation, and implied that the Mamianshan Group formed during the Neoproterozoic.

Upper Neoproterozoic (Sinian) to Ordovician strata are represented by marine facies sandy-muddy rocks, which underwent sub-greenschist to lower-greenschist metamorphism. The Silurian is lacking in the area (Shu et al., 2014). The Upper Paleozoic to Lower-Middle Triassic sequences are made of a succession of shallow-marine and littoral deposits: Upper Devonian