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Zircon U–Pb chronology and elemental and Sr–Nd–Hf isotope geochemistry of two Triassic A-type granites in South China: Implication for petrogenesis and Indosinian transtensional tectonism

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ABSTRACT

A detailed study utilizing zircon U–Pb dating, major and trace element geochemistry, and Sr–Nd–Hf isotope geochemistry has been carried out for the Caijiang granite in Jiangxi Province and the Gaoxi granite in Fujian Province, South China. The new data indicate that the Caijiang and Gaoxi granites are Triassic (228–230 Ma) and have the petrographic and geochemical characteristics of A-type granites. In both granites, biotite occurs along the boundary of euhedral plagioclase and quartz, which implies that the primary magma could have been anhydrous. The two granites show high contents of total alkalis (Na_2O+K_2O = 7.81–12.15%), high field strength elements (e.g. Zr = 240–458 ppm, Y = 16.8–38.0 ppm, Nb = 13.5–33.8 ppm and Zr + Nb + Ce + Y = 382–604 ppm) and rare earth elements (total REE = 211–373 ppm) as well as high Ga/Al ratios (10000 × Ga/Al = 2.41–3.53). The lowest magmatic temperatures estimated from zircon saturation thermometer were 800–840 °C for the Caijiang granite and 820–850 °C for the Gaoxi granite, respectively. The Caijiang granite has relatively high $(^{87}Sr/^{86}Sr)_i$ ratios of 0.71288 to 0.72009, low $\varepsilon_{Nd}(t)$ values of −9.9 to −9.3, and low zircon $\varepsilon_{Hf}(t)$ values (peak value of −7.5). Whole-rock Nd isotopic model ages and zircon Hf isotopic model ages mostly vary from 1.65 Ga to 1.80 Ga. The Gaoxi granite has also high $(^{87}Sr/^{86}Sr)_i$ ratios of 0.71252 to 0.71356, low $\varepsilon_{Nd}(t)$ value of −13.8 and low zircon $\varepsilon_{Hf}(t)$ values (peak value of −12.0). Whole-rock Nd isotopic model ages and zircon Hf isotopic model ages mostly vary from 1.95 Ga to 2.10 Ga. According to these data, we suggest that the two granites might have been derived from partial melting of Precambrian crustal rocks that had been granulitized during an earlier thermal event. Our study of the Caijiang and Gaoxi granites, together with previous studies on two Triassic alkaline syenites (Tieshan and Yangfang) in Fujian Province and one A-type granite (Wengshan) in Zhejiang Province in South China, indicate a wide transtensional tectonic environment in the Cathaysia Block that lasted at least from 254 Ma to 225 Ma. Combined with extant data for the Indosinian granites and tectonic evolution in South China, we suggest that the formation of A-type granites was related to the local NE-trending extensional faults probably caused by collision between the South China Block and the Indochina Block or the North China Block.

1. Introduction

Tectonic evolution and magmatism of the South China Block (SCB) during the Mesozoic have been intensively studied for more than half a century. The Mesozoic magmatic activity in southeastern China took place in three episodes, i.e., late Permian-Triassic (commonly referred to as "Indosinian"), Jurassic ("Early Yanshanian"), and Cretaceous ("Late Yanshanian") (Zhou et al., 2006). Previous studies have revealed that the Indosinian granites mainly occur in the interior region of the SCB, far away from the continental margins (Fig. 1). Different tectonic regimes responsible for emplacement of these Indosinian granites in the SCB have been proposed in the last several years. Over 90% of these granites are peraluminous and can be grouped as S-type granites, and minor are considered as I-type (Zhou et al., 2006). It is suggested that these granites were syn- and late-collisional and related to a compressional tectonic regime due to the collision of SCB and the Indochina Block (e.g. Mao et al., 2011; Y. Wang et al., 2007; Yu et al., 2007a; Zhou et al., 2006). Different to this model, Li and Li (2007) proposed a flat-slab subduction orogeny of the paleo-Pacific plate to account for genesis of the Indosinian granites in the SCB. However, Wang et al. (2005) firstly reported two Indosinian alkaline syenites (Tieshan and Yangfang, 254 Ma and 242 Ma, respectively) in Fujian Province and suggested that a transtensional tectonic environment was responsible for the formation of these syenites. Recently, Sun et al. (2011) reported an Indosinian A-type granite (Wengshan, ca. 225 Ma) in southwest Zhejiang Province, which also supported an extensional tectonic environment for the eastern Cathaysia Block in Triassic. The extensional environment was suggested to be related to oblique subduction of the paleo-Pacific plate underneath the SCB (Sun et al., 2011; Wang et al., 2005).

In order to verify the various models, systematic geochronological, geochemical and isotopic investigations of all the Indosinian granites

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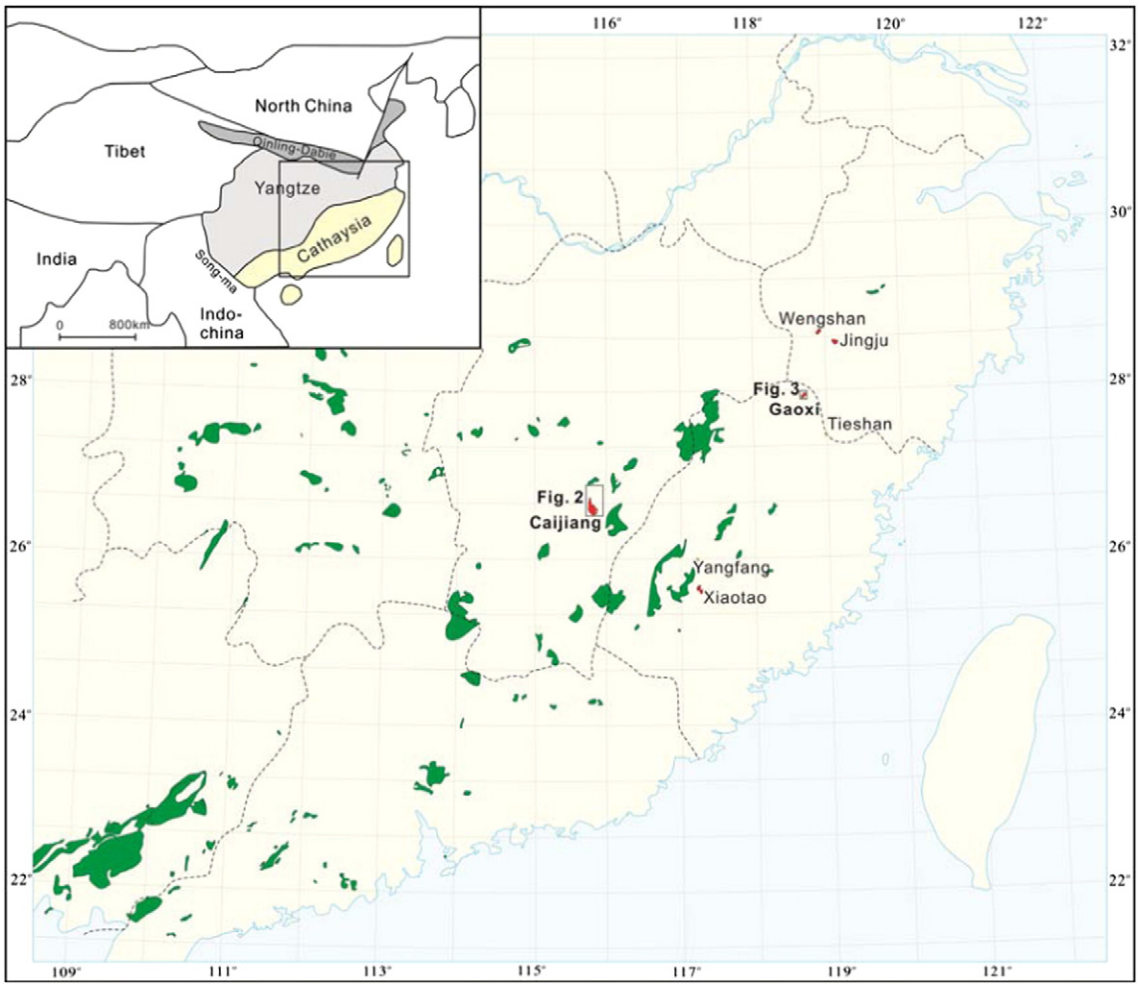

Fig. 1. Schematic map showing the distribution of the Indosinian A-type (in red) and other type granites (in green) in South China, in which study area is shown (modified from Sun, 2006; Wengshan, Jingju and Xiaotao A-type granites, according to Sun et al., 2011; Tieshan and Yangfang alkaline syenites, according to Wang et al., 2005).

in South China are needed, especially for those A-type granites. The A-type granites are particularly important because they may indicate an extensional tectonic environment on a local or regional scale (e.g. Bonin, 2007; Eby, 1992; Loiselle and Wones, 1979; Turner et al., 1992; Whalen et al., 1987). Our recent work has led to recognition of two new Indosinian A-type granites in Jiangxi Province and Fujian Province, respectively. In this paper, we present zircon U–Pb ages, major and trace element concentrations, and Sr–Nd–Hf isotopic composition data for the two A-type granites. These results were used to constraint their petrogeneses, magma sources and tectonic environments. Combining with other studies on late Permian-Triassic tectonic evolution of the SCB, we propose a geodynamic mechanism responsible for the Indosinian transtensional tectonic environment.

2. Geological setting

The SCB was formed in the early Neoproterozoic through the amalgamation of the Yangtze Block and the Cathaysia Block (Fig. 1, e.g. Li et al., 2009). The Yangtze Block was mainly built upon a stable Proterozoic basement, consisting of Archean rocks up to 3.2 Ga, with an average age of 2.7–2.8 Ga (Gao et al., 1991; Qiu et al., 2000). The Cathaysia Block appears to be much younger and consists predominantly of Paleoproterozoic basement and sporadic crustal fragments with late Archean ages of about 2.5 Ga (Chen and Jahn, 1998; Shen et al., 2000; Yu et al., 2009). Then the SCB was reworked by an intra-plate orogenic event in the early Paleozoic (e.g. the Wuyi–Yunkai Orogeny, Li et al., 2010). The Permo-Triassic was an actively period concerning the tectonic evolution of the SCB and neighboring areas as documented by two significant events. Firstly, the Indochina Block collided with the SCB along the Songma suture, and the peak age of the collision is dated at 258–242 Ma (Carter et al., 2001; Lepvrier et al., 1997; Nam et al., 1998). Subsequently, the SCB moved toward northern and collided with the North China Block along the Dabie–Sulu ultrahigh-pressure metamorphic belt, and the peak age of the collision is dated at 240–225 Ma (Li et al., 1993; Zheng, 2008). During this period, strong folding, thrust faulting and nappe structure were developed in the SCB (Liang et al., 2005; Shu et al., 1994; Zhang and Zhu, 2003; Zhang et al., 2009). Most Indosinian folds were EW-trending and were superimposed by Jurassic NE-trending folds (Zhang et al., 2009). Late Permian–Triassic granites are widespread both in the Cathaysia and the Yangtze Blocks (Fig. 1), but no coeval volcanic rocks such as basalts are found in the region (Zhou et al., 2006).

3. The Caijiang and Gaoxi granites

3.1. The Caijiang granite

The Caijiang granite is located in Central Jiangxi Province, South China. It was emplaced into Sinian–Cambrian metamorphic rocks and was intruded by the Jurassic Huangpi granite (Fig. 2). The outcropping oldest basement in Central Jiangxi Province is the Zhoutan Group, which consists mainly of schists, granulites and amphibolites. Hu and