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I-type granitoids in the eastern Yangtze Block: implications for the Early Paleozoic intracontinental orogeny in South China

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ABSTRACT

The Early Paleozoic intracontinental orogenic belt in the South China Block (SCB) is composed of massive granitoids and high-grade metamorphic rocks. Compared to the widespread distributions of early Paleozoic S-type granites in the eastern SCB, coeval I-type granitoids are rare and consequently receive much less attention. Two spatially associated granodiorite plutons in the northwestern rim of the orogen, namely the Banshanpu pluton and Hongxiaqiao pluton, have been investigated in order to determine how they fit into the geodynamic setting. The Hongxiaqiao pluton shares many lithological similarities with the Banshanpu pluton, except for the presence of abundant mafic microgranular enclaves (MMEs) in the Hongxiaqiao pluton. Zircon U–Pb dating has yielded weighted mean $^{206}Pb/^{238}U$ ages of 432 ± 3 Ma and 434 ± 3 Ma for the Banshanpu and Hongxiaqiao plutons, respectively, indicating that they were emplaced coevally in the early Silurian. Samples from the two plutons possess similar Nd–Sr isotope compositions ($\varepsilon Nd_T = -8.32$ to -6.88; $^{87}Sr/^{86}Sr_i = 0.7109$–$0.7169$), indicating that they were derived from a similar crustal source. Rocks from the Banshanpu pluton are intermediate- to high-K calc-alkaline and show strongly peraluminous (A/CNK > 1.1), adakite-like characteristics (Sr/Y ratios > 31; Yb < 0.91 ppm), consistent with an origin of partial melting of amphibolite in the garnet stability field. Samples from the Hongxiaqiao pluton contain lower SiO_2 but considerably higher $Fe_2O_3^T$, TiO_2, P_2O_5 and highly incompatible elements (e.g. Rb, Cs, Th and U) than those of the Banshanpu pluton. The MMEs from the Hongxiaqiao pluton give ages similar to that of their host granite (429 ± 5 Ma), and their Nd–Sr isotope compositions ($\varepsilon Nd_T = -7.45$ to -7.03; $^{87}Sr/^{86}Sr_i = 0.7115$–$0.7143$) imply an origin from metasomatized lithospheric mantle. The Hongxiaqiao pluton was possibly produced by a magma mixing between a crustal melt and a lithospheric mantle-derived melt. Because the MMEs have relatively low Sr/Y (9–17) and $(La/Yb)_N$ (3–15) ratios, mixing of the lithospheric mantle-derived melt with an adakite-like melt would dilute the adakitic signature and make composition of the mixture deviate from adakitic characteristics. A comprehensive evaluation of geochronological data for magmatism and metamorphism in the orogeny reveals two phases of orogenesis: one before and one after ca. 440 Ma. The temporal and spatial developments of tectonomagmatism, as well as the increase in metamorphic grade, are interpreted to record the progress of the intracontinental orogeny, which started in the Wuyi-Yunkai domains of the Cathysia Block in the Ordovician and propagated westward into the Yangtze Block in the Silurian.

1. Introduction

Orogenic belts commonly form at convergent plate margins and preserve important information of continental accretion and amalgamation (Wilson, 1965). Two categories for orogenic belts have been recognized (Windley, 1995), i.e. collisional orogens formed by collision of two continents (e.g. Himalaya and Alps, Sengör et al., 1993; Yin and Harrison, 2000; Rossetti et al., 2004), and accretionary orogens generated by accretion of juvenile materials such as seamounts and island-arcs (Sengör et al., 1993; Windley, 1995). Distinctly different from the conventional orogenic belts along plate margins, a third category, namely intra-continental (or intraplate) orogenic belt, has also been recognized. Orogenic belts of the third type are normally located hundreds or even thousands of kilometers away from the edge of the continent, and commonly associated with continental reactivation and reworking (Cawood and Tyler, 2004; Holdsworth et al., 2001; Sandiford and Hand, 1998). Examples include the Cenozoic Tianshan orogenic belt in Central Asia (Yin et al., 1998), the Petermann and Alice Springs orogenic belts in central Australia (Hand and Sandiford, 1999; Raimondo et al., 2010), and

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the Laramide orogenic belt in Western America (English and Johnston, 2004). The most remarkable features of intracontinental orogenic belts are high-grade metamorphism and intensive deformation, with or without sporadic magmatism.

The South China Block (SCB) consists of the Yangtze and Cathysia blocks, which were amalgamated during the Early Neoproterozoic (~880 Ma) (Li et al., 2008b, 2009a). After the amalgamation, the SCB experienced three major orogenic events, i.e. Early Paleozoic, Triassic, and Jurassic to Cretaceous (Y.J. Wang et al., 2013, and references therein). The Early Paleozoic orogenic event, also called as Wuyi-Yunkai Orogen (Z.X. Li et al., 2010) or Kwangsian Orogeny (Wang et al., 2010), has been demonstrated to be an intracontinental orogen in response to the closure of the pre-existing Nanhua rift (Charvet et al., 2010; Faure et al., 2009; Z.X. Li et al., 2010; Wang et al., 2010). The Wuyi-Yunkai Orogen is a broad orogen covering the entire Cathysia Block and part of the Yangtze Block (Fig. 1), and could probably extend to the Korean Peninsula and the Indochina Block (Z.X. Li et al., 2010, and references therein). Besides the coeval metamorphism and deformation, a distinct feature of the Wuyi-Yunkai Orogen is the extensive distribution of early Paleozoic granites, which is quite unique among intracontinental orogens worldwide. In order to unravel the tectonic evolution and genesis of the granites in the Wuyi-Yunkai Orogen, several geodynamic scenarios have been proposed, e.g., transpression along faults (Charvet et al., 2010), far-field response to the assembly of the Australian–Indian plate with the Cathaysia Block (Y.J. Wang et al., 2011), heat accumulation through decay of radioactive elements (Z.X. Li et al., 2010) and post-kinematic lithospheric delamination (Yao et al., 2012), have been proposed, and all these models considered that the Wuyi-Yunkai Orogen must have experienced strong crustal thickening by crust thrusting or intracontinental subduction.

Granites record important information regarding the nature and timing of orogenesis. Three primary features of granitic magmatism in the Wuyi-Yunkai Orogen should be noted. First, almost all the granitic intrusions with ages >440 Ma are located in the eastern Wuyi-Yunkai Orogen (i.e. Wuyi-Yunkai domains, Fig. 1), whereas those with ages <440 Ma occur throughout the Wuyi-Yunkai Orogen. Second, felsic intrusions in the Wuyi-Yunkai Orogen are dominated by peraluminous S-type granite, and granites of other types (e.g. I-type and A-type) are sparse (Shu, 2006). Third, no adakitic rocks have been reported in the orogenic core (Wuyi-Yunkai domains), even though crust in the core area was doubled in thickened. So far, most workers have focused their studies on the Wuyi-Yunkai domains where peraluminous granite is predominant. Here, we report geochemical data and zircon U–Pb ages for I-type granitic intrusions in the Yangtze Block, at the northwestern margin of the Wuyi-Yunkai Orogen, aimed at: (1) testing previous models; and (2) improving our understanding of the mechanism and geodynamic process that generated the early Paleozoic intracontinental orogensis.

2. Geological background and sample descriptions

2.1. Geological background

The SCB is composed of the Yangtze Block in the northwest and the Cathaysia Block in the southeast (Fig. 1), which amalgamated along the 2000 km-long Jiangshan-Shaoxing-Chenzhou-Linwu Fault in the early Neoproterozoic (~880 Ma) (Li et al., 2008b, 2009a). Subsequently, a rift, named the Nanhua rift developed in the eastern SCB from the Neoproterozoic to early Paleozoic and was filled with thick (>10,000 m) sediments (Li et al., 2008a; Shu, 2006; Wang and Li, 2003). The rift failed

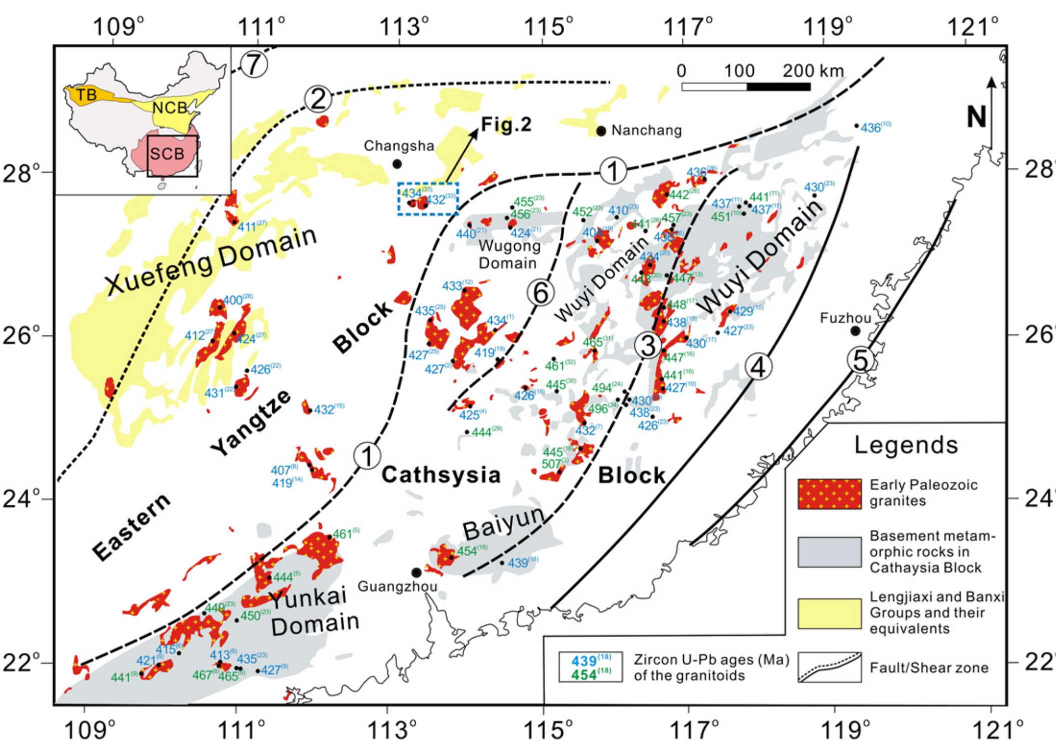

Fig. 1. Geological map and distribution of the Early Paleozoic granitic plutons in the South China Block (modified after Sun, 2006; W.X. Li et al., 2010; Y.J. Wang et al., 2011). SCB, South China Block; NCB, North China Block; TB, Tarim Block. Faults: 1, Jiangshan-Shaoxing-Chenzhou-Linwu Fault; 2, Anhua-Luocheng Fault; 3, Heyuan-Guangfeng Fault; 4, Zhenghe-Dapu Fault; 5, Changle-Nan'ao Fault; 6, Ganjiang Fault; 7, Zhangjiajie-Huayuan-Kaili fault. Age data source (zircon U–Pb) for Early Paleozoic granitoids and migmatites in the eastern SCB: 1-Li et al. (1989); 2-Li (1994); 3-Ding et al. (2005); 4-Xu et al. (2005); 5-Geng et al. (2006); 6-Peng et al. (2006); 7-Sun (2006); 8-Zhu et al. (2006); 9-Wang et al. (2007); 10-Chen et al. (2008); 11-Liu et al. (2008); 12-Shen et al. (2008); 13-Zeng et al. (2008); 14-Cheng et al. (2009a); 15-Cheng et al. (2009b); 16-Xu et al. (2009); 17-A.M. Zhang et al. (2010); 18-Yang et al. (2010); 19-F.R. Zhang et al. (2010); 20-F.R. Zhang et al. (2010); 21-F.F. Zhang et al. (2010); 22-Chen et al. (2011); 23-Y.J. Wang et al. (2011); 24-A.M. Zhang et al. (2011); 25-W.L. Zhang et al. (2011); 26-Y. Zhang et al. (2011); 27-Chu et al. (2012); 28-Zhao et al. (2013); 29-Wu et al. (2012); 30-J.K. Li et al. (2012); 31-Liu et al. (2012); 32-Zhao et al. (2012); 33-this study.