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Earliest Neoproterozoic (ca. 1.0 Ga) arc–back-arc basin nature along the northern Yunkai Domain of the Cathaysia Block: Geochronological and geochemical evidence from the metabasite

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ABSTRACT

The tectonic nature of the Cathaysia Block during earliest Neoproterozoic period has been long disputed and attracted considerable attentions. One reason for this problem is rare exposure and few data for the igneous rocks of Grenvillian age in this Block. In this paper, a set of new U–Pb zircon geochronological, elemental and Nd isotopic data are presented for the metabasites in the Yunkai Group which shows WNW-trending extension with a length of more than 100 km along the northern Yunkai Domain of the Cathaysia Block. The plagioclase amphibolite and metabasite from Shiwo (Beiliu) and Tantu (Xinyi) from the northern Yunkai Domain, representative of Groups 1 and 2, yielded the $^{206}Pb/^{238}U$ weighted mean ages of 997 ± 21 Ma and 978 ± 19 Ma, respectively, evidencing the presence of the Grenvillian mafic rocks within the Cathaysia Block. Based on the Nb, Nb/La and Nb/U, these samples can be geochemically subdivided into two groups (Groups 1 and 2). Group 1 has Nb/La = 0.33–0.54 and Nb = 1.71–2.85 ppm, and exhibits similar geochemical signatures to those of Saunders island-arc. Group 2 gives Nb/La of 0.57–0.86 and Nb of 7.58–12.70 ppm, resembling to those of Phanerozoic Nb-enriched basalts, and shows the geochemical affinity to the Okinawa back-arc basin basalt. Both groups have positive $\varepsilon_{Nd}(t)$ values, ranging from +3.84 to +5.36 and +3.93 to +6.55, respectively. These geochemical and isotopic characteristics suggest that Group 1 might have been originated from a MORB-like source modified by subduction-derived fluids. The source of Group 2 Nb-enriched basalt might be metasomatized by melt released from a newly subducted slab. In conjunction with other geological observations, it is identified for the Grenville-aged (ca. 1.0 Ga) arc and back-arc basin along the northern Yunkai Domain of the Cathaysia Block, analog to the modern West Pacific. The South China Block probably located at the margin of Rodinia supercontinent between west Australia and east India.

1. Introduction

The amalgamation process of the Yangtze Block to the northwest and Cathaysia Block to the southeast has been paid much attention due to its important significance for the Precambrian tectonic evolution of the South China Block (SCB) and assembly and breakup of the supercontinent Rodinia (e.g., Li and McCulloch, 1996; Li, 1999; Li et al., 2003a,b, 2008c; Zhou et al., 2004, 2009; Wang et al., 2006, 2008c, 2011a; Zheng et al., 2006, 2007, 2008; Zhao et al., 2011). The amalgamation boundary has been accepted as the Jiangshan-Shaoxing suture for the northeast segment (northeast Jiangxi) but probably along the southern margin of the Jiangnan Domain (southwest Jiangxi, western Hunan, northern Guangxi and southern Guizhou Provinces) for the southwest segment (e.g., Zhou and Zhu, 1993; Zhang and Yan, 2005; Li et al., 2008b, 2009; Wong et al., 2011). In the past two decades, numerous geochronological results for the ophiolite suite, adakite and arc-related igneous rocks at the northeast Jiangxi show that the subduction and collision along the Jiangshan-Shaoxing suture might occur at 970–880 Ma (e.g., Shui, 1988; Chen et al., 2009; Li et al., 2003a, 2008a, 2009; Shu et al., 2011; Gao et al., 2009). However, the associated rocks with the amalgamation of the Yangtze and Cathaysia Blocks along the south Jiangnan Domain were dated at ca. 835–800 Ma, thus the final amalgamation has been proposed to last until ~830 Ma, even later (e.g., Zhou et al., 2004, 2009; Wang et al., 2004a, 2006, 2007b, 2008c; Wu et al., 2006b; Zheng et al., 2007; Zhao et al., 2011; Zhang et al., 2012). It is obvious that the available data for these igneous rocks along the south

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Jiangnan Domain are significantly younger than those of the typical Grenville-aged (ca. 1.0 Ga) orogenic event associated with the assembly of Rodinia despite that some researchers persisted the amalgamation should be a part of the worldwide Grenvillian orogenic event (e.g., Li et al., 2002, 2006b, 2007, 2008a,c; Greentree et al., 2006; Ye et al., 2007).

An important fact is that abundant Grenville-aged (ca. 1.0 Ga) detrital zircons have been reserved in the Neoproterozoic–Silurian sequences from the eastern Yangtze and Cathaysia Blocks (e.g., Yu et al., 2008, 2010; Wan et al., 2007, 2010; Wang et al., 2007b,c, 2010a,b; Yao et al., 2011; Zhou et al., 2009; Li et al., 2011; Greentree et al., 2006; Sun et al., 2009). These ~1.0 Ga detrital grains constitute a main peak of age-spectrum of the late Neoproterozoic and Phanerozoic sandstones of the Cathaysia Block (e.g., Yu et al., 2008, 2010; Wan et al., 2010; Wang et al., 2010b). Taking into account the geological observation that the Yangtze and Cathaysia Blocks have remained contiguous and have never been rifted to form an open ocean since late Neoproterozoic period (e.g., Rong et al., 2002, 2007; Li et al., 2010; Chen et al., 2010; Wang et al., 2007c,d, 2010b; Wan et al., 2007, 2010; Shu, 2006; Shu et al., 2008; Charvet et al., 1996, 2010). The above-mentioned data suggest that the Greenvillian orogenic belt seems to have developed within the SCB or close to the Cathaysia Block. However, it is poorly reported for the Grenville-aged batholith and associated igneous rocks within the eastern SCB (e.g., Yu et al., 2008, 2010). This is in contradiction with the geochronological data of the detrital zircons. Therefore, this paper focuses on whether the Grenvillian igneous rocks develop within the Cathaysia Block, and if they occur, where they are and what tectonic signatures are.

In our recent survey, the metabasites have been identified along the northern margin of the Yunkai Domain in the Cathaysia Block. The rocks extend along the E–W trending with a length of more than 100 km and have commonly experienced greenschist- and amphibolite-facies metamorphism. They occurred as interlayer or lens in the Proterozoic Yunkai complex and can provide better constraint on the Precambrian tectonic nature of the Cathaysia Block and its relationship with the Yangtze Block. In this paper, we report the zircon U–Pb geochronological, elemental and Nd isotopic data for these metabasites along the northern Yunkai Domain. Our results demonstrate that the metabasite forms at 978–998 Ma and has geochemical affinity to both MORB- and arc-like sources, suggesting an origination in Grenville-aged arc–back-arc basin setting.

2. Geological background and petrological description

The SCB is traditionally considered to be composed of the Yangtze and Cathaysia Blocks (Fig. 1) which is separated by Jiangshan-Shaoxing Fault. The Yangtze crystallized basement is represented by the Kongling Group with the crystallization ages of 3.2–2.4 Ga (e.g., Gao et al., 1999, 2011; Qiu et al., 2000; Zheng et al., 2006). The exposed fold-basement is characterized by the Lengjiaxi Group and its equivalents (e.g., Sibao and Shuangqiaoshan Groups) with a deposition age ranging from ca. 870 Ma to ca. 830 Ma (e.g., Wang et al., 2006, 2007b, 2011a; Zhang et al., 2012 and reference therein). The Cathaysia basement has been traditionally considered to be characterized by the Paleoproterozoic Badou, Mayuan, Taoxi, Zhoutan and Yunkai Groups exposed mainly along the Wuyi–Nanling–Yunkai Domain (e.g., Yu et al., 2009; Li, 1997; Li et al., 2011). They composed lithologically of the schist, gneiss, amphibolite, migmatite and volcanoclastics and have been regarded as representative of the oldest rocks of the Cathaysia Block (e.g., Fujian BGMR, 1985; Zhejiang BGMR, 1989; Liu et al., 2010; Yu et al., 2009, 2010; Wang et al., 2007c, 2011b). However, the new geochronological data show that the migmatite and gneissoid granites that were previously mapped as the Paleoproterozoic basement, have age range of 410–1890 Ma (e.g., Fujian BGMR, 1985; Guangdong BGMR, 1988; Wang et al., 2007c, 2010b, 2011b; Wan et al., 2007, 2010; Yu et al., 2009, 2010; Li et al., 2010).

The NE/ENE-trending Yunkai Domain with a width of 150 km and a length of over 300 km extends eastward to the Nanling (e.g., Baiyunshan) and then northeastward into the Wuyi metamorphic Domain (Fig. 1a). It separates the Cathaysia Block from the Permian to middle Triassic Shiwandashan foreland basin of the Yangtze Block by the Bobai-Cenxi Fault (probably as southern extension of the Jiangshan-Shaoxing Fault, e.g., Guangxi BGMR, 1985; Chen and Jahn, 1998; Liang and Li, 2005; Wang et al., 2007c). This Domain is bounded to the east by the NE-trending Wuchuan-Sihui Fault. To the northern margin, there developed a roughly WNW-trending shearing zone overprinted by the Mesozoic thrust and fold sheets (e.g., Luoding and Fenjie thrust sheets). It is mainly composed of the metamorphic Yunkai and Gaozhou groups previously mapped as Precambrian basement and Phanerozoic sedimentary cover as well as voluminous peraluminous granites (467–413 Ma and 243–120 Ma; e.g., Peng et al., 1996, 2000; Guangxi BGMR, 1985; Guangdong BGMR, 1988; Wang et al., 2007c, 2010b, 2011b).

The so-called Precambrian Gaozhou Group, also named as the Gaozhou–Xinyi Complex, dominantly developed at the core of the Yunkai Domain. Available data show that it was mainly constituted by amphibolite-facies metamorphic rocks metamorphosed at Kwangsian (ca. 420–460 Ma) period, and migmatite and gneissoid granite predominantly crystallized at 413–467 Ma (e.g., Wang et al., 2007c, 2011b; Peng et al., 2006; Wan et al., 2010). The actual extent of the Precambrian Gaozhou Group may be less than previously estimated and almost of the originally defined Gaozhou Group is actually of early Paleozoic age (e.g., Wang et al., 2007c, 2011b; Wan et al., 2010). The Yunkai Group consists of high-grade metamorphic rocks at the lower part (also named lower basement) and greenschist-facies sedimentary rocks with volcanic interlayers at the upper part (also named the upper basement) (e.g., Guangdong BGMR, 1988; Guangxi BGMR, 1985; Peng et al., 2000, 2004). The lower part of the group has a thickness of more than 1300 m and contains lithological graphite-bearing paragneiss, greenschist, arcose sandstone, greywacke, quartz-schist, magnetite quartzite, migmatite, marble, and silicolite with abundant pyroxenite, augiteperidotite, metabasite and amphibolite interlayers/lens. Its upper part with a thickness of greater than 1345 m consists mainly of metamorphic siltstone, phyllite, silicolite and quartz schist. There are two viewpoints proposed for the formation age of the Yunkai Group. Some researchers, such as Nan (1994), Zhang et al. (1997a,b) and Lao and Hu (1997), believed that the sequence formed at earliest Neoproterozoic based on the species of fossils and isotopic data of the dacitic porphyry and silicolite. The others (Guangxi BGMR, 1985; Guangdong BGMR, 1988) considered a Mesoproterozoic period according to the micropaleontologic fossils (e.g., *Dictyosphaera* sp., *Asperalopsophosphaera* sp.).

In the Yunkai Group, there occur abundant mafic-ultramafic rocks as interlayers, lens and pods. These rocks have commonly experienced strong deformation and greenschist- to amphibolite-facies metamorphism (e.g., Guangxi BGMR, 1985; Guangdong BGMR, 1988; Peng et al., 2004, 2006). They are mainly characterized by serpentinized augiteperidotite, hornblende pyroxenite, metabasite, amphibolite and metagabbro, and exposed dominantly at Qingshuikou and Shiwo (Beiliu), Liuwan and Licun (Rongxian), Jintong and Guizi (Xinyi) and Fenjie and Yuchakeng (Luoding). It extends along a roughly WNW-trending with the length of more than 100 km along the northern margin of the Yunkai Domain, and further east link to the Neoproterozoic spilite and keratophyre at Xinqiao, south of Guangzhou (Guo et al., 2005; Han et al., 1998 and authors' unpublished data).