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Mid-Neoproterozoic diabase dykes from Xide in the western Yangtze Block, South China: New evidence for continental rifting related to the breakup of Rodinia supercontinent

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ABSTRACT

The petrogenesis of widespread Mid-Neoproterozoic mafic dykes is crucial for the paleographic position of the South China Block (SCB) in Rodinia supercontinent and the mechanism of Rodinia breakup. Here, new detailed geochronological and geochemical data on the diabase dykes from Xide in the western Yangtze Block are presented. Zircon SHRIMP/LA-ICP-MS U-Pb dating shows that four diabase samples yield uniform crystallization age varying from 796 ± 6 Ma to 809 ± 15 Ma, while one sample gives a slight older age of 824 ± 11 Ma that is overlapped with ca. 810 Ma within uncertainties. This suggests that the Xide diabase dykes emplaced at ca. 800–810 Ma and were coeval with regional bimodal magmatism (e.g., the Suxiong bimodal volcanics). The Xide diabase dykes are characterized by low SiO_2 contents, high Mg# values and Cr, Ni contents, relative enrichment of light rare-earth elements, and slight depletion of high field strength elements (e.g., Nb, Ta, Zr, and Hf) and nearly constant Zr/Hf, Nb/Ta and Nb/La ratios. Our analyses indicate that the diabase was mainly produced by interaction between lithospheric and asthenospheric mantle. Moreover, the diabase samples display geochemical characteristics affinity with typical intra-plate basalts. Together with the widespread coeval bimodal magmatic suite and sedimentary records in the Kangdian Rift, we proposed that the western Yangtze Block once experienced continental rifting during the Mid-Neoproterozoic, which also occurred in other Rodinia blocks, such as Tarim, Australia and North America. In addition, the Grenville-aged magmatism records throughout SCB with the widespread Mid-Neoproterozoic rift-related magmatism and sedimentation records imply that SCB probably played a key role in the assembly and breakup of Rodinia supercontinent.

1. Introduction

Assembly and breakup of supercontinents exert major influences on global tectonic framework, mantle dynamics, mineral systems, and surface geological features (e.g., Rogers and Santosh, 2003; Zhao et al., 2004, 2006; Santosh, 2010; Pirajno and Santosh, 2015). The Rodinia supercontinent, assembled between 1.3 and 0.9 Ga and broken up between 850 and 740 Ma (Li et al., 2008a), has been topics of great interest in the last decades (e.g. Wingate et al., 1998; Li et al., 1999, 2003a, 2008a; Li et al., 2002a, 2003b, 2010a; Ling et al., 2003; Wang and Li, 2003; Wang et al., 2007, 2008a, 2010a; Ernst et al., 2008; Jacobs et al., 2008; Wang et al., 2010b; Shu et al., 2011; Zhang et al., 2012a; Deng et al., 2013; McClellan and Gazel, 2014; Teixeira et al., 2014). Multiple episodic records of anorogenic magmatism during 850–740 Ma are widespread on several blocks, including South China, Tarim, North America, India, Southern Africa, and Australia (Powell et al., 1994; Park et al., 1995; Wingate et al., 1998; Li et al., 1999, 2003a, 2008a; Preiss, 2000; Frimmel et al., 2001; Li et al., 2002a, 2003b, 2008c, 2010a; Ling et al., 2003; Wang et al., 2007, 2008a, 2010a; Ernst et al., 2008; Xu et al., 2013; Zhang et al., 2013a; McClellan and Gazel, 2014). These

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magmatic records provide important constraints on the process and mechanism of Rodinia breakup.

The South China Block (SCB) is generally thought to have retained some of the best-preserved 850–720 Ma magmatism and sedimentary records (Li et al., 2003a, 2008a; Li et al., 2002a, 2003b, 2008b,c, 2010a,b; Ling et al., 2003; Wang and Li, 2003; Lin et al., 2007; Wang et al., 2009, 2011a, 2012a; Wang et al., 2010b; Shu et al., 2011; Zhao et al., 2011; Xia et al., 2012; Zhao and Cawood, 2012; Wang et al., 2012b) (Fig. 1). However, petrogenesis and tectonic interpretations of these widespread magmatic events are still highly debating, and two main, but conflicting, models have been proposed. One model suggests that these igneous rocks were produced within a intracontinental rift setting as a result of mantle plume activities, which finally caused the breakup of Rodinia (Li et al., 1999, 2003a, 2008a; Li et al., 2002a,c, 2003b, 2010a,b; Ling et al., 2003; Lin et al., 2007; Zhu et al., 2006, 2007, 2008; Wang et al., 2007, 2008a, 2009; Wang et al., 2010b). The other model argues that most of these rocks formed under either an arc setting related to the steeply dipping subduction of the oceanic lithosphere eastward (present-day orientation) underneath the Yangtze Block (Yan et al., 2002; Zhou et al., 2002a,b, 2006a,b; Zhao and Zhou, 2007a,b; Dong et al., 2011, 2012; Zhao et al., 2008, 2011; Meng et al., 2014) or collision-related environments (Zhao and Cawood, 1999; Wang et al., 2004, 2006). A growing agreement is that these 850–720 Ma magmatism and sedimentary records in SCB were formed in an extensional setting; however, the remaining controversy is its dynamics.

Mafic dykes can yield insights on the study of mechanism and processes of supercontinent breakup (e.g. Yang et al., 2011; Stepanova et al., 2014; Wang et al., 2014a). Neoproterozoic mafic dykes widespread in many Rodinia blocks have been well studied and demonstrated to record the information related to the breakup of Rodinia supercontinent (e.g., Park et al., 1995; Wingate et al., 1998; Li et al., 1999, 2003a, 2008a; Li et al., 2002c, 2006a; Ernst et al., 2008; Pisarevsky et al., 2008). Abundant diabase dykes are widely distributed in the Xide region (Fig. 2), which intruded into the Mesoproterozoic Dengxiangying Group. However, their petrogenesis and tectonic implications have not been well studied by geochronological and geochemical data. In this contribution, we present detailed field, petrological, geochronological and geochemical studies on the Xide diabase dykes. These new data, in combination with available regional geological data, are crucial not only for constraining the Mid-Neoproterozoic continental rifting in the western Yangtze Block, but also for understanding the Neoproterozoic tectonic setting of SCB.

2. Geological background and samples

The SCB consists of the Yangtze Block to the northwest and the Cathaysia Block to the southeast (Fig. 1). It is separated from the North China Craton by the Qinling-Dabie-Sulu orogenic belt to the north, from the Songpan-Gantze terrane by the Longmenshan Fault Zone to the northwest, and from the Indochina Block by the Ailaoshan-Red River Fault to the southwest, and bounded by the continental slope of the Pacific Ocean to the southeast (Fig. 1). Although it is generally accepted that the Yangtze and Cathaysia blocks amalgamated during the Proterozoic Sibao orogeny (a.k.a the "Jiangnan" or "Jinning" orogeny), the timing of this orogeny is still controversial (e.g., Li et al., 1995, 2002b, 2007, 2008a; Zhao and Cawood, 1999; Wang et al., 2004, 2006, 2014b; Greentree et al., 2006; Ye et al., 2007; Zhang et al., 2012b; Yin et al., 2013; Zhang et al., 2013b; Zhao, 2015). Nonetheless, there are significant numbers of Grenvillian subduction- or collision-related magmatism records in the western (Mou et al., 2003; Greentree et al., 2006; Geng et al., 2007; Zhang et al., 2007; Yang et al., 2009; Wang et al., 2012c; Li et al., 2013; Zhang et al., 2013c) and northern Yangtze (Qiu et al., 2011, 2015; Wang et al., 2013a) and the Cathaysia blocks (Wang et al., 2008b; Shu et al., 2011; Zhang et al., 2012d; Cawood et al., 2013; Wang et al., 2013b, 2014c).

Outcrops of Archean rocks are mainly distributed in the northern Yangtze Block, whereas Paleoproterozoic basement rocks occur sporadically in the western and northwestern Yangtze Block (Greentree et al., 2006; Zhao and Cawood, 2012; Chen et al., 2013; Wu et al., 2014a; Zhou et al., 2015). However, the Mid-Neoproterozoic (mainly 820–725 Ma) magmatism and sedimentary records, which were preserved as wedge-shaped rift successions (Wang and Li, 2003; Wang et al., 2015), are widely distributed within the three major rift basins in SCB: the roughly E-W trending Bikou-Hannan Rift along the northwestern Yangtze Block, the N-S trending Kangdian Rift near the present western Yangtze Block, and the major NE-SW trending Nanhua Rift to the southeast (Fig. 1) (Li et al., 1999, 2003a, 2008a; Wang and Li, 2003; Wang et al., 2008a, 2009, 2011a, 2012a; Cui et al., 2014; Wang et al., 2015). These successions consist of continental and marine siliciclastic and volcaniclastic rocks interbedded with bimodal volcanics and tuffs (Li et al., 2002a; Wang and Li, 2003; Wang et al., 2011a, 2012a; Jiang et al., 2012; Wang et al., 2015). In the Kangdian Rift, the wedge-shaped rift successions include the Suxiong, Kaijianqiao, Chengjiang, Luliang, and Niutoushan Formations (Wang and Li, 2003; Jiang et al., 2012; Zhuo et al., 2013, 2015; Cui et al., 2013, 2014).

In the western Yangtze Block, the rift basement (pre-rift successions) is composed of the Paleoproterozoic and Mesoproterozoic strata. The Paleoproterozoic strata include the Dahongshan, Dongchuan and Hekou Groups, while the Mesoproterozoic strata include the Kunyang, Huili, Dengxiangying and Ebian Groups (Greentree et al., 2006; Geng et al., 2007, 2008; Chen et al., 2013; Li et al., 2013). Among them, the Dengxiangying Group is mainly distributed in the Xide County, western Sichuan Province, and covers an area of approximately 200 km^2 (Fig. 2). The Dengxiangying Group is a sequence of meta-sedimentary and volcanic rocks including phyllite, slate, quartzite and marble interbedded with meta-dacite and has a total thickness of more than 8500 m (BGMR, 1991, 1996). It underwent lower greenschist facies metamorphism and strong deformation. A meta-dacite sample from the Dengxiangying Group gave a SHRIMP zircon U-Pb age of 1017 ± 17 Ma (Geng et al., 2008), which is consistent with those ages of the Kunyang, Huili and Ebian Groups (Zhang et al., 2007; Geng et al., 2007, 2008; Li et al., 2013; Authors' unpublished data). The Dengxiangying Group is unconformably overlain by the Suxiong and Kaijianqiao Formations to the north, by the Sinian and younger strata to the east and south, and intruded by granites to the west (Fig. 2).

The diabase dykes (with minor sills) in the Xide region intruded into the pre-rift meta-sedimentary and volcanic rocks (Dengxiangying Group), but did not penetrate the Neoproterozoic rift successions (Fig. 3a, b). Their intrusive contacts are very clear and thin baked zones or thermal recrystallization that can be observed near the boundary of the dykes. These diabase dykes are rarely subjected to deformation and metamorphism in contrast to their strongly deformed metamorphic wall-rocks. They are commonly several meters wide and tens of meters strike length. The weathered surface of these diabase dykes is yellowish-gray in color, while the fresh surface is grayish-black (Fig. 3a–c). Most diabase dykes have a dominant N-S trend that is sub-parallel to the Kangdian Rift and are oblique or nearly vertical. All the diabase samples, collected from the Xide region, display typical diabasic texture (Fig. 3d) and are massive structure (Fig. 3c). These diabase samples have similar mineral compositions of plagioclase (40–55%), pyroxene (20–30%), Fe-Ti oxides (5–15%), ordinary hornblende (5–10%), and olivine (5–10%) with minor opaque minerals such as apatite (Fig. 3d). In this study, a total of thirty diabase samples were collected, of which