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Precambrian crustal evolution of the South China Block and its relation to supercontinent history: Constraints from U–Pb ages, Lu–Hf isotopes and REE geochemistry of zircons from sandstones and granodiorite

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ABSTRACT

The unified South China Block, comprising the Yangtze Block to the northwest and the Cathaysia Block to the southeast, has been central to recent studies on the Precambrian crustal evolution and position of South China in Proterozoic supercontinents. Here we present results from detailed U–Pb geochronology, Lu–Hf isotopes and rare earth geochemistry on zircons from three Ordovician and Devonian sandstone samples of southeastern Yangtze, together with those from a granodiorite sample and three Triassic sandstone samples in northeast and southeast Cathaysia. The southeastern Yangtze Block is characterized by extensive tectono-thermal events during 850–730 Ma and 470–410 Ma, which corresponded to the breakup of Rodinia and the Caledonian orogenic event, respectively. Major zircon populations with ages of 2800–2500 Ma, 1990–1580 Ma and 1260–920 Ma are recorded from southeastern Yangtze, which are correlated, respectively, with the Neoarchean crustal growth, and histories of the Paleo-Mesoproterozoic Columbia and Neoproterozoic Rodinia supercontinents. In contrast, zircon U–Pb ages from southeast Cathaysia reveal prominent magmatic events during 2630–2300 Ma, 2030–1770 Ma and 280–190 Ma, correlated with Neoarchean continental growth and the tectonothermal regimes associated with the history of the Columbia supercontinent as well as the Indosinian movement. The sector-zoned zircons from the granodiorite in northeast Cathaysia yielded weighted mean ages of 846.7 ± 9.8 Ma and 826.4 ± 7.6 Ma and positive εHf values, constraining the initial breakup of South China at ca. 848 Ma and extensive rift-related magmatism at ca. 826 Ma. The Hf data suggest important episodes of juvenile magmatic addition at 3.1–2.8 Ga and 2.4–1.5 Ga for Yangtze, and at 3.3–2.3 Ga for Cathaysia, indicating the existence of older crustal components in South China. The Hf data suggest that most zircons in both the blocks were derived from crustal magmas. Our results suggest distinct crustal evolution histories for the Yangtze and Cathaysia Blocks albeit with close affinities.

1. Introduction

U–Pb analysis of detrital zircons provides age spectra, and their Hf composition offers information on the source characteristics (juvenile mantle versus reworked crust). A combination of these approaches has proven to be a useful tool for reconstructing the tectonic evolution of continental blocks (e.g., Condie et al., 2009; Geng et al., 2011; Griffin et al., 2004; Kuznetsov et al., 2010; Liu et al., 2012; Long et al., 2011; Rino et al., 2008; Veevers and Saeed, 2009; Wang et al., 2010a,b; Ying et al., 2011; Yu et al., 2010; Diwu et al., 2011). Furthermore, trace element data on zircons as a complement to the U–Pb ages and Hf-isotope analyses offer potential information on the nature of the magma from which the zircons crystallized. Thus, an integration of different analytical datasets applied to detrital zircons in sediments can be used to trace the magmatic pulses in continental crustal blocks from which sediments were derived in terms of age, rock types and sources material. Detrital zircons in a sedimentary basin are derived from the weathering of rocks in the provenance and their subsequent transportation in fluvial systems. Therefore, if a large number of detrital zircons are analyzed, the age spectra can be used to assess the distribution of source rocks in the provenance, and detrital zircons identified to be of igneous origin can be used to determine major magmatic events in the source regions (Condie et al., 2009; Cho et al., 2010; Duan et al., 2011; Nutman et al., 2011; Liu et al., 2011a, 2011b; Long et al., 2010a,b; Rojas-Agramonte et al., 2011;

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Sevastjanova et al., 2011; Yao et al., 2011). Since sediments also carry zircons from source rocks that are no longer exposed, detrital zircons have been effectively employed for evaluating crustal history (e.g., Griffin et al., 2004; Belousova et al., 2010). Detrital zircons are thus important proxies for the history of growth and destruction of continental crust, as well as the assembly and dispersal of supercontinents (Carter and Moss, 1999; Diez Fernandez et al., 2010; Wysoczanski et al., 1997; Veevers and Saeed, 2009; Roberts, 2011).

The South China Block, composed of two major Precambrian blocks – the Yangtze Block to the northwest and the Cathaysia Block to the southeast – is one of the most important crustal blocks in Asia (Fig. 1). The geodynamic evolution of the South China Block is critical to understanding of the assembly and breakup of the Proterozoic supercontinents such as Columbia, Rodinia and Gondwana. Controversy has long surrounded the age distribution, source characteristics, and the spatial and temporal evolution of the South China Block, as well as the affinity of the Yangtze and Cathaysia Blocks (Zhang et al., 2006b; Qiu et al., 2000; Xiao and He, 2005; Greentree and Li, 2008; Greentree et al., 2006; Lu, 2006; Yu et al., 2007; Wang et al., 2008a, 2010a,b; Li et al., 2002; Shu et al., 2008a; Wan et al., 2007; Peng et al., 2011). For the past 10 years, the application of advanced geochronological methods has led to the refinement of previous tectonic models for the South China Block, which consists of the Yangtze Block and the Cathaysia Block (Fig. 1) (Charvet et al., 1996; Chen et al., 1991; Chen and Jahn, 1998; Dong et al., 2011; Guo et al., 1989; Li et al., 2010a; Shu and Charvet, 1996; Wang et al., 1986; Yu et al., 2010; Xiang and Shu, 2010). At latest early Neoproterozoic, the Yangtze Block amalgamated with the Cathaysia Block to form the unified South China Block (Greentree et al., 2006; Ye et al., 2007; Zheng et al., 2008; Zhao and Cawood, 1999; Wang et al., 2008b; Li et al., 2008b,c). With the widespread magmatic activities which broke up the Neoproterozoic supercontinent Rodinia at ca. 825 Ma (Zheng et al., 2008; Li et al., 2008a,c), the South China Block split apart along the JiangShan-Shaoxing fault zone (Fig. 1), which is generally believed to be a lithosphere scale break-up (e.g., Rong et al., 2010; Shu, 2006). Subsequently, the Yangtze Block rapidly subsided and middle Neoproterozoic rift basins were formed in the South China Block. Meanwhile, the Cathaysia Block was broken up into three controversial sub-blocks, namely, the Wuyi, South Jiangxi-Nanling and Yunkai, which are separated from one another by intracontinental rift zones (Shu, 2006). The region between these sub-Blocks evolved from an intracontinental rift into shallow basins, with the individual basins filled by middle Neoproterozoic-Ordovician clastic sedimentary rocks. Several granitoids, bimodal igneous rocks, composite magmatic flow, basic dyke swarm and continental rift-type basins that correspond to the breakup of South China during Neoproterozoic time were well developed (Li et al., 2005; Xiang and Shu, 2010; Zhou et al., 2007; Zheng et al., 2008).

During late Ordovician and Silurian (460–415 Ma), the Caledonian intraplate orogenic activity led to the closure of intracontinental shallow marine basins of South China, followed by deformation, magma intrusion and intracontinental orogeny (Shu et al., 2008c; Faure et al., 2009; Li et al., 2010b; Charvet et al., 2010; Wang et al., 2007b). The Caledonian tectonic event in the region is evidenced from a series of geological observations, including an unconformity between the middle–upper Devonian and pre-Devonian sequences, and the absence of upper Silurian sediments and voluminous Silurian granitic intrusions (BGMRJX, 1984; BGMRFJ, 1985; Huang et al., 1987; BGMRHN, 1988; Shu et al., 1991; Charvet et al., 1996). Following the above event, intense magmatic activity took place from the Early Permian to the Late Cretaceous, partially associated with the subduction of the paleo-Pacific Plate under the eastern flank of the South China Craton (e.g., Jahn et al., 1976, 1990). In the Triassic, the South China Block collided with the North China Block along the Qingling-Dabie-Sulu orogenic belt (Ames et al., 1996; Hacker et al., 1998; Li et al., 2010, 2011a,b) and with the Indochina Block in the southwest (Cai and Zhang, 2009), finally joining the Tibetan Plateau to the west during Late Triassic–Early Jurassic time (Burchfiel et al., 1995; Sengor, 1984).

Recent advances in our understanding of the tectonic events within the crustal blocks constituting the South China Block have raised a number of interesting and intriguing questions such as: (1) the similarities and differences of the crustal evolution of the Cathaysia Block and the Yangtze Block including the question whether the Cathaysia Block and Yangtze Block possess Neoarchean crystalline basements; (2) the existence of any prominent signature of the impact of the assembly and breakup of the Columbia supercontinent within the South China Block; (3) whether the South China Block witnessed the Grenville orogeny during latest Mesoproterozoic; (4) the imprints of the assembly and breakup of the Rodinia supercontinent in South China; (5) the mechanism and signature of the Caledonian event in South China; and (6) how and when the Caledonian and Indosinian movements affected South China.

The Jiangshan, Chun'an and Zhuji domains in Zhejiang Province are located across the boundary of the Yangtze and Cathaysia Blocks, whereas the Jian'ou domain in northeast Fujian Province is located at the southeastern segment of Cathaysia. These domains are surrounded by Proterozoic metamorphic rocks. Thus, these domains preserve important clues to investigate some of the above questions.

In this study, we undertook systematic field investigations in the Fujian and Zhejiang regions. LA-ICP–MS U–Pb analysis was performed on detrital and magmatic zircons from seven representative samples. Three of the samples are Devonian and Ordovician sandstones from Jiangshan and Chun'an in southwest Zhejiang (southeastern margin of the Yangtze Block) (Fig. 2). One granodiorite sample was collected from Zhuji in northeast Cathaysia, near the boundary between the Yangtze and Cathaysia sub-Blocks (Fig. 2). Another three samples are Triassic sandstones collected from Jian'ou in Northwest Fujian (southeast Cathaysia) (Fig. 3). We report 393 U–Pb analyses on single detrital and magmatic zircons. The same zircon grains were also analyzed for Hf isotope composition and trace element geochemistry. A total of 127 analyses of zircon Hf data and 97 analyses of trace element data were obtained. The age data were used to compute concordia diagrams as well as to identify different age populations. The results from this study provide information on the history of pre-Devonian and pre-Triassic tectonothermal events in the source region, and thus offer important constraints on the crustal evolution history of the South China Block.

2. Geological setting and stratigraphy

2.1. Geological setting

The Precambrian crust of South China can be divided into two distinct tectonic domains with the basement rocks composed of different components. The Precambrian basement of South China is rarely exposed. The basement rocks of the Yangtze Block range from Archean to Proterozoic (e.g., Qiu et al., 2000, 2011; Zhang et al., 2006a,b,c; Greentree and Li, 2008) (Fig. 1), whereas those of the Cathaysia Block mostly show Proterozoic ages (e.g., Chen and Jahn, 1998; Wan et al., 2007; Xu et al., 2007; Yu et al., 2008) with the oldest rocks exposed in the eastern Cathaysia Block with an age of 1.9 Ga (Gan et al., 1995; Hu, 1994). The crystalline basement of the Yangtze Block is mainly overlain by Neoproterozoic to Middle Triassic marine sedimentary sequences (Sawaki et al., 2010; Yan et al., 2004; Jiang et al., 2011). However, the Cathaysia Block