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Zircon U-Pb age and Hf-O isotope evidence for Paleoproterozoic metamorphic event in South China

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Abstract

To understand the connection between continental cratonization and global tectonothermal event is essential for recognizing the formation and evolution of continental crust. Paleoproterozoic is an important era with occurrence of megascale tectonomagmatism in the world, but it has been intriguing whether they also influenced the oldest continent in South China. In order to decipher the nature of Paleoproterozoic event in South China, a combined study of zircon U-Pb dating, Hf and O isotope analyses was carried out for metasediments and amphibolite from the Kongling terrane, the only Archean microcontinent outcropped in South China. U-Pb ages of 1.97 ± 0.03 Ga were obtained with low Th/U ratios of 0.01–0.14, indicating that the ages are a record of Paleoproterozoic metamorphic event. $\delta^{18}O$ values of ~11‰ and ~8‰ were measured for quartz from the metasediments and garnet from the amphibolite, respectively, suggesting that their sources experienced supracrustal recycling. $\varepsilon_{Hf}(t)$ values of about −6.5 and model Hf ages of about 3.0 Ga were acquired for zircons from the metapelites, suggesting an Archean source. Thus a response to the Paleoproterozoic global tectonothermal event in South China is reworking of Archean continental nucleus. Compared with Archean rocks at Kongling, abrupt changes in K_2O/Na_2O, REE and other trace elements are observed in the Paleoproterozoic metasedimentary rocks. This is interpreted to reflect a change in upper crustal composition at the Archean–Proterozoic boundary. A survey of Paleoproterozoic ages throughout the Yangtze Block suggests that metamorphic event and subsequent magmatic activity occurred in the north, but only magmatic activity in the south. Both metamorphic and magmatic activities are associated with formation of a unified basement responsible for cratonization of the Yangtze Block. This provides a geodynamic connection between the formation of this craton and the global tectonomagmatism in the Paleoproterozoic, marking continental accretion by arc-continent collision orogeny during assembly of the supercontinent Columbia.

Keywords: Zircon; U-Pb age; Hf isotope; O isotope; Paleoproterozoic; Continental accretion; Cratonization; South China

1. Introduction

The Paleoproterozoic era is of great importance in the evolution of the Earth. In this period occurred not only high production rates of juvenile crust (Condie, 1995,

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1998, 2000, 2002; Sato and Siga, 2002) but also assembly of a supercontinent (Rogers and Santosh, 2002; Zhao et al., 2002, 2004). Condie (1995, 1998) revealed three striking global peaks at about 2.7 Ga, 1.9 Ga and 1.2 Ga from the survey of zircon U-Pb ages from juvenile continental crust, implying episodic growth and reworking of continental crust. Although it is hypothesized that episodic growth of juvenile crust is related to superplume or supercontinental cycle (Stein and Hofmann, 1994; Condie, 1995, 1998, 2000; Albarede, 1998), juvenile crust in 1.9-Ga orogens is largely of oceanic arc origin with most of them in the setting of continental arcs. This type of juvenile crust was accreted to continental margins by arc-continent collisions during the initial stages of supercontinent formation.

Hoffman (1989) provided geological evidence for a supercontinent assembled in the period of 2.0–1.8 Ga. Rogers and Santosh (2002) and Zhao et al. (2002, 2004) proposed a Paleo-Mesoproterozoic supercontinent, referred to as Columbia, with different configurations between the proponents. Although exact details about the history of this proposed supercontinent still remain shadowy, it is generally accepted that the Paleoproterozoic supercontinent was assembled at 2.0–1.8 Ga. This period corresponds to global collision events around the world, such as the Trans-Hudson Orogen in North America (Hoffman, 1988), the Transamazonian Orogen in South America (Alkmim and Marshak, 1998), the Eburnean Orogen in West Africa (Bertrand and Jardim de Saĭ, 1990), the Limpopo Belt in Southern Africa (Bertrand and Jardim de Saĭ, 1990), the Central Indian Tectonic Zone in India (Zhao et al., 2003), the Trans-North China Orogen in North China (Zhao et al., 2000). Either high rates of juvenile crust or assembly of supercontinent indicates that global tectonothermal activities were widespread and frequent in the period of 2.0–1.8 Ga.

South China is composed of the Yangtze Block in northwest and the Cathaysia Block in southeast. Whole-rock Sm-Nd isotope studies of Chen and Jahn (1998) suggest that the most important crustal formation took place in the Paleoproterozoic to Mesoproterozoic, with a very minor production in the Archean. Despite the widespread occurrence of Neoproterozoic igneous rocks in South China, Paleoproterozoic to Archean rocks only sporadically occurred in a few localities such as Kongling near the Yangtze Gorge (Ames et al., 1996; Qiu et al., 2000; Zhang et al., 2006), Houhe southwest of the Qinling orogen (Ling et al., 1997), and Dongling southeast of the Dabie orogen (Xing et al., 1994; Grimmer et al., 2003). Until now, the fate of these old rocks in the middle Paleoproterozoic (2.0–1.8 Ga) global tectonic activity remains unknown. Furthermore, a connection between the Paleoproterozoic tectonomagmatism and the formation of South China basement remains to be explored. In order to gain some insight into these issues, we conducted a combined study of zircon U-Pb age, Hf and O isotopes in metamorphic rocks from the Kongling terrane in the Yangtze Block.

Zircon is readily amenable to U-Pb dating because it robustly records the crystallization and high-grade metamorphic ages (e.g., Hanchar and Hoskin, 2003). Analysis of Lu-Hf isotopes on zircon grains has been revolutionized by recent advances in LA-MC-ICPMS techniques (e.g., Griffin et al., 2000; Woodhead et al., 2004; Iizuka and Hirata, 2005). Zircon Lu-Hf isotopes can be used to constrain the nature of igneous or metamorphic event in which zircon grew (e.g., Griffin et al., 2002, 2004; Zheng et al., 2005a, 2006a; Kemp et al., 2006). Zircon O isotopes are eminently suitable to recognize whether a rock underwent supracrustal processes or not (Valley, 2003; Zheng et al., 2004). The combination of these approaches provides an opportunity to decipher the nature of crustal evolution from Archean to Paleoproterozoic for the Kongling terrane. Thus a better understanding of basement rocks in South China can result from this combined study of zircon U-Pb, Lu-Hf and O isotope systematics.

2. Geological setting

The Kongling terrane is located in the northern part of the Yangtze Block (Fig. 1) and about 100 km north of Yichang in Hubei Province. Although only a small dome of about 360 km^2, the terrane is unique because it represents the only Archean microcontinent in South China. The unit was intruded by the 1.85 Ga K-feldspar-rich Quanyishang granite in north (Yuan et al., 1991), and by the Neoproterozoic (∼820 Ma) Huangling batholith to south (Ma et al., 1984). Generally, this unit consists of three types of rock associations: (1) dioritic, tonalitic, trondhjemitic and granitic gneisses (DTTG) of intrusive origin, with dominant trondhjemitic and tonalitic members; (2) metasedimentary rocks dominated by metapelites; (3) amphibolite and locally preserved mafic granulite, usually occurring as lenses, boudins and layers within the gneisses. The proportion of the felsic gneisses, clastic metasediments, and amphibolite is about 0.51, 0.44 and 0.05, respectively. The clastic metasediments can be divided into three distinct groups according to their mineralogical and geochemical compositions (Gao et al., 1999): (1) Group A shows negligibly to slightly negative Eu anomalies and is dominated by feldspar, biotite and quartz with variable garnet and amphibole; (2) Group B is characterized by negative Eu anomalies and