Gondwana Research 23 (2013) 1241–1260

Contents lists available at SciVerse ScienceDirect

Gondwana Research

journal homepage: www.elsevier.com/locate/gr

Formation and evolution of Precambrian continental lithosphere in South China

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ARTICLE INFO

Article history:
Received 2 April 2012
Received in revised form 11 September 2012
Accepted 11 September 2012
Available online 7 October 2012

Keywords:
Continental lithosphere
Precambrian
Crustal growth
Crustal reworking
Zircon

ABSTRACT

An overview is presented for the formation and evolution of Precambrian continental lithosphere in South China. This is primarily based on an integrated study of zircon U–Pb ages and Lu–Hf isotopes in crustal rocks, with additional constraints from Re–Os isotopes in mantle-derived rocks. Available Re–Os isotope data on xenolith peridotites suggest that the oldest subcontinental lithospheric mantle beneath South China is primarily of Paleoproterozoic age. The zircon U–Pb ages and Lu–Hf isotope studies reveal growth and reworking of the juvenile crust at different ages. Both the Yangtze and Cathaysia terranes contain crustal materials of Archean U–Pb ages. Nevertheless, zircon U–Pb ages exhibit two peaks at 2.9–3.0 Ga and ~2.5 Ga in Yangtze but only one peak at ~2.5 Ga in Cathaysia. Both massive rocks and crustal remnants (i.e., zircon) of Archean U–Pb ages occur in Yangtze, but only crustal remnants of Archean U–Pb ages occur in Cathaysia. Zircon U–Pb and Lu–Hf isotopes in the Kongling complex of Yangtze suggest the earliest episode of crustal growth in the Paleoarchean and two episodes of crustal reworking at 3.1–3.3 Ga and 2.8–3.0 Ga. Both negative and positive $\varepsilon_{Hf}(t)$ values are associated with Archean U–Pb ages of zircon in South China, indicating both the growth of juvenile crust and the reworking of ancient crust in the Archean. Paleoproterozoic rocks in Yangtze exhibit four groups of U–Pb ages at 2.1 Ga, 1.9–2.0 Ga, ~1.85 Ga and ~1.7 Ga, respectively. They are associated not only with reworking of the ancient Archean crust in the interior of Yangtze, but also with the growth of the contemporaneous juvenile crust in the periphery of Yangtze. In contrast, Paleoproterozoic rocks in Cathaysia were primarily derived from reworking of Archean crust at 1.8–1.9 Ga. The exposure of Mesoproterozoic rocks are very limited in South China, but zircon Hf model ages suggest the growth of juvenile crust in this period due to island arc magmatism of the Grenvillian oceanic subduction. Magmatic rocks of middle Neoproterozoic U–Pb ages are widespread in South China, exhibiting two peaks at about 830–800 Ma and 780–740 Ma, respectively. Both negative and positive $\varepsilon_{Hf}(t)$ values are associated with the middle Neoproterozoic U–Pb ages of zircon, suggesting not only growth and reworking of the juvenile Mesoproterozoic crust but also reworking of the ancient Archean and Paleoproterozoic crust in the middle Neoproterozoic. The tectonic setting for this period of magmatism would be transformed from arc–continent collision to continental rifting with reference to the plate tectonic regime in South China.

1. Introduction

The continental lithosphere is rigid, highly viscous lid of Earth and consists of continental crust and subcontinental lithospheric mantle (SCLM). The continental lithosphere is broken into different tectonic plates which move on the underlying asthenospheric mantle. The thickness of continental lithosphere varies from 40 km to 350 km as suggested by seismic tomographic studies (Artemieva and Mooney, 2002; Artemieva, 2009), but geotherms based on mantle-derived xenolith data suggest a maximum thickness of 200–250 km for cratonic lithosphere (Niu and Song, 2007; Pearson and Wittig, 2008; O'Reilly and Griffin, 2010). When and how the continental lithosphere formed is very important to development of the plate tectonic theory (Zheng and Wu, 2009; O'Reilly and Griffin, 2010). The Precambrian formation and evolution of continental lithosphere are particularly so because this not only involves the regional tectonics but also the crust–mantle differentiation with respect to the compositional relationship between the continental lithosphere and the asthenospheric mantle in the history of Earth.

Tectonically, South China is composed of two major terranes, Yangtze and Cathaysia (Fig. 1). They have been assumed to be amalgamated along the Jiangnan orogen during the Neoproterozoic (Charvet et al., 1996; X.H. Li et al., 2003a; X.L. Wang et al., 2008b; Zheng et al., 2008). A characteristic feature in geology of China is that the magmatic rocks of middle Neoproterozoic age crop out widely in South China (Zheng and Zhang, 2007), but they are absent in North China (Zheng, 2012). Unlike the North China Block where Archean crustal rocks are widely present (e.g., Wu et al., 2005; Zhai and Santosh, 2011; Geng et al., 2012), the crust of South China is usually considered much younger (Chen and Jahn, 1998; Zheng and Zhang, 2007). In other words, Archean rocks are scarce in South China (Fig. 1). The thickness of crust in South

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1342-937X/$ – see front matter
http://dx.doi.org/10.1016/j.gr.2012.09.005

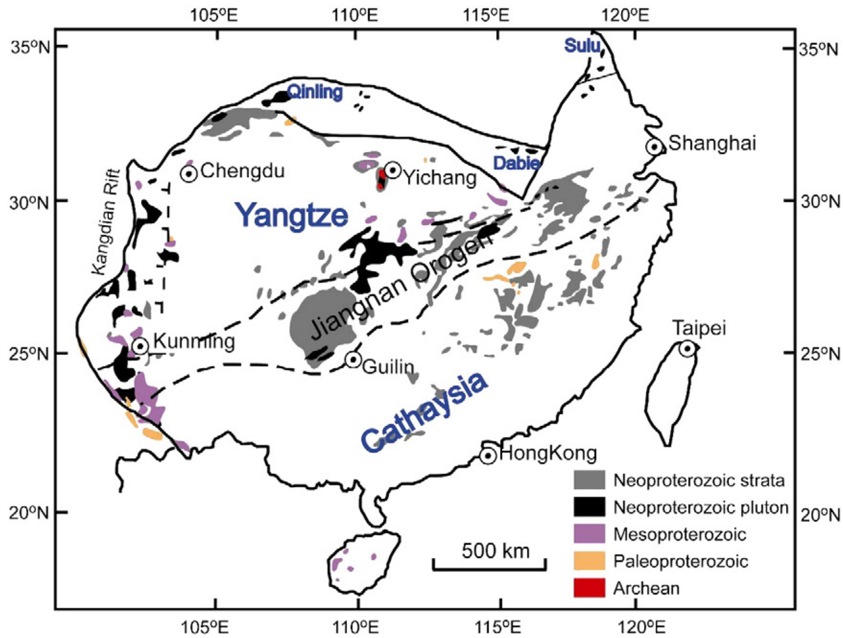

Fig. 1. Simplified tectonic division of South China and distribution of Precambrian rocks and strata. Modified after Geological Atlas of China (Ma et al., 2002).

China ranges from ~30 km in the east to 46 km in the west (S. Li et al., 2006a). The thickness of continental lithosphere in South China ranges from less than 80 km in the east to about 180 km in the west (An and Shi, 2006; Huang and Zhao, 2006). While these geophysical observations only provide a constraint on the current state of continental lithosphere in South China, geochemical studies provide more constraints on its formation and evolution in the Precambrian.

Generally, the Yangtze and Cathaysia terranes exhibit different records of Precambrian tectonothermal events and thus different evolution histories. Earlier studies of whole-rock Sm–Nd isotopes suggested that the Yangtze basement would form primarily in the Paleoproterozoic and secondarily in the Archean, whereas the Cathaysia basement terrane is relatively younger (e.g., Chen and Jahn, 1998) despite the sporadic occurrences of some Paleoproterozoic rocks (e.g., Hu, 1994; Gan et al., 1995). With progress in microbeam analyses of zircon U–Pb and Lu–Hf isotopes, however, it appears that Precambrian crustal materials in South China are more widely distributed than previously thought. This overview focuses on the formation and evolution of Precambrian continental lithosphere in South China. This is based on an integrated study of Re–Os isotope data for SCLM, zircon U–Pb and Lu–Hf isotope data for continental crust in South China. The results enable us to build up a tectonic framework for the growth and reworking of continental lithosphere during the Precambrian in South China.

2. Re–Os isotope constraints on formation time of SCLM

Because the continental crust generally experienced multiple episodes of reworking after the initial growth around the most ancient continental nucleus, the SCLM is commonly considered to suffer less episodes of reworking after isolation from the convective asthenosphere (Zheng and Wu, 2009). Thus, the formation time of subarc refractory mantle can be used to mark the formation time of SCLM. The Re–Os isotope analysis of mantle-derived rocks is a powerful tool to determine the age of mafic melt extraction from the asthenospheric mantle peridotite. This age corresponds to the formation age of SCLM if the crustal metasomatism of SCLM by later tectonic processes can be precluded. Although there are still many ambiguities when interpreting Re–Os isotope data of peridotites (Rudnick and Walker, 2009), their Re depletion ages (T_{RD}) can provide a first-order approximate to the separation time of SCLM from the normal asthenospheric mantle (i.e. the time of crust–mantle differentiation). Fig. 2a presents a summary of Re depletion ages for SCLM beneath South China.

Reisberg et al. (2005) analyzed whole-rock Re–Os isotopes in ultramafic xenoliths from basalts at Lianshan and Panshishan in northern Jiangsu, the northeastern edge of the Yangtze terrane. The results suggest that these xenoliths record an ~1.8 Ga event of melt extraction and later melt percolation. Re–Os isotope data on harzburgite xenoliths from Nushan in the northeastern edge of the Yangtze terrane (Zhi et al., 2007; Z.C. Liu et al., 2010b) suggest that the oldest melt extraction took place at about 2.0 Ga although most T_{RD} ages for the other peridotites are significantly younger. H.-F. Zhang et al. (2008a) analyzed Re–Os isotopes in garnet lherzolite xenolith from the late Paleozoic kimberlite at Dahongshan in the northern Yangtze terrane, yielding a Re depletion age of ~1.04 Ga. They also analyzed spinel lherzolite xenolith from the Mesozoic Ningyuan basalt in the Cathaysia terrane, giving Re depletion ages of 0.67–0.99 Ga. C.Z. Liu et al. (2012a) reported Re depletion ages of 0.40–1.26 Ga and 1.82 Ga for lherzolite and harzburgite xenoliths from Ningyuan, suggesting the formation of SCLM in the Paleoproterozoic and melt metasomatism in the Paleozoic. The Re–Os isotope data from peridotite xenoliths at Xinchang in the Cathaysia terrane give T_{RD} ages of 0.99–1.35 Ga for harzburgite and younger T_{RD} age of 0.22–0.75 Ga for lhzerlite (C.Z. Liu et al., 2012b), suggesting that not only the existence of Precambrian SCLM relict but also its reworking in the Phanerozoic. Xu et al. (2008) carried out laser in-situ Re–Os isotope analyses on sulfides in mantle-derived xenoliths from Yangtze and Cathaysia. Their Re depletion ages were obtained from low Re/Os sulfides, mainly Neoproterozoic to Mesozoic for Yangtze, and Paleoproterozoic to Paleozoic for Cathaysia.

In the northern margin of South China, Re–Os isotope analyses were performed on orogenic peridotites at Xugou in the Sulu orogen (Yuan et al., 2007) and at Raobazhai in the Dabie orogen (L. Zheng et al., 2009), yielding Re depletion ages of 1.6–2.0 Ga and 0.2–1.9 Ga, respectively. However, these orogenic peridotites would originally belong to the SCLM of the North China Block rather than the South China Block and they experienced the crustal metasomatism during the Triassic continental collision (Zheng, 2012). Thus their Re depletion ages are a mixing due to the melt–peridotite reaction rather than an indicative of the crust–mantle differentiation for the SCLM