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The evolution of the Central Yangtze Block during early Neoarchean time: Evidence from geochronology and geochemistry

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ABSTRACT

Although some Archean zircons (xenocrysts) have been reported in various places in the South China, Archean outcrops within the Yangtze Block have been spotted only in the Kongling terrain. Recently, the findings of a Neoarchean K-granite pluton emplaced within the Yangpo Group have opened a new window to study the formation and evolution of the Yangtze Block. We conducted a combined study of zircon U–Pb and whole-rock major and trace elements for seven quartz schist and two granite samples from the Yangpo Group in the Huji region, South China. It is another Archean outcrop in the Yangtze Block except for the Kongling terrain. Results of LA-ICP-MS dating for the detrital zircons from the quartz schist of the Yangpo Group indicate two age groups originating from two significant magmatic events at ~2.8 Ga and ~3.05 Ga, as well as the ~2.9 Ga and ~3.2–3.3 Ga magmatism identified in a previous study. The quartz schists of the Yangpo Group show high SiO_2 content and K_2O/Na_2O ratios, and low TiO_2, Fe_2O_3, and MgO contents. Two granitic samples from the Yaozishan pluton display relatively high SiO_2 and high alkali contents, low MgO, TiO_2, and P_2O_5 content, and high A/KNC ratios (1.21–1.31), exhibiting an aluminous feature. At the same time, the two samples show positive anomalies of HFSE (Zr, Hf, Y) and LILE (Rb, U, Th, La), and high Rb/Sr and $10^4 \times$ Ga/Al ratios. These geochemical observations are typical of A-type granites. The LA-ICP-MS dating results of the Jinshan and Yaozishan Granitic plutons further confirm the within-plate rifting and A-type granite emplacing event at ~2.65 Ga. Compared with the Jinshan A-type granite, the Yaozishan A-type granite has a distinct feature of abnormally high 10^4 Ga/Al ratios (6.19–6.23) and lower zirconium saturation temperature (772–778 °C), which indicates that the Yaozishan A-type granite emplacing at ~2673 Ma be associated with an early episode of the plate rifting event in the middle Neoarchean. These results suggest that the Yangpo Group be developed from ~2.8 Ga to ~2.7 Ga, as filling sequence of a passive continental margin or intracratonic basin. Thus, our study reveals for the first time that the preliminary cratonization of the Central Yangtze Block ended ~2.8 Ga followed by the filling of the craton basin, plate collision at ~2.7 Ga, and post-collision rifting at ~2.65 Ga.

1. Introduction

Archean terranes are generally regarded as volumetrically dominated by sodium-rich granitoids of tonalite–trondhjemite–granodiorite (TTG) suites (Jahn et al., 1981; Martin, 1987; Drummond and Defant, 1990). showed that the initial growth of the continental nuclei is characterized by the development of TTG rocks, which were generally derived by the partial melting of the lower crust in the garnet stability field. Therefore, the study of the formation and tectonic significance of Archean TTGs is considered essential for understanding the origin and evolution of early continental crust (e.g. Smithies et al., 2003; Condie, 2005; Martin et al., 2005; Moyen and Martin, 2012; Sarma et al., 2012; Yang et al., 2013; Huang et al., 2013). Over the last 10 years, with the advancement of microbeam analysis of zircon U–Pb and Lu–Hf isotopes, more detailed and reliable information from Archean TTG suites has been obtained (e.g. Qiu et al., 2000; Griffin et al., 2004; Davis et al., 2005; Halpin et al., 2005; Zhang et al., 2006a; Jiao et al., 2009; Kemp et al., 2010; Gao et al., 2011; Chen et al., 2013). Based on new data, significant insights into the complex formation mechanisms of Archean cratons has been gained, particularly regarding whether such cratons originate from accretion of new crustal additions or from the reworking of a pre-existing crust (Andersen et al., 2002; Griffin et al., 2004;

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Woodhead et al., 2004; Gerdes and Zeh, 2009; Kemp et al., 2009; Hawkesworth et al., 2010; Sarma et al., 2012; Huang et al., 2013).

However, most Archean TTGs experienced complex subsequent reworking and alteration, which makes dating them extremely challenging. Unlike the well-studied North China craton, which shows widespread exposure of Archean rocks back to ~3.8 Ga and has a complex and multi-stage growth history (Song et al., 1996; Zhao et al., 2001, 2005, 2007, 2010, 2012; Gao et al., 2004; Zheng et al., 2004; Wilde and Zhao, 2005; Lu et al., 2008; Wu et al., 2008a; Nutman et al., 2011; Peng et al., 2011, 2012b; Zhai and Santosh, 2011; Geng et al., 2012; Li et al., 2012; Liu et al., 2012a,b,c; Wu et al., 2012a; Zhao and Zhai, 2013), the Yangtze craton consists mainly of Proterozoic rocks with only sporadic outcrops of Archean basement in the Kongling terrain (Chen and Jahn, 1998; Gao et al., 1999, 2011; Qiu et al., 2000; Wu et al., 2012b), which makes the study of the Archean basement of the Yangtze Block limited to the Kongling terrain. Exploring the Yangtze Block for other outcrops of Archean basement is important for gaining further understanding of the formation and evolution of the Yangtze craton.

Although some Archean zircons (xenocrysts) have been reported in various places in the Yangtze craton and in the northern Dabie Orogen (Zheng et al., (2006, 2006c, 2008, 2009); Sun et al., 2008; Wu et al., 2008b; Zheng et al., 2006), Archean outcrops within the Yangtze craton have been spotted only in the Kongling terrain. Recently, findings of a Neoarchean K-granite pluton emplaced within the Yangpo Group have opened a new window to study the formation and evolution of the Yangtze craton (Wang et al., 2013b).

In this work, we report on the whole-rock major and trace elements and the zircon Laser Ablation Inductively Coupled Plasma Mass Spectrometry (LA-ICP-MS) U–Pb ages of the Yangpo Group and the granite pluton emplaced within this group in Huji town, Zhongxiang City, Hubei Province. Our new data, combined with recent results from research conducted in the Yangtze craton (Chen et al., 2013), reveal three main events that occurred during the early evolution of the Yangtze Craton in the Neoarchean: the basin filling at ~2800–2700 Ma, the plate colliding at ~2700–2680 Ma and the plate rifting at ~2680–2620 Ma.

2. Geological setting and sampling

The South China block was formed by the middle Neoproterozoic continental collision between the Yangtze craton and the Cathaysia block, though the timing of the collision is still controversial with one school of thought arguing that it occurred coincidently with the global-scale Grenvillian events that led to the assembly of Rodinia (Li et al., 2002, 2008), whereas others consider that it happened at 860–800 Ma (Zhao and Cawood, 2012; Dong et al., 2011, 2012; Shu et al., 2011; Wang et al., 2012a,b,c, 2013a; Zhang et al., 2012a,b, 2013b; Yao et al., 2013; Xu et al., 2013).

According to the tectonic paleogeographic framework from Neoproterozoic to Mesozoic Era (Liu and Xu, 1994), Yangtze Craton could be divided into three units in common, named the Upper Yangtze lying in the west of Shennongjia and Enshi City, Lower Yangtze which is located in the east of Poyang Lake and Jiujiang City, and Central Yangtze between them (Fig. 1a). Geographically, the Central Yangtze Block is comprised of the most of Hubei Province and the northwestern of Hunan Province.

The Yangpo Group outcrop area extends along a northwest-striking narrow belt (Fangmashan–Yangjiapo), over an area of about 8 km^2 in the Huji area of Zhongxiang City. It lies along the west bank of the Hanshui River in the interior of the Central Yangtze Block. This depositional sequence is overlain by tillite of the Nantuo Formation of the Nanhua System to the west, and covered by Quaternary sediments to the east. Intrusions of K-granites were found in the northern and southern reaches of the Yangpo Group. Thus, the Yangpo sequence is considered to constitute the basement rocks of the Yangpo horst in the Zhongxiang fault-rift (BGMRHP, 1990) (Fig. 1b). However, the Yangpo Group is not completely exposed, since its base was intruded and therefore obscured by the K-granite pluton.

The Yangpo Group is composed mainly of quartz schists, granulite, quartzite, and quartzose wackestone, with a few amphibolite intercalations (BGMRHP, 1990). These observations suggest that the protolith was a shallow marine shelf sedimentary sequence deposited in a relatively stable tectonic setting. Geologic mapping indicates that the K-granites emplaced within the Yangpo Group are mainly stocks or apophyses, with the largest stock (about 3 km^2) located in the area from Jinshan to Wangji village in Huji town (Fig. 1b). Macroscopically, the oriented biotites impart a bedded appearance or striped structure to the granites.

The samples for this study were collected at Yangpo (YP-1 and YPH-1, 3, 4, 5, 6, 7, 8) in the west and in Yaozishan (YPH-9 and YPH-11) in the northwestern part of Wangji village, Huji Town. The GPS coordinates of the two locations are N31°28′51″, E112°14′11″, and N31°30′14″, E112°13′22″, respectively. Sample JS-1 for the zircon LA-ICP-MS U–Pb dating was collected from the Jinshan granite pluton (Wang et al., 2013).

The quartz schist samples are light-gray or light-yellow with schistose textures (Fig. 2(a)). The major minerals are quartz (80–85%) and mica (15–20%). Magnetite, ilmenite, apatite, and zircon are the main accessory minerals (<1%), and only a small amount of feldspar was found. The quartzes were mainly pisolitic in shape, and irregularly intercalated with biotite or muscovite. Some large grains contained mica micro-crystals, mainly biotite and muscovite. The muscovite crystals may have been transformed by diaphthoresis of the biotite by liberating ferrous ion. Some quartz crystals clearly show wavy extinction.

The granitic rock samples are purplish-red with coarse-grained porphyritic textures (Fig. 2(b)). The major minerals are K-feldspar (30–40%), plagioclase (20–35%), quartz (18–25%), and biotite (<5%). Ilmenite, apatite, and zircon are the main accessory minerals (<1%). The K-feldspars (~2–5 mm in diameter) are mainly orthoclase with minor perthite and microcline. They are granular in shape, and irregularly intercalated with plagioclase. Some large grains generally contain quartz and plagioclase micro-crystals. The plagioclases are mainly oligoclase and albites characterized by regular tabular crystals and the development of multiple twinning, with some grains containing quartz micro-crystals. The quartz occurs as subhedral to anhedral crystals of 0.5–1 mm diameter that irregularly fill the gaps between the feldspars. Some quartz crystals show wavy extinction.

3. Analytical methods

3.1. Whole-rock major and trace element analyses

The whole-rock major elements were analyzed by X-ray fluorescence (XRF) using glass disks at the Southwest Monitoring Center of Geological and Mineral Resources, Ministry of Land and Resources, PRC. The FeO contents were determined using a wet chemical method. The analytical precision and accuracy were better than 5% based on international analysis standards BCR-2, GSR-1, and GSR-3. The whole-rock trace elements were analyzed at the State Key Laboratory of Geological Processes and Mineral Resources, China University of Geosciences, Wuhan. About 50 mg of powdered sample was digested by $HF + HNO_3$ in Teflon bombs and analyzed with an Agilent 7500a ICP-MS. The analytical precision was better than 5% for elements with concentrations greater than 10 ppm, and less than 10% for those with concentra-