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Geochronological and geochemical evidence for the nature of the Dongling Complex in South China

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ABSTRACT

The ancient basement of the Yangtze craton in South China is poorly exposed and its early evolution is loosely constrained yet. The Dongling Complex is usually advocated as the ancient basement of the Yangtze craton without an intensive study yet. Schist and gneiss from the Dongling Complex have high SiO_2 and Al_2O_3 contents, low CIA values. Their REE and trace element distribution patterns are similar to PAAS and average upper crust. Their $\delta^{18}O$ values are generally higher than 10‰ for quartz, demonstrating a sedimentary origin for their protolith. Detrital zircon U–Pb dating yields three distinct age populations for the Dongling metasediments: (1) >2.4 Ga with negative $\varepsilon_{Hf}(t)$ values, mostly on cores and unzoned grains; (2) ~2.0 Ga with negative $\varepsilon_{Hf}(t)$ values on weak luminance and unzoned domains; (3) 730–830 Ma with $\varepsilon_{Hf}(t)$ values ranging from −24.8 to 4.9 on oscillatory zonings and fragmented euhedral grains. The zircons of different U–Pb ages exhibit similar REE patterns but different Ti-in-zircon temperatures. The zircon age populations are consistent with provenances from both the Yangtze craton and the Jiangnan orogen for the Dongling sediments. The youngest detrital zircon age of 731 ± 13 Ma provides an upper limit for the deposition age; the geological occurrence of overlying strata provides a lower limit of 635 Ma for the deposition age. In view of the extensional setting in South China during the middle Neoproterozoic, the most plausible tectonic environment for deposition of the Dongling sediments is a failed continental rift basin between the Yangtze craton and the Jiangnan orogen. Therefore, the Dongling Complex is not the ancient basement of the Yangtze craton despite the involvement of some basement materials in its protolith.

1. Introduction

The Yangtze craton in South China is a small and special one compared to classical cratons elsewhere in the world, for instance of the Kaapvaal craton in South Africa (Jahn and Condie, 1995), the Pilbara craton in Australia (Van Kranendonk et al., 2007), the Slave craton in Canada (Isachsen and Bowring, 1994), and the North China craton (Zhao and Zhai, 2013). Usually, this is ascribed to its poor exposure of the ancient basement (e.g., Chen and Jahn, 1998; Zheng and Zhang, 2007; Zhang and Zheng, 2013; Zheng et al., 2013). Crystalline rocks of Archean U–Pb ages were reported only in the northern part of the Yangtze craton, i.e., the Kongling complex (Gao et al., 2001, 2011; Zhang et al., 2006a; Wu et al., 2009; Chen et al., 2013; Guo et al., 2014). A few fragmentary rocks were reported to have Archean age, including the ~2.76 Ga Huangtuling granulite (Wu et al., 2008), the ~2.7 Ga Jinshan granite (Wang et al., 2013a), the ~2.5 Ga Douling Complex (Hu et al., 2013), the ~2.6 Ga Yudongzi complex (Zhang et al., 2010; Wang et al., 2011) and ~2.5 Ga Nanhuang gneiss (Tu et al., 2001). Available studies on the basement growth and evolution history of the Yangtze craton are unexceptionally based on the results from these Archean rocks. However, it is still intriguing how the Yangtze craton was formed and evolved to its modern state.

On the other hand, the ancient basement of the Yangtze craton may be more widespread than exposed on the surface. This is indicated by geophysical observation (An and Shi, 2006), detrital zircon U–Pb ages from volcanoes (Zhang et al., 2003; Zheng et al., 2006) and Re–Os model ages from the subcontinental lithospheric mantle peridotite (Reisberg et al., 2005; Zhang et al., 2008a). Besides the Kongling complex in the Yichang area of Hubei Province, the Dongling Complex in the Anqing area of Anhui Province was considered as another possible but poorly studied basement of the Yangtze craton (Dong and Qiu, 1993; Xing et al., 1993; Chang et al., 1996). In this regard, a comprehensive study of the Dongling Complex will improve our understanding of this special craton. This paper presents a combined geochronological and geochemical

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study of metamorphic rocks from the Dongling Complex. The results place tight constraints on the deposition and metamorphic ages for the Dongling Complex, providing insights into the tectonic evolution of ancient basement in the Yangtze craton.

2. Geological setting and samples

The Yangtze craton is the ancient continental nucleus of the South China Block (Fig. 1a). Together with the North China craton and the Tarim craton, it builds up the three major cratons of China (Zhao and Cawood, 2012). It is tectonically bordered by the Qinling-Tongbai-Hong'an-Dabie-Sulu orogenic belt in the north, by the Jiangnan orogen in the southeast and by the Kang-Dian rift in the west (Zheng et al., 2013). The South China Block is composed of the Yangtze craton, the Jiangnan orogen and the Cathaysian terrane (Zhang and Zheng, 2013). In the literature, the Yangtze Block was usually defined to represent a Precambrian landmass in South China that is composed of the Yangtze craton and its surrounding Neoproterozoic orogens and separated from the Cathaysian Block in its southeast along the Jiangshan-Shaoxing fault in the northeast and Chenzhou-Linwu fault in the southwest. Increasing studies of various rocks from the Jiangnan orogen indicate that this orogen is substantially an accretionary-type arc-continent collision orogen that is much wider than traditionally thought (Fig. 1a). It is primarily composed of early to middle Neoproterozoic magmatic rocks and weakly metamorphic rocks. All these rocks would originally be oceanic and continental arcs and their adjacent accretionary wedge (Zheng et al., 2013), but underwent repeated reworking primarily in two episodes of tectonism. One is the arc-continent collision at about 820–800 Ma (Zhang et al., 2012) and the other is the continental extension in response to the breakup of supercontinent Rodinia at about 780–740 Ma (Zheng et al., 2013). Because of these tectonic overprinting, the northwestern zone of the Jiangnan orogen was considered as part of the Yangtze Block, whereas the southeastern zone was considered as the part of the Cathaysian Block. Substantially, the Cathaysian Block would be composed of the Cathaysian terrane and its adjacent southeastern zone of the Jiangnan orogen. It was also called as the Cathaysian Foldbelt in some literature because of its strong deformation in the Mesozoic. In contrast, there is only weak deformation in the Yangtze Block.

The existing studies on the metamorphic rocks of Archean age in the Yangtze craton are primarily derived from the Kongling Complex in Yichang City of Hubei province. Available results have convincingly demonstrated that growth of the Yangtze craton can be traced back to as early as 3.8 Ga with multiple episodes of magmatism and metamorphism in the Archean and Paleoproterozoic (Gao et al., 2001, 2011; Zhang et al., 2006a,b; Wu et al., 2009; Chen et al., 2013; Guo et al., 2014). A compilation of zircon U–Pb ages throughout the Yangtze craton exhibits two peaks of magmatism at 2.9–3.0 Ga and ~2.5 Ga, respectively, and the extensive reworking of preexisting crust and the growth of juvenile crust in the middle Paleoproterozoic (Zhang and Zheng, 2013). Then it experienced a silent period of Mesoproterozoic era with very limited magmatism. The Neoproterozoic magmatism is widespread in the periphery of the Yangtze craton, primarily falling in two episodes of about 830–800 Ma and 780–740 Ma, respectively (Li et al., 2003a; Zheng et al., 2008, 2009; Zhang and Zheng, 2013). The Neoproterozoic magmatism could have destructed the ancient basement of the Yangtze craton significantly. Subsequently, nearly continued strata developed from Cryogenian to Cenozoic on the whole Yangtze craton and its adjacent regions.

The Dongling Complex in Anqing City of Anhui province was traditionally named as the Dongling Group in the regional geological survey. It lies in the middle of the Middle-Lower Yangtze Valley, geographically southeast to the Dabie orogen (Fig. 1a). Tectonically it is traditionally assigned in the southeastern edge of the Yangtze Block. It is exposed in an area of 20–30 km^2 near the Hongzhen Town in Anqing City. Samples from drilling cores in the geological survey showed that metamorphic rocks of the Dongling Complex are composed of phyllite, muscovite quartz schist, albite quartz schist, interlayered with silicate layers and amphibolitic schist in the upper part, and biotite plagioclase gneiss, biotite K-feldspar gneiss and amphibolites in the lower part (Anhui, 1987). These lithologies suggest that their protoliths may be of sedimentary and volcanic origins. Thickness of the bulk metamorphic sequence is about 1600 m.

The Dongling Complex occurs as an elongated anticline with a trend of NE40°. It was intruded by the Mesozoic Hongzhen granite in the southeast that has an Ar/Ar platform age of 127.7 Ma (no error reported, Zhou et al., 1988) and a zircon U–Pb age of 126.8 ± 1.0 Ma (Zhang et al., 2011). It is overlain by continuous sedimentary sequence from Sinian (the traditional name for Cryogenian and Ediacaran) to Permian in its west and north, which are then uncomfortably covered by Cretaceous strata (Anhui, 1987). In detail, the strata which are in direct contact with the Dongling Complex range from lower Sinian (~800–635 Ma) to upper Ordovician. Preliminary studies by geological surveys gave whole-rock Sm–Nd isochron ages of 1895 ± 72 Ma (Xing et al., 1993) and 1439 ± 56 Ma (Dong and Qiu, 1993) for the amphibolites and gneisses. Single zircon evaporation $^{207}Pb/^{206}Pb$ dating yielded variable ages from 2372 ± 10 Ma to 692 ± 10 Ma (Grimmer et al., 2003).

Samples used in this study were collected from several localities in the Dongling Complex. The sampled rocks include muscovite quartz schist, feldspar quartz schist and gneiss. In a tectonic sequence, six samples 09AQ12–09AQ17 are from the upper part and three samples 09AQ24–09AQ26 are from the lower part (Fig. 1b). Field observations show that rocks in the southwestern part of the Dongling Complex are mainly muscovite quartz schists with well-developed foliation, whereas rocks in its northeastern part are mainly gneisses of granitic composition with obvious gneissic texture.

Thin sections were prepared for the all samples in order to examine their petrography under a microscope. The thin section examination shows that the muscovite quartz schists are primarily composed of 80–90% quartz, 5–10% muscovite, minor plagioclase and biotite, with accessory apatite and rutile (Fig. 2a and b). The orientation of mica is well developed. The quartz grains are usually granular but some are elongated. Many quartz grains have serrate boundaries. The feldspar quartz schist is composed of about 85% quartz, 10% plagioclase, minor muscovite and accessory minerals (Fig. 2c). The orientation of minerals is not obvious although foliation is well developed in hand specimen. The gneisses of granitic composition are composed of 60–75% quartz, 15–30% K-feldspar and 10–15% plagioclase with minor muscovite (Fig. 2d).

3. Analytical methods

Whole-rock major and trace element compositions were analyzed by XRF and ICP-MS at the ALS Chemex Company in Guangzhou, China. The analytical procedure is similar with that described by Chen et al. (2014). A national standard (granitic gneiss GSR-14) was simultaneously analyzed to monitor the analytical quality. The uncertainty is within ±2% for major elements and within ±5% for most trace elements.

Mineral oxygen isotopes were analyzed by the laser fluorination technique at CAS Key Laboratory of Crust-Mantle Materials and Environments in University of Science and Technology of China, Hefei. O_2 was extracted from the minerals by a CO_2 laser