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Detrital zircon U-Pb and Hf isotopic data from the Liuling Group in the South Qinling belt: Provenance and tectonic implications

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ABSTRACT

The Liuling Group is exposed in the Northern part of the South Qinling orogenic belt. LA-ICP-MS U-Pb analysis of detrital zircons from the meta-sandstones in this Group yields ages ranging between 400 Ma and 3200 Ma, with three prominent age clusters at 500–400 Ma, 850–700 Ma and 1000–900 Ma. A few older zircon populations with U–Pb ages of 1750–1450 Ma, 2000 Ma and 2600–2400 Ma are also present. Age data integrated with cathodoluminescence, trace element data and $\varepsilon_{Hf}(t)$ values of zircon grains show that the Liuling sediments have a complex source. Source rocks mainly include Early Neoproterozoic and Early Paleozoic granitoids, together with minor ultra-high pressure/high pressure (HP-UHP) metamorphic rocks, and paragneiss in the North Qinling belt, and Middle-Late Neoproterozoic magmatic rocks in the South Qinling belt. The dominant population of detrital zircon grains with ages between 500 Ma and 400 Ma show the characteristics of both magmatic and metamorphic zircons. They show three age clusters at 497 Ma, 451 Ma, and ca. 420 Ma and show marked correlation with the three stages of Palaeozoic magmatism, as well as with the peak and retrograde HP-UHP metamorphic stages in the North Qinling belt. This correlation demonstrates that these Early Palaeozoic granitoids and HP-UHP metamorphic rocks in the North Qinling belt were already exhumed to the surface, underwent erosion prior to Middle Devonian time and were then deposited in an extensional basin. Based on the results from detrital zircon U-Pb dating, combined with geochemical data and the regional geology, the deposition of Liuling sediments is inferred to have occurred in a post-orogenic extensional basin, rather than a subduction-related fore-arc basin or a foreland basin formed during or after continental collision.

1. Introduction

The exhumation of ancient orogens leads to erosion and deposition of detritus into sedimentary basin. The composition, age and successions of clastic sediments provide important constraints on the tectonic evolution of the orogen from where the sediments are sourced (Taylor and McLennan, 1985). Detrital zircons in clastic sediments are sourced through weathering of rocks in the provenance and their geochronology provides a powerful tool for provenance analysis, particularly for reconstructing crustal evolution and tectonics (e.g., Roback and Walker, 1995; Ireland et al., 1998; Hoskin and Ireland, 2000; Fedo et al., 2003; Adams et al., 2007; Cawood et al., 2007; Yang et al., 2010; Wang et al., 2013a; George, 2014). Generally, sedimentary provenance studies use similarities between the detrital zircon age spectra and potential source regions to make interpretations. However, this approach has limitations because of the biases in apparent zircon age populations due to insufficient analyses with equivalent age events unrelated to tectonic systems (Andersen, 2005; Howard et al., 2009). To overcome this limitation, additional information, such as (1) careful analysis of cathodoluminscence (CL) images of detrital zircons (Fedo et al., 2003; Tucker et al., 2013); (2) zircon REE pattern and other trace element (e.g., Belousova et al., 2002; Rubatto, 2002); and (3) zircon Lu-Hf isotope data (e.g., Howard et al., 2009) are employed.

The Middle-Upper Devonian Liuling Group is exposed in the northern part of the South Qinling belt in northwestern China. Previous studies have addressed the regional geology (Mattauer et al., 1985; Xu et al., 1988; Yu and Meng, 1995; Zhang et al., 2001; Zhou

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et al., 2002), sedimentology (Meng, 1994; Meng et al., 1995; Mei et al., 1999), geochemistry (Gao et al., 1995; Yan et al., 2007, 2012) and detrital zircon geochronology (Duan, 2010; Dong et al., 2013; Chen et al., 2014a) of the sedimentary rocks from the Liuling Group. However, the provenance of the sediments and their depositional setting are debated with diverse models including: (1) an active continental margin basin or a fore-arc basin as a result of northward subduction of oceanic crust (Mei et al., 1999; Chen et al., 2014a; Yan et al., 2007, 2012, 2016; Liu et al., 2013b); (2) a foreland basin formed after the continental collision between North China and Yangtze Blocks (Ren et al., 1991; Dong et al., 2013); and (3) a rift basin in extensional setting (Meng et al., 1995; Zhou et al., 2002). In this paper, we present new LA-ICP-MS U-Pb age and Lu-Hf isotope data of detrital zircons from the Middle Devonian Liuling Group integrated with CL images and trace element analysis in order to constrain the provenance and tectonic setting.

2. Geological setting

The Qinling orogenic belt, located between the North China Block and the South China Block, is a collage of multiple orogenic systems (Dong and Santosh, 2016). This belt is located in a key tectonic position in Central China linking the Tongbai-Hong'an-Dabie Mountains in the east and the Qilian and Kunlun Mountains to the west. Geologic framework of the major units in the Qinling region (and parts of the Qinling orogen located in the western side of Nanyang basin) from north to south and surrounding basement blocks (Fig. 1a) are described in the following subsections.

2.1. North China Block

In the North China Block (NCB), Precambrian basement rocks are dominated by Neoarchean tonalite–trondhjemite–granodiorite (TTG) gneisses and Paleo-Neoproterozoic sedimentary sequences (e.g., Wilde and Zhao, 2005; Wilde et al., 2005; Zhai and Liu, 2003; Zhai and Santosh, 2011; Zhao et al., 2000, 2002, 2005; Zhao and Zhai, 2013; Yang et al., 2016). Zircon U–Pb ages for the gneisses mostly range from late Archean to early Paleoproterozoic with age peak at 2.6–2.5 Ga (Fig. 2a; e.g., Zhao, 2001; Zhao et al., 2002, 2007, 2010a; Wilde et al., 2005; Wan et al., 2011a; Zhao and Zhai, 2013, and reference therein). The basement rocks of the NCB underwent regional amphibolite - to granulite - facies metamorphism at 1.95–1.8 Ga (Fig. 2a; e.g., Zhao et al., 2000; Wan et al., 2006, 2011a; Zhai and Liu, 2003; Zhao and Zhai, 2013; Qian et al., 2013, 2015). In addition to the major magmatic and metamorphic events during 2.6–2.5 Ga Ma and 1.95–1.8 Ga (Zhai and Santosh, 2011; Yang and Santosh, 2015), Paleo-Mesoproterozoic multistage rifting is also recorded in the southern margin of the NCB, represented by the Xiong'er volcanic rocks that erupted intermittently during 1.78–1.45 Ga (He et al., 2009; Zhao et al., 2009; Zhai et al., 2014).

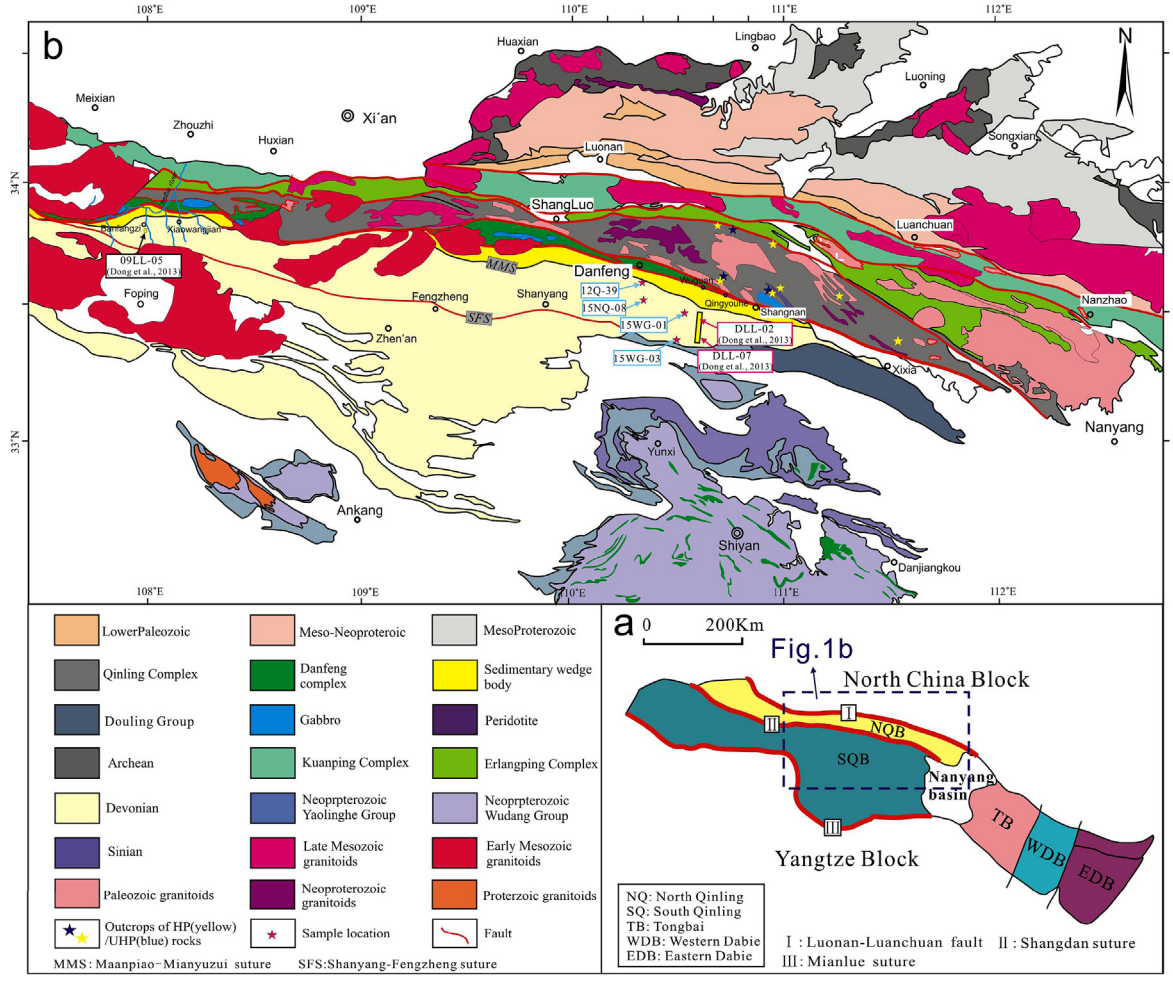

Fig. 1. (a) Simplified geological map showing the location of the Qinling orogen (Dong et al., 2011a). (b) Geological map of the Qinling belt (NQB) showing the major geological units and sample locations. This figure is modified from Fig. 2 by Dong et al. (2013).