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Deep subduction of continental crust in accretionary orogen: Evidence from U–Pb dating on diamond-bearing zircons from the Qinling orogen, central China

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ABSTRACT

Accretionary orogenic belts are considered the most important sites for the generation of continental crust. However, it is still not very clear whether in such settings the continental crust has been significantly transported back to the mantle accompanied with its lateral growth. Continental UHP rocks, the best indicators of the recycling of the continental crust, have rarely been discovered in accretionary orogenic belts, which hinder the exploration of this essential process. The possible occurrence of early Paleozoic UHP metamorphism in the Qinling orogen provides an excellent opportunity to address this question. This article reports an integrated study of U–Pb age, trace element and mineral inclusion of zircon from an amphibolite sample in the Qinling orogen. The zircon crystals show typical metamorphic growth zoning, low Th/U ratios, flat HREE patterns, and insignificant Eu anomalies. They give a weighted mean U–Pb age of 490.4 ± 5.8 Ma. Most importantly, an in situ diamond inclusion was identified from one of the zircon crystals. Therefore, the obtained 490.4 ± 5.8 Ma age was taken as registering the peak UHP metamorphism. The discovery of in situ diamond inclusion provides important evidence for the UHP metamorphism of the Qinling orogen and indicates that the North Qinling microcontinent was subducted to mantle depths of >120 km when it collided with the Erlangping arc attached to the southern margin of the North China Block. Combining with previous results, we suggested that the North Qinling UHP terrane underwent fast exhumation from >120 km to ca. 30 km within 10 Myr intervals. As a few examples of UHP metamorphism have been discovered in some accretionary orogens, more attention needs to be paid to the occurrence of continental UHP metamorphism during accretionary orogenic process. Furthermore, evident crustal growth has been documented in the North Qinling orogen during the early Paleozoic. It is inferred that the accretionary orogenic belts may play important roles in recycling of continental crust into the mantle besides generation of continental crust.

1. Introduction

The growth and evolution of the continental crust have always been significant research topics in earth sciences (e.g. Jahn et al., 2000; Rudnick, 1995). Since the trace element signature of Earth's continental crust resembles that of arc lavas (Davidson and Arculus, 2006; Rudnick and Gao, 2003), the role of accretionary orogenic belts in the generation of continental crust has been widely discussed (e.g. Collins, 2002; Jahn et al., 2000; Wang et al., 2013a). Their contribution to transporting continental crust back to the mantle is still poorly constrained. Although ultra-high pressure (UHP) metamorphism of continental rocks is regarded as the most important witness for recycling of continental crust into the mantle (e.g. Ernst, 2001; Zheng, 2012), clear evidence for UHP metamorphism is poorly documented in composite accretionary orogenic belts (Baldwin et al., 2008; Bostick et al., 2003; Leech and Ernst, 1998). The main reason is that prolonged high heat flow in accretionary orogenic belts induced the repeated occurrence of intensive magmatic and metamorphic activities. Consequently, the early records were easily obliterated by the latter (Stern, 1987, 2002). The resolution of the metamorphic records hinges on the relict inclusions within refractory minerals. Zircon is one of the best containers of relict inclusions because of its resistance to physical and chemical changes (Rubatto and Hermann, 2007). In addition, in situ zircon U–Pb dating can be used as a powerful tool to reveal different stages of metamorphic history (Foster et al., 2001; Liu and Liou, 2011; Rubatto and Hermann, 2007; Wu et al., 2007). Consequently, a combined study of mineral inclusion with in situ U–Pb dating of zircon can provide

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an effective approach not only to recognize the possible occurrence of UHP metamorphism in accretionary orogenic belts, but also to relate its U–Pb ages to specific metamorphic P–T conditions (Liu and Liou, 2011; Rubatto and Hermann, 2007; Wang et al., 2011a; Wu et al., 2009a).

The Qinling–Tongbai–Dabie orogenic belt was formed by multi-stage amalgamation among the South China Block (SCB), the North China Block (NCB) and their interposed microcontinent and/or island arc (Wu and Zheng, 2013 and the references therein). The final continental collision was recorded by the Triassic UHP metamorphism in the Dabie orogen (Zheng, 2008 and references therein), whereas the Paleozoic accretion process occurred in the Qinling–Tongbai orogen. The North Qinling (NQ) orogen was viewed as registering early Paleozoic events with evident crustal growth and potential (U)HP metamorphic relic (Ratschbacher et al., 2003; Wang et al., 2011b, 2013a, b), and thus provides an excellent target to explore the deep subduction of continental crust during accretionary orogenic process. Although both coesite pseudomorph and diamond were reported in the eclogite and gneiss of the NQ microcontinent (Hu et al., 1995; Yang et al., 2003), these findings were limited in the Guanpo area, in the northernmost part of the NQ microcontinent. In addition, some investigators questioned the UHP metamorphism of the NQ microcontinent, due to the enlarged secondary electron image showing the existence of diamond in small holes on the surface of zircon crystals and failed confirmation of their presence by the subsequent extensive search (Liou et al., 2009). In this study, micro-Raman spectroscopy was employed to analyze inclusions in zircon crystals, which confirmed the presence of diamond in the NQ microcontinent. U–Pb dating was performed on these zircon crystals by means of the LA-ICPMS method, which was used to constrain the exact age of the peak diamond-phase UHP metamorphism of the Qinling orogen. In the light of these results, here we document the deep subduction of continental crust during the accretionary orogenic process and its implication for the tectonic evolution of the Qinling orogen was discussed as well.

2. Geological setting and samples

The Qinling orogen is divided into the South and North Qinling orogens by the Shangdan Fault (SDF) (Fig. 1) (Dong et al., 2011a; Meng and Zhang, 1999). The rock associations of the South Qinling (SQ) orogen are comparable with those of the northern margin of the SCB (Hu et al., 2013; Mattauer et al., 1985; Ratschbacher et al., 2003; Zhang et al., 2001). Triassic HP blueschists and garnet amphibolites in the SQ orogen (Mattauer et al., 1985; Ratschbacher et al., 2003) may correspond to the Triassic HP–UHP rocks in the Tongbai–Dabie–Sulu orogenic belt (Liu et al., 2008; Wu et al., 2008; Zheng, 2008). The NQ orogen includes three fault-bounded, penetrative deformed units from north to south: the Kuanping, Erlangping, and the NQ units (Fig. 1) (Wu and Zheng, 2013 and the references therein).

The Kuanping unit comprises at least two subunits, containing meta-basites (greenschists and amphibolites) and meta-sedimentary rocks (quartz-rich micaschists, quartzites, and marbles) (Liu et al., 2011; Wu and Zheng, 2013 and the references therein). The meta-basites have Proterozoic ages of ca. 900–600 Ma (Diwu et al., 2010; Yan et al., 2008), and the meta-sedimentary rocks show detrital age spectra comparable with those of the NQ unit (Diwu et al., 2010; Liu et al., 2013a; Shi et al., 2013; Zhu et al., 2011). Three in situ zircon SHRIMP U–Pb isotopic analyses on a meta-tuff sample yielded a weighted mean of 492.7 ± 3.9 Ma (MSWD = 0.9) with low Th/U ratios of 0.03–0.05, which was suggested to record the metamorphic age of the

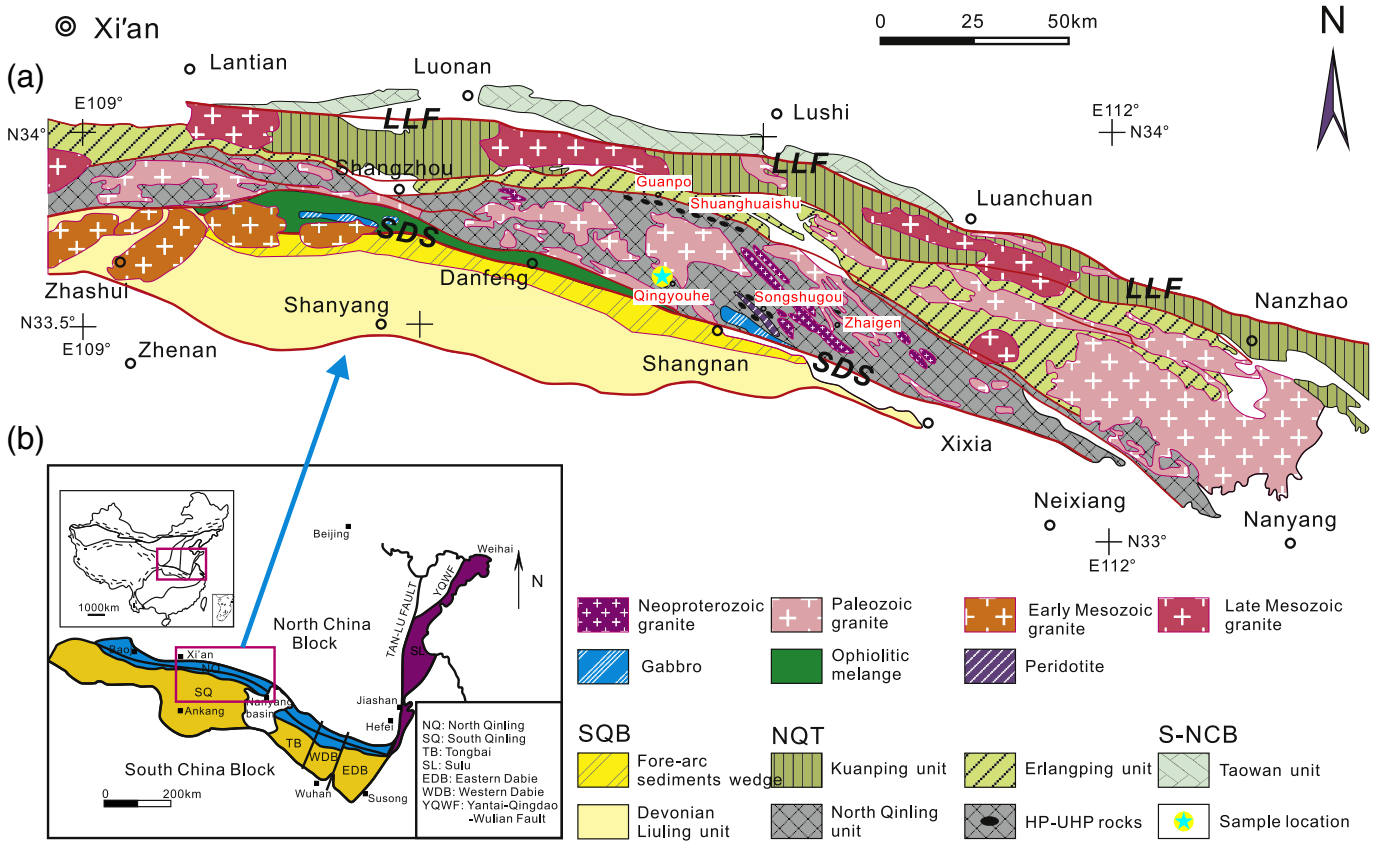

Fig. 1. Geological sketch of the NQ terrane with inserted map showing the Qinling–Dabie–Sulu orogenic belt. SDS: Shangdan suture; LLF: Luonan–Luanchuan Fault. Modified after Dong et al. (2011c).