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Zircon Hf–O isotope and whole-rock geochemical constraints on origin of postcollisional mafic to felsic dykes in the Sulu orogen

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ABSTRACT

Postcollisional mafic to felsic dykes in the western part of the Sulu orogen consist of monzogranite, diorite, plagioclase-bearing hornblendite and gabbro. LA-ICPMS zircon U–Pb dating yielded broadly consistent ages of 111 ± 3 to 129 ± 1 Ma for their crystallization, with Neoproterozoic ages of 743 ± 9 to 773 ± 9 Ma for residual cores. The mafic to felsic dykes are characterized by the arc-like patterns of trace element distribution with positive LILE and LREE anomalies but negative HFSE anomalies in the spidergram. They have high initial $^{87}Sr/^{86}Sr$ ratios of 0.7079 to 0.7100 and variably negative $\varepsilon_{Nd}(t)$ values of −21.6 to −13.6 for whole-rock. Zircons also have highly negative $\varepsilon_{Hf}(t)$ values of −36.7 to −10.6, with two-stage Hf model ages of 1.84 to 3.47 Ga. The zircons exhibit relatively consistent $\delta^{18}O$ values of 4.57 to 5.98‰, only some of them being slightly deviated from those for the normal mantle. The radiogenic isotope signatures for the mafic dykes require their derivations from isotopically enriched mantle sources, whereas the trace element compositions suggest that the mantle sources were metasomatized by arc-like crustal melts. Thus, the mantle sources may be generated by the reaction between the mantle-wedge peridotite and the felsic melts from the subducting continental crust during the Triassic continental collision. Nevertheless, there are significant differences in some element contents and slight differences in Nd–Hf isotope compositions between the gabbro and hornblendite, suggesting their derivation from different compositions of orogenic lithospheric mantle. The gabbro has relatively high MgO, Cr and Ni contents but low Al_2O_3 contents, indicating its derivation from an orthopyroxene-rich mantle source. The hornblendite displays relatively high Al_2O_3 and K_2O contents but low MgO, Cr and Ni contents, suggesting its derivation from a hydrous (amphibole-rich) mantle source. On the other hand, there are general similarities in element and isotope characteristics between the felsic-intermediate dykes (monzogranite and diorite) and the widespread postcollisional Early Cretaceous granitoids in the Dabie–Sulu orogenic belt. This indicates their derivation from similar crustal sources, i.e. the subducted continental crust of the South China Block. Therefore, the mafic to felsic dykes originated from partial melting of the orogenic lithosphere that included ultramafic pyroxenite and hornblendite which acted as sources for the mafic magmatism.

1. Introduction

Pyroxenite and hornblendite are the second and third most common ultramafic rocks after peridotite in the upper mantle. They can form by reaction of mantle-wedge peridotite with adakitic to felsic melts derived from the subducting oceanic crust (Kogiso et al., 2004; Pertermann and Hirschmann, 2003; Yaxley and Green, 1998). Like peridotite, partial melting of the two ultramafic rocks can produce mafic melts, which commonly show either island arc basalts (IAB)-like or oceanic island basalts (OIB)-like patterns of trace element distribution (Kelemen et al., 1998; Pilet et al., 2008; Sobolev et al., 2007; Zhang et al., 2009). In this regard, the crust–mantle interaction in oceanic subduction zones is recorded by the two ultramafic rocks via the melt-peridotite reaction. As a consequence, the two ultramafic rocks have became an important lithology in mantle petrology because partial melting of them is capable of producing many geochemical features observed in various mafic igneous rocks which otherwise cannot be produced by partial melting of the peridotite lithology.

While crust–mantle interaction is explicit by the melt-peridotite reaction during subduction of the oceanic crust, it is unclear whether there is crust–mantle interaction during subduction of the continental crust. Findings of coesite and microdiamond in regional metamorphic rocks of supracrustal origin demonstrate that the continental crust can be subducted to mantle depths of greater than 100 km (Chopin, 2003; Zheng, 2008). In this regard, it is intriguing whether postcollisional mafic rocks in continental subduction zones were derived from partial melting of pyroxenite/hornblendite and whether the two ultramafic rocks can be generated by the reaction of the subcontinental lithospheric mantle

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(SCLM)-wedge peridotite with felsic melts derived from the subducting continental crust during continental collision. This can be tested by examination of the collisional orogens where ultrahigh-pressure (UHP) metamorphic rocks were generated by deep subduction of the continental crust. In particular, late- and postcollisional mafic igneous rocks may bear the geochemical record of crust–mantle interaction during continental deep subduction.

Postcollisional mafic rocks are common in the Dabie–Sulu orogenic belt that is generally considered as a result of the Triassic continental collision between the South China Block and the North China Block (e.g., Cong, 1996; Li et al., 1999; Liou et al., 1996; Zheng et al., 2003). This provides us with an excellent opportunity to examine the crust–mantle interaction during continental collision. Previous studies have revealed that the mafic rocks have arc-like patterns of trace element distribution such as positive LREE and LILE anomalies but negative HFSE anomalies in spidergrams, and enriched radiogenic isotope compositions like ancient crust such as high initial Sr isotope ratios and negative $\varepsilon_{Nd}(t)$ values (e.g., Huang et al., 2007; Jahn et al., 1999; Liu et al., 2008; Yang et al., 2004, 2005a; Zhao et al., 2005; Zhao and Zheng, 2009). These geochemical features are generally considered to originate from certain mantle sources with recycling of the subducted continental crust and thus correspond to certain types of crust–mantle interaction (e.g., Guo et al., 2004; Huang et al., 2007; Jahn et al., 1999; Zhao et al., 2005). However, it is still uncertain with respect to the time and mechanism of the crust–mantle interaction as well as the properties of the mantle involved. In particular, it is unclear whether pyroxenite/hornblendite would form as part of the orogenic lithospheric mantle during the continental collision and then served as mantle sources for the postcollisional mafic rocks in the continental collision zone.

Beside the mafic rocks, voluminous postcollisional felsic rocks are also widespread in the Dabie–Sulu orogenic belt (e.g., Guo et al., 2006; Huang et al., 2006; Yang et al., 2005a,b; Zhang et al., 2010). Substantially, all the postcollisional igneous rocks are composed of voluminous granitoid and sporadic mafic-ultramafic plutons, with local volcanic rocks and dykes (e.g., Fan et al., 2001, 2004; Guo et al., 2004; Wang et al., 2005; Yang et al., 2004). Geochronological studies have established that they mainly formed in the Early Cretaceous (e.g., Bryant et al., 2004; Jahn et al., 1999; Zhao et al., 2004, 2005, 2007; Zhao and Zheng, 2009). This provides us with sound targets to understand the origin of continental igneous rocks with reference to the known tectonic background. This paper presents a combined study of zircon U–Pb ages, O and Lu–Hf isotopes as well as whole-rock major-trace elements and Sr–Nd isotopes for postcollisional mafic to felsic dykes in the Sulu orogen. The results are used to examine whether pyroxenite/hornblendite formed by the crust–mantle interaction in the continental collision zone and then served as the mantle source for the continental mafic rocks. As a consequence, geochemical insights are gained not only into the source nature of mafic to felsic dykes, but also into the formation of orogenic lithospheric mantle in the continental collision zone.

2. Geological setting and samples

The Dabie–Sulu orogenic belt formed by the Triassic subduction of the South China Block beneath the North China Block, and it contains the

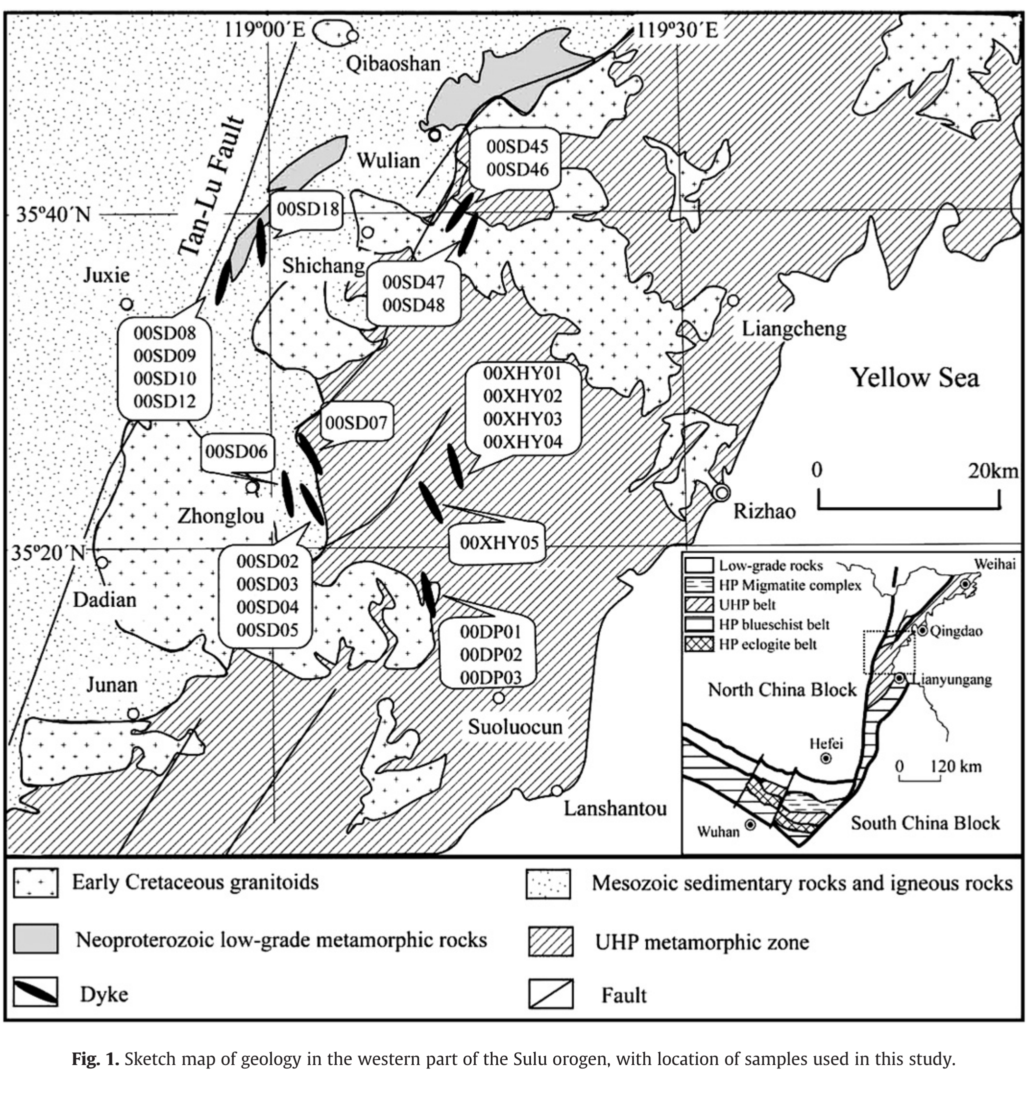

Fig. 1. Sketch map of geology in the western part of the Sulu orogen, with location of samples used in this study.