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Subduction-related metasomatism of the lithospheric mantle beneath the southeastern North China Craton: Evidence from mafic to intermediate dykes in the northern Sulu orogen

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ABSTRACT

The widespread mafic to intermediate dykes in the northern Sulu orogen provide important constrains on mantle source characteristics and geodynamic setting. Here we present LA-ICPMS zircon U–Pb ages which indicate that the dykes were emplaced during Early Cretaceous (~113–108 Ma). The rocks show SiO_2 in the range of 46.2 to 59.5 wt.% and alkalic and shoshonitic affinity with high concentrations of MgO (up to 7.6 wt.%), Cr (up to 422 ppm) and Ni (up to 307 ppm). They are enriched in light rare earth elements LREE (La, Ce, Pr, Nd, Sm and Eu) and large ion lithophile elements (LILE, Rb, Sr, Ba, U and Th) and show strong depletion in high field strength elements (HFSE, Nb, Ta, Ti and P). The dykes possess uniformly high $(^{87}Sr/^{86}Sr)_i$ (0.70824–0.70983), low $\varepsilon_{Nd}(t)$ (−14.0 to −17.4) and $(^{206}Pb/^{204}Pb)_i$ (16.66–17.02) and negative $\varepsilon_{Hf}(t)$ (−23.5 to −13.7). Our results suggest that the source magma did not undergo any significant crustal contamination during ascent. The systematic variation trends between MgO and major and trace elements suggest fractionation of olivine and clinopyroxene. The highly enriched mantle source for these rocks might have involved melts derived from the subducted lower crust of Yangtze Craton that metasomatized the ancient lithospheric mantle of the North China Craton.

1. Introduction

The northern Sulu orogen, located in the southeastern part of the Jiaodong Peninsula, formed through the Triassic subduction of the Yangtze Craton (YC) beneath the North China Craton (NCC) (Wu and Zheng, 2013; Zhang et al., 2009). Previous subduction models were mostly based on results of ultrahigh-pressure (UHP) metamorphic rocks (Zheng, 2008; Zheng et al., 2006). However, fewer studies and progresses have been made for the post-collisional Mesozoic magmatic rocks, especially the Mesozoic mafic to intermediate dykes in the last few decades. The dykes are the primary conduit and pulse for magma transport into the crust from the mantle source (Ernst and Baragar, 1992). The geochemical and isotopic characteristics of the dykes can provide important insights on mantle sources and geodynamic processes (e.g., Girardi et al., 2013; Hastie et al., 2014; Ma et al., 2014). Mafic to intermediate dykes are widely distributed within the Sulu orogen, especially in the Mesozoic gold-mineralized belt of Jiaodong, the largest gold producing region in China (Fan et al., 2003; Goldfarb and Santosh, 2014; Guo et al., 2013; Yang and Santosh, 2015; Yang et al., 2014). The dykes intruded the Precambrian basement as well as the Mesozoic granitoids of the Sulu orogen and in some places they also cut across the gold lodes and have been the focus of several studies (e.g. Cai et al., 2013; Guo et al., 2004; Yang et al., 2004; Zhang et al., 2012). However, their ages, petrogenesis, nature of mantle source and implications on regional dynamics remain equivocal. The main concepts are including: (1) the enriched mantle source of mafic dykes from Jiaodong was related to multiple metasomatic events resulting from subduction-related processes in the Late Archean and Mesoproterozoic (Yang et al., 2004); (2) mantle enrichment was owed to hybridization of the foundered lower crust at mantle depths (Liu et al., 2009a); (3) the dykes were originated from the mixing between mantle-derived mafic and crust-derived felsic magmas (Tan, 2009); (4) the mechanism of source enrichment may be related to source metasomatism caused by the subducted lower crust of the YC (Cai et al., 2013; Zhang et al., 2008, 2012).

In this study, we present the results from zircon U–Pb LA-ICP-MS geochronology and Lu–Hf isotopes, whole rock major and trace element analysis, and Sr–Nd–Pb isotopic compositions in an attempt to investigate the petrogenesis of mafic to intermediate dykes (SMDs) in the northern Sulu orogen. The data are employed to constrain their mantle source, and to evaluate the geodynamic processes.

2. Geological background

The Jiaodong Peninsula is bound by the Tan-Lu fault in the west and the Yangtze Craton (YC) in the south (Fig. 1a). The region separated by

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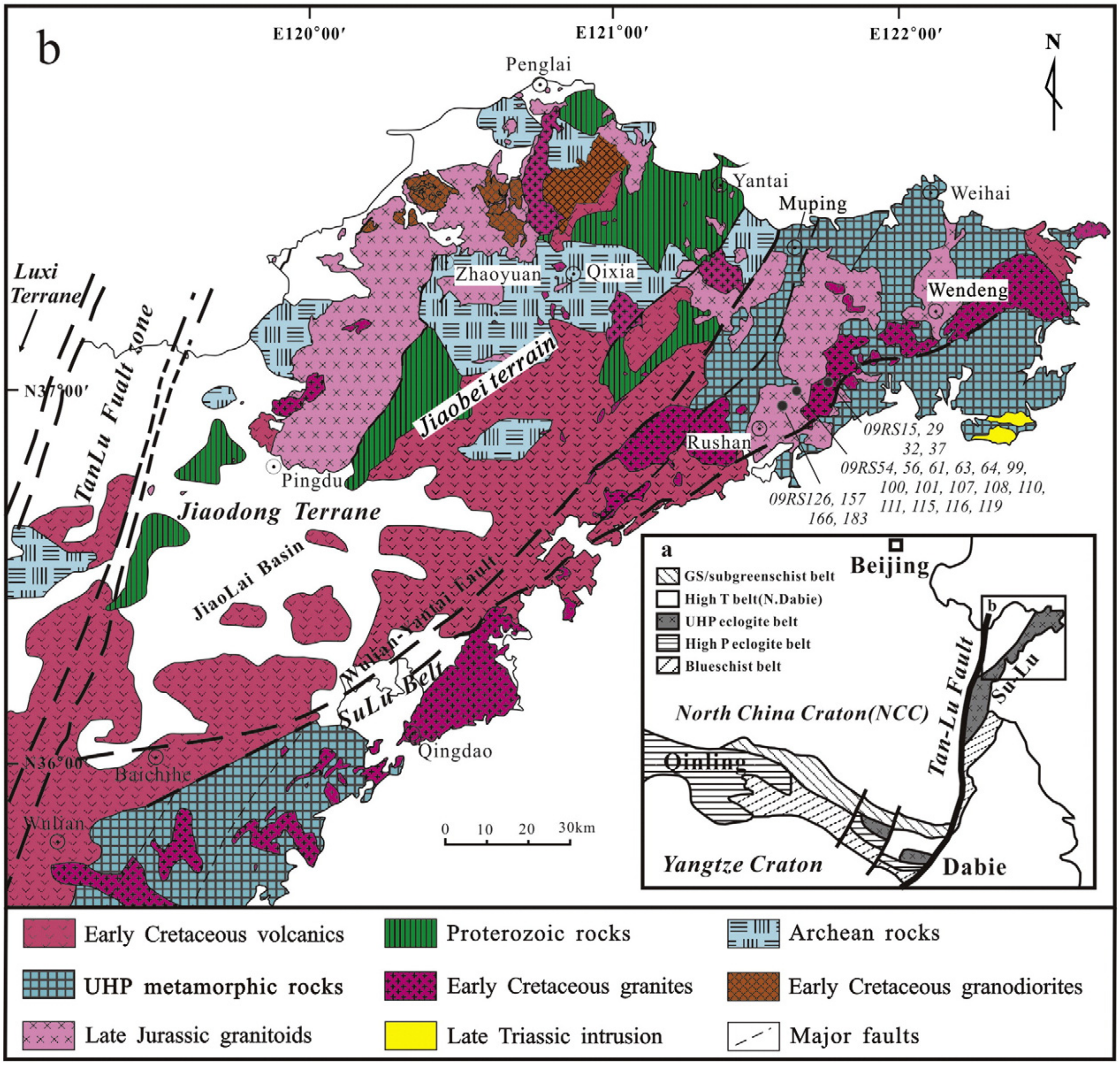

Fig. 1. (a) Simplified geological map showing the major tectonic units of the NCC. (b) Geological map showing distribution of the basement, UHP metamorphic rocks, Mesozoic igneous rocks and sample locations. Panel a is modified after Zheng (2008). Panel b is modified after Goss et al. (2010) and Yang et al. (2012b).

the Wulian-Yantai fault consists of the Jiaobei terrain and Sulu orogen (Zheng et al., 2003). The Jiaobei terrain, located in the northwestern segment of the Jiaodong Peninsula (Fig. 1b), is the southeastern boundary of the NCC. The Precambrian basement rocks in the Jiaobei terrain mainly consists of Neoarchean Jiaodong Group TTG gneisses (tonalite–trondhjemite–granodiorite), Paleoproterozoic Fenzishan and Jinshan Group metasedimentary sequences with ~1.8 Ga amphibolite- to granulite-facies metamorphism, and the Meso-Neoproterozoic Penglai Group (Lu, 1998; Tang et al., 2007, 2008; Wallis et al., 1999; Zhai et al., 2000). Mesozoic magmatic rocks widely occur in the Jiaobei terrain and are mainly composed of the late Jurassic Linglong biotite granite and Luanjiahe monzogranite (150–160 Ma) (Hou et al., 2007; K.F. Yang et al., 2012; Miao et al., 1997; Wang et al., 1998), Early Cretaceous Guojialing granodiorite (126–130 Ma) (K.F. Yang et al., 2012; Miao et al., 1997; Wang et al., 1998; Yang et al., 2014), Cretaceous Qingshan Group volcanic rocks (98–124 Ma) (Liu et al., 2009b; Tang et al., 2008), and widespread mafic dykes (86–132 Ma) (Cai et al., 2013; Liu et al., 2008b; Yang et al., 2004; Zhang et al., 2008). The Early Cretaceous marks a period of extensive gold mineralization in the Jiaobei terrain with the major gold deposits hosted by the Mesozoic granitoids (Fan et al., 2003; Goldfarb and Santosh, 2014; Li and Santosh, 2014; Wang et al., 1998).

The Sulu orogen is considered to have formed by the Triassic northward subduction of the YC beneath the NCC (Cong, 1996; Liou et al., 1996; Zheng et al., 2003). The presence of high-pressure (HP) to ultrahigh-pressure (UHP) minerals such as coesite and diamond inclusions in eclogites within the Sulu orogen (Jahn et al., 1996; Ye et al., 2000) suggest that continental crust was subducted to mantle depths of >200 km. The left-lateral Tan-Lu fault caused major displacement in the Cretaceous transferring the Sulu region from Qinling–Dabie region for nearly 500 km (Li et al., 1999; Okay and Sengör, 1992; Xu et al., 1987; Ye et al., 2000). The UHP metamorphic rocks in the Sulu orogenic belt are mainly composed of Neoproterozoic granitic gneisses with subordinate coesite-bearing eclogites, schist, and quartzite (Huang et al., 2006; Zhang et al., 2012; Zheng et al., 2003). A small syenite complex of age ~210 Ma has been identified at Shidao (Fig. 1b) in the southeastern Jiaodong Peninsular (Chen et al., 2003; Yang et al., 2005). Numerous Mesozoic plutons are exposed within the UHP metamorphic terrane in the Sulu orogen and the late Jurassic granitoids in the eastern part of the orogen include the Duogushan, Wendeng, and Kunyushan plutons,