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Reactivation of the Archean lower crust: Implications for zircon geochronology, elemental and Sr–Nd–Hf isotopic geochemistry of late Mesozoic granitoids from northwestern Jiaodong Terrane, the North China Craton

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ABSTRACT

The late Mesozoic granitoids widely distributed in the northwestern Jiaodong Terrane are important markers of cratonic destruction and lithospheric thinning of the eastern North China Craton (NCC). Here we investigate the Late Jurassic Linglong and Luanjiahe granites and report zircon U–Pb emplacement ages of 157–159 Ma. These rocks also contain abundant late Archean, Paleoproterozoic, Neoproterozoic, early Paleozoic and Triassic inherited zircons, suggesting the involvement of continental crustal materials from both the NCC and Yangtze Craton in magma tectonics. The rocks investigated in this study show high $Na_2O + K_2O$ and low MgO and are peraluminous, with enrichment in LREEs and LILEs (Rb, Ba, U, and Sr) and depletion in HFSEs (Nb, Ta, P, and Ti). They also display low $\varepsilon_{Hf}(t)$ values and high Sr/Y ratios, comparable to adakitic rocks, suggesting that the Linglong and Luanjiahe granitoids formed under relatively high pressure conditions and were likely derived from the partial melting of the thickened lower crust of the NCC. The Guojialing granodiorites were emplaced in the early Cretaceous (129 Ma), and also contain abundant late Archean and Paleoproterozoic inherited zircons. The rocks possess high CaO, TFe_2O_3 and MgO, and are metaluminous, with enrichment in LREEs and LILEs and depletion in HFSEs. They are also characterized by high Sr/Y ratios, and have higher $\varepsilon_{Nd}(t)$ and $\varepsilon_{Hf}(t)$ values than the Late Jurassic granitoids, suggesting the involvement of mantle components in the magmatic source. We correlate the magma tectonics with the processes accompanying the subduction of the Pacific Plate beneath the NCC and the associated asthenospheric upwelling.

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1. Introduction

The North China Craton (NCC) preserves some of the oldest records of crustal evolution in the Precambrian Earth (Liu et al., 1992; Zhai and Santosh, 2011). The eastern part of the NCC had a thick (>200 km) lithosphere until the early Paleozoic as inferred from the presence of diamondiferous kimberlites such as those at Mengyin and Fuxian (Menzies et al., 1993; Yang et al., 2009; Zhang et al., 2010) (Fig. 1a). However, by the Cenozoic, the craton lost at least 75–80 km of its keel, as recognized by the presence of spinel–facies xenoliths in alkali basalts, as well as through evidence from geochemical and geophysical data (Gao et al., 2002; Rudnick et al., 2004; Wu et al., 2005; Yang et al., 2008; Zhang, 2012; Zhang et al., 2009, 2011; Zhou et al., 2002). The onset of lithospheric thinning has been linked to the Central Asian Orogeny since the Late Carboniferous at the northern margin of the NCC (Li et al., 2009; Meng, 2003; Zhang et al., 2003, 2007; Zorin, 1999), and to the collision between the NCC and Yangtze Craton since the Late Triassic at the southern margin of the NCC (Gao et al., 1998; Li et al., 1993; Yang et al., 2007a, b; Zhang et al., 2002). The destruction of the NCC was a relatively slow process (continuing for more than 100 Ma), rather than a dramatic event (Xu et al., 2009). Many recent papers favor hydrous weakening over a considerable period of time as the potential cause for the lithospheric thinning (Kusky et al., 2007b; Santosh, 2010; Windley et al., 2010). During this period, abundant granitoids developed in the northwestern Jiaodong Terrane in the eastern NCC (Fig. 1b), and these have traditionally been divided into two 77 groups. Those of Late Jurassic ages (155–160 Ma, e.g. Miao et al., 1997; Wang et al., 1998) are known locally as the Linglong and Luanjiahe suites. Those of Early Cretaceous ages (126–130 Ma, e.g. Miao et al., 1997; Wang et al., 1998) are referred to as the Guojialing suite. Since these granitic rocks were coeval with lithospheric thinning of the eastern NCC (Wu et al., 2005),

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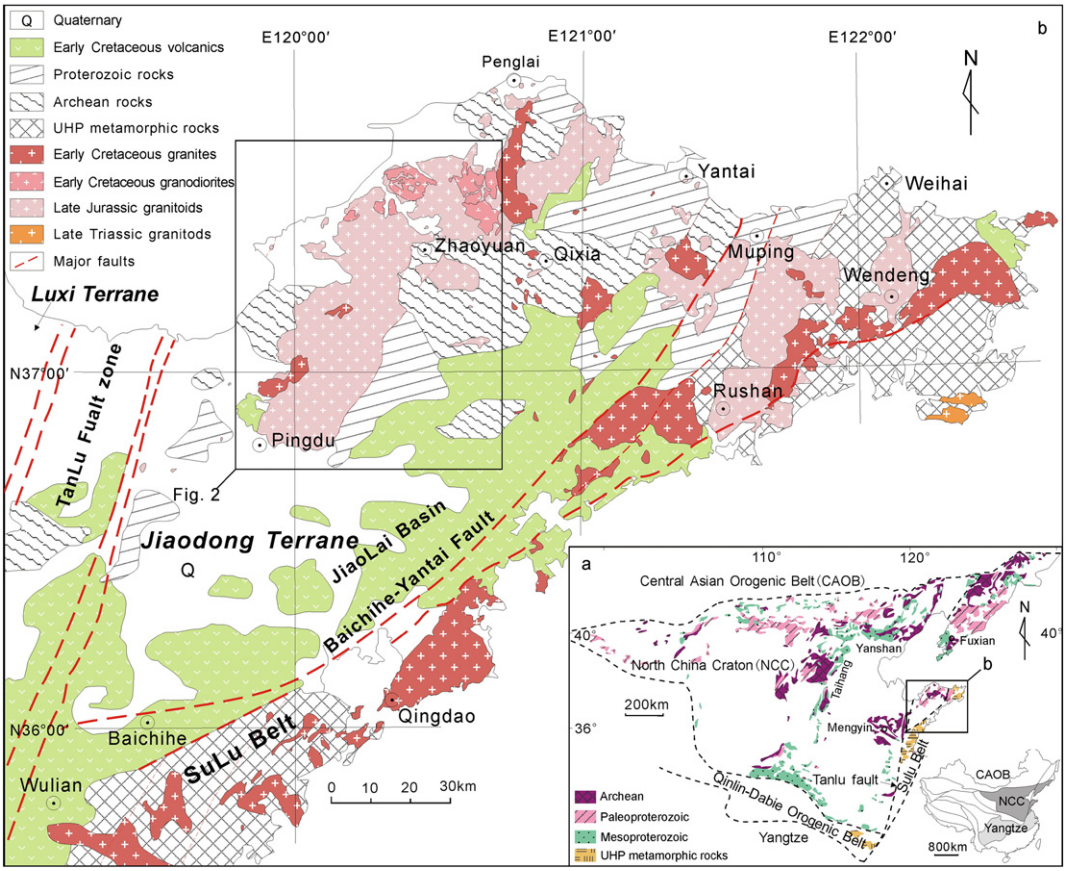

Fig. 1. Geological map of the North China Craton (a) and the Jiaodong Terrane (b), showing the distribution of the basement rocks, UHP metamorphic rocks and Mesozoic igneous rocks. Modified after Kusky et al. (2007a), Peng et al. (2007) and Goss et al. (2010).

they possess important significance in providing information on the nature of the continental crust at this time.

Of particular importance in this regard are the abundant Neoproterozoic magmatic inherited zircons with age at 683–773 Ma, which are present in the Late Jurassic Linglong and Luanjiahe granitoids. Such Neoproterozoic ages are a prominent feature of the Yangtze Craton (Ames et al., 1996; Gao et al., 1996; Guo et al., 2005; Hacker et al., 1998; Rowley et al., 1997; Zheng et al., 2007; Zhou et al., 2006), and the corresponding igneous rocks were considered to have formed as a response to the breakup of the supercontinent Rodinia (Li et al., 2003; Ling et al., 2003; Zheng et al., 2006, 2007). The absence of Neoproterozoic granitic magmatism in the eastern NCC during this period is deemed to be an important basis to distinguish the eastern NCC and the Yangtze Craton (Hacker et al., 1998; Tang et al., 2008; Wan and Zeng, 2002). Miao et al. (1997) conducted a detailed statistical analysis of inherited zircon ages in these rocks, but they did not carry out in-depth discussion about their significance. The occurrence of Neoproterozoic magmatic zircons with an age signature of the Yangtze Craton within the eastern NCC more than 100 km north of the Sulu orogenic belt is noteworthy and provided the impetus for us to conduct further work in the area. This region is of critical importance to evaluate the lithosphere interaction during continental collision (Sulu–Dabie orogen), and for reconstructing the Mesozoic lithospheric structure and crustal composition of the eastern margin of the NCC.

In this paper, based on detailed petrological, geochronological and geochemical studies on the Late Mesozoic granitic rocks in the northwestern Jiaodong Terrane in the eastern NCC, we attempt to define their magmatic origin and tectonic setting, and to constrain the lithospheric composition and evolution history in the Late Mesozoic.

2. Geological background

The NCC is bounded by the Central Asian Orogenic Belt (CAOB) to the north, the Sulu ultrahigh-pressure (UHP) metamorphic belt to the east and the Qinling–Dabie orogenic belt to the south (Fig. 1a). The Sulu belt was originally part of the Qinling–Dabie belt, but has subsequently been transported more than 500 km northeast along the Tanlu Fault (Ames et al., 1993; Xu and Zhu, 1994; Zhou et al., 2008a). The Qinling–Dabie–Sulu metamorphic belt is the result of subduction and collision between the NCC and Yangtze Craton (Mattauer et al., 1985).

The Jiaodong Terrane refers to the area east of the Tanlu Fault, and forms the eastern margin of the NCC. The Sulu UHP metamorphic belt lies to the east and they are separated by the Baichihe–Yantai Fault (Zhou et al., 2008b) (Fig. 1b). The Precambrian basement of the eastern NCC in the Jiaodong Terrane comprises the Archean Jiaodong Group composed of metamorphic volcanic sedimentary rocks and TTG gneiss, and the Paleoproterozoic Jingshan Group composed of metamorphic clastic rocks together with the Fenzhishan Group composed of metamorphosed chemical sediments (Guo et al., 2005). Jahn et al. (2008) offered new zircon U–Pb SHRIMP data that established the existence of Mesoarchean (ca. 2.90 Ga) and Neoarchean (2.71 to 2.73 Ga) continental crust in the Jiaodong Terrane. However, the basement rocks of the Sulu Belt to the east are mainly composed of Neoproterozoic granitic gneisses. Zheng et al. (2006, 2008) considered that the protoliths of these granitic gneisses were produced by partial melting of continental crust in the northern margin of Yangtze Craton, which underwent Triassic UHP metamorphism (Ames et al., 1996; Guo et al., 2005; Hacker et al., 1998).

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