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Petrogenesis of the early Cretaceous Funiushan granites on the southern margin of the North China Craton: Implications for the Mesozoic geological evolution

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ABSTRACT

Late Mesozoic granitoids are ubiquitous in the southern margin of the North China Craton and are keys to the understanding of the Mesozoic geological evolution. The early Cretaceous Funiushan granitic pluton in the southern margin of the North China Craton is composed of porphyritic biotite monzogranites. Rocks from the Funiushan pluton have high SiO_2 (64.45–73.98 wt.%), Na_2O (3.19–4.67 wt.%) and K_2O (3.76–7.95 wt.%) and low MgO (0.11–1.34 wt.%). They are enriched in Rb, Ba, Th, U and LREE ($(La/Yb)_N$ = 9.63–45.0), and depleted in Nb, Ta, Ti and P, and have negative Eu anomalies (Eu/Eu^* = 0.29–0.72). This geochemical feature is similar to those of typical I-type granites. Zircons from the granites were dated using LA-ICP-MS and SIMS, and yielded $^{206}Pb/^{238}U$ ages of 115–131 Ma. They have $\varepsilon_{Hf}(t)$ values mainly vary from −17.7 to +0.9 and T_{DM}^{C} ages mainly from 2301 to 1118 Ma. Whole rock $\varepsilon_{Nd}(t)$ values range from −20.3 to −9.6 and T_{DM} ages from 1.49 to 2.29 Ga, indicating that the magma was produced by partial melting of the Neoarchean to Paleoproterozoic crustal rocks, as represented by the Taihua Group basement rocks, with minor involvement of mantle-derived melts. The Funiushan pluton is considered to have been formed through a strong crust-mantle interaction process under a low pressure condition in an extensional setting, due to the lithospheric thinning caused by westward subduction of the Paleo-Pacific oceanic crust.

1. Introduction

The North China Craton (NCC) underwent craton destruction and lithospheric thinning during the late Mesozoic, accompanied by extensive magmatic activity and increased surface heat flux, led to large-scale tectonic extension (e.g. Xu, 2001; Xu et al., 2004; Gao et al., 2004; Wu et al., 2005a; Guo et al., 2013; Li et al., 2013). The ancient subcontinental lithosphere mantle of the NCC was replaced by hot, thin and relatively fresh juvenile lithosphere mantle (e.g. Zheng et al., 2007; Zhang, 2012; Zhang et al., 2013). It is estimated that more than 100 km of the ancient lithosphere may have been destroyed and removed beneath the NCC (e.g. Zhai and Santosh, 2013; Li and Santosh, 2014). The southern margin of the NCC records intense tectonic–magmatic activity during the late Mesozoic, with development of voluminous felsic igneous rocks which are spatially and genetically associated with many world-class Au and Mo ore deposits (e.g. Mao et al., 2008; Chen et al., 2009; Li et al., 2012a). The links among the contemporarily occurrence of the granites, metallogeny and lithospheric thinning in the southern margin of the NCC are important to evaluate the geodynamics of craton destruction.

The origin of the late Mesozoic granites along the southern margin of the NCC has been extensively investigated in the past two decades (e.g. Mao et al., 2008, 2010; Li et al., 2012a). They were considered to be produced by partial melting of the NCC ancient crystalline basement (e.g. Guo et al., 2009; Gao et al., 2010; Ding et al., 2011; Hu et al., 2012; Li et al., 2012b; Zhao et al., 2012), or the subducted continental crust of the Yangtze Craton (e.g. Bao et al., 2014). Nevertheless, it remains unclear if the mantle-derived components were involved in the petrogenesis of these granitic intrusions, and to what extent basaltic melts are required (e.g. Hu et al., 2012; Li et al., 2012b; Zhao et al., 2012).

On the other hand, precise formation ages of the granites and their geodynamic background remains unclear. Some of the researchers suggest that the Late Jurassic to Early Cretaceous granites along the southern margin of the NCC formed in a post-collisional extensional setting in response to the collapse of the Qinling Orogenic Belt (QOB) (Hu et al., 1990; Chen et al., 2000), whereas the other think that their generation were formed in a

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lithosphere thinning environment resulted from subduction of the Paleo-Pacific Plate (Sun et al., 2007; Wu et al., 2008; Mao et al., 2010; Li et al., 2012a).

The Funiushan granitic pluton is located at the Funiushan area of the southern margin of the NCC, adjoining the Qinling micro-continent. In late 1980s, the pluton was dated at 613–97.4 Ma (K–Ar and Ar^{40}–Ar^{39}) (Wang and Lu, 1998) and therefore was suggested to be formed in the Early Cretaceous (Lu, 1995). It was also regarded as Neoproterozoic migmatitic granites according to their deformation textures (Zhang and Lu, 1990; HIGS, 2002). This study presents newly obtained zircon U–Pb and Hf isotope data, major and trace elements, and whole-rock Sr–Nd isotopes for the Funiushan granitic pluton. Based on the geochemical data, we investigated its petrogenesis and discussed the Mesozoic tectonic framework in the region. Our results may be valuable for understanding the Mesozoic giant mineralization and geological evolution of the southern margin of the NCC.

2. Geological background and field occurence

The QOB separated is located between the NCC and Yangtze Craton (YZC) (Fig. 1A; Zhang et al., 2001). It comprises three units, including the southern margin of the NCC, the Qinling micro-continent, and the north margin of the YZC (Fig. 1A). The belt underwent multi-stage tectono-magmatic thermal events from Archaean–Proterozoic to Mesozoic (Zhang et al., 2001; Ratschbacher et al., 2003; Dong et al., 2011; Wu and Zheng, 2013; Li et al., 2013; Zheng et al., 2013).

The southern margin of the NCC is bounded by the Sanmenxia–Lushan Fault to the north and the Luonan – Luanchuan Fault to the south (Fig. 1B), and consists mainly of a Neoarchean – Paleoproterozoic basement rocks (2.26–2.84 Ga; Kröner et al., 1988; Wan et al., 2006; Xu et al., 2009a) that is unconformably overlain by Proterozoic volcanic and sedimentary sequences. The basement is denominated by the Taihua Group that is composed of amphibolite to granulite facies metamorphic rocks. Proterozoic strata consist mainly of mafic to felsic volcanic rocks with minor sedimentary rocks, typically represented by the 1.75–1.78 Ga Xiong'er Group (Zhao et al., 2004a, 2009) and the Meso-Neoproterozoic Guandaokou and Luanchuan Group. Since the earliest Cretaceous, the lacustrine or alluvial sediments began to deposit in the southern margin of the NCC. Magmatic activity is extensive in this area. Pre-Mesozoic granites mainly consists of Neoarchean tonalite–trondhjemite–granodiorite (TTG) rocks, Mesoproterozoic and Neoproterozoic alkaline granites. The late Mesozoic magmatic activity produced voluminous acid intrusive rocks and

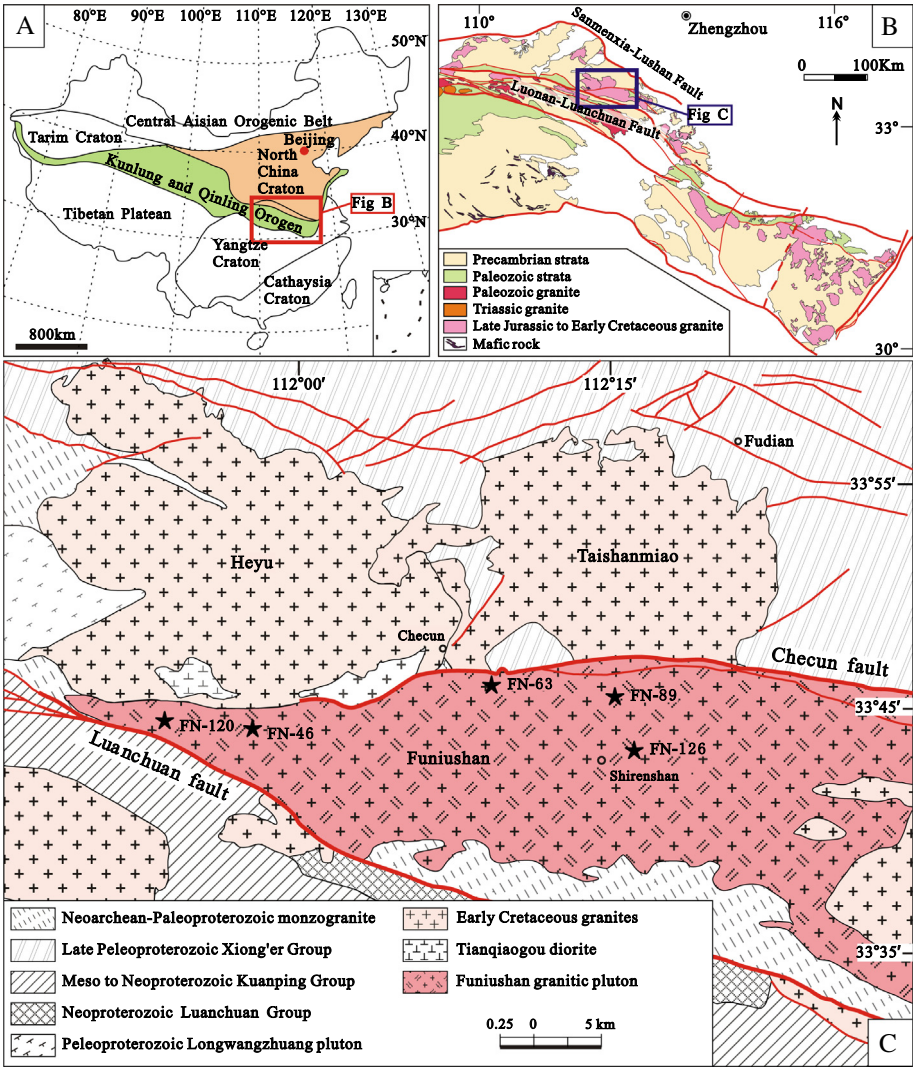

Fig. 1. Geological map in Waifangshan area, southern margin of the North China Craton (NCC). (A) Simplified tectonic map of China showing major tectonic phases surrounding the North China Craton and the location of the Qinling Orogen Belt. (B) Geological map of the Qinling Orogen Belt (modified from Zhang et al., 1996). (C) Geological map of the Funiushan pluton.