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Neoarchean Andean-type active continental margin in the northeastern North China Craton: Geochemical and geochronological evidence from metavolcanic rocks in the Jiapigou granite-greenstone belt, Southern Jilin Province

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ABSTRACT

The Jiapigou granite-greenstone belt of Southern Jilin Province is located at the northeastern margin of the North China Craton (NCC). The Neoarchean metavolcanic rocks of this region provide strong lines of evidence in petrology and geochemistry for Neoarchean crust–mantle geodynamic evolution and significant crustal growth events. The metavolcanic rock assemblage is dominated by amphibolite, hornblende/garnet biotite plagioclase gneiss, and minor felsic gneiss. Zircon LA–ICP–MS U–Pb isotopic analyses reveal that these supracrustal rocks may be formed by two episodes of magmatism. The first magmatic episode occurred at ~2688 Ma and was recorded by minor felsic gneiss. The second episode occurred at ~2588–2536 Ma and was marked by a major lithological assemblage of metavolcanic rocks in this area. All the supracrustal rocks experienced amphibolite facies metamorphism at ~2510–2480 Ma.

Except for the felsic gneiss, seventeen metavolcanic rock samples can be geochemically classified into three groups. Group #1 has tholeiitic basaltic chemical composition, and is characterized by slightly LREE-enriched chondrite-normalized REE pattern with low $(La/Yb)_N$ ratio and weakly negative Nb anomalies, similar to those of primitive arc tholeiite. Their magmatic precursor was most likely generated by partial melting of upper sub-arc mantle wedge slightly metasomatized by slab-derived fluids or melts in a subduction initiation environment. Group #2 with basaltic composition is akin to typical calc-alkaline basalt (CAB), showing fractionated chondrite-normalized REE patterns and evidently negative Nb, Ta and Ti anomalies. The magmatic precursor of the Group #2 was derived from partial melting of a sub-arc mantle wedge at relatively deeper levels, significantly metasomatized by slab-derived fluids or melts. Group #3 show chemical composition of andesite to dacite, and is distinguished by wide variations in SiO_2, MgO and Mg# values, strongly fractionated chondrite-normalized REE patterns with higher $(La/Yb)_N$ ratios, low Yb and Y contents, and negative Nb, Ta, Ti and P anomalies, analogous to the Phanerozoic adakites. They might be derived from magma mixing between the mantle wedge melts metasomatized by slab-derived melts with perhaps an ancient crustal contribution.

The felsic gneiss shows positive zircon $\varepsilon_{Hf}(t_2)$ values (+2.2 to +4.5), together with ~2.7 Ga metamorphic volcanic rocks in the neighboring area, indicating a ~2.7 Ga crustal growth episode. Most of the metavolcanic rocks display positive $\varepsilon_{Hf}(t_2)$ values of +0.4 to +7.4, the highest of which is close to the value of contemporaneous depleted mantle, suggesting a significant crustal growth event at ~2.59–2.54 Ga. Combined with numerous ~2.83–2.65 Ga inherited zircons and ~2688 Ma felsic gneiss, the Jiapigou granite-greenstone belt evolved at an Andean-type active continental margin, recording the transition from primitive arc to mature arc.

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1. Introduction

The formation and evolution of the early continental crust, and related crust–mantle–atmosphere–hydrosphere interactions and geodynamic processes have been considered as a crucial issue of modern solid earth sciences (Rollinson, 2010; Kemp, 2014; Nutman et al., 2015a; Sizova et al., 2015). Supracrustal greenstone sequences are dominated by ultramafic to mafic metavolcanic rocks, and provide the direct geological information for understanding of early continent growth and relevant geodynamic mechanism (Nutman and Friend, 2009; Polat et al., 2011; Manikyamba et al., 2015). Based on the discovery of Meso- to Neoarchean eclogites and subduction-related lithological assemblages, the plate tectonic regime most probably has already operated and played an important role in the growth of continental crust and crust–mantle interactions during the Neoarchean (e.g. Wang et al., 2015a, 2016; Tappe et al., 2011; Mints et al., 2014; Santosh et al., 2015a; Nutman et al., 2015b).

As one of the major ancient cratonic nuclei in eastern Eurasia, the North China Craton (NCC) is dominated by Neoarchean tectonothermal events, especially in its Eastern Block (EB) (Fig. 1A; Zhao et al., 2005, 2012; Liu et al., 2004, 2011a; Zhai and Santosh, 2011, 2013; Wan et al., 2014; Wang et al., 2015a, 2016). With regard to the Archean crystalline basement of the EB, the Neoarchean geodynamic setting has become a hot topic in recent years. Some researchers proposed a mantle plume regime for the formation and evolution of the EB mainly on the basis of the presence of ~2.7 Ga komatiites in the Taishan greenstone belt, large volumes of Neoarchean granitoid gneisses and counterclockwise metamorphic P–T–t paths of mafic granulites (Zhao et al., 2001, 2005, 2006, 2012; Geng et al., 2006, 2012; Yang et al., 2008; Wu et al., 2012, 2014). By contrast, some other researchers suggested a modern-style plate tectonic regime operating at Neoarchean, dominantly recorded in the Wutai and Fuping complexes (Liu et al., 2002, 2004; Lü et al., 2006; Liu et al., 2016a,b), Northern and Northwestern Hebei (Liu et al., 2006, 2011a, 2012a); Eastern Hebei (Bai et al., 2014a, 2015, 2016; Guo et al., 2013, 2015a; Nutman et al., 2011); Western Liaoning (Liu et al., 2010, 2011c; Wang et al., 2011, 2012, 2013, 2015a); Northern Liaoning (Wan et al., 2005; Bai et al., 2014b; Peng et al., 2015; Wang et al., 2016). The Neoarchean lithological assemblages of these terranes exhibit typical subduction-related lithological assemblages and geochemical features, as exemplified by normal mid-ocean ridge basalts (N-MORBs), arc-type tholeiite and calc-alkaline basaltic to dacitic rocks (e.g. Nb-enriched basalts, low-Ti tholeiitic basalts, boninite-like rocks, high-magnesium andesites (HMAs) and adakites), and granitoid gneisses with adakite- and sanukitoid-like geochemical characteristics (Liu et al., 2011c; Wang et al., 2011, 2012, 2013, 2015a; Bai et al., 2014a, 2015, 2016; Guo et al., 2013, 2015a; Fu et al., 2016). These metamorphic basements constitute a giant NEE trending Neoarchean arc tectonomagmatic belt along the northern margin of the EB (Wang et al., 2015a; Liu et al., 2015), with the arc-type magmatic rocks formed between ~2.61 and ~2.51 Ga (Bai et al., 2014a, 2015, 2016; Guo et al., 2013, 2015a; Liu et al., 2004, 2006, 2011c; Nutman et al., 2011; Wang et al., 2011, 2012, 2013; Zhang et al., 2012). In the south of this arc magmatic belt, a monzodiorite–granodiorite–monzogranite suite (MGMS) contains some microblocks older than ~2.68 Ga in the Qian'an area of Eastern Hebei, Anshan area of Eastern Liaoning and Helong area of Southern Jilin (Song et al., 1996; Nutman et al., 2011; Wan et al., 2013; Guo et al., 2015b). In addition, ~2.7 Ga or older units are only preserved in the Fuping–Hengshan–Qian'an–Eastern Liaoning and Southern Jilin areas (Liu et al., 2004; Nutman et al., 2011; Wan et al., 2013; Guo et al., 2015b). These zoned features of space–time tectono–lithological assemblages indicate a Neoarchean subduction setting along the northwestern margin of the EB (Wang et al., 2015a,c, 2016; Liu et al., 2015; Wan et al., 2011).

The Southern Jilin Province (SJP) is one of the major units of Archean crystalline basement along the northeastern margin of

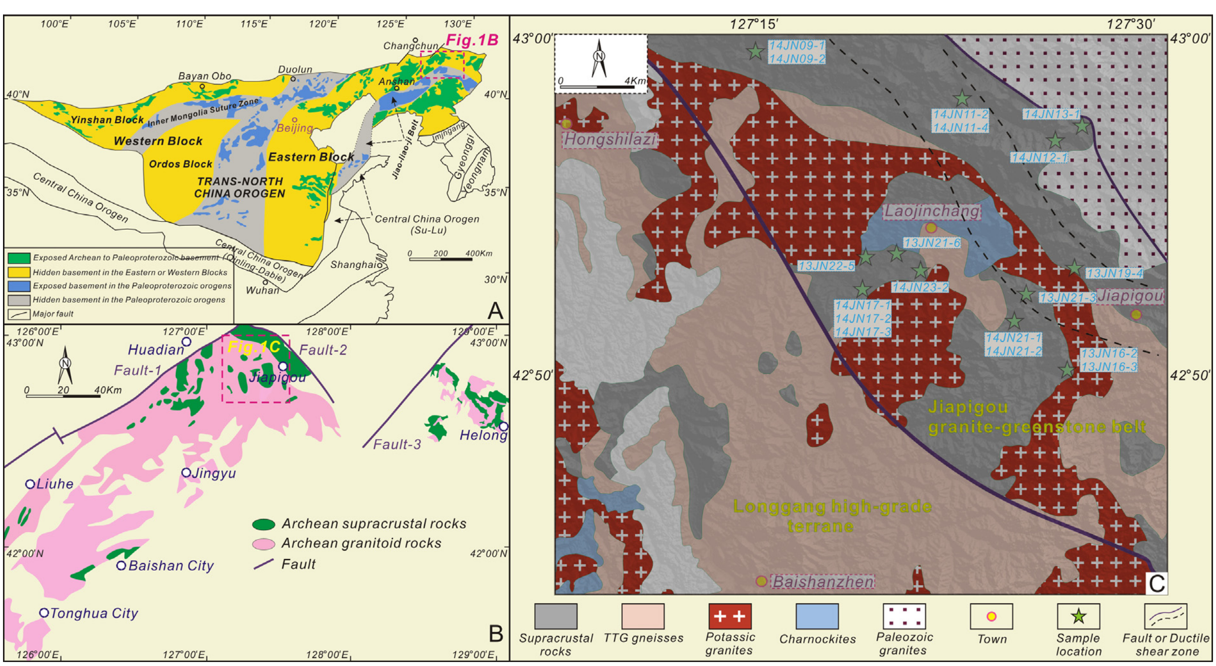

Fig. 1. (A) Tectonic subdivision of the North China Craton (modified after Zhao et al., 2005; Santosh, 2010), showing Southern Jilin Province (SJP) by the rectangle. (B) Simplified geological map of the SJP illustrating the two major lithological assemblages: the supracrustal rocks and granitoid rocks (Shen et al., 1994). The location of the study area in this paper is marked by rectangle. Abbreviations for the major faults: Fault-1 = Huifahe Fault (a branch of the deep-seated Tan–Lu Fault); Fault-2 = Jinyinbie Fault; Fault-3 = Liangjiang Fault. (C) Detailed geological map of the Jiapigou granite-greenstone belt in the SJP, showing regional geological setting and sampling locations of supracrustal rock assemblages. Elevation data from http://gdem.ersdac.jspacesystems.or.jp/index.jsp.