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Petrogenesis and geochronology of the Neoarchean-Paleoproterozoic granitoid and monzonitic gneisses in the Taihua complex: Episodic magmatism of the southwestern Trans-North China Orogen

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ABSTRACT

The Taihua metamorphic complex exposes in the southern Trans-North China Orogen (TNCO) and records at least three episodes of magmatism. The Shanxian TTG gneisses obtained at 2.54–2.48 Ga have high SiO_2, variable Mg# with high $(La/Yb)_N$ and Sr/Y ratios (15.08–93.26 with average of 37.31 and 7.33–115.05 with average of 49.59, respectively). They show negative Nb and Ta but positive Zr and Hf anomalies with low Nb/Ta and Gd/Yb, and high Zr/Hf and Zr/Sm ratios (4.97–18.8, 1.92–6.37, 23.71–50.26, and 29.18–75.23, respectively), and have positive ε_{Hf} (t) values (+1.7 to +7.9) and ε_{Nd}(t) values (+0.72 to +2.55), indicating that they were possibly produced by partial melting of lower crust derived from metasomatized lithospheric mantle with the residue of minor garnet. The Sihe granitic gneisses recorded at 2.35–2.30 Ga are enriched in silica, Al_2O_3 contents (13.59–15.33), K_2O/Na_2O ratios (1.13–1.7), defined as high-Al TTG. They exhibit high Sr/Y, Zr/Sm and Zr/Hf ratios and low Nb/Ta and Gd/Yb ratios (44.71–83.09, 47.79–62.58, 36.05–37.43, 12.04–16.36, and 2.95–3.68, respectively) with negative Eu anomaly. Combined with Hf and Nd isotopes (−2.5 to +4.7 and −0.74 to +0.36), the Sihe granitic gneiss was possibly generated from partial melting of lower crust with minor ancient material contributions, leaving residual amphibole and minor garnet in the source. The Muce monzonitic gneisses emplaced at 2.17–2.16 Ga have high Mg#, Ni and Cr contents, constant Sr/Y and $(La/Yb)_N$ (42.39–50.33, 19.8–41.4, 33.6–74.2, 31.32–34.14, and 15.32–16.7, respectively), with relatively low and constant Dy/Yb ratio (1.82–1.85). Together with Hf and Nd isotopes (−6.5 to −0.9 and −2.07 to −2.86), the Muce monzonitic gneisses might be derived from partial melting of Neoarchean pre-existing crustal materials, possibly in an arc setting. It is therefore found that four episodes of crustal growth and/or reworking in the southern segment of the TNCO have occurred at 2.85–2.72 Ga, 2.57–2.48 Ga, 2.35–2.30 Ga and 2.2–2.0 Ga, respectively, likely to connect with the subduction–collision between the Eastern and Western Blocks along the TNCO in the North China Craton.

1. Introduction

The tonalite–trondhjemite–granodiorite (TTG) suite (Jahn et al., 1981) is comprised of a greater proportion of the preserved Archean crust. However, after more than forty years of the TTG research there still remains some controversies on the petrogenetic and tectonic scenarios and the processes of the earliest continental crust (Moyen and Martin, 2012). Based on the systematic investigation and experimental data of the Archean crust which grew via various geodynamic processes, including the mantle plume, plate subduction and some combination of subduction and plume (e.g., Condie, 1994, 1997; Abbott, 1996; Hollings and Wyman, 1999; Wyman, 1999), TTGs is generally considered to be partial melt products of hydrous mafic crust leaving behind (garnet–) amphibolite (<15 kbar) or eclogite residues (>15–20 kbar) with a characteristic signature of Sr/Y ratio (e.g., Barker and Arth, 1976; Drummond and Defant, 1990; Rapp et al., 1991, 2003; Smithies and Champion, 2000; Foley et al., 2002; Condie, 2005; Martin et al., 2005; Moyen, 2011). However, considerable controversy revolves around the tectonic site of TTGs formation, including partial melting of subducted slabs, oceanic plateaus or root zones of volcanic arcs related to Archean subduction (see Martin, 1999; Martin et al., 2005, 2014; Condie, 2005), partial melting of thickened mafic crust without direct subduction (Smithies, 2000; Whalen et al., 2002; Condie, 2005; Hoffmann et al., 2011; Moyen, 2011; Moyen and Martin, 2012) or fractionated melts from

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metasomatized mantle wedge (Kamber et al., 2002; Kleinhanns et al., 2003).

Because of the difference of isotope compositions in various tectonic scenarios (e.g., Whalen et al., 2002), isotopic compositions of TTG rocks can be mentioned to constrain source characteristics and tectonic settings of their formation. Although Sm–Nd isotopic compositions are imprecise by later metamorphic events in most Archean rocks, the Nd isotopic system is important to constrain the age and mechanism of continental formation since the pioneering work of McCulloch and Wasserburg (1978). The Hf isotope record of depleted mantle evolution assists in the Sm–Nd system for similar behaviors in the crust and mantle (Vervoort et al., 1999; Vervoort and Blichert-Toft, 1999). In addition, zircon, an inert accessory mineral in igneous rocks, has very low diffusivity of Pb, and Hf isotopes (Cherniak and Watson, 2000, 2003), so that can preserve pristine isotopic compositions of the primary magmas from which it crystallized (Vervoort and Patchett, 1996; Valley et al., 2005). Zircon Hf isotope and whole rock Sm–Nd isotopes can be used to identify the involvement of crustal components during the evolution and constrain the timing of the crustal resident from its host rocks (Vervoort and Patchett, 1996; Zeh et al., 2009; Hoffmann et al., 2011; Moyen and Martin, 2012; Næraa et al., 2012; Wu et al., 2005a,b).

In this paper, we report an integrated study of whole rock geochemistry, zircon U–Pb ages and Hf isotope, as well as bulk rock Sm–Nd isotopes for Shanxian TTG gneisses, Sihe granitic gneisses and Muce monzonitic gneisses from the Taihua complex, located in the southern terminal of the Trans-North China Orogen (TNCO; Fig. 1a). By discussing the crystallization age and magma sources of these rocks, and investigating their petrogenetic process, the ultimate aim is to provide a better understanding of the Precambrian crustal evolution in the southern margin of the North China Craton (NCC). In addition, the results also shed some light on the formation and evolution of Archean TTG rocks.

2. Geological setting

The NCC is one of the oldest known continental rocks (Liu et al., 1992; Song et al., 1996), of which the boundary is the late Paleozoic Central Asian orogenic belt in the north, the early Paleozoic Qilian orogenic belt to the west and the south boundary of the Mesozoic Qinling-Dabie-Sulu ultrahigh-pressure metamorphic belt. According the lithological, structural, metamorphic and geochronological data, the NCC can be divided into the Eastern and Western Blocks amalgamated by the Paleoproterozoic TNCO (Zhao et al., 1998, 2001). Although there is still no consensus on the timing and mechanism to form the coherent basement of the NCC, the TNCO is lithologically characterized by a large amount of 2.5 Ga supracrustal rocks, TTGs and granitoids, although a few domains are dominated by 2.5 Ga TTG gneisses (Fig. 1b; Zhao et al., 2000, 2001, 2002), with details of calc-alkaline volcanics and clastic sediments metamorphosed from lower greenschist to lower amphibolite facies in the Paleoproterozoic lithotectonic assemblage and syn- and post-orogenic mafic dykes swarms in the Paleo-Mesoproterozoic assemblage (Zhao and Zhai, 2013).

The Shanxian TTG gneisses, Sihe granitic gneisses and Muce monzonitic gneisses are located in the Taihua Complex, which lies on the southern terminal of the TNCO and consists of metavolcanic rocks and metasedimentary sequences (Zhang et al., 1985; Guan, 1996; Zhang and Li, 1998; Ni et al., 2003) exposing in the discrete metamorphic terranes, e.g., the Mts. Huashan, Shanxian, Luoning, Yiyang, Lushan and Wugang terranes, from the northwest to the southeast. Metamorphic and geochronological studies on the Taihua metamorphic complex have been reported by workers. The Taihua complex is characterized by clockwise *P–T* paths including near isothermal decompression (ITD) processes, whose metamorphic event was dated to be 1.97–1.75 Ga (Sun, 1983; Jiang et al., 2011; Wang et al., 2012, 2013, 2014; Lu et al., 2013b, 2014b,c, 2015; Chen et al., 2015). Furthermore, there are many published chronological and geochemical

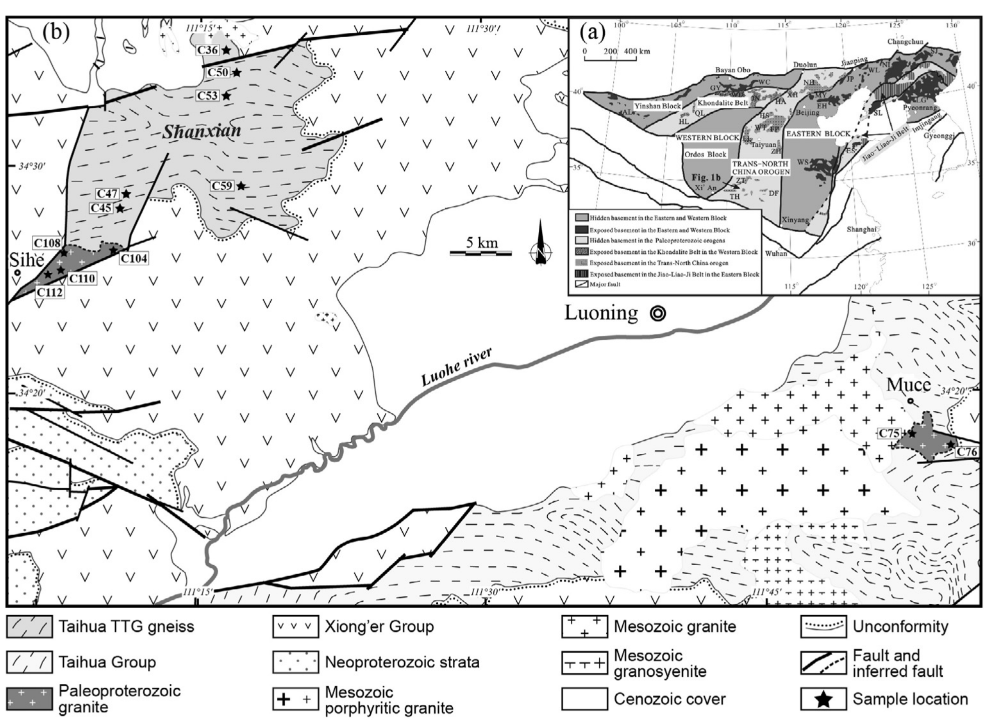

Fig. 1. (a) Tectonic sketch map of the Trans-North China Orogen (Zhao and Guo, 2012); (b) Lithological sketch map of the Shanxian terrane, modified after the 1:200,000 Luoning Geological Map (BGMR (Bureau of Geology and Mineral Resources), 1965). Sample locations are shown.