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Late Paleoproterozoic charnockite suite within post-collisional setting from the North China Craton: Petrology, geochemistry, zircon U–Pb geochronology and Lu–Hf isotopes

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ABSTRACT

Charnockites (pyroxene-bearing granitoids) of magmatic origin in diverse tectonic settings and ranging in age from Mesoarchean to Cretaceous constitute important components of the continental crust. Here we report charnockites displaying both magnesian and ferroan compositions associated with gabbros from an AMCG (anorthosite–mangerite–charnockite–granite) suite in the North China Craton. The orthopyroxene in the magnesian charnockite is characterized by moderate X_{Mg} of 0.63–0.65 ($Wo_{1-2}En_{62-63}Fs_{35-36}$), and low Al_2O_3 content of 0.59–0.71 wt.%. The magnesian charnockites show medium- to high-K contents, and high Mg# (~47–69) similar to that of gabbros, whereas the Mg# of the ferroan charnockites is low (~6–28). The ferroan charnockites are alkali-calcic to alkalic, and weakly peralkaline to metaluminous, whereas the magnesian charnockites are calcic to calc-alkalic, and metaluminous. Although magnesian charnockites are in general considered to have formed in subduction setting, the medium- to high-K contents, high Mg# values with a wide range, and the highly negative εHf values of the zircons in these rocks (−8. 4 to −13.6), suggest inheritance of the arc signature from the melting of ancient arc-related crustal material. The ferroan charnockites show tholeiitic affinity and define a common differentiation trend with the gabbroic anorthosites and likely represent fractionated end-members with or without crustal interaction in a post-collisional rift setting. We present U–Pb age data from zircon grains on seven samples including two ferroan charnockites, three magnesian charnockites, one gabbroic enclave in magnesian charnockite and one gabbroic anorthosite which show emplacement ages of 1748.8 ± 6.4 Ma, 1747.1 ± 9.5 Ma, 1756.4 ± 7.3 Ma, 1756.7 ± 9.2 Ma, 1731 ± 17 Ma, 1731.6 ± 8.2 Ma and 1746.5 ± 7.3 Ma respectively. The negative εHf values (−1.2 to −13.6) of zircon grains from these rocks and the older crustal model ages ranging from Mesoarchean to Paleoproterozoic suggest that the magma sources of these rocks involved the melting of ancient crustal components. The age data suggest that the magmatic suite was emplaced within a relatively short time interval between1.73 and 1.76 Ga, during late Paleoproterozoic, placing the rocks suite in a post-collisional scenario, following the amalgamation between the Eastern and Western Blocks of the North China Craton along the Trans-North China Orogen at ca. 1.85–1.80 Ga.

1. Introduction

Pyroxene-bearing granitoids (referred to as charnockites; e.g., Frost and Frost, 2008a; Rajesh and Santosh, 2012) occur in a variety of tectonic settings in different terranes of the world ranging in age from Mesoarchean (e.g., Santosh et al., 2013a) to Cretaceous (e.g., Zhang et al., 2010) and even younger. Based on their geochemical characteristics, charnockites can be grouped into magnesian, calcic to calc-alkalic, metaluminous (referred as magnesian charnockites), ferroan, alkali-calcic to alkalic, peralkaline to metaluminous (referred to as ferroan charnockites), and transitional; the third type showing geochemical characteristics that straddle from ferroan to magnesian charnockites (e.g., Rajesh and Santosh, 2004; Frost and Frost, 2008a,b; Rajesh, 2012). Charnockites forming part of anorthosite–mangerite–charnockite–granite (AMCG) suites are dominantly ferroan charnockites occurring as differentiated end members in extensional settings (e.g. Emslie, 1991; Keppie et al., 2003). In contrast, magnesian charnockites, which

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dominantly occur in subduction-related arc settings (e.g. Frost et al., 2001; Rajesh et al., 2011), are not usually reported from AMCG suites. Further, rarely do these geochemically diverse types of charnockites occur together in a region within a common tectonic framework. We report here an example of late Paleoproterozoic magnesian and ferroan charnockites associated with gabbroic rocks in a post-collisional tectonic setting from the North China Craton.

The North China Craton (NCC) is a collage of crustal blocks built through micro-continent amalgamation during the Archean and these blocks were unified through prolonged subducted-accretion tectonics with final collision in the late Paleoproterozoic (e.g., Santosh et al., 2012, 2013a; Zhai, 2014; Zhai and Santosh, 2011; Zhai and Santosh, 2013; Zhao and Zhai, 2013, among others). Charnockites and associated rock suites are widely distributed in the NCC and occur in Neoarchean and Paleoproterozoic tectonic settings that range from arc suites associated with convergent margins to extensional settings. Examples for the Neoarchean suite include the charnockites of the Yinshan Block with emplacement ages of 2524–2533 Ma, followed by metamorphism at 2498 Ma (Ma et al., 2013). The arc-related charnockites formed during the early to late Paleoproterozoic prolonged subduction-accretion history are more widely distributed and include those in Xinghe within the Trans-North China Orogen emplaced at 2477–2147 Ma and metamorphosed at 1834–1807 Ma (Santosh et al., 2013a; Yang et al., 2014a), and the charnockites within the Inner Mongolia Suture Zone emplaced at 1932 Ma and metamorphosed at 1858 Ma (Santosh et al., 2013a), among other occurrences. One of the typical examples for post-collisional charnockite magmatism within extensional setting in the NCC has been reported from the Jianping complex (Liu et al., 2011).

Charnockites also occur in association with AMCG suites in the NCC, a typical example being the Dayingzi pluton, north of the Damiao anorthosite complex near Chengde city (e.g., Zhang et al., 2007; Zhao et al., 2009) (Fig. 1). The charnockites in this complex have not been investigated in detail in previous studies. In this study we present petrography, zircon U–Pb geochronology and Lu–Hf isotopes and geochemical data from charnockites and associated gabbroic rocks. We also evaluate the implications of our results on the tectonic history of the NCC.

2. Geological setting

The NCC (Fig. 1) is composed of three major blocks — the Yinshan Block, the Ordos Block and the Eastern Block, all of which were incorporated into a coherent cratonic framework at the end of the Paleoproterozoic, broadly coinciding with the timing of amalgamation of the supercontinent Columbia (e.g., Santosh, 2010; Santosh et al., 2012, 2013a,b; Yang et al., 2014a,b; Zhao and Zhai, 2013; Zhao et al., 2005). The Yinshan and Ordos Blocks collided along the Inner Mongolia Suture Zone (incorporating the Khondalite Belt; e.g., Santosh, 2010; Yang et al., 2014a,b,c; Zhao et al., 2005) and built the unified Western Block. Subsequently, the amalgamation between the Eastern Block and Western Block occurred along the Trans-North China Orogen (Zhao and Zhai, 2013; Zhao et al., 2005), thus marking a prolonged subduction–accretion–collision history from early to late Paleoproterozoic (Santosh et al., 2013b). The Yinshan and Eastern Blocks preserve imprints of Archean history, with the latter preserving the evidence for major crustal growth and recycling events at 2.7 and 2.5 Ga. Zhai and Santosh (2011) traced the tectonic history of the NCC and identified at least five major cycles as follows. (1) Neoarchean crustal growth and stabilization, (2) Paleoproterozoic rifting–subduction–accretion–collision, (3) Late Paleoproterozoic–Neoproterozoic multi-stage rifting, (4) Paleozoic orogenesis at the margins of the craton, and (5) Mesozoic extensional tectonics associated with lithospheric thinning and decratonization.

The present study area is to the north of the Chengde City within the Trans-North China Orogen (TNCO) which marks the collisional suture between the Western and Eastern Blocks of the NCC (Figs. 1, 2). This region is well known for the Damiao anorthosite–gabbro norite suite where the gabbro norites are mined for iron ore.

The Damiao suite forms part of a larger magmatic complex of anorthosite–mangerite–charnockite–granite (AMCG), spread over a wide area around Chengde. Zhang et al. (2007) reported zircon U–Pb from the Damiao anorthosite, Changsaoying K-feldspar granite, Lanying anorthosite and quartz syenite, and the Gubeikou K-feldspar granite which show a range of 1750 to 1680 Ma. The emplacement of the magmatic complex is therefore considered to have occurred between 1750 and 1680 Ma.

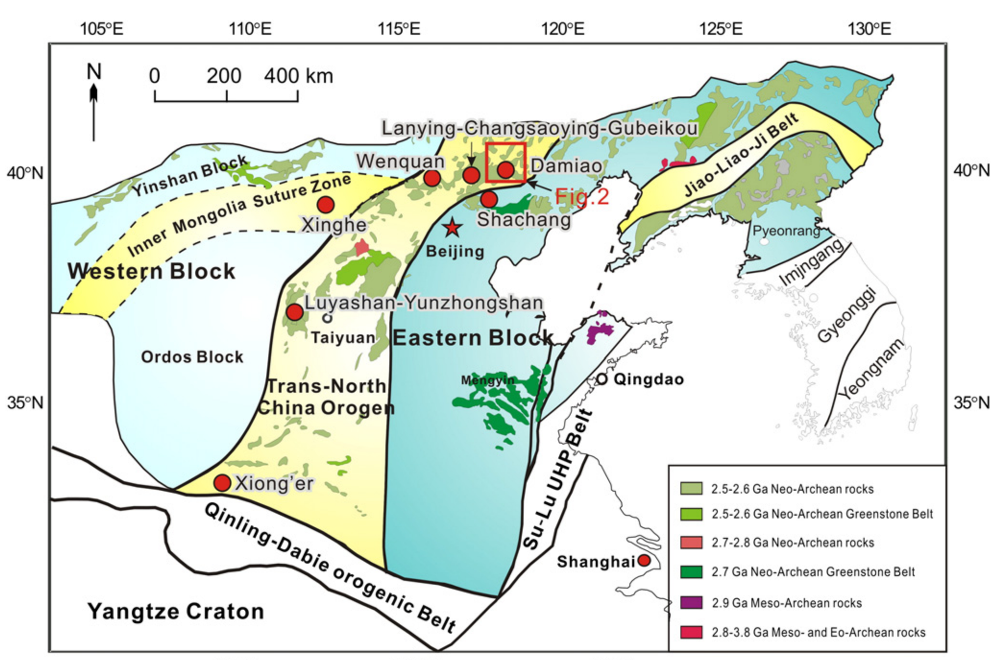

Fig. 1. Tectonic framework of the North China Craton showing the major crustal blocks and intervening suture zones (after Santosh, 2010; Zhao et al., 2005). The location of Fig. 2 is shown by box. The locations of other major Paleoproterozoic magmatic suites as discussed in the text are also shown.