Precambrian Research 281 (2016) 521–536

Contents lists available at ScienceDirect

Precambrian Research

journal homepage: www.elsevier.com/locate/precamres

Mesoproterozoic continental breakup in NW China: Evidence from gray gneisses from the North Wulan terrane

Lu Wang [a], Heng Wang [a], Chuan He [a], Nengsong Chen [a,b,e,f,*], M. Santosh [c,d], Min Sun [b], Qinyan Wang [a], Lanlan Jin [f], Fanxi Liao [a]

[a] *School of Earth Science, China University of Geosciences, Lumo Road 388, Wuhan 430074, China*
[b] *Department of Earth Sciences, The University of Hong Kong, Pokfulam Road, Hong Kong Special Administrative Region*
[c] *Department of Earth Sciences, University of Adelaide, SA 5005, Australia*
[d] *School of Earth Science and Resources, China University of Geosciences Beijing, 29 Xueyuan Road, Beijing 100083, China*
[e] *Center for Global Tectonics, China University of Geosciences, Wuhan 430074, China*
[f] *State Key Laboratory of Biogeology and Environmental Geology, China University of Geosciences, Lumo Road 388, Wuhan 430074, China*

ARTICLE INFO

Article history:
Received 5 December 2015
Revised 6 May 2016
Accepted 6 June 2016
Available online 11 June 2016

Keywords:
North Wulan terrane
Low-Al trondhjemites
Zircon U–Pb geochronology
Mesoproterozoic continental breakup
Supercontinent Columbia

ABSTRACT

The North Wulan terrane forms part of the micro-continental blocks in the early Paleozoic Qilian and North Qaidam orogenic belts in NW China. LA-ICP-MS dating of magmatic zircons from two gray gneisses from this terrane yielded U–Pb ages of 1519 ± 5 Ma and 1497 ± 8 Ma, suggesting emplacement of their precursor magmas at ~1.5 Ga. The rocks have high SiO_2 (70.6–75.6 wt.%) and Na_2O (3.96–4.84 wt.%), but relatively low Al_2O_3 (mostly <15 wt.%) and K_2O (0.90–2.52 wt.%) contents. They possess low contents of Ni, Cr, Sc, Sr, Rb and moderate Y, with slightly enriched LREE ($(La/Yb)_N$ = 3.46–11.3) and flat HREE ($(Gd/Yb)_N$ = 0.95–2.06) patterns and strongly negative Eu anomalies (Eu/Eu^* = 0.22–0.38). Thus, these rocks have trondhjemite compositions and are comparable to the low-Al or low-pressure TTG gneisses worldwide. Zircons from these rocks yielded $\varepsilon Hf(t)$ and T_{DM2} values of −2.2–5.1 and 1.93–2.39 Ga, respectively. Our data suggest that the precursor low-Al trondhjemite magma was generated from partial melting of the early Paleoproterozoic mafic rocks at shallow crust level through possible heat input from upwelling mantle in a continental rifting setting. We suggest that these ~1.5 Ga gneissic rocks were formed in a tectonic setting identical to that of coeval mafic sills and dykes in the northern Tarim Craton and western Yangtze Craton, and can be broadly correlated with the anorogenic magmatism associated with the initial fragmentation of the supercontinent Columbia.

1. Introduction

The episodic assembly and breakup of supercontinents, such as the formation and fragmentation of the Kenorland, Columbia, Rodinia, Gondwana and Pangea constitute the supercontinent cycles on the earth (Worsley et al., 1982, 1984, 1985; Rogers and Santosh, 2003, 2004; Meert, 2012; Nance and Murphy, 2013; Nance et al., 2014; Young, 2015). The Columbia (Nuna) supercontinent is considered as the first coherent supercontinent in the Earth history, and its assembly and breakup have received much attention in recent years (Hoffman, 1997; Meert, 2002, 2012; Zhao et al., 2002, 2004a; Zhao et al., 2011; Ernst et al., 2008, 2013; Hou et al., 2008; Evans and Mitchell, 2011; Nance et al., 2014). There is now a broad consensus that the Columbia supercontinent was assembled through the global 2.1–1.8 Ga collisional orogeny (Rogers and Santosh, 2002; Zhao et al., 2002, 2004a; Zhao et al., 2011). However, timing of the final assembly and initial breakup of this supercontinent remains debated. One school of thought considered that the fragmentation of the supercontinent Columbia began at ca. 1.6 Ga associated with continental rifting and anorogenic magmatism in most of its constituent continents and continued until about 1.3–1.2 Ga, marked by the coeval emplacement of mafic dyke swarms (Zhao et al., 2004a, 2011 and references therein). However, the other school of thought argued that the Columbia had not fully assembled until ca. 1.5 Ga and the breakup of this supercontinent occurred between ca. 1450 and 1380 Ma or even later (Skridlaite et al., 2008; Mertanen and Pesonen, 2012; Pisarevsky et al., 2014).

The Tarim Craton (TC) together with the North China Craton (NCC) and Yangtze Craton (YC) constitute the main Precambrian

---

* Corresponding author at: School of Earth Science, China University of Geosciences, Lumo Road 388, Wuhan 430074, China.
E-mail address: chennengsong@163.com (N. Chen).

http://dx.doi.org/10.1016/j.precamres.2016.06.016
0301-9268/

continental cratons of China (Fig. 1a). Previous studies have suggested that the TC, NCC and YC were all probable parts of the Columbia supercontinent and were assembled through prolonged subduction, accretion and collision process associated with the global assembly of Columbia in 2.1–1.8 Ga (Rogers and Santosh, 2002; Zhao et al., 2002, 2003, 2004a, 2011; Zhang et al., 2006, 2011b, 2012a,b, 2013; Chen et al., 2007, 2009, 2013; Wu et al., 2009; Xiong et al., 2009; Long et al., 2010, 2012; Shu et al., 2011; Lei et al., 2012; Ge et al., 2013; He et al., 2013; Ma et al., 2013; Yin et al., 2013; Liao et al., 2014). However, timing of the initial breakup of each of the continental cratons remains uncertain. Some researchers suggested that the breakup of the NCC had initiated with the emplacement of the mafic dyke swarms at ∼1.78–1.73 Ga (Peng et al., 2005, 2008, 2012; Hou et al., 2008), anortho site-mangerite-charnockite-granite (AMCG) suite at 1.75–1.68 Ga (Zhai et al., 2000; Zhao et al., 2004b; Lu et al., 2008) and rapakivi granites at 1.74–1.68 Ga (Yang et al., 2005; Gao et al., 2008; He et al., 2011), followed by the deposition of thick K-rich volcanics and terrigenous clastic sediments at ∼1.67–1.4 Ga (Meng et al., 2011). However, the others considered that these magmatic suites were formed in a post-orogenic setting at ∼1.85–1.68 Ga (Zhang et al., 2007b; Zhao and Zhou, 2009; Zhao et al., 2011). Timing of the initial breakup of the TC and YC is poorly understood, because tectonothermal events fingerprinting the continental rifting have not been identified until recently when ca. 1.5 Ga mafic sills and dykes that are considered to be related with the mantle plume within continental rifting settings were reported from both northeastern Tarim Craton (Wu et al., 2014a) and western Yangtze Craton (Fan et al., 2013). In this study, we first report a ∼1.5 Ga gray gneiss suite with low-Al trondhjemite characteristics from the North Wulan terrane, northwestern China. Our new data provide new constraints on the relationships between the North Wulan terrane with the TC and YC, and also offer insights into the tectonic evolution of the northwestern China in relation to the initial breakup of the supercontinent Columbia during the Mesoproterozoic.

2. Geological setting

The North Wulan terrane is a small lenticular massif sandwiched between the southwestern Qilian Block and northeastern Quanji Massif, and was together involved as micro-continental blocks in the early Paleozoic Qilian and North Qaidam orogenic belts of the Central China Orogen (Fig. 1a and b). To the northwest, the North Wulan terrane is separated from the Tarim Craton by the sinistral Altyn Tagn Fault. The Alxa Block (probably part of the Western Block of the NCC) is exposed to the north adjacent to the Qilian Block.

2.1. Tarim Craton

The Precambrian basement rocks of the Tarim Craton (TC) are dominantly exposed along the northern (Quruqtagh area), southeastern (Altyn Tagh-Dunhuang area) and southwestern (West Kunlun area) margins of the craton (Lu et al., 2008; Long et al., 2010, 2011; Shu et al., 2011; Zhang et al., 2012b; Zhao and Cawood, 2012; Zheng et al., 2013). They are composed of the strongly deformed late Neoarchean-early Paleoproterozoic tonalite–trondhjemite–granodiorite (TTG) gneisses with metamorphosed supracrustal xenoliths, and Paleoproterozoic mafic-felsic intrusions and dykes, metamorphosed supracrustal rocks and anatectic granites (Lu and Yuan, 2003; Long et al., 2010, 2012; Xin et al., 2011; Lei et al., 2012; Zhang et al., 2012a,b; He et al., 2013). These Archean to Paleoproterozoic rocks witnessed high-grade metamorphism at 2.0–1.8 Ga (Zhang et al., 2007a, 2012a; Dong et al., 2011; Xin et al., 2011; Ge et al., 2013). The late Paleoproterozoic magmatic and metamorphic events are coincident with the global collisional event associated with the assembly of the supercontinent Columbia (Xin et al., 2011; Lei et al., 2012; Long et al., 2012; Zhang et al., 2012a; Ge et al., 2013; He et al., 2013). Detrital zircon ages of ca. 1600 and 1400 Ma have been reported for the Tarim Craton (Rojas-Agramonte et al., 2011; Shu et al., 2011; Ma et al., 2012) and may probably record a Mesoproterozoic magmatic event correlated with the breakup of the Columbia supercontinent. Recently,

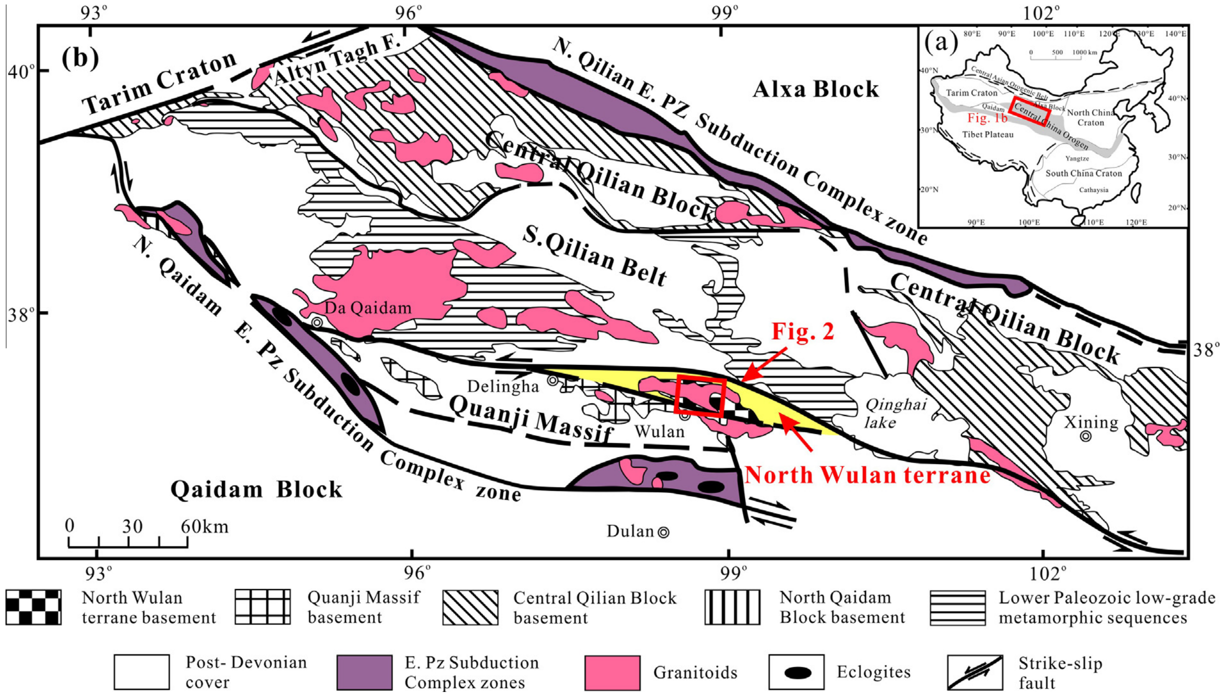

Fig. 1. (a) Tectonic framework of China (modified after Zhao and Cawood, 2012). (b) Geological sketch map of the North Wulan terrane and its adjacent micro-continental blocks (modified after Xu et al., 2006; Chen et al., 2009, 2013).