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The generation and evolution of Archean continental crust in the Dunhuang block, northeastern Tarim craton, northwestern China

Keqing Zong[a,*], Yongsheng Liu[a], Zeming Zhang[b], Zhenyu He[b], Zhaochu Hu[a], Jingliang Guo[a], Kang Chen[a]

[a] State Key Laboratory of Geological Processes and Mineral Resources, China University of Geosciences, Wuhan 430074, China
[b] Institute of Geology, Chinese Academy of Geological Sciences, No. 26, Baiwanzhuang Road, Beijing 100037, China

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ABSTRACT

Tonalite–trondhjemite–granodiorite (TTG) preserved in Archean cratons can provide insights into the generation and evolution of the early continental crust. In this study, typical TTG gneisses from the Dunhuang block in the northeastern Tarim craton were studied in detail regarding their geochemistry and geochronology to constrain the generation and evolution of the Archean continental crust in this region. These TTG gneisses are characterized by high contents of SiO_2 (68.3–71.6%), Al_2O_3 (15.3–16.9%), Na_2O (4.43–4.85%), low K_2O/Na_2O ratios (0.20–0.37) and a very low HREE content (Yb < 1 ppm) and show two-stage Nd isotope model ages of ~3.06–2.84 Ga. Zircon U–Pb analyses reveal that these TTG gneisses were formed ~2.7–2.6 Ga ago, as shown by inherited magmatic zircon cores, and were later altered by Paleoproterozoic (~2.0–1.9 Ga) and early Paleozoic (~430 Ma) high-grade metamorphic events. Two samples show positive $\varepsilon_{Hf}(t)$ values of 1.5–5.4 for magmatic zircons with ages of ~2.7–2.6 Ga and give a two-stage Hf isotope model age of ~2.95 Ga, while one sample exhibits negative $\varepsilon_{Hf}(t)$ values of −3.4 to −7.2 for magmatic zircons with ages of ~2.7–2.6 Ga and gives a two-stage Hf isotope model age of ~3.4 Ga, suggesting that the Paleoarchean and Mesoarchean Eras were important periods for the generation of juvenile continental crust in the Dunhuang block. Lastly, based on analyses of previous studies, we speculate that the Tarim craton has been subjected to episodic crustal growths at ~3.4 Ga, ~3.2 Ga, ~2.95 Ga, ~2.8 Ga and ~2.6 Ga and reworking events at ~2.7–2.6 Ga and ~2.5 Ga

1. Introduction

The continental crust is the archive of the geological history of the Earth (Cawood et al., 2013; Condie and Kröner, 2013; Hawkesworth et al., 2010; Roberts, 2012). Understanding the generation and evolution of the continental crust plays a key role in the earth sciences because changes in the volume of the continental crust and the distribution of continents on Earth's surface have profound effects on many geological processes through Earth's history (Condie, 2005; Hawkesworth et al., 2010). It is widely accepted the majority of the continental crust (>70%) most likely formed in the Archean (Cawood et al., 2013; Taylor and McLennan, 1995). Sodium-rich tonalite–trondhjemite–granodiorite (TTG) suites are generally considered to be one of the most important lithologies of Archean rocks, which constitute more than 80% of the surviving Archean continental crust (Martin et al., 2005; Moyen and Martin, 2012). Therefore, TTG gneisses preserved in various Archean cratons can be used to decipher the generation and evolution of the early continental crust.

The North China, South China and Tarim cratons are the three largest cratons in China and are separated from and sutured to each other by Phanerozoic orogenic belts and faults (insert figure in Fig. 1). Compared to the extensively studied North China and South China cratons, the Tarim craton is poorly understood (Zhao and Cawood, 2012; Zheng et al., 2013 and within references). This is largely because more than 85% of the Tarim craton is covered by desert and gobi, and as a result the Precambrian basement rocks are only locally exposed on the margins of this craton (Lu et al., 2008; Zhang et al., 2012b; Zhao and Guo, 2012). The Archean TTG gneisses are primarily exposed in the Kuluketage and Dunhuang blocks on the northern and northeastern margins of the Tarim craton, respectively (Fig. 1). The Neoarchean TTG gneisses within the Kuluketage area have been studied recently (Long et al., 2010, 2011; Lu et al., 2008; Zhang et al., 2012a). Those results revealed that these TTG gneisses mainly formed ~2.65–2.5 Ga ago (Long et al., 2010, 2011; Lu et al., 2008; Zhang et al., 2012a) and were overprinted by Paleoproterozoic (~1.9–1.8 Ga) tectonothermal events (Zhang et al., 2012a). However, detailed geochemical and

* Corresponding author. Tel.: +86 15994222021; fax: +86-27-67885096.
E-mail address: kqzong@hotmail.com (K. Zong).

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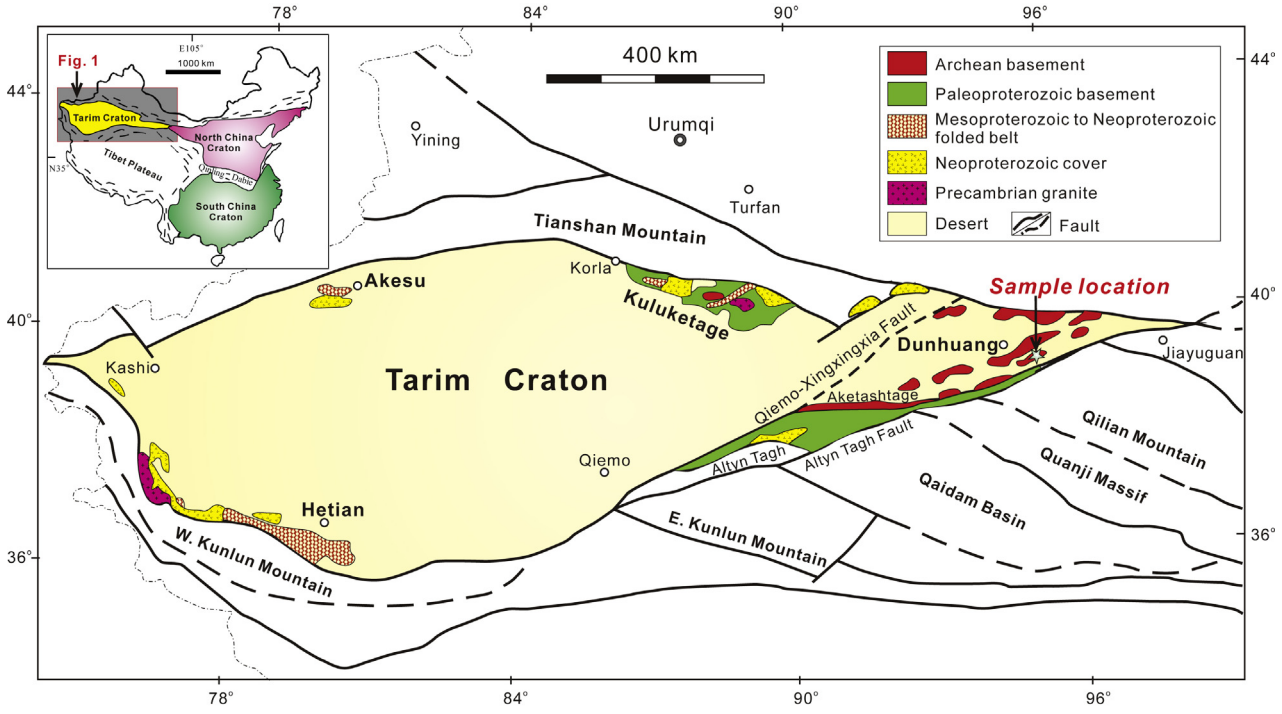

Fig. 1. Simplified geological map of the Tarim craton and adjacent areas (modified after Lu et al., 2008; Zhao and Cawood, 2012). Insert figure shows a simplified tectonic map of China.

geochronological information from the Archean TTG in the Dunhuang block, in which significant amounts of the Archean rocks in the Tarim craton are exposed (Fig. 1), is scarce. On the basis of thermal ionization mass spectrometer (TIMS) U–Pb zircon dating of one tonalite, Mei et al. (1998) suggested that TTG in the Dunhuang block formed in 2.67 Ga and underwent Neoproterozoic (~1.0 Ga) alteration. Recently, Zhang et al. (2013b) proposed that TTG gneiss in the Dunhuang block underwent a ~2.5 Ga magmatic–metamorphic event. In contrast, episodes of Paleoproterozoic (~1.85 Ga) and early Paleozoic (~430 Ma) high-pressure granulite metamorphism have been well described in the Dunhuang block by Zhang et al. (2012c) and Zong et al. (2012), respectively, and these findings indicate that the Neoarchean-generated TTG in the Dunhuang block most likely experienced a prolonged and complex continental crust evolution. Thus, more detailed work on Archean TTG gneiss in the Dunhuang block especially regarding its in situ geochronology is needed to refine the constraints on the generation and evolution of the early continental crust in the Tarim craton.

In this paper, we summarize our petrological investigation and analyses of element and Sr–Nd isotope compositions of whole-rock and in situ zircon U–Pb dating and Hf isotope compositions of three typical TTG gneisses from the Dunhuang block. In situ zircon U–Pb results showed that these TTG gneisses formed ~2.7–2.6 Ga ago and were overprinted by Paleoproterozoic (~2.0–1.9 Ga old) and Paleozoic (~430 Ma old) tectonothermal events. When combining our findings with previous studies, we found that the Hf isotope compositions of zircons revealed the episodic continental crustal growth during the Paleoarchean to Neoarchean Eras and that Paleoarchean continental crust as old as ~3.4 Ga may have existed in the Dunhuang block.

2. Geological background and samples

The Tarim craton, located in the northwestern China, is one of three major Precambrian cratonic blocks in China and covers an area of more than 600,000 km^2. This craton has the physiographic appearance of a large eyeball when viewed from high altitude and is bounded by the Tianshan Mountains on the north, the western Kunlun Mountains on the south, and the Altyn Tagh on the southeast (Fig. 1). Its central part is covered by Cenozoic desert, and the Precambrian basement rocks are only distributed along the margins of the Tarim Basin, including Akesu area in the northwestern margin, Hetian area in the southwestern margin, the Kuluketage area in the northern margin, the North Altyn Tagh and the Dunhuang area in the northeastern margin (Fig. 1). The Aksu group in Aksu area have suffered from blueschist-facies metamorphism with disputed Neoproterozoic metamorphic ages of ~872–700 Ma (Chen et al., 2004; Liou et al., 1996; Nakajima et al., 1990; Yong et al., 2013). The oldest rock in the Hetian area is Akazi granodiorite with formation age of ~2.41 Ga and metamorphic age at ~1.9 Ga (Zhang et al., 2012b). The Neoarchean (~2.65–2.5) rocks in the Kuluketage area are mainly consisted of TTG gneiss with amphibolite enclaves, calc-alkaline granites and high Ba–Sr granites, which underwent metamorphic event at ~1.9–1.8 Ga (Long et al., 2010, 2011; Zhang et al., 2012a). The North Altyn Tagh–Dunhuang area in the northeastern margin of Tarim craton is traditionally called the Dunhuang block, which is a triangular block bounded on the north by Beishan Mountain, on the northwest by the Qiemo-Xingxingxia fault and on the southeast by the Altyn Tagh fault (Fig. 1). The Dunhuang block is composed of a series of supracrustal rocks that underwent medium- to high-grade metamorphism, called the “Dunhuang Group”, and subordinate volumes of TTG intrusions (Mei et al., 1997). The Dunhuang Group is dominated by metasedimentary rocks, including garnet-kyanite schist, graphite-bearing marble, garnet amphibolite, gneiss and quartzite, and a few metavolcanic rocks and has some features of “khondalite series” (Mei et al., 1997; Yu et al., 1998). Although Archean TTG gneiss was emphasized as an important lithology in the Dunhuang block (Mei et al., 1997; Yu et al., 1998), the limited geochronological work only focused on the southern margin of the Dunhuang block (Mei et al., 1998; Zhang et al., 2013b). These Archean rocks include the tonalitic gneiss at the Shibaocheng area with a TIMS U–Pb zircon age of 2670 ± 12 Ma (Mei et al., 1998),