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Geochemistry and geochronology of the Precambrian high-grade metamorphic complex in the Southern Central Tianshan ophiolitic mélange, NW China

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ABSTRACT

The Central Tianshan Arc Terrane is one of the major constituents of the Tianshan orogen in the southwestern Altaids. Thus its Precambrian evolution is important for unravelling the geodynamic and continental evolution of the Altaids. Biotite-plagioclase-hornblende orthogneisses intruded by leucogranite dykes are exposed as exotic blocks within the Southern Central Tianshan ophiolitic mélange. Zircon U–Pb age dating of one orthogneiss sample yields an upper intercept age of 2466 ± 51 Ma and a weighted mean $^{207}Pb/^{206}Pb$ age of 1812 ± 19 Ma around the lower intercept. These ages are interpreted as protolith crystallization age and subsequent metamorphic overprint age, respectively. The orthogneisses have moderate SiO_2 contents, high MgO and Na_2O contents, high Sr/Y ratios (32–43) and moderately fractionated REE patterns ($[La/Yb]_N = 7.59–13.64$) with negligible Eu anomalies, enriched Sr contents and pronounced negative Th–U, Nb–Ta, Zr–Hf and Ti anomalies resembling high-SiO_2 TTGs derived from subducted basaltic slab-melts. Positive $\varepsilon_{Hf}(t)$ values (+3.4 to +9.2) and low $(^{176}Hf/^{177}Hf)_i$ ratios (0.281304–0.281469) with Neoarchaean to early Paleoproterozoic single-stage Hf model ages ($T_{DM1} = 2431–2652$ Ma) suggest that the orthogneisses probably originated from partial melting of juvenile subducted oceanic crust. The orthogneisses were subsequently also affected by collisional orogenic events associated with the assembly of the supercontinent Columbia. In contrast, the zircon U–Pb age of 785 ± 15 Ma obtained for the intrusive leucogranite dykes is consistent with the timing of rifting events associated with the breakup of Rodinia. The leucogranites have a high-Al trondhjemitic composition characterized by extremely low MgO and K_2O contents as well as high SiO_2, Al_2O_3 and Na_2O contents, dramatically low $\sum$REE abundances and REE patterns with moderate LREE enrichments ($[La/Yb]_N = 3.55–8.4$) and pronounced positive Eu anomalies ($Eu/Eu^* = 1.29–2.61$). The high zircon initial Hf compositions (0.281670–0.281841) and negative $\varepsilon_{Hf}(t)$ values (−21.7 to −15.4), in conjunction with high whole-rock initial $^{87}Sr/^{86}Sr$ ratios (0.70737–0.70751) and negative $\varepsilon_{Nd}(t)$ values (−4.7 to −5.1) suggest that the leucogranite resulted from reworking of ancient lower crust. Based on the presented data we conclude that the Central Tianshan Arc Terrane has undergone three tectonothermal events, namely ~2.5 Ga continental crustal growth, ~1.8 Ga collision related to the Columbia assembly and ~785 Ma crustal reworking due to the Rodinia breakup. The Central Tianshan Arc Terrane, which experienced the same tectonic events as the Tarim Craton during the Precambrian, is considered to be a micro-Precambrian block that separated from the Tarim Craton during the Rodinia breakup.

1. Introduction

The Central Tianshan Arc Terrane (CTA), an important constituent of the Tianshan orogen in the south-western Altaids (Fig. 1A; Sengör et al., 1993; Gao et al., 2009a; Xiao et al., 2010; Long et al., 2011a), underwent a polyphase tectonic evolution and

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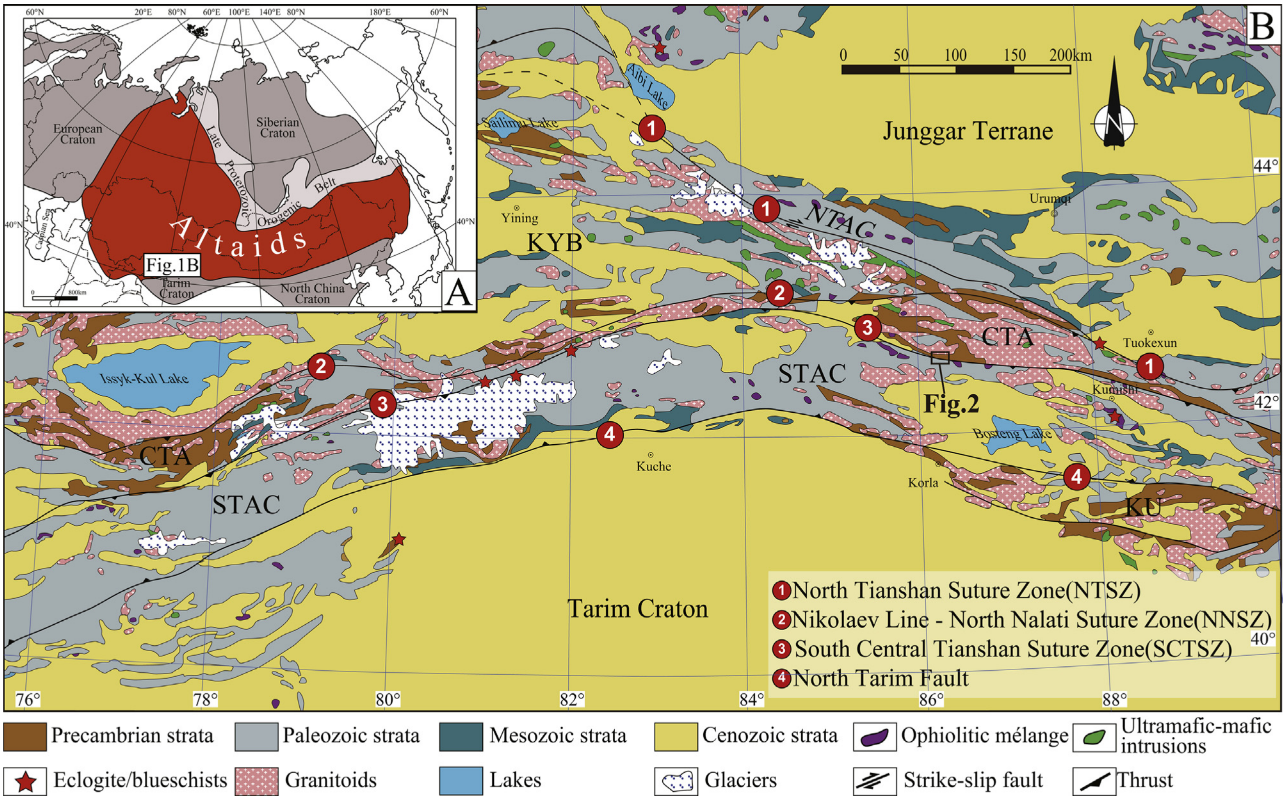

Fig. 1. (A) Tectonic framework of the Altaids (also called Central Asian Orogenic Belt; modified after Sengör et al., 1993). (B) Geological map of the Western Chinese Tianshan orogen (modified after Gao et al., 1998, 2009a). NTAC = North Tianshan Accretionary Complex; KYB = Kazakhstan–Yili Block; CTA = Central Tianshan Arc Terrane; STAC = South Tianshan Accretionary Complex; KU = Kuluqtagh (also spelled as Quruqtagh) Uplift.

crustal growth with voluminous magmatism during the Paleozoic (Charvet et al., 2007; Dong et al., 2011; Ma et al., 2013a, 2014). However, the Precambrian tectonic evolution of the CTA, including the crustal growth and its tectonic affinity, is currently of considerable ambiguity due to the lack of systematic fieldwork and precise geochronological studies, especially in the high-grade metamorphic complexes. Previous authors have proposed various tectonic models regarding the CTA as an eastern segment of the Yili–Central Tianshan plate (Allen et al., 1992; Qian et al., 2009), as a volcanic island arc during the late Paleozoic (Chen et al., 1999), as juvenile crust derived from mantle differentiation at 2.0–1.8 Ga (Hu et al., 1998, 2000) or as a former part of the Junggar plate (Xu et al., 2003). However, some authors argued that the CTA is a cratonic fragment, which separated either from the Tarim Craton or the Baltica Craton during the early Paleozoic (Li et al., 1981; Gao and Peng, 1985; Wang et al., 2008, 2010, 2011; Gao et al., 2009a; Shu et al., 2011a; Ma et al., 2012a,b, 2013a,b, 2014) or the Mesoproterozoic (He et al., 2012, 2014), respectively.

Several geochronological studies revealed that the CTA has a Precambrian basement (e.g., Chen et al., 2000, 2009; Yang et al., 2008; Long et al., 2011a; Ma et al., 2012a,b, 2013b; He et al., 2013; Lei et al., 2013). However, reported igneous rock ages mainly vary between late Mesoproterozoic and Neoproterozoic (~1.4 Ga to ~0.7 Ga) times, while Archaean to Paleoproterozoic ages were predominantly obtained from inherited zircon grains in igneous rocks and detrital zircon grains in sedimentary rocks (e.g., Ma et al., 2012a,b, 2013b). Thus, the presently available age data are insufficient to unravel the crustal growth and tectonic evolution of the CTA, especially during the pre-Neoproterozoic period.

Previous studies mainly focused on the Paleozoic magmatism, structural deformation and comprehensive detrital zircon analyses; therefore, a lack of direct magmatic and metamorphic ages in the CTA hampers the understanding of its early crustal evolution. High-grade metamorphic complexes are often considered as relics of Precambrian microcontinents and generally provide important constraints for the reconstruction of their tectonothermal evolution. Therefore, the widespread outcrops of high-grade gneissic rocks across the CTA and surrounding orogenic belts (Che et al., 1994; Gao et al., 1998; Shu et al., 2011a; Yang et al., 2008; Ma et al., 2013b; He et al., 2014) provide important information regarding the tectonothermal evolution of the CTA.

Based on intensive metamorphism and deformation most rocks in the Baluntai area, which forms the central part of the CTA, were previously assigned to the Precambrian basement (Che et al., 1994; Gao et al., 1998). Recent studies have however confirmed that they are actually Paleozoic metasedimentary or arc-related magmatic rocks (Ma et al., 2012a,b, 2013a,b, 2014). Therefore the precise isotopic ages and tectonic setting of these high-grade metamorphic complexes are still unclear and require a systematic re-evaluation.

Systematic detrital zircon U–Pb and Lu–Hf isotopic studies on the Devonian sandstones and Paleoproterozoic schists in the Baluntai area led to a conclusion that the CTA hosts Archaean to Paleoproterozoic crust and was part of the Tarim Craton during the Precambrian (Ma et al., 2012a,b, 2013b). In contrast, analogous study for Neoproterozoic metasedimentary rocks and orthogneisses from the Xingxingxia Complex in the eastern segment of CTA suggested that the CTA originally was part of the Baltica Craton (He et al., 2014). He et al. (2014) used the absence of Neoarchaean crustal basement in the CTA, which is abundant along the north-eastern margin of the Tarim Craton (Long et al., 2010; Shu et al., 2011a; He et al., 2012, 2013; Zhang et al., 2013; Zong et al., 2013) as an important argument that the CTA and the Tarim Block underwent different Precambrian tectonothermal evolution. This is supported by recently obtained zircon U–Pb ages ranging between 970 and 920 Ma for intrusion of granitic gneisses within the Chinese Eastern Tianshan, which are absent in the Tarim Block (e.g., Huang