Precambrian Research 231 (2013) 1–18

Contents lists available at SciVerse ScienceDirect

Precambrian Research

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

Zircon U–Pb ages and Lu–Hf isotopes of Paleoproterozoic metasedimentary rocks in the Korla Complex, NW China: Implications for metamorphic zircon formation and geological evolution of the Tarim Craton

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ARTICLE INFO

Article history:
Received 5 January 2013
Received in revised form 10 March 2013
Accepted 12 March 2013
Available online 21 March 2013

Keywords:
Zircon
U–Pb–Lu–Hf isotopes
Korla Complex
Tarim Craton
Paleoproterozoic orogeny
Columbia Supercontinent

ABSTRACT

Widespread Paleoproterozoic supracrustal rocks in the northern Tarim Craton contain important information about its geological evolution and correlation with adjacent blocks. We present new in situ LA-(MC-)ICP-MS zircon U–Pb and Lu–Hf isotopic data for six mica schist samples from the Korla Complex. Field and petrological studies indicate a pelitic to semi-pelitic protolith and a high pressure upper amphibolite-facies peak metamorphic condition ($T = 690 \pm 50\,^{\circ}$C and $P = 11 \pm 2$ kbar) for these samples. CL-images reveal that zircons in these samples are dominantly metamorphic origin and only a few detrital zircons occur as relics in sample T1, the ages of which suggest a maximum deposition age of ca. 2.0 Ga and a sedimentary provenance from the Tarim Craton itself. All metamorphic zircons consistently record a metamorphic age of ca. 1.85 Ga, despite of various degrees of discordance probably due to later Pb-loss. Both recrystallization and new zircon growth are recognized for the genesis of these metamorphic zircons. The metamorphic zircon domains in sample T1 show a relatively large range of initial ^{176}Hf/^{177}Hf ratios similar to the detrital cores, whereas those in the other samples show similar initial ^{176}Hf/^{177}Hf ratios (ca. 0.28140 ± 0.00010, 2σ) regardless of their internal structures and degrees of discordance. The former is interpreted as a result of complete U–Pb resetting through fluid-mediated recrystallization, whereas the later probably implies a large-scale Hf isotopic homogenization during new zircon growth. Petrological and zircon isotopic evidence supports that the new zircon growth and Hf isotopic homogenization probably resulted from the mixing of Hf–Zr derived from dissolution of tiny detrital zircons and decomposition of garnet to chlorite in hydrothermal fluids during retrograde metamorphism. Accordingly, the ages of these new zircon growths may postdate the peak metamorphism, which was probably related to a late Paleoproterozoic collisional orogenic event in the northern Tarim Craton. A compilation of available geological and geochronological data enables us to identify two Late Paleoproterozoic orogenic belts: the ca. 1.9–1.8 Ga North Tarim Orogen and the ca. 2.0–1.9 Ga South Tarim Orogen. It is suggested that the Tarim Craton, including the Dunhuang and Quanji Blocks, was correlative with the Alxa–Yinshan Block of the North China Craton, and they probably formed a coherent massif during the Neoarchean–early Paleoproterozoic, which collided with the Ordos Block and its western extension along the ca. 1.95 Ga Khondalite Belt–South Tarim Orogen to form a larger landmass in the Columbia Supercontinent.

1. Introduction

Zircon is an ideal mineral for U–Th–Pb dating and Lu–Hf isotopic measurement, because it contains moderate U, Th and Hf but very low common Pb and Lu. Once incorporated into zircon lattice, the U–Pb and Lu–Hf systems can hardly be disturbed due to the extremely low diffusion rates of these isotopes (e.g., Cherniak and Watson, 2003). Zircon is also one of the most robust minerals that can survive from weathering, transportation and sedimentation, making it a ubiquitous detrital accessory mineral in clastic sedimentary rocks. Therefore, combined U–Pb and Lu–Hf study of detrital zircons has been widely used to constrain the maximum depositional age, sedimentary provenance, tectonic processes and crustal evolution (e.g., Griffin et al., 2004; Andersen, 2005; Xia et al., 2006a; Dickinson and Gehrels, 2009; Cawood et al., 2012).

However, the application of detrital zircon systematics to metamorphosed sedimentary rocks is usually fraught because zircon grains in these rocks, particularly from Archean to Proterozoic high-grade metamorphic terranes, usually show complex internal structures and age patterns due to influence of subsequent

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0301-9268/$ – see front matter
http://dx.doi.org/10.1016/j.precamres.2013.03.003

multiple tectonothermal overprints (e.g., Luo et al., 2004, 2008; Xia et al., 2006a,b; Yin et al., 2009, 2011; Zeh and Gerdes, 2012; Liu et al., 2012a,b). Two distinct processes have been documented for the formation of these metamorphic zircons: solid-state recrystallization and new zircon growth/overgrowth (e.g., Vavra et al., 1996; Schaltegger et al., 1999; Zheng et al., 2005; Wu et al., 2006a; Xia et al., 2009; Gerdes and Zeh, 2009; Zeh et al., 2010a; Chen et al., 2010). During solid-state recrystallization, the U–Pb ages of primary (detrital) zircons are differently reset, leading to more or less discordant younger apparent ages. Their primary zoning patterns are gradually smeared out, but the external morphologies almost remain unchanged (e.g., Pidgeon et al., 1998). This is usually ascribed to a preferential expulsion of radiogenic Pb from the zircon lattice, a process known as radiogenic Pb-loss. Recent geological and experimental studies have documented several mechanisms leading to Pb-loss, including: (1) diffusion of radiogenic Pb from lattice defects (e.g., Hoskin and Black, 2000) or highly metamict zircons with severe radiogenic damage due to α-decay of Th and U (e.g., Mezger and Krogstad, 1997); (2) diffusion-reaction of zircon with infiltrating hydrothermal fluids (e.g., Pidgeon et al., 1998; Geisler et al., 2007); and (3) coupled dissolution–reprecipitation at a intersurface between zircon and fluids/melts (e.g., Vavra et al., 1999; Geisler et al., 2007). The latter two mechanisms are especially efficient so that other constituent elements, such as Th and U, even Si and Zr, can be significantly leached out of zircon lattice. Thus primary detrital zircons can partially or totally lose their information. Fortunately, Lu–Hf isotopic studies have shown that the ^{176}Hf/^{177}Hf of these highly altered/recrystallized zircon domains remains nearly unchanged, substantiating the extreme robust of Lu–Hf isotopic system (e.g., Gerdes and Zeh, 2009; Zeh et al., 2009, 2010a; Zeh and Gerdes, 2012). In contrast, new zircon growth/overgrowth can occur through: (1) metamorphic reaction that releases Zr (e.g., Vavra et al., 1996; Fraser et al., 1997; Sláma et al., 2007); (2) dissolution–transportation–reprecipitation of preexisting zircons in anatectic melts (e.g., Vavra et al., 1999; Flowerdew et al., 2006; Wu et al., 2007) or hydrothermal fluids (e.g., Wu et al., 2006a, 2009; Zeh et al., 2010b); and (3) Ostward Ripening (e.g., Vavra et al., 1999; Nemchin et al., 2001). The newly grown zircons or zircon domains usually have higher ^{176}Hf/^{177}Hf values than the detrital zircons, because they inevitably incorporate more or less radiogenic ^{176}Hf from their surroundings, which have higher ^{176}Lu/^{177}Hf ratios and radiogenic ^{176}Hf (e.g., Flowerdew et al., 2006; Wu et al., 2007; Gerdes and Zeh, 2009; Zeh et al., 2009, 2010a,b; Zeh and Gerdes, 2012). Furthermore, during high-grade metamorphism that produces considerable silicate melts, Hf isotopic homogenization of the new zircon growth/overgrowth is expected due to relatively high Lu–Hf diffusion rates in silicate melts (e.g., Flowerdew et al., 2006; Wu et al., 2007; Gerdes and Zeh, 2009; Zeh et al., 2010a). Recently, Zeh et al. (2010b) reported homogeneous Hf isotopic patterns for new zircons and overgrowths from the lower amphibolite facies metasedimentary rocks in the Shackleton Range, showing that Hf isotopic homogenization can even occur at relatively low-grade metamorphism conditions within metamorphic fluids. Therefore, combined application of cathodoluminescence (CL) images and in situ U–Th–Pb and Lu–Hf isotopic analyses to various metamorphic zircons can provide abundant information not only for the interpretation of U–Pb ages but also for the complex metamorphic, hydrothermal and melting processes.

In this contribution, we present in situ LA-ICP-MS zircon U–Pb ages and Lu–Hf isotopic data for zircon grains from metasedimentary rocks of the Korla Complex in the northern Tarim Craton. This study aims to: (1) distinguish detrital zircons from metamorphic zircons formed by different mechanisms of metamorphic recrystallization and growth/overgrowth; (2) characterize Th–U and Lu–Hf isotopic behaviors of zircons during amphibolite-facies metamorphism; (3) determine the depositional and metamorphic ages of supracrustal rocks in the Korla Complex; and (4) reveal the geological and tectonic significance of the Paleoproterozoic metamorphic-orogenic events in the evolution of the Tarim Craton and the reconstruction of the Columbia Supercontinent.

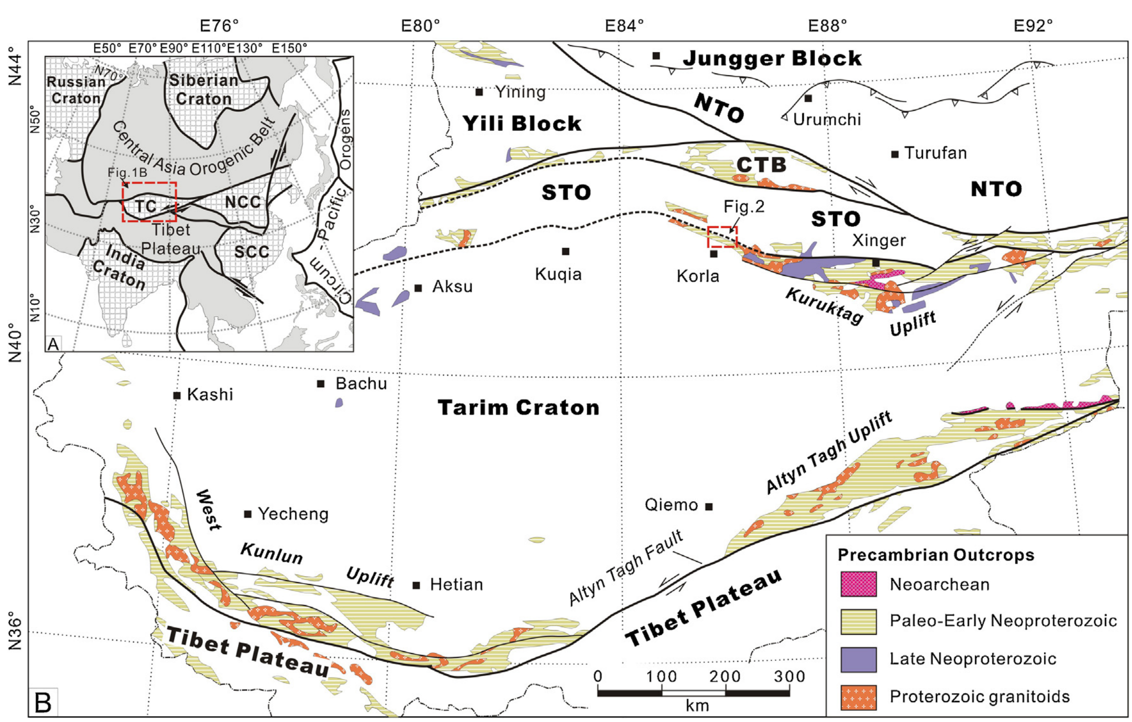

Fig. 1. (A) Simplified tectonic map of Eurasia showing the major tectonic units and the location of the Tarim Craton (TC); NCC: North China Craton; SCC: South China Craton. (B) Distribution of Precambrian rocks in the Tarim Craton modified after XBGMR (1993). STO: Southern Tianshan Orogen; NTO: Northern Tianshan Orogen; CTB: Central Tianshan Block; note the location of the Korla Complex.