Precambrian Research 228 (2013) 1–19

Contents lists available at SciVerse ScienceDirect

Precambrian Research

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

Paleoproterozoic collisional orogeny in Central Tianshan: Assembling the Tarim Block within the Columbia supercontinent

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ARTICLE INFO

Article history:
Received 28 July 2012
Received in revised form
31 December 2012
Accepted 2 January 2013
Available online 11 January 2013

Keywords:
Zircon geochronology
Hf isotopes
Central Tianshan
Tarim
Columbia Supercontinent

ABSTRACT

The Central Tianshan region is a key to evaluate the Paleoproterozoic evolution of the Tarim Block and its correlation with the Columbia supercontinent. In this study, we present U–Pb age data on detrital zircons in Paleoproterozoic schists from Central Tianshan and employ the magmatic age spectra to probe the Precambrian history of the region. We use the U–Pb ages of metamorphic zircons to constrain the Paleoproterozoic collisional event of the Tarim Block, and to evaluate its link with the Columbia supercontinent. The age populations of the detrital igneous zircons and inherited cores show peaks at ∼2544 Ma, ∼2397 Ma, ∼2264 Ma, ∼2161 Ma, ∼1970 Ma and ∼1882 Ma, corresponding to the major tectonomagmatic events previously recorded in the Tarim Block. Combined with the results from previous studies, we conclude that the northern Tarim was an active continental margin from late Neoarchean to late Paleoproterozoic. Zircons in the Paleoproterozoic schists display a wide range of two-stage model ages (3.3–2.7 Ga), revealing prolonged growth of juvenile crust in Tarim from late Paleoarchean to early Neoarchean. The tightly constrained age range of 1830–1788 Ma (weighted mean 1808 Ma) obtained from the metamorphic zircons and overgrowth mantles mark the timing of the thermal event associated with the final collisional orogeny along the northern margin of Tarim, coinciding with the assembly of the Columbia supercontinent.

1. Introduction

Supercontinents play a unique role in Earth's history, gathering nearly all of the earth's continental crust (>75%) into a tightly packed assembly at various periods in Earth's history (Zhao et al., 2006a; Rogers and Santosh, 2009; Meert, 2012; Murphy and Nance, 2012). The assembly and disruption have had major impacts on earth's biogeochemical cycle and the evolution and extinction of life forms (e.g., Santosh, 2010). The history of evolution of supercontinents such as Columbia, Rodinia and Pangea have been topics of several investigations (e.g., Hoffman, 1991, 1999; Rogers, 1996; Wingate et al., 1998, 2002; Condie, 2001; Rogers and Santosh, 2002, 2003; Wilde et al., 2002; Zhao et al., 2002, 2003, 2004; Meert and Torsvik, 2003; Li et al., 2008; Ernst et al., 2008). Among these, the Paleoproterozoic Columbia supercontinent is considered to represent the oldest coherent supercontinental assembly, although the history of its formation, evolution and dispersal are still unclear due to the paucity of precise paleomagnetic and geochronological data from various component blocks (Meert, 2002, 2012; Santosh, 2010; Long et al., 2012).

During the period of 2.0–1.8 Ga, several microcontinents in Greenland and North America were welded by collisional orogens to form the Laurentia protocraton, possibly forming a supercontinent (Hoffman, 1989; Gower et al., 1990). Rogers and Santosh (2002) named this supercontinent Columbia, which contained all of the preserved continental crust based on the fit of mid-Proterozoic rift valleys in eastern India with similar rifts in western cratonic North America. However, in their reconstruction, the Tarim Block was not included. In a parallel proposal, Zhao et al. (2002) identified the connections between continental blocks (East Antarctica vs. Laurentia, Laurentia vs. Baltica, Laurentia vs. Central Australia, North China vs. India, South America vs. West Africa, Siberia vs. Laurentia, and Western Australia vs. South Africa) based on a synthesis of the available global paleomagnetic, lithostratigraphic, geochronological and tectonothermal data from cratonic blocks and related orogenic belts of 2.1–1.8 Ga. In their model, the Tarim Block was placed at the northern margin of Central Australia based on the argument that the Tarim Block was connected to the Kimberley Block of Northern Australia from the Paleoproterozoic to early Cambrian because both these blocks have similar Paleoproterozoic

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http://dx.doi.org/10.1016/j.precamres.2013.01.009

basement rocks and slightly metamorphosed Meso- to Neoproterozoic sedimentary successions (Li et al., 1996).

An alternative configuration of Columbia (1.93–1.85 Ga) (Kusky et al., 2007; Kusky and Santosh, 2009; Santosh, 2010) proposes that the Paleoproterozoic Northern Hebei collisional orogen continues for 3000 km across the North China Block and through the Tarim Block, and then connects with Baltica, West Africa and South America. This collisional orogen was proposed to represent the zone of amalgamation of the blocks within the Columbia supercontinent (Santosh et al., 2009). Yakubchuk (2008, 2010) proposed yet another model for Columbia where the Tarim Block was placed between North China, Amazonia and Eastern European Blocks.

However, as argued by Zhao et al. (2006b, 2012) and Jian et al. (2012), the Inner-Mongolia portion of the inferred Paleoproterozoic Inner Mongolia-North Hebei orogen is an Archean block as the rocks in this region recorded Neoarchean, and not Paleoproterozoic, metamorphic ages. Furthermore, the Paleoproterozoic rocks in the north Hebei segment of this inferred orogen is spatially coincident with the northern segment of the Trans-North China Orogen which formed by Paleoproterozoic collision between the Eastern and Western Blocks of North China Craton at about ~1.85 Ga. Thus, there is no evidence for the so-called Paleoproterozoic Inner Mongolia-North Hebei orogen in the northern margin of the North China Craton. In addition, the collision between Tarim, North China Block and Baltica is speculative and lack any precise lines of evidence, such as similar and contemporaneous features post-dating the collision.

The various models above are still equivocal and emphasize the need for further studies to identify and characterize the magmatic and metamorphic events associated with the Paleoproterozoic orogeny with the constituent blocks, particularly, the Tarim Block in Columbia.

The tectonic history of the Tarim Block, particularly with reference to its relationship with the Columbia supercontinent (Zhao et al., 2002, 2009), has been the subject of global interest in recent years, and isotope geochronology offers a powerful tool to address one of the main points of debate as to whether Tarim was part of the Paleoproterozoic supercontinent assembly. As outlined in the published reconstructions, the various models mentioned above attribute different views and positions for Tarim in the Columbia configuration, and a coherent paleo-reconstruction of the Columbia supercontinent incorporating Tarim, and defining its close connections with other blocks has not yet been presented.

In this study, we present more geological and new geochronological data from the Paleoproterozoic schists in Central Tianshan, a region that was part of Tarim during Precambrian, with the aim of improving our understanding of the geological history of Tarim and its affinity with the Columbia supercontinent during Paleoproterozoic. Our investigation focuses on: (1) the geological significance of the age populations of detrital igneous zircons; (2) the evolutionary history of juvenile crustal growth in Tarim; and (3) the evidence for a late Paleoproterozoic collisional orogenic event.

2. Geological setting

2.1. Central Asian Orogenic Belt (CAOB)

The CAOB (Fig. 1a), one of the long-lived and large-scale accretionary orogens of the Earth (Allen et al., 1993; Sengör et al., 1993; Windley et al., 1990, 2007; Cawood et al., 2009; Xiao et al., 2012), formed through the multiple accretions and collisions of terranes of various origin from the late Neoproterozoic, and these processes resulted in terrane reorganizations of the ancient subduction systems (Shu et al., 2002, 2004; Kröner et al., 2005, 2007; Charvet et al., 2007, 2011; Sun et al., 2008, 2009; Zhang et al., 2011a; Wilhem et al., 2012). Among these terranes, several continental fragments played an important role in the formation of the CAOB. Thus, the tectonic collage of the CAOB and its geodynamic significance on Phanerozoic crustal evolution have been topics of wide global interest (e.g., Jahn, 2004; Jahn et al., 2000, 2004; Li, 2006; Xiao and Kusky, 2009; de Jong et al., 2006, 2009; Yuan et al., 2010). However, several issues related to the origin, evolution and tectonic affinity of these terranes of the CAOB remain equivocal (Kröner et al., 2012).

2.2. Central Tianshan

The Tianshan (Fig. 1b), extending E–W for a length of ca. 2500 km from eastern Xinjiang of China to central Uzbekistan, is a large thrust-and-fold orogen located in the southern margin of the CAOB (Coleman, 1989; Brookfield, 2000; Kröner et al., 2012). As the most important segment of the CAOB that connects the Siberian and Tarim Blocks to the north and south, the Tianshan range formed through several tectonic events during Paleozoic (Windley et al., 1990; Allen et al., 1993; Wang et al., 2010a, 2011a). Tectonically, the Chinese Tianshan is comprised of fault-bounded North, Central, and South tectonic domains (Charvet et al., 2007, 2011), which have significantly different geological history, and separated by the Paleozoic South and North Tianshan sutures (Shu et al., 2002; Wang et al., 2008). Furthermore, the Cenozoic tectonic processes resulting from the India–Asia collision and subsequent ongoing convergence have greatly influenced the present architecture and orientation of the Tianshan (Metelkin et al., 2010; Bullen et al., 2003; Shu et al., 2011a; Glorie et al., 2011; Charvet et al., 2007, 2011).

The Central Tianshan is characterized by the Precambrian metamorphic basement, Ordovician–Early Devonian arc, and Carboniferous and post-Carboniferous sedimentary rocks (Gao et al., 1998; Shu et al., 2002; Charvet et al., 2011; Wilhem et al., 2012) (Fig. 1b). The Central Tianshan region is considered as a continental margin arc, developed on the Precambrian basement (Shu et al., 2002, 2004). The Precambrian amphibolite facies metamorphic rocks such as mica gneisses, schists, amphibolites and marbles are widely exposed in the Xingxingxia, Weiya, Gangou, Bingdaban and Baluntai areas. Precambrian granitoids, orthogneisses and migmatites occur in the Weiya and Xingxingxia regions.

The Precambrian crustal evolution of Central Tianshan has been debated for decades, particularly with regard to its tectonic affinity (e.g., Allen et al., 1993; Chen et al., 1999; Hu et al., 2000; Xu et al., 2003a). The general consensus from recent studies is that the Central Tianshan was part of the Tarim Block during Precambrian (Li, 1981; Shu et al., 1998, 2011b; Gao et al., 1998, 2009; Zhu et al., 2004; Charvet et al., 2007, 2011; Wang et al., 2008, 2011b; Lin et al., 2009; Lei et al., 2011; Ma et al., 2012a,b; Wilhem et al., 2012).

The tectonic affinity of Central Tianshan with Tarim is evidenced from several common features in both regions. Gao and Peng (1985) suggested that the Groups of Tianhu, Kawabulag and Xingxingxia in the Central Tianshan belt are stratigraphically analogous with the Groups of Paergangtage, Aierji and Yangjibulake in Kuruqtagh (NE Tarim), respectively. In the Central Tianshan region, the Precambrian metamorphic basement has undergone greenschist to lower amphibolite facies metamorphism, as well as that of Tarim (Liu et al., 2004; Shu et al., 2004). Moreover, the Precambrian metamorphic rocks consisting of intrusive rocks, volcanics, carbonatites and clastic rocks and extensively exposed in the Central Tianshan area, are similar to those in Kuruqtagh (Shu et al., 2002, 2011b). A complementary occurrence of the Neoproterozoic littoral–neritic marbles, clastic rocks and carbonates is the common feature of the latest Neoproterozoic Sinian strata, in conjunction with Sinian tillites in both regions lying unconformably on the ancient basement (Nakajima et al., 1990; Gao et al., 1998; Xu et al., 2003b, 2009; Zhu et al., 2004). The Cambrian stratabound phosphorus and vanadium mineralizations occur in both Central Tianshan and