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Neoproterozoic diamictite-bearing sedimentary rocks in the northern Yili Block and their constraints on the Precambrian evolution of microcontinents in the Western Central Asian Orogenic Belt

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ABSTRACT

The origin and tectonic setting of Precambrian sequences in the Central Asian Orogenic Belt (CAOB) have been debated due to a lack of high resolution geochronological data. Answering this question is essential for the understanding of the tectonic framework and Precambrian evolution of the blocks within the CAOB. Here we reported LA-ICP-MS detrital zircon U–Pb ages and in-situ Hf isotopic data for Neoproterozoic sedimentary cover in the northern Yili Block, an important component of the CAOB, in order to provide information on possible provenance and regional tectonic evolution.

A total of 271 concordant U–Pb zircon ages from Neoproterozoic sedimentary cover in the northern Yili Block define three major age populations of 1900–1400 Ma, 1300–1150 Ma and 700–580 Ma, which are quite different from cratons and microcontinents involved in the CAOB. Although it is not completely consistent with the local basement ages, an autochthonous provenance interpretation is more suitable. Some zircon grains show significant old Hf model ages (T_{DM}^{C}; 3.9–2.4 Ga) and reveal continental crust as old as Paleoarchean probably existed. Continuous Mesoproterozoic zircon age populations exhibit large variations in the εHf(t) ratios, suggesting the long-time involvement of both reworked ancient crust and juvenile material. Similar Mesoproterozoic evolution pattern is identified in many continental terranes involved in the CAOB that surround the Tarim Craton. Based on our analysis and published research, we postulate that the northern Yili Block, together with Chinese Central Tianshan, Kyrgyz North Tianshan and some other microcontinents surrounding the Tarim Craton, once constituted the continental margin of the Tarim Craton in the Mesoproterozoic, formed by long-lived accretionary processes. Most of the late Neoproterozoic zircons exhibit significant positive εHf(t) ratios, suggesting the addition of juvenile crust. It is consistent with the tectonic event related to the East Africa Orogen in the Arabian-Nubian Shield and the northern Tarim Craton, indicating the affinity between them in Gondwana.

1. Introduction

As one of the largest accretion–collision orogen on Earth, the Central Asian Orogenic Belt (CAOB) is situated between the Siberian Craton in the north and the North China (Sino-Korean) and Tarim Cratons in the south. It extends from the Urals Mountains to the Pacific coast of the Okhotsk Sea, via Kazakhstan, Kyrgyzstan, northwestern China, Mongolia and northeastern China (e.g. Ge et al., 2012; Glorie et al., 2015; Kröner et al., 2008, 2014; Rojas-Agramonte et al., 2011; Song et al., 2013; Wang et al., 2012; Windley et al., 2007). It has been widely accepted that the CAOB was formed by successive accretion and amalgamation of various microcontinents, continental fragments, accretionary prisms, island arcs and ophiolitic domains from the late Neoproterozoic to the Paleozoic, related to the closure of the Paleo-Asian Ocean between Baltica (East European Craton), Siberia and blocks of central Asia (Tarim, Kazakhstan, North China) (e.g. Alexeiev et al., 2011; Demoux et al., 2009; Glorie et al., 2011; Hegner et al., 2010; Jahn et al., 2004; Kröner et al., 2012, 2014; Windley et al., 2007; Xiao et al., 2010, 2013). However, Precambrian crustal materials which are involved in the orogenic processes of the CAOB have still been a subject to plenty of controversy. The origin and affinity of many terranes with Precambrian crystalline basement in the CAOB remain uncertain. Some authors have postulated that these were fragments of either the northern Gondwana (Biske and Seltmann, 2010; Buslov et al., 2001; Dobretsov and Buslov, 2007) or the Siberian Craton (Turkina et al., 2007). Whereas detrital zircon age data from the Chinese Central Tianshan (Ma et al., 2012a,b), Kyrgyz Tianshan (Rojas-Agramonte et al., 2014), Mongolia (Rojas-Agramonte et al., 2011) and North Da Xing'an Mountains, NE China (Han et al., 2011) concluded that the most likely origin is the Tarim Craton. Levashova et al. (2011) even suggested that the continental slivers in the CAOB had

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originally belonged either to Tarim or South China through paleomagnetic data. On the other hand, early Precambrian lithological units are rare within the CAOB (Kovach et al., 2013) and many metamorphic assemblages which were previously interpreted as parts of coherent Precambrian basement are in fact much younger and consists of several continental and ophiolitic slivers associated with terrane accretion and subduction during the Paleozoic (e.g. Alexeiev et al., 2011; Konopelko et al., 2012; Kröner et al., 2012, 2014; Wang et al., 2012). Therefore, there are many unclear and contradictive aspects concerning the Precambrian evolution history of the microcontinents or fragments involved in the CAOB.

The Chinese Tianshan belt, together with the Kazakh–Kyrgyz Tianshan orogenic belt, is located in the southwestern part of the CAOB (Kröner et al., 2012, 2013). Previous studies generally divided the Chinese Tianshan into North Tianshan, Central Tianshan and South Tianshan (Allen et al., 1992; Gao et al., 1998, 2009; Windley et al., 1990). Uncertainty exists on correlating the subunits of Chinese Tianshan with their continuous units in the Kazakh–Kyrgyz Tianshan which is generally divided into North, Middle and South Tianshan (Rojas-Agramonte et al., 2014; Xiao et al., 2013). The Yili Block is a major continental constituent of the westernmost part of the Chinese Tianshan. Because of westward extension of the Nalati fault is likely joining with the Nikolaev Line in Kyrgyzstan (Wang et al., 1990, 2008), the Yili Block is generally regarded as the equivalent part of the Kyrgyz North Tianshan (Rojas-Agramonte et al., 2014; Wang et al., 2008, 2010; Xiao et al., 2013). They together constitute a major tectonic block which is called “Kazakhstan–Yili” or “North Tianshan–Yili” in the literature (Charvet et al., 2007; Gao et al., 2009; Wang et al., 2008). According to this tectonic configuration, the Kyrgyzstan North Tianshan are considered as the southern parts of the Kazakhstan–Yili Block (Biske and Seltmann, 2010; Ren et al., 2011). The Middle Tianshan in Kyrgyzstan appears to wedge out near the Kyrgyz–Chinese border and the equivalent is not recognized in China (Rojas-Agramonte et al., 2014; Xiao et al., 2013), but the South Tianshan Orogen (includes the Kyrgyz and Chinese South Tianshan) is continuous from west to east, just situated between the Tarim Craton in the south and the Kazakhstan–Yili Block in the north (Biske and Seltmann, 2010; Charvet et al., 2007; Gao and Klemd, 2003; Gao et al., 1998, 2009; Glorie et al., 2010; Metelkin et al., 2010). Some regard the Yili Block as a microcontinent corresponding to the westward extension of the Chinese Central Tianshan (Allen et al., 1992; Gao et al., 1998) or as the part of the Aktau–Junggar continental fragment (Alexeiev et al., 2011; Wang et al., 2014a; Windley et al., 2007). Therefore, its relationships with subunits in the Chinese Tianshan and Kazakhstan–Kyrgyz Tianshan remain controversial. The Precambrian crustal evolution of the Yili Block and its affinity with other blocks in the CAOB has also been debated. The nature and tectonic significance of the Precambrian outcrops of the continental domains are important for understanding the continental evolution of the Yili Block. On the other hand, Neoproterozoic glacial diamictites in the northern Yili Block are also well-exposed and of wide interest due to their significance in understanding the Snowball Earth hypothesis and supercontinent reconstruction (Gao et al., 1993, 2013; Zhu and Wang, 2011). However, many controversies exist about the age and correlation of these diamictites due to a lack of precise isotopic age constraints.

Based on the uncertainties mentioned above, the establishment of reliable ages as well as origin, boundaries, and evolution of the Yili Block is a primary target of this research. Here, we present results of a combined in situ analysis of LA–ICP–MS detrital zircon U–Pb ages as well as Hf isotopic data from Neoproterozoic diamictite-bearing sedimentary strata in the northern Yili Block in order to identify periods of major tectono-magmatic events and provide paleogeographic constraints. Through these data, we aim to reveal the crustal evolution of the region and find the link between the northern Yili Block and other nearby crustal blocks involved in the CAOB.

2. Geological background

The Yili Block, a triangular area that extends westward into Kazakhstan and Kyrgyzstan (Wang et al., 2007, 2008), is located in the most northwestern part of China. It is bordered by the North Tianshan fault in the north and the Nalati fault in the south that separate the Yili Block from the North Tianshan and the Central–South Tianshan in China (Wang et al., 2007; Fig. 1). Wang et al. (2008) further separated the Bole area from the Yili Block through their different paleomagnetic poles and Paleozoic series.

Precambrian rocks of the Yili Block mainly crop out discontinuously along its boundaries in the Sailimu–Wenquan area in the northern branch and along the Nalati fault near the South Tianshan. They are considered to represent the continental basement of the Yili Block (Gao et al., 1998; Hu et al., 2000, 2006; Wang et al., 2008). The Sailimu–Wenquan area in the northern Yili Block is one of the largest regions with mass exposure of Precambrian rocks in the Tianshan belt. Proterozoic rocks are mainly exposed in the Wenquan Group, which is known to have emplaced during the Paleoproterozoic (XBGMR, 1988a, b). Recent isotopic dating identified various lithological units of different ages from the Wenquan Group, including pre-Neoproterozoic meta-sedimentary and meta-volcanic rocks (paragneiss, micaschist, marble, quartzite and amphibolite), Neoproterozoic migmatite, orthogneiss, various granitic plutons and leucogranitic dykes and Paleozoic arc-type magmatic rocks (Hu et al., 2000, 2006, 2008, 2010; Wang et al., 2011, 2012, 2014b). The concept of “Wenquan Metamorphic Complex” (WMC) has been used in the literature, accordingly (Liu et al., 2014; Wang et al., 2014a,b). The other Precambrian rocks mainly outcrop around the Sailimu Lake (Fig. 2). Bedded or intensively deformed crystalline limestone and interlayered phyllite form the Mesoproterozoic Jixian System (XBGMR, 1988a,b). The Neoproterozoic Qingbaikou System comprises stromatolite-bearing limestone and dolomite.

The Nanhua–Sinian Kailaketi Group is mainly exposed in Guozigou and Keguqing Mountain at the south of the Sailimu Lake (Fig. 2) and is characterized by three intervals of glacial deposits (Gao et al., 1993; Zhu and Wang, 2011). In ascending order from the oldest to the youngest, it is subdivided into six formations: the Kulutielieketi, Tulasu, Biexibasitao, Kayingdi, Taerqiate and Talisayi formations (Fig. 3A). A basal conglomerate interval with clasts derived from the underlying Qingbaikou System was found at the bottom of the Kulutielieketi Formation. It is overlain by greenish massive basalt. The subsequent Kulutielieketi Formation in the top consists of gray massive diamictite interval. The clasts in the Kulutielieketi diamictite are mainly composed of dolostone, limestone, marble, chert and basalt. However, the glacial origin of the Kulutielieketi diamictite is ambiguous (Gao et al., 1993; Zhu and Wang, 2011). The overlying Tulasu Formation consists of black carbonaceous and silicified mudstone with black siltstone interbed. The Biexibasitao Formation contains siltstone and sandstone in the lower part and diamictite in the upper part. The clasts in the Biexibasitao diamictite are dominated by carbonate, chert and volcanic clasts. Striated clasts exist in the Biexibasitao diamictite which is a distinct glaciogenic feature (Zhu and Wang, 2011). Black-grayish muddy siltstone constitutes the major part of the Kayingdi Formation. The Taerqiate Formation is also dominated by muddy siltstone, but distinguished by variation in color from the Kayingdi Formation. The Talisayi Formation contains three yellow diamictite intervals interbedded with two sandstone layers. Clasts in the Talisayi diamictite are dominated by quartz, carbonate and sandstone. They are mostly less than 15 cm in diameter, poorly sorted and sub-angular (Fig. 4A). The largest clasts are generally found in the lowest diamictite layer with diameter up to 50–80 cm (Fig. 4B). Previous researches discovered some striated clasts in the Talisayi diamictite, proving its glacial origin (Zhu and Wang, 2011). The Talisayi Formation is overlain disconformably by the Cambrian Lingkuanggou Formation.

In order to provide constraints on the depositional ages of glacial deposits as well as crustal evolution and continental affinity of the