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Significant Carboniferous magmatism and continental growth in the northern West Tianshan orogen, NW China: Revealed by detrital zircon U-Pb and Lu-Hf analyses for turbidites from the North Tianshan Accretionary Complex

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ABSTRACT

We conducted an integrated study including U-Pb dating and Lu-Hf isotope analysis for detrital zircons from the turbidites of the North Tianshan Accretionary Complex, northern Chinese West Tianshan, to constrain their depositional age, source characteristics and tectonic setting. Almost all the detrital zircons display well developed oscillatory zoning textures and have high Th/U ratios, reflecting an igneous origin. Based on the analytical results, the depositional ages of the four samples were 303 Ma–312 Ma, 310 Ma and 321 Ma. The studied samples all display unimodal detrital zircon spectra, with few Precambrian zircons, coinciding with the age spectra of sediments deposited in convergent basins, most likely a forearc basin. Most of the zircons and other mineral grains have euhedral to subhedral shapes, reflecting a relatively short transportation distance. Considering the occurrence of volcanic lithic fragments in thin-sections of the sandstones, we propose that the northern edge of Yili Block, which is widely accepted as a Paleozoic continental arc formed by subduction of the North Tianshan Ocean, was the most likely source area for the North Tianshan turbidites. There are 137 Lu-Hf isotope analyses on zircons with concordant U-Pb ages, all showing positive $\varepsilon_{Hf}(t)$ values ($\varepsilon_{Hf}(t) = +2.9–+15.8$), and young T_{DM}^{C} ages (328–1152 Ma, peak at 400–800 Ma). The Hf isotope characteristics indicate important growth of juvenile crust and minor crustal contamination during the formation of the zircons' host rocks. When we examine the Hf isotope of reported magmatic rocks from the northern Yili Block, we found an increasing trend of $\varepsilon_{Hf}(t)$ values from the Early Paleozoic to Late Paleozoic. This indicates that there was a large amount of juvenile material extracted from the depleted mantle in the Carboniferous. Taking into account of previous research, we conclude that the northern West Tianshan was a subduction-arc system during the Carboniferous, and the studied turbidites from the North Tianshan Accretionary Complex were sourced from the magmatic arc of the northern Yili Block and most likely deposited in a fore-arc basin in the Late Carboniferous.

1. Introduction

Convergent plate boundaries are locations where oceanic crust is subducted into mantle and new continental crust is created (Clift et al., 2009). Accretionary complexes are a fundamental element of the active continental margins, and contain detailed material record of interaction between plates (Amato and Pavlis, 2010). Sedimentary rocks within the complexes are commonly sourced from the upper plate (i.e., the arc and fore-arc), thus recorded the tectonic and magmatic evolution of the active plate boundaries (Kochelek et al., 2011). Detrital zircon geochronology has developed rapidly over the past two decades, due to increasingly universal use of ion probes or laser ablation techniques for analysis (Carroll et al., 2013). In particular, the combined U-Pb and Lu-Hf isotopic analyses for detrital zircons can reflect not only chronological framework but also source nature of the host rocks, becoming a powerful tool in tectonic reconstructions (Long et al., 2007; Wu et al., 2010; Li et al., 2012).

The Central Asian Orogenic Belt (CAOB), which was built during ~1.0 Ga–250 Ma, is one of the most famous orogenic belts on earth that preserves crucial evidence for accretionary orogensis and Phanerozoic continental growth (Jahn et al., 2004; Wang et al., 2006; Windley et al., 2007; Şengör et al., 1993; Cawood et al., 2009; Cai et al., 2011; Long et al., 2011; Xiao et al., 2013; Chen et al., 2016). The Chinese West Tianshan orogenic belt, which is located in the southernmost of the

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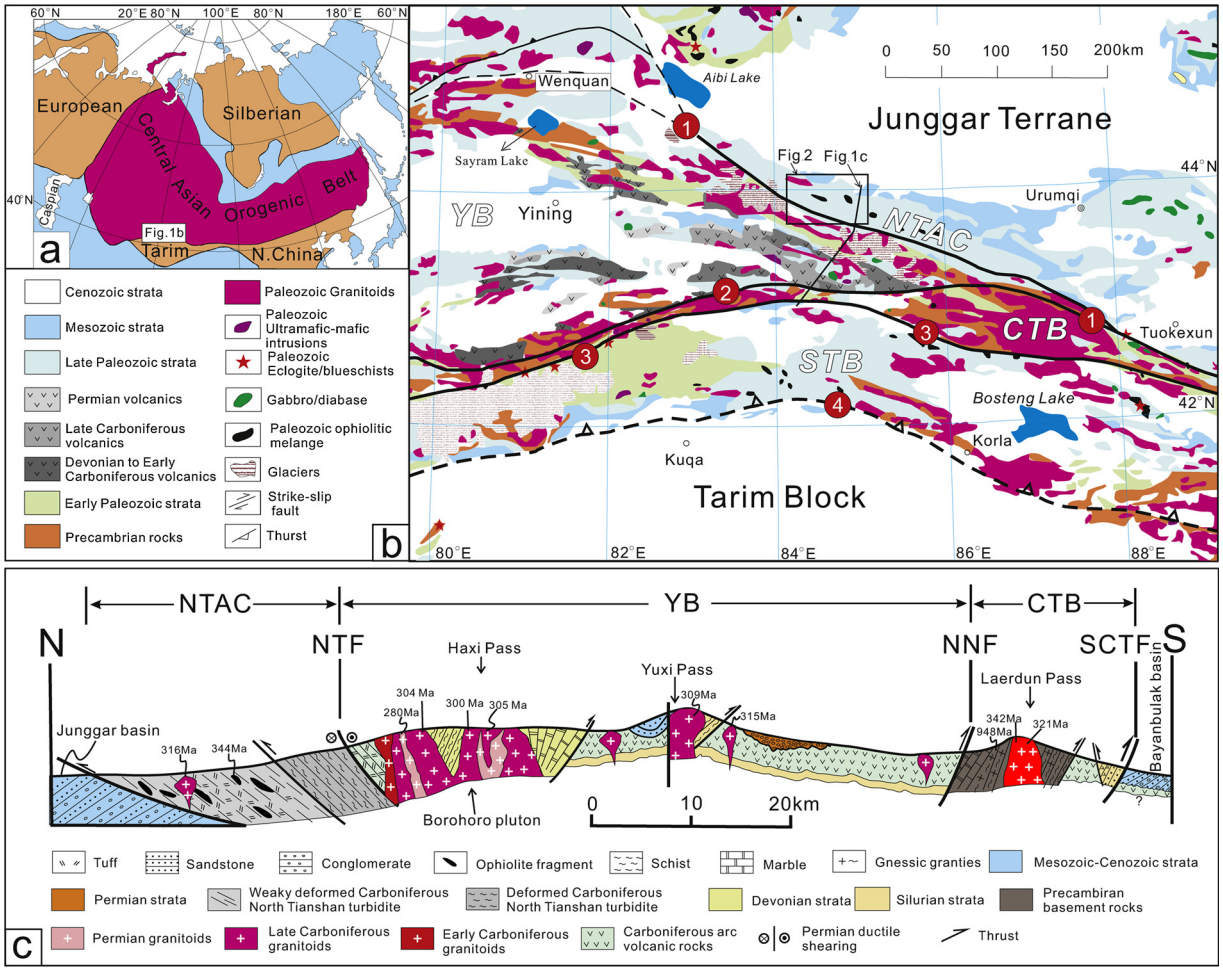

Fig. 1. (a) Tectonic framework of the Central Asian Orogenic Belt (modified after Şengör et al., 1993 and Xiao et al., 2013). (b) Geological map of the Chinese West Tianshan Orogen and adjacent regions (modified after Gao et al., 2009 and Zhu et al., 2012). Numbers in circle refer to the tectonic boundaries: 1) North Tianshan Suture Zone; 2) Nikolaev line-North Nalati Suture Zone; 3) Southern Central Tianshan Suture Zone; and 4) North Tarim Thrust. Abbreviations for the tectonic unites are: NTAC = North Tianshan Accretionary Complex; YB = Yili Block; CTB = Central Tianshan Block; STB = South Tianshan Belt. (c) Cross section from Dushanzi to Bayanbulak along the Du-Ku highway, showing geological units of the northern West Tianshan orogen. Abbreviations for the faults are: NTF = North Tianshan Fault; NNF = Northern Narat Fault; SCTF = Southern Central Tianshan Fault.

CAOB, is an ideal area to explore the accretionary process and mechanism of continental growth (Xiao et al., 2013). The continuous subduction of the North Tianshan oceanic crust beneath the Yili Block and subsequent closure of the ancient ocean gave birth to the North Tianshan Accretionary Complex (NTAC). For the sake of a better understanding of tectonic evolution of the NTAC, numberous studies have been conducted for the ophiolites in the NTAC (Xia et al., 2004; Xu et al., 2006a,b; Li et al., 2015), and for the magmatic rocks in the northern margin of the Yili Block (Zhu et al., 2005; Wang et al., 2006, 2007, 2009; Zhang et al., 2016; An et al., 2017; Wang et al., 2018a). However, the widely distributed and well-exposed turbidites in the NTAC have not been studied yet, which in fact are critical to reveal the accretionary process of the northern Chinese West Tianshan orogenic belt.

In this contribution, we conducted a comprehensive U-Pb and Lu-Hf isotopic study on detrital zircons from the turbidites in the NTAC. These data are used to: (1) place constraint on the formation ages of the turbidites; (2) reveal nature of the magma source that originally hosted the detrital zircons, and trace the source area of the turbidite.

2. Geological setting

The Tianshan orogenic belt stretches for more than 2500 km across central Asia and Xinjiang Autonomous Region of northwestern China. The Chinese West Tianshan orogenic belt is part of this orogenic belt, and can be divided into four tectonic units from north to south, i.e. the NTAC, the YB, the Central Tianshan Block (CTB) and the South Tianshan Belt (STB) (Fig. 1(b); Xiao et al., 2013). It was formed by collision and/or accretion processes between the Junggar Terrane, the YB, the CTB and the Tarim Craton during the Paleozoic (Gao et al., 1998, 2009; Qian et al., 2009; Han et al., 2010; Xiao et al., 2013; Wang et al., 2018a).

The NTAC is in fact a Late Paleozoic suture, which record the subduction and final closure process of the North Tianshan Ocean (NTO). To the south of the NTAC, a NW-striking major fault was called the North Tianshan Fault (NTF) (Zhou et al., 2001; Wang et al., 2006). And to the north, there is a south-dipping thrust fault, which led to the override of the accretionary complex onto the Permian and Mesozoic sediments in southern Junggar basin (Fig. 1(b) and (c)). It consists mainly of two different lithologies: 1) the ophiolitic remnants (Wang et al., 2006; Xu et al., 2006a; Han et al., 2010) and 2) the Carboniferous volcano-sedimentary rocks which were regarded as turbidites (Wang et al., 2006, 2008). The ophiolites are exposed discontinuously over an area of ~250 km in length and 5–15 km in width (Fig. 1(b)), and the Bayingou ophiolite is one of the best exposed (Xu et al., 2006a). The Bayingou ophiolite is composed of strongly serpentinised ultramafic rocks (including harzburgite, iherzolite, pyroxenite, dunite and peridotite), basalts, gabbros, plagiogranite and radiolarian cherts, forming a