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Provenance of the southern Junggar Basin in the Jurassic: Evidence from detrital zircon geochronology and depositional environments

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ABSTRACT

The goal of this paper is to study the provenance of the southern Junggar Basin during the late Triassic to early Cretaceous, based on the detrital U-Pb geochronology, petrography and depositional environments. Eight sandstone samples from the Upper Triassic to Lower Cretaceous were collected for detrital zircon U-Pb dating. A total of 794 effective U-Pb ages was obtained and divided into four groups: 488–2537 Ma (basement zircons), 328–482 Ma (subduction-related magmatic zircons), 254–322 Ma (post-collisional magmatic zircons), and 135–250 Ma (syndepositional magmatic zircons). These ages relate to three stages of basin evolution. (1) From the early to middle Jurassic, Tian Shan experienced continued exhumation, accompanied by progressive southward expansion of the Junggar Basin, and a peneplain was formed by the time Xishanyao Formation was deposited. Organic-rich sediments formed in a delta environment were well-developed in the southern Junggar Basin, with source rocks gradually switching from post-collisional volcanic rocks (295–307 Ma with a peak age of 300 Ma) of the southern North Tian Shan to post-collisional volcanic rocks of the Central Tian Shan (280–320 Ma with a peak age of 316 Ma) and then to subduction-related island arc rocks (402–423 Ma with a peak age of 415 Ma) of the Central Tian Shan. (2) During deposition of the Toutunhe and Qigu Formations, large scale volcanic activities occurred along the North Tian Shan Fault. Source rocks at this time include syndepositional volcanic rocks (151–161 Ma), and post-collisional volcanic rocks (290–320 Ma) of the North Tian Shan. By the time of deposition of the Kalazha Formation, Tian Shan experienced rapid tectonic uplift, leading to rapid lake regression. Alluvial fans were well developed in the southern Junggar Basin with source rocks being the underlying sedimentary strata of the north margin of the North Tian Shan. (3) During the early Cretaceous, exhumation of the Tian Shan and lake transgression in the Junggar Basin happened again. Shallow lake sediments were developed in the southern Junggar Basin with source rocks being subduction-related volcanic rocks (339–419 Ma with a peak age of 415 Ma) of the Central Tian Shan and post-collisional volcanic rocks (254–305 Ma with a peak age of 298 Ma) of the North Tian Shan.

1. Introduction

The Junggar Basin, located in the northern part of the Tian Shan, is an important oil and coal-bearing basin (Fig. 1b). Organic-rich Jurassic strata are widespread throughout the Junggar Basin and act as an important source rocks for petroleum and gas accumulations (Ulmishek, 1984; Graham et al., 1990; Hendrix et al., 1992, 1995; Ding et al., 2003; Ashraf et al., 2010; Zhou et al., 2010; J. Li et al., 2012). Provenance and depositional environment are important in predicting the distribution of petroleum source rocks (Allen and Allen, 2013). However, the provenance and depositional environments of the southern Junggar Basin in the Jurassic still remain controversial (Hendrix et al., 1992, 1995; Fang et al., 2005, 2006a, 2007; Bian et al., 2010; Zhou et al., 2010; Yang et al., 2013).

The Tian Shan was considered as the dominant provenance of southern Junggar Basin sediments based on paleocurrents (Hendrix et al., 1992; Fang et al., 2005). According to the uniformly volcanic-rich sandstone composition, principal source rocks were attributed to the Devonian-Carboniferous andesitic arc volcanic rocks of the Tian Shan (Hendrix, 2000; Fang et al., 2006a, 2007). Yang et al. (2013) suggested the possible source rock areas based on detrital zircon geochronology, but no detailed study on the source rock was conducted. The depositional environments of the southern Junggar Basin remain controversial in the Lower Jurassic where braided river (Fang et al., 2005), meandering river (Hendrix et al., 1992, 1995), or

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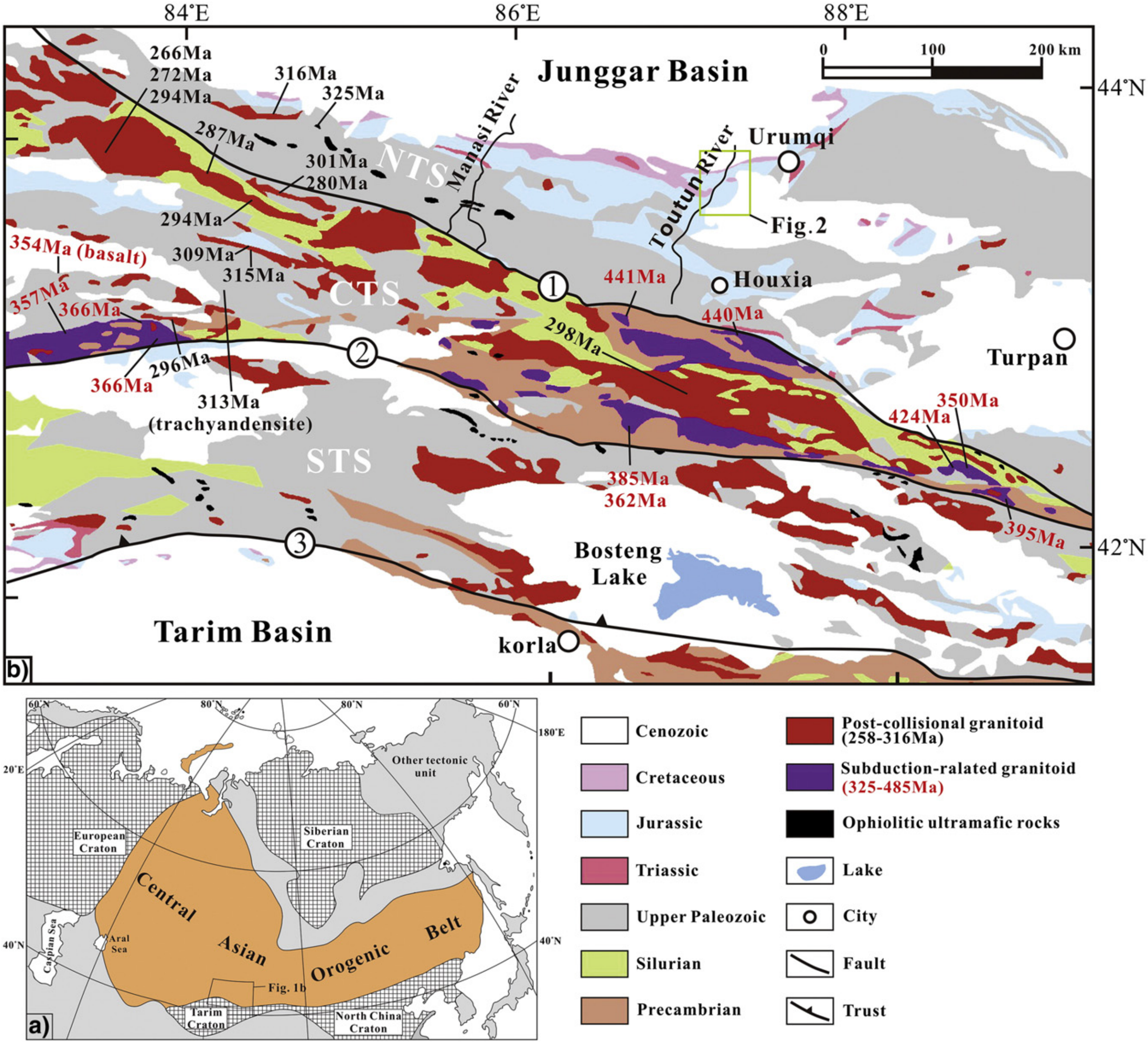

Fig. 1. (a) Tectonic location of the Central Asian Orogenic Belt (modified from Han et al., 2011); (b) Geological map and tectonic units of the Chinese Tian Shan Orogen. ① The North Tian Shan Fault, ② The Qinbulak-Qawabulak Fault, ③ The North Tarim Thrust. NTS – North Tian Shan, CTS – Central Tian Shan, STS – South Tian Shan (modified from Allen et al., 1992; BGMRXUAR, 1992). The age data marked in red indicate the crystallization age of the subduction-related magmatic rocks (Zhu et al., 2005; Zhu and Song, 2006; Chen et al., 2012; P. Li et al., 2012); The age data marked in black indicate the crystallization age of the post-collisional magmatic rocks (Xu et al., 2005, 2006; Zhu et al., 2005; Wang et al., 2006b, 2007a; Chen, 2007; Han et al., 2010; P. Li et al., 2012).

braided-delta conditions prevailed (Bian et al., 2010; Zhou et al., 2010). For the Middle Jurassic, meandering river (Hendrix et al., 1992, 1995; Fang et al., 2005) or lacustrine environments existed (e.g., Zhou et al., 2010). In the Upper Jurassic, most researchers suggested that the red beds were deposited in braided fluvial environments, overlain by uppermost Jurassic alluvial conglomerates (e.g., Hendrix et al., 1992; Fang et al., 2005); however, distinct carbonate cemented sandstones are observed in the red beds, which may be formed in lacustrine rather than braided river environments (Morad, 1998).

These uncertainties require more evidence to accurately determine the detailed source rocks and depositional environments of the southern Junggar Basin during the Jurassic. Detrital zircon U-Pb dating is a powerful tool for provenance analysis (e.g., Cawood and Nemchin, 2000; Dickinson and Gehrels, 2003; Gillis et al., 2005; Nemchin and Cawood, 2005; Sircombe, 2007; Morton et al., 2008; Veevers et al., 2008; Xu et al., 2012; Albardeiro et al., 2014; Xie and Mann, 2014). Eight sandstone samples from the Upper Triassic to Lower Cretaceous were collected from the Toutun River section for detrital U-Pb dating (Fig. 2). Petrographic study and detailed sedimentary facies analysis along two continuous sections of the Manasi River and Toutun River were also carried out with the aim of identifying the detailed provenance of the southern Junggar Basin in the Jurassic.

2. Geological setting

The Central Asian Orogenic Belt (CAOB) is a tectonic assembly of continental and oceanic terranes formed during closure of the paleo-Asian ocean in the Phanerozoic (e.g., Jahn et al., 2000; Kovalenko et al., 2004; Windley et al., 2007; Han et al., 2011) (Fig. 1a). The present-day Tian Shan, located in the southwest part of the CAOB, is a late Paleozoic orogeny belt, which was strongly modified by the Cenozoic India-Asia collision (e.g., Avouac et al., 1993; Hendrix et al., 1994; Abdrakhmatov et al., 1996; Yin et al., 1998; Bullen et al., 2001, 2003; Charreau et al., 2005, 2006; De Grave et al., 2007; Sun et al., 2009; Jian et al., 2013).