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Provenance and tectonic setting of the Carboniferous sedimentary rocks of the East Junggar Basin, China: Evidence from geochemistry and U–Pb zircon geochronology

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ABSTRACT

The modern Junggar Basin was located in the Central Asian Orogenic Belt (CAOB) during the Devonian and Carboniferous. Few data concerning the weathering, provenance and tectonic setting of the Carboniferous sedimentary rocks in the Junggar Basin have been published. The recent discovery of an oil–gas field in the East Junggar Basin provides the impetus for this study. Twenty-eight sediment samples were recovered from eight boreholes, and all were analysed for major and trace element geochemistry. Two samples of sedimentary rocks were selected for zircon U–Pb dating. Low chemical index of alteration (CIA) values (44–71) and relatively high index of compositional variability (ICV) values (0.72–1.83) suggested weak chemical weathering and an immature source for these samples. The relatively low Th/U (2.16–10.55) and Rb/Sr (0.03–5.44) ratios of the drill core samples reflect a simple recycling history. Two samples indicated upper Carboniferous ages (314.6 Ma) and a lower-middle Devonian age (397.9 Ma). Geochemistry and detrital zircon geochronology from the East Junggar Basin reveal a distinct difference in the composition and source rock ages of clastic rocks from the lower and the upper Carboniferous. Major and trace element compositions of the lower Carboniferous sedimentary rocks (LCRs) were derived from typical mafic rocks and an intermediate ocean island arc of early to middle Devonian age, whereas the upper Carboniferous sedimentary rocks (UCRs) were derived from a continental island arc or active continental margin setting with a dominantly felsic to intermediate late Carboniferous age. The current data provide little support for tectonic models that show a passive continental margin of a Precambrian crystalline basement; our study suggests that a volcanic arc accretion or archipelago (early Carboniferous to early-middle Devonian) model for the East Junggar Basin is more viable.

1. Introduction

The Junggar Basin is located in the Central Asian Orogenic Belt (CAOB), or the Altaids. The CAOB is one of the largest accretionary orogens on Earth and is thought to have evolved from the Neoproterozoic through the late Paleozoic by subduction and accretion of juvenile material and microcontinental fragments (Fig. 1A; Şengör et al., 1993; Khain et al., 2003; Jahn et al., 2004; Windley et al., 2007; Kröner et al., 2008; Geng et al., 2009a, 2009b; Xiao et al., 2010). The final closure of the Paleo-Asian Ocean probably occurred by the late Carboniferous due to the oroclinal bending of the western part of the Altaids (Şengör et al., 1993) or during the Permian when the North China Craton was attached to the CAOB (Jahn et al., 2006). Several authors (Zheng et al., 2000; Wang et al., 2002a; Zheng et al., 2007; Su et al., 2010) reported on the geochronology and geochemistry of the Carboniferous volcanic rocks within the Junggar Basin. Several papers have discussed the sedimentary geochemical studies of the outcrops (Zhang et al., 2001; Yang et al., 2007; Long et al., 2008), but no data concerning the weathering, provenance and tectonic setting of the Carboniferous sedimentary rocks from the Junggar Basin have been published. However, the sedimentary sequences that accumulate in arc-related basins can be valuable records of the tectonic evolution of that active plate boundary (Clift et al., 2000). The provenance of sedimentary rocks can also provide palaeogeographic constraints if it can be plausibly connected to their potential source regions (Cawood et al., 2007).

We chose to study the Carboniferous East Junggar Basin, where good quality seismic data and numerous drill cores could be acquired. Despite the strong tectonic deformation around the Junggar Basin, sediments of the East Junggar Basin are well-bedded and not pervasively deformed. Abundant sedimentary rocks in the Carboniferous geological record of the East Junggar Basin preserve a wealth of information regarding the evolution of tectonics and basin filling. The most robust and accurate technique for dating sedimentary successions is U–Pb geochronology of zircon in intercalated volcanic or volcaniclastic rocks (Rasmussen and Fletcher, 2010). Although fossils are

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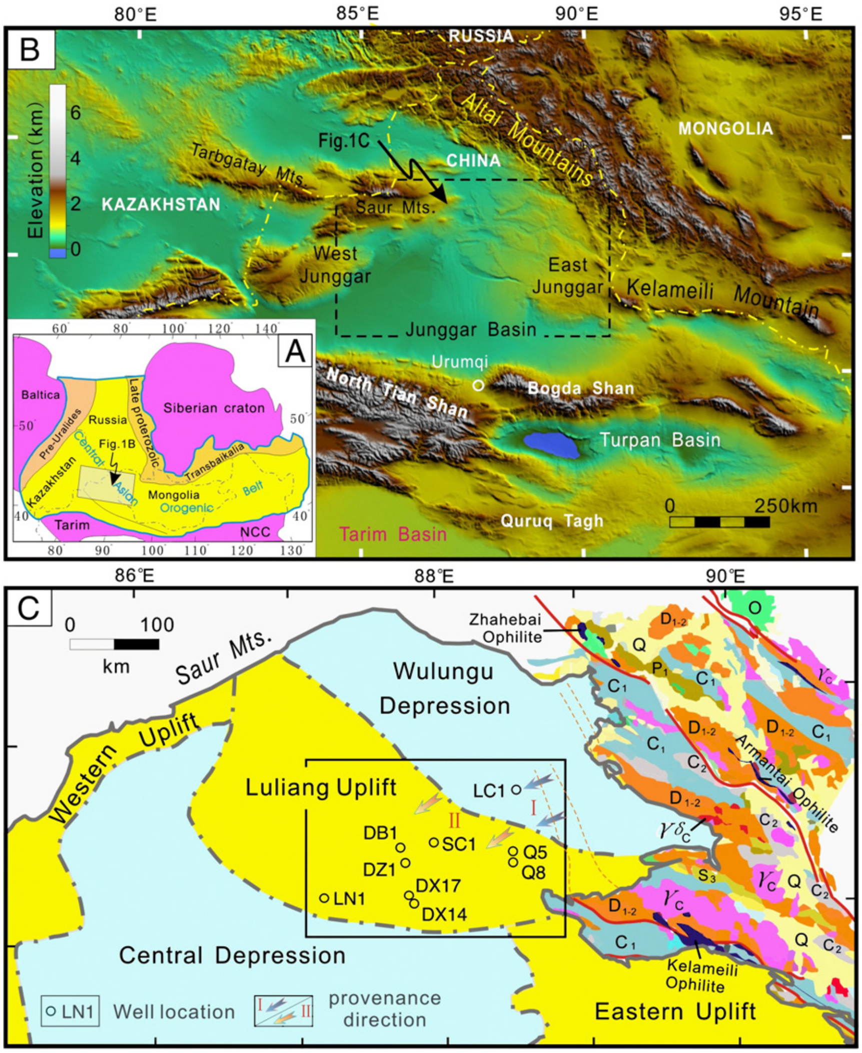

Fig. 1. (A) Location of the study area in the Central Asian Orogenic Belt (modified from Jahn et al., 2004; Windley et al., 2007; Geng et al., 2009b). (B) Topographic map showing the location of the East Junggar in Central Asia Orogenic Belt (modified from Han et al., 2010). (C) Map of the East Junggar Basin showing the locations of nine boreholes containing samples for major and trace element analyses and zircon U–Pb dating, and simplified geological map of the East Junggar Terrane (simplified from He, 2003). Arrows show the dominant provenance directions over time: I = provenance direction showing potential source terranes and major sediment transport path into the East Junggar Basin during the early Carboniferous; II = provenance direction showing potential source regions and major sediment transport path during the late Carboniferous. C_1 = lower Carboniferous, C_2 = upper Carboniferous, D_{1-2} = late to middle Devonian, S_3 = late Silurian, Q = Quaternary, O = Ordovician, r_c = Carboniferous granite, $r\delta_c$ = Carboniferous granodiorite.

uncommon in volcanogenic rocks, several fossil zones of pollen and spore assemblage (PSA) have been recognised (Ouyang et al., 1993). Thus, sedimentary rocks, which are interbedded with volcanic rocks, allow the origin stratigraphy to be reconstructed (Fig. 2). Sedimentary geochemistry has not been mentioned in previous studies, and thus, little is known about the sedimentary geochemistry and crustal accretion processes that affected the reconstruction of the evolution of this region. The lack of information regarding Carboniferous sedimentary geochemistry in the Junggar Basin hinders complete understanding of its tectonic and basin-fill evolution.

Here, we report the geochemistry and zircon U–Pb ages of Carboniferous sedimentary rocks that were recovered from boreholes in the Junggar Basin in NW China. These age determinations, which include previous volcanic zircon ages from the basin (Wang et al., 2002a; Zheng et al., 2007; Su et al., 2010), provide chronostratigraphic constraints for a Carboniferous volcanic-sedimentary succession. These new zircon U–Pb ages and sedimentary geochemical data substantially enhance our understanding of the stratigraphy by contributing to the geochemical evolution of the sedimentary succession during the Carboniferous. Furthermore, the whole-rock geochemistry of sedimentary successions can be applied in studies of provenance, tectonic setting and terrane relationships (Bhatia, 1983; Bhatia and Crook, 1986; Roser and Korsch, 1986; Herron, 1988; Roser and Korsch, 1988; McLennan et al., 1993; Cullers, 1995; Cawood et al., 2007; Diskin et al., 2011).

2. Geological setting

The Junggar Terrane of western China is situated in the central part of the CAOB and is bounded by the Siberian and Kazakhstan plates and the Tianshan Range (Fig. 1A). The Junggar Terrane is traditionally divided into the East Junggar Terrane, the West Junggar Terrane and the Junggar Basin (Zhang et al., 2009; Han et al., 2010; Xiao et al., 2011). The West Junggar Terrane largely consists of Paleozoic accretionary complexes in the south and volcanic arcs in the north (Windley et al., 1990; Chen and Jahn, 2004; Xiao et al., 2004; Windley et al., 2007; Xiao et al., 2008; Zhou et al., 2008; Zhang et al., 2009; Zhang et al., 2011; Xiao et al., 2010; Yin et al., 2010), and the tectonic units may extend westward to Kazakhstan (Chen and Jahn, 2004; Chen et al., 2010). The East Junggar Terrane includes several accretionary complexes that were generated by subduction–accretion processes in the Paleozoic (Coleman, 1989; Feng et al., 1989;