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Late Carboniferous crustal uplift of the Tarim plate and its constraints on the evolution of the Early Permian Tarim Large Igneous Province

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ABSTRACT

The Early Permian Tarim Large Igneous Province (LIP) in northwestern China has been related to a mantle plume, mostly constrained by petrology and geochemistry. However, the crustal uplift/erosion related to a mantle plume has rarely been addressed. In order to improve our understanding of crustal uplift/erosion we have studied the stratigraphy and sedimentology of eighty-five boreholes/outcrops and two seismic profiles. The results indicate a regional unconformity and onlap contact between the earliest Permian and Carboniferous strata, with denudation of Carboniferous and deposition of earliest Permian strata. The denudation of Carboniferous strata has been divided into three types of erosion: deep, partial and weak, with a deep erosion zone located in Northern Tarim region (east of Keping and west of Northern Tarim) which gradually weakens towards the south. Above the unconformity, the Early Permian pre-eruption deposit is thinnest (<100 m) in Northern Tarim region, and thickens gradually to the south (>300 m), which is consistent with the spatial distribution of Late Carboniferous erosion. This unconformity represents a spatial distribution of denudation forced by doming uplift/erosion at the end of the Carboniferous, with minimum estimation of its vertical and lateral extent of 887 m and ~300 km, respectively, which are comparable to those of other mantle-plume-generated LIPs. Both the Late Carboniferous erosion and Early Permian sedimentary records indicate a crustal uplift event at ~300 Ma. The uplift was short-term and approximately dome-shaped, occurring immediately before the Tarim LIP (~290 Ma). These results provide new stratigraphic and sedimentological constraints on the role of a mantle plume in the formation Early Permian Tarim LIP, from a crustal uplift perspective. The spatial distribution of denudation suggests that the regions of Northern Tarim, or further north, represent the centre of the potential plume head.

1. Introduction

The Early Permian large-volume intraplate magmatism in the Tarim Basin of northwestern China has been recognized as a Large Igneous Province (LIP) (Bryan and Ernst, 2008; Bryan and Ferrari, 2013; C.L. Zhang et al., 2010, 2013; Yang et al., 2006c, 2013). Outcrop and borehole investigations indicate that the Tarim LIP covers an area of 25×10^4 km^2, of which over 80% is occupied by the continental flood basalts (Yang et al., 2005, 2006a,b). Three episodes of this LIP event have been recently summarized by Xu et al. (2014), including the first episode featured by the diamond-poor kimberlitic rocks at ~300 Ma in the Wajilitag area (D. Y. Zhang et al., 2013), the second episode represented by the flood basalts and the low-Nb-Ta rhyolites at ~292 to ~287 Ma (Chen et al., 2009; Li et al., 2011; Liu et al., 2014; Tian et al., 2010; Wei et al., 2014; Yu et al., 2011; Zhang et al., 2012), and the last episode characterized by a ultramafic-mafic and felsic intrusions, low- and high-Nb-Ta rhyolites, and mafic and felic dyke swarms ~284–~ 272 Ma (Tian et al., 2010; Wei and Xu, 2011; Yang et al., 2006b, 2007b; C.L. Zhang et al., 2008, 2010).

Geochemical work reveals that the widespread Tarim basalts exhibit trace element patterns generally similar to those of ocean island basalts, enriched in large-ion lithophile and high rare-earth elements but with relatively high $^{87}Sr/^{86}Sr$ ratios and negative $\varepsilon Nd(t)$ values (Yu et al., 2011; C.L. Zhang et al., 2010; Zhou et al., 2009), which are probably related to the likely interaction between the mantle plume and lithosphere (Wei et al., 2014; Yu, 2009; Yu et al., 2012; Y.T. Zhang et al., 2010). Apart from the basalts, the other igneous rocks in the Tarim LIP, such as the ultramafic-mafic layered intrusions and dike swarms and syenitic rocks (or A-type granites) (e.g., Cao et al., 2013; Li et al., 2012; Yang et al., 2006b; C.L. Zhang et al., 2008, 2010), and picrites and kimberlitic rocks (Tian et al., 2010; Yang et al., 2007b; D.Y. Zhang et al., 2013) have also been studied for their petrogenesis and proposed to be genetically linked to a mantle plume (Xu et al., 2014).

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Despite these geochemical and petrological interpretations, the geological evidence for a mantle plume under Tarim during the Early Permian is still insufficient. This problem can be partly solved by independently evaluating regional doming and crustal uplift/erosion with stratigraphic and sedimentological records predating the LIP (Campbell and Griffiths, 1990; Cox, 1989; Dam et al., 1998; He et al., 2003; Kent, 1991; Kerans, 1983; Morgan, 1971, 1981; Nadin et al., 1997; Rainbird, 1993; Richards et al., 1989, 1991; White and McKenzie, 1989; Williams and Gostin, 2000; Wilson, 1965), which has been proposed to be a key criteria to identify a fossil mantle plume (e.g. Campbell, 2001; Xu, 2002).

This sort of crustal uplift/erosion evaluation on Tarim LIP was initially attempted by Chen et al. (2006), who presented a preliminary investigation on sedimentary facies variations related to mantle plume doming. Based on eighty-five boreholes/outcrops and two seismic profiles, we here improve the understanding with a comprehensive stratigraphic and sedimentological correlation, and establishing stratigraphic thickness distribution and sedimentary facies variation, which provide an insight into the predating surface uplift/erosion related to a mantle plume.

2. Geological background

The Tarim plate is one of three major plates in China, surrounded by the Tianshan, western Kunlun, and Altyn orogenic belts (Lu et al., 2008; C.L. Zhang et al., 2013; Zheng et al., 2013) (Fig. 1). The Tianshan orogenic belt, as part of the Central Asian orogenic belt, is the result of subduction-related accretion in the Junggar-Balkash and South Tianshan ocean during the Palaeozoic (Allen et al., 1992; Charvet et al., 2011; Chen et al., 1999; Sengor and Burtman, 1993; Windley et al., 2007; Xiao et al., 2013). The western Kunlun orogenic belt extends from the Pamir syntax to the east Kunlun orogen along the northern margin of the Tibetan Plateau, which was a passive margin from the Carboniferous to the Early Permian (Bi et al., 1999; Xiao et al., 2002, 2005). The Altyn orogenic belt, one of the major active tectonic features during the India-Asia collision, extends along the northern edge of the expanding Tibetan Plateau (Khain et al., 2003; Sobel and Arnaud, 1999; Yin et al., 2012; Z.L. Chen et al., 2001).

The structural and sedimentary background of Tarim Basin has been well defined due to hydrocarbon exploration (e.g., Chen et al., 2004; Guo et al., 1995; Jin and Wang, 2004; Lin et al., 2011). A typical double-layered structure has been identified, which comprises a Proterozoic basement overlain by Neoproterozoic to Cambrian sequences (C.L. Zhang et al., 2013), exhibiting a generally cratonic basin setting. This stable tectonic setting allows for a stable deposition, dominated by deep-water black phosphorus siliceous rock and radiolarian silicate during Neoproterozoic to the Cambrian (Lin et al., 2009). In the Early Palaeozoic, carbonate platforms developed in the northern and southern parts of the basin (Bao et al., 2006), followed by open platform carbonate sediments in southwest Tarim within a passive continental margin setting during Late Palaeozoic (Chen et al., 1999; Golonka and Ford, 2000; Liu et al., 2010). The Mesozoic Tarim Basin underwent marked uplift and erosion with sediments shifting into continental facies (Chen and Wang, 2000). In the Cenozoic, the India-Asian collision reactivated the surrounding orogenic belts, and lacustrine, fluvial and alluvial sediments overlying epeiric marine sequences deposited within foreland regions of Tarim Basin (J. Chen et al., 2001).

This paper focuses on the Carboniferous to Permian sedimentary evolution, in an attempt to understand the sedimentary records of the Tarim LIP evolving during this period. Tectonically, the Tarim Basin has been a relatively stable region since the end of Devonian. During this time, as a stable craton basin, the Tarim Basin has experienced large-scale transgression. Seawater entered the basin from the southwest, resulting in the deposition of the Donghetang Formation, which covered the basin lowlands. Eustatic changes occurred frequently during the Carboniferous and the sedimentary facies of the Bachu and Kalashayi Formations changed repeatedly along the continental shelf, open platform, and coastal regions (Wang et al., 1998; Zhu et al., 2002). In the early Permian, the Tarim Basin experienced large-scale regression and seawater retreated gradually from the southwest of the basin. The Tarim Basin then underwent a phase of terrestrial deposition, during which delta dominated the clastic sedimentation in the northern

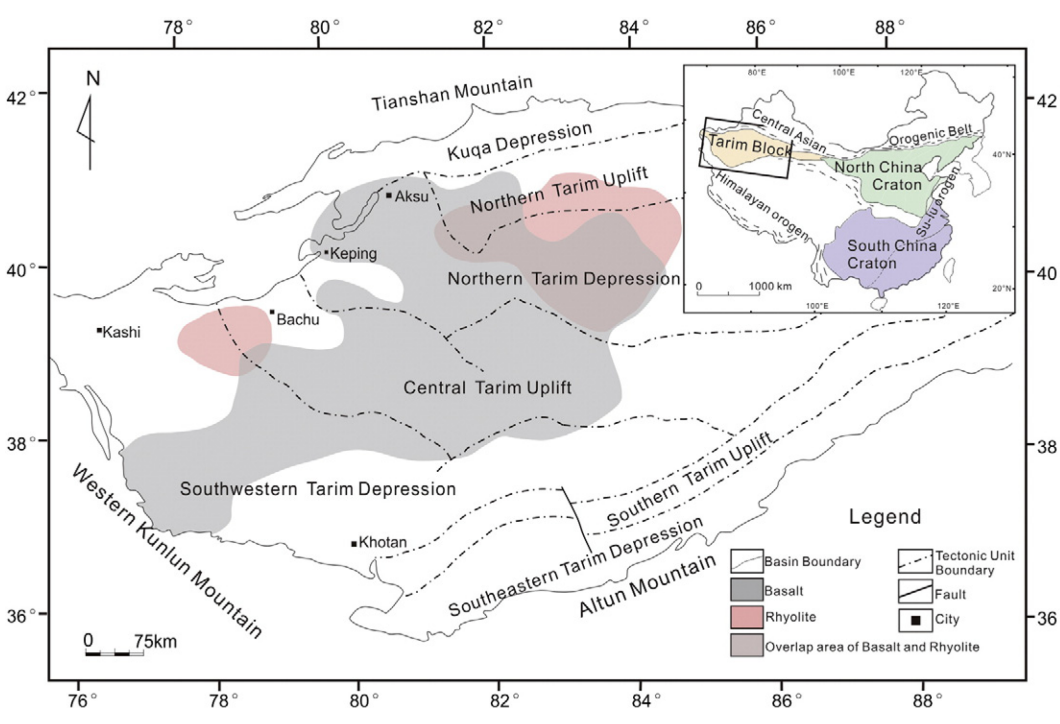

Fig. 1. A simplified map of Tarim Large Igneous Province (Tarim LIP) with the inset shows main tectonic units in China (modified from Yang et al., 2013; Lu et al., 2008; Wang et al., 2009).