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Ordovician stable carbon isotope stratigraphy in the Tarim Basin, NW China

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ABSTRACT

The Tarim Basin, located in NW-China, represents one of China's major palaeoplates. Its palaeogeographic position in the Ordovician, however, is debated. In this study we present biostratigraphically controlled stable carbon isotope data from some 600 samples spanning almost the entire Ordovician in order to provide a tool that can be used for future chemostratigraphic correlations. The data correlate well with results from South China, and several major global $\delta^{13}C$ excursions such as the MDICE (Dw2/3), SAICE (Sa2), GICE (Ka1), and Whitewater excursion (Ka4) are documented for the first time from the Tarim Basin. Major sedimentary gaps are detected in the lower Floian between the Penglaiba and Yinshan formations, in the upper Darriwilian to lower Sandbian between the Dawangou and Saergan (or Kanling) formations, and in the latest Sandbian between the Kanling and Qilang formations as well as between the Tumuxiuke and Lianglitag formations. Three scenarios for the depositional history of the late Darriwilian to early Sandbian Saergan Formation, which represents an important hydrocarbon source rock in the Tarim Basin, are discussed with respect to their bio- and chemostratigraphic implications. The mid-upper Ordovician rocks recording high $\delta^{13}C$ values have been deposited during transgressive or highstand intervals, whereas the regressive intervals are mostly missing. This results in a stacking of several positive excursions, and thus chemostratigraphic correlation without biostratigraphic control might produce misleading results, especially for shallow-water carbonates.

1. Introduction

The Tarim Basin, separated from Junggar Basin to the north by the Tianshan Mountains and bound to the south by the West Kunlun-Altun Mountain range of the Qinghai–Tibet Plateau, represents one of China's six major palaeoplates or blocks (Chen and Rong, 1992; Chen et al., 2010a). It is located in north-western China, but its precise palaeogeographic position in the Ordovician is debated. During this time the plate was either positioned close to the equator (Zhu et al., 1998), or south of it in the northeast peri-Gondwanan region (Rong et al., 1999; Huang et al., 2000; Goldman et al., 2011; Chen et al., 2013), or reconstructed as moving rapidly from south to north of the equator (Fang and Shen, 2001; Sun and Huang, 2009). Anyway, based on palaeontological evidence it seems likely that Tarim was an independent block or terrane in the northeastern Gondwanan region (Fortey and Cocks, 2003; Zhou and Zhen, 2008). It has been proposed that Tarim amalgamated with the Junggar Basin (Kazakhstan Block) in the late Permian to early Triassic along with the formation of the Tianshan Mountains, and collided with the Tibet Block in the Late Cretaceous to early Palaeogene along with the subduction of Tarim and the uplift of the Qinghai–Tibet Plateau (Xu et al., 2011).

As the Tarim Basin is largely covered by extensive desert today (Taklimakan Desert), outcrops are restricted to the periphery regions, especially in the north-western and north-eastern parts, whereas in the thickly-covered central part only some drill cores are available for stratigraphic and palaeontological studies. In the past decades the Ordovician of Tarim has attracted many petroleum geologists as extensive petroleum and gas reservoirs have been found in Darriwilian and early Katian reef carbonates (Jia et al., 2004; Jin, 2006). Source rocks for the hydrocarbon are probably Cambrian and Darriwilian–early Katian black shales (Zhou et al., 1992). In the Cambrian and Ordovician, Tarim tilted to the east with platform carbonates developed in the west and shale and silty shale in the east. Later, in the Silurian to Permian, it tilted in the opposite direction, manifesting a seesaw pattern (Jin, 2006).

Only a few papers have published stable carbon isotope data from the Tarim Basin so far, mostly with low resolution and poor biostratigraphic control (e.g. Wang and Yang, 1994; Jiang et al., 2001; Jing et al., 2008; Wang et al., 2008; Zhu et al., 2008). A comprehensive curve is published by Hu et al. (2010) who provide data for the interval from the Penglaiba to the Yingan formations (Tremadocian to Early Katian) in the Kalpin area, northwest Tarim. Recently, carbon isotope records of Ordovician rocks are reported from three wells in central Tarim,

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which range from Floian to early Katian, but with a significant gap of Darriwilian–Sandbian age (Zhang et al., 2014b). Although these data are of rather low resolution they fit well with our data, except for the black shale interval of the Saergan Formation, which however represents an important source rock. A more detailed curve for about the same interval is presented by Zhao et al. (2009, 2010), who proposed a close relationship between stable carbon isotope and sea-level development for the Tarim Basin.

The steering mechanisms of Early Palaeozoic δ^{13}C fluctuations, and especially their relation to sea-level changes are still poorly understood (e.g., Munnecke et al., 2010; Thompson and Kah, 2012; Pancost et al., 2013). Nevertheless, the fluctuations in the global carbon cycle are clearly associated with environmental changes as they show a close correlation, e.g., with graptoloid evolutionary rates (Cooper et al., 2014). But regardless of the causes of the fluctuations stable carbon isotope curves have been proven in many studies to be reliable chemostratigraphic proxies for refining global correlations (e.g., Ainsaar et al., 2007, 2010; Bergström et al., 2010, 2012; Albanesi et al., 2013; Sial et al., 2013; Hints et al., 2014). Purposes of our study therefore are: a) to establish biostratigraphically well controlled high-resolution δ^{13}C curves for the Ordovician of Tarim Basin, that can be used for future chemostratigraphic correlations, b) to reveal any unknown or poorly documented disconformities in the basin, c) to develop a depositional model for the Saergan black shales, which represent an important hydrocarbon source rock, and d) finally, to provide a brief up-to-date review of the conodont and graptolite biostratigraphy of the Tarim Basin, because many papers were published in Chinese and difficult to access.

2. Geological settings and biostratigraphy

The Tarim Block is bounded by the Kegan Fault and the Qiemo-Xingxing Gorge Strike Fault to the south, and by the Hantengri-Kumux Fault or the Aibi Lake-Xingxing Gorge Fault to the north (Fig. 1). The block became solid and stable roughly since the middle Neoproterozoic, when it formed as a northern part of the supercontinent Rodinia (Li et al., 1996). Since the late Neoproterozoic the basin became extensional, and accumulated thick sedimentary sequences until the late Ordovician. Then, subductions and collisions occurred both at the northern and southern margins and lead to extensive uplift of the central craton, whilst only the marginal belts accumulated sediments during the Silurian and Devonian. In the Carboniferous the northern margin became extensional again with active volcanism until late Permian–Triassic when the Tarim Block was eventually amalgamated with the northern Junggar Block to form the Tienshan Suture and produce some molasses as well. In the Mesozoic, intermittent terrestrial deposits were accumulated in

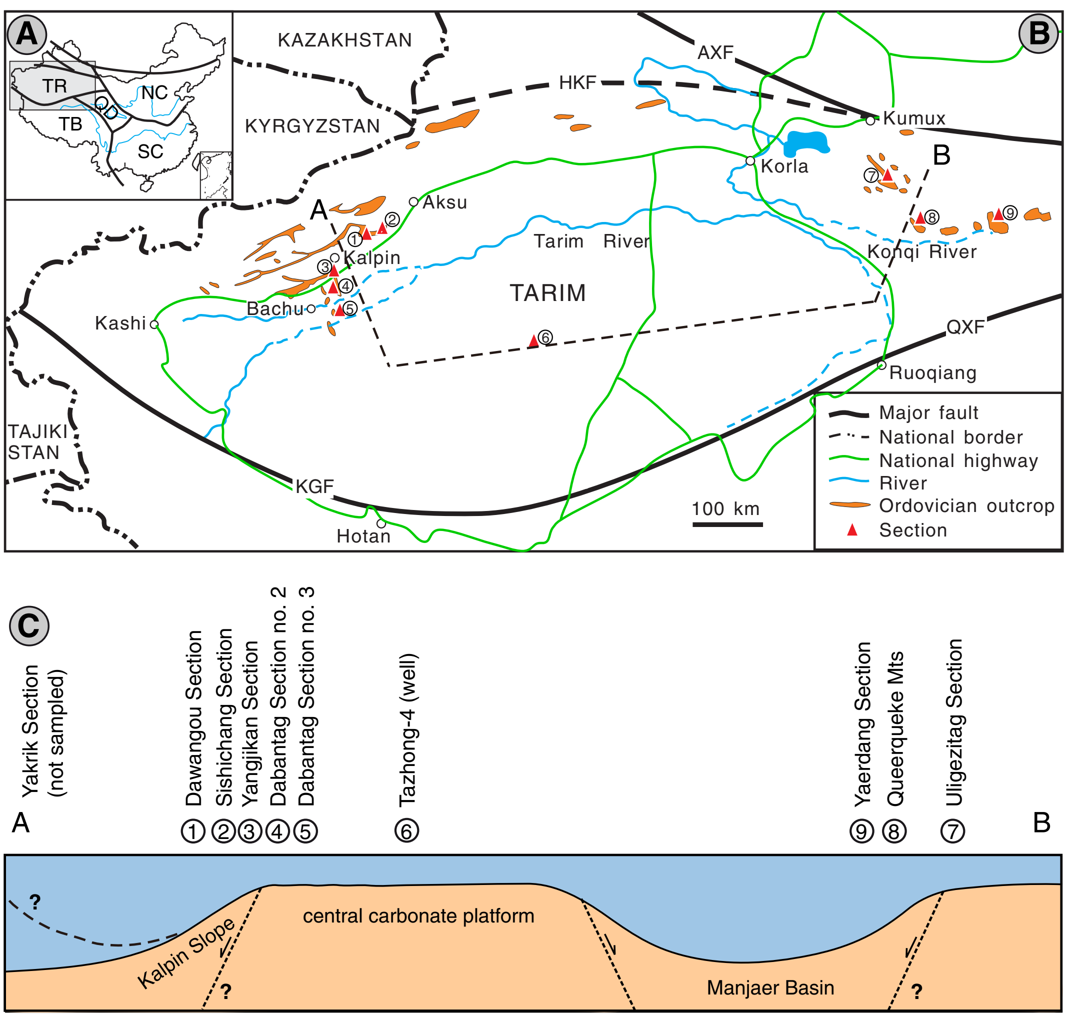

Fig. 1. Geographic positions of the studied sections. A) Major tectonic plates of China (NC = North China, SC = South China, TB = Tibet, TR = Tarim, QD = Qaidam). B) Map of Ordovician outcrops in Tarim Basin, and positions of sampled sections (dotted line A–B gives the position of the schematic profile shown in C). Tectonic boundaries (after Chen et al., 1992): AXF: Aibi Lake-Xingxing Gorge Fault, HKF: Hantengri-Kumux Fault, KGF: Kegan Fault, QXF, Qiemo-Xingxing Gorge Strike Fault. Section localities: ① Dawangou, Kalpin; ② Sishichang, Aksu; ③ Yangjikan, Kalpin; ④ Dabantag section no. 2, Bachu; ⑤ Dabantag section no. 3, Bachu; ⑥ Drill core Tazhong-4; ⑦ Uligezitag; ⑧ Queerqueke Mts.; ⑨ Yaerdang). C) Simplified profile across the Tarim Basin showing the palaeobathymetric positions of the studied sections in the Ordovician (for position of the profile see B, the dotted line indicates a possible northwards shallowing, for more details see the text).