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Research paper

Stable isotope ($\delta^{13}C_{ker}$, $\delta^{13}C_{carb}$, $\delta^{18}O_{carb}$) distribution along a Cambrian outcrop section in the eastern Tarim Basin, NW China and its geochemical significance

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ABSTRACT

This study investigated the geochemical features of the lower Paleozoic strata of Yaerdang Mountain outcrop along with the core samples from well TD2∊ in the eastern Tarim Basin, NW China. The total organic carbon abundance, hydrocarbon-generating precursor biospecies, and stable isotope ratios of organics and carbonate ($\delta^{13}C_{ker}$, $\delta^{13}C_{carb}$ and $\delta^{18}O_{carb}$) were comprehensively studied for their possible correlative constraints during sedimentary evolution. The results revealed that the $\delta^{13}C_{ker}$ (VPDB) of Cambrian kerogens along the outcrop section varied from −34.6‰ to −28.4‰, indicating an increasing tendency from the lower Cambrian to the upper Cambrian. This was on the whole accompanied by the variation in the $\delta^{13}C_{carb}$ and $\delta^{18}O_{carb}$ along the profile, which might be associated with the changes in the sea level and also in the compositional variation of benthic and planktonic biomass. The large variation in the stable carbon isotope ratios up to 6‰ along the outcrop section reflected the heterogeneity of the Cambrian source rocks from the eastern Tarim Basin. Hence, the ^{13}C-enriched crude oils from well TD2∊ might have been derived from a localized stratum of Cambrian source rocks. The results from this study showed the possibility of multiple source kitchens in the Cambrian–lower Ordovician portion of Tarim Basin.

1. Introduction

The Tarim Basin is one of the most important petroleum basins in China (Li et al., 1996), a paleozoic cratonic basin, overlaid by Mesozoic–Cenozoic foreland depressions. The two main marine oil source units identified in the basin are the Cambrian–lower Ordovician and middle–upper Ordovician strata (Liang et al., 2000; Zhang et al., 2000). Recently, it has been reported that oils typically from the Cambrian–lower Ordovician source rocks in the Tarim Basin are ^{13}C-enriched, such as crude oils of TD2∊ and TZ62S with bulk stable carbon isotopic ratios around −28‰ (Zhang et al., 2004a; Xiao et al., 2005; Tian et al., 2012), which are much heavier (usually by 3–6‰) than the oils from middle–upper Ordovician source rocks. Researchers have previously attributed the ^{13}C-enrichment in the crude oils to the post-depositional evolution due to the geochemical transformation of organic material after sedimentation, and the origin-controlling mechanisms resulting from contribution from primary biomass (Liu et al., 2013).

In this work, outcrop samples from the Yaerdang Mountain profile and core samples from well TD2∊ were investigated for the basic geochemical features of the lower Paleozoic strata in the eastern Tarim Basin, NW China. Primarily, the correlations between total organic carbon (TOC) abundance, stable isotope ratios and their depositional conditions were probed. And then TOC abundance, primary biomass, $\delta^{13}C_{ker}$ and their constraints between lower Cambrian and upper Cambrian strata were discussed. Finally, the diagnostic explanations to the origins of ^{13}C-enriched oils in the Tarim Basin such as TD2∊ and TZ62S were supposed.

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2. Samples and experimental analysis

2.1. Geological background and sample collecting

As an important part of the Rodinia supercontinent during the Jinningian (1000–800 Ma), the Tarim Basin had undergone two evolution phases — the initial Sinian formation phase of passive continent and the Cambrian–early Ordovician maturation phase. The primitive basin experienced a series of evolutions of Sinian craton central uplifting, craton marginal depression and Cambrian–early Ordovician intracratonic depression, craton marginal depression (Jia, 1997; Jia et al., 2007; Zhang et al., 2007).

During the Cambrian period, the partial pressure of carbon dioxide in the atmosphere ($p(CO_2)$) was quickly declining (Berner, 1991, 1994, 1998; Berner and Kothavala, 2001), accompanying the climate alternation between warm humid and hot arid. The Manjiaer depression in the eastern Tarim Basin (Fig. 1) had experienced a sea level change cycle from early Cambrian sea level rising to middle–late Cambrian falling (Zhang et al., 2006). In the early Cambrian, along with the sea level rising, the upturning of ocean currents could reach the inner shelf, even to the onshore region. On one hand, the cool upwelling currents which were oxygen-deficient, phosphorus and silicon-rich are beneficial for the thriving of planktonic algae and benthic algae. On the other hand, the enhanced basinal accommodation could favor the marine sedimentation enriched in phosphorus, silicon and organic matter (Zhang et al., 2004b). During the middle–late Cambrian period, along with the sea level declining, the basinal accommodation controlled by the preservation and upwelling complex pattern gradually decreased. As a result, light colored carbonate and clastic rocks were deposited from the platform to the shallow shelf region.

In order to investigate the basic geochemical features of the lower Paleozoic strata, which would hopefully explain the origins of ^{13}C-enriched oils in the Tarim Basin, a series of outcrop samples were collected from the Yaerdang Mountain profile (YI and YII, at the basin edge) and a few core samples from the well TD2∊ in the eastern Tarim Basin, NW China (Fig. 1, Tables 1 and 2). Among which, 14 rock samples were from profile YI covering the strata of

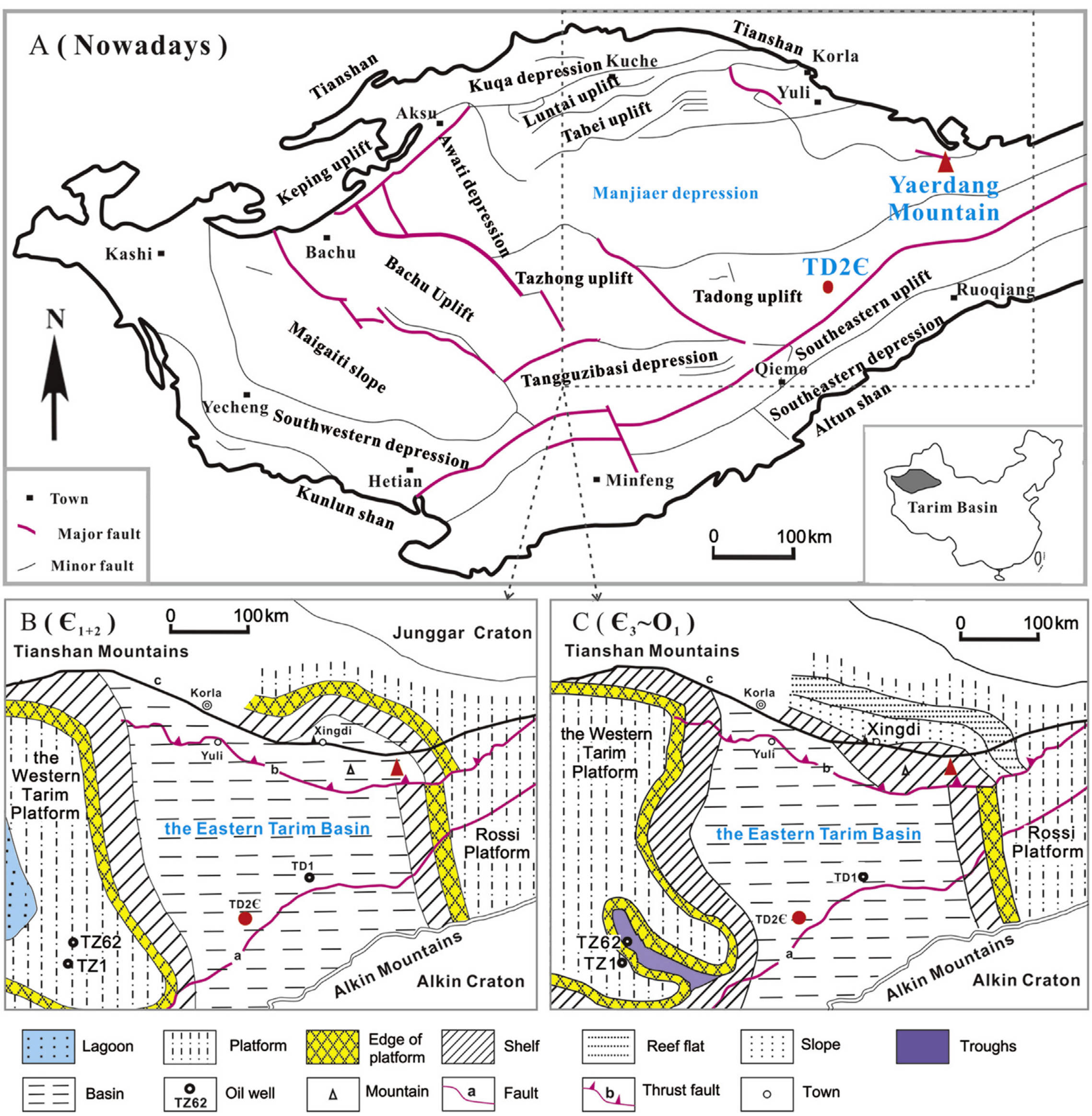

Figure 1. (A) Structure map of the present Tarim Basin (modified after Zhang et al., 2000). (B, C) Cambrian sedimentary facies of the eastern Tarim Basin (modified after Huang et al., 2009). (a) Che'erchen fracture. (b) Kongquehe fracture. (c) Xingdi fracture.