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RESEARCH PAPER

# Carbon isotopic compositions and origin of Paleozoic crude oil in the platform region of Tarim Basin, NW China

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**Abstract:** Based on the carbon isotopic compositions of Cambrian-Ordovician source rocks Kerogen Samples and Paleozoic crude oil in the platform region of Tarim Basin, the origin and source of Paleozoic crude oil were investigated. There are at least two sets of source rocks with different carbon isotope compositions in the Cambrian, the Lower Cambrian source rock with lighter carbon isotope composition and Middle-Upper Cambrian source rock with heavier carbon isotope composition, while the Ordovician source rock is somewhere in between. The $\delta^{13}C$ values of Paleozoic crude oil samples are wide in distribution range, from −35.2‰ to −28.1‰. The crude oil with lighter carbon isotopic compositions ($\delta^{13}C<-34.0$‰) was mainly derived from Lower Cambrian source rock, and the crude oil with heavier carbon isotopic composition ($\delta^{13}C>-29.0$‰) was mainly derived from the Middle-Upper Cambrian source rocks, and the crude oil with $\delta^{13}C$ value in between may be derived from Cambrian source rocks. It is concluded through analysis that the Cambrian source rock could become the major source rock in the Tarim Basin and the platform region has huge potential oil and gas resources in the deep formations.

**Key words:** Tarim Basin; Cambrian; Ordovician; marine hydrocarbon; oil source; carbon isotope composition

## Introduction

The origin of oil and gas in the platform region of the Tarim Basin, NW China has long been controversial, restricting the exploration of deep formations in the basin[1–4]. Previous biomarkers correlation between crude oil and source rocks shows that the biomarkers in the oil from Cambrian are characterized by six highs and one low (high contents of $C_{28}$ sterane, gammacerane, triaromatic dinoslerane, 4-methyl-sterane, 24-norcholestane, tricyclic terpane and low content of diasterane), while biomarkers in the oil from the Ordovician have opposite characteristics, which have been the basis for identification of Cambrian or Ordovician oil sources[5–8]. Study on carbon isotope features of oil shows the oil produced by Cambrian source rock has heavier carbon isotopic composition than that produced by Ordovician source rock, so it is believed that the oil produced by Cambrian source rock in Tarim Basin should have more heavier carbon isotopes, while the oil from Ordovician should have more lighter carbon isotope[9–12].

In 2013, commercial oil and gas flow was obtained from the Cambrian dolomite below the thick gypsum in Well ZS1, Tazhong Uplift, which brought about new questions on the understanding of marine hydrocarbon source rocks in the platform region[13–20]. According to the geological background, the oil and gas in the Cambrian dolomite in Well ZS1 may originate from the Cambrian source rock[17]; but the geochemical characteristics of Cambrian oil and gas in this well differ widely from the previous knowledge on Cambrian oil, and are similar to those of Ordovician crude oil[9]. Analysis of geological conditions show the Cambrian oil in Well ZS1 cannot come from the Ordovician, which implies that the current understanding on the geochemical characteristics of the Cambrian oil isn't comprehensive.

The Paleozoic hydrocarbon reservoirs in the platform region are buried deep and higher in thermal evolution degree, so some biomarkers indicating the origin and sedimentary environment of parental material have changed due to the effect of thermal evolution. With the increase of maturity, the components with poor thermal stability in biomarkers in source rock and oil gradually reduce, hence the conventional biomarkers in different oil or source rocks may become similar. Besides, the concentration of biomarkers in crude oil with high thermal evolution degree would also significantly reduce, thus the characteristics of biomarkers will change considerably when oils of different thermal evolution degrees mix[21].

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Due to the relatively high thermal evolution degree of Paleozoic reservoirs and multiple sets of hydrocarbon source rocks in the platform region, identifying oil source by biomarkers can be ambiguous.

A large number of studies reveal that the carbon isotopic composition of crude oil is mainly controlled by the carbon isotopic composition of source rock[11–12,22–25]. The effect of thermal evolution on the carbon isotopic composition of crude oil is relatively small, and in the process of thermal evolution, the change of the carbon isotopic composition of crude oil does not exceed 2‰ generally[22–23]. Therefore, the carbon isotopic composition of crude oil can be used as an effective means of identifying the origin of oil in deep strata in the platform region.

The carbon isotopic compositions of the oil in Well ZS1 and Well ZS5 are relatively light, which is consistent with the carbon isotopic composition characteristic of the global Cambrian crude oil, with $\delta^{13}C$ values of generally less than –34‰[26–30]. The carbon isotopic composition shows that there is not just one type oil from Cambrian with heavier carbon isotopic composition in the platform region and it can't be concluded that the oil with lighter carbon isotopic composition is from Ordovician. In order to clarify the origin and source of the marine oil in the platform region, carbon isotopic composition features of Paleozoic oil in the platform region are examined, and the major source rock in the region is sorted out according to the carbon isotopic composition of kerogen of different Cambrian and Ordovician formations in this study, which can provide a scientific basis for the next step oil and gas exploration.

## 1. Geological setting

The Tarim Basin, located at the northwest edge of China is a large superimposed sedimentary basin developed on pre-Sinian continental crust base. The platform region of Tarim Basin mainly include Tabei Uplift, Tazhong Uplift, Bagchu Uplift, Tadong Uplift and Northern Depression, which are characteristic by the Paleozoic marine sedimentation (Fig. 1). The main exploration target in the platform region is the Paleozoic hydrocarbon system. The main potential source rocks include the Ordovician, the Tuershaketage Formation and Moheershan Formation in the Middle - Upper Cambrian and the Yuertusi Formation and Xidashan Formation in the Lower Cambrian[4–8,31]. The current knowledge indicates that the Ordovician source rock is mainly distributed in the slope of the Tazhong and Tabei area, the Middle - Upper Cambrian source rocks are mainly in the Tadong area, and Lower Cambrian source rocks mainly in the Keping-Bachu area in north section of the Bachu Uplift and Tadong area[8]. Carboniferous, Silurian and especially Ordovician and Cambrian are the main reservoirs of the hydrocarbon system in the Paleozoic in the platform region of the Tarim Basin, and reservoirs in different regions are different to some extent in era (Fig. 2).

## 2. Samples and methods

One hundred and thirty-three crude oil samples were collected in the Cambrian, Ordovician, Silurian and Carboniferous strata from 10 oil and gas fields in the platform region of the Tarim Basin (Fig. 1). The source rock samples were mainly collected from Cambrian - Ordovician source rocks. The samples of Cambrian source rocks were taken from Well H4 in Bauchu Uplift, Well XH1 in Tabei Uplift, Well TD2 in Tadong Uplift and the outcrop section (Sugetbulak, Xiaoerbulake, Shiairike) in Keping – Aksu area, western Tarim Basin and Kuruktag outcrop section in eastern Tarim Basin. The samples of Ordovician source rocks were taken from Well

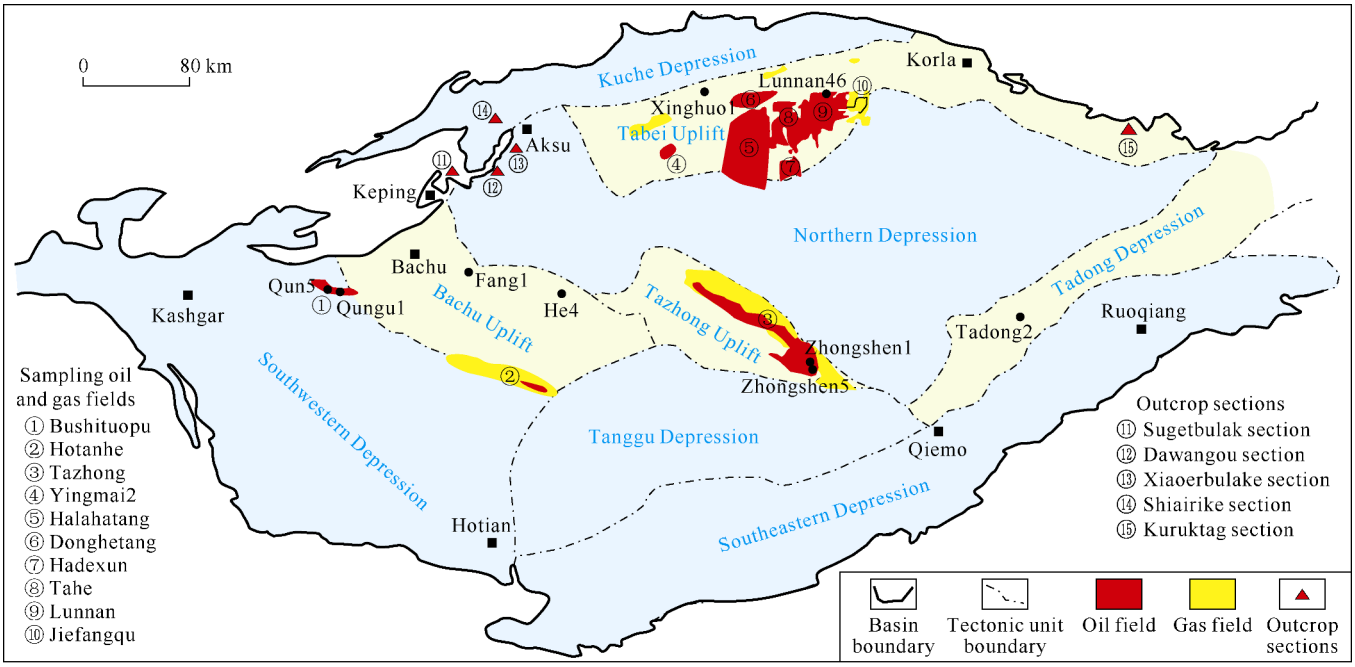


**Fig. 1. Distribution of structure units, outcrop profiles and sampling oil fields in Tarim Basin.**