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Original research paper

Stable carbon isotopic composition of light hydrocarbons and *n*-alkanes of condensates in the Tarim Basin, NW China

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Abstract

The carbon isotope ratios of individual light hydrocarbons and the *n*-alkanes of twenty-one condensates from the Tarim Basin, as well as 47 condensates and oils from other petroliferous basins (Ordos Basin, Sichuan Basin, Turpan-Harmi Basin, Qiongdongnan Basin, Beibuwan Basin and Bohay Bay Basin) in China, were analyzed. We investigated the oil–oil correlation, the effects of gas washing and maturity, as well as the distinguishing parameters of humic and sapropelic condensates, and have come to the following conclusion. The carbon isotopic patterns of condensates and oils in the Ordovician strata of Tarim Basin are very similar, indicating they originate from the same type of source rocks. The condensates from Dawanqi oil field and Yinan 2, as well as Ti'ergen and Yitikelike gas fields, have similar carbon isotopic patterns. Thus, they probably have originated from the same terrestrial Jurassic source rock. The carbon isotopic patterns of the condensates from the Dabei, Kela 2, and Keshen gas fields are also similar, indicating they are of the same oil family and sourced from the Triassic and Jurassic terrestrial source rock. The carbon isotopic ratios of 2MP, 3-MP, 3-MH, and $nC_{5\text{-}8}$ are much more susceptible to maturity level than other light hydrocarbons. Gas washing has minor effects on the $\delta^{13}C$ compositions of individual light hydrocarbons and *n*-alkanes, although it causes <2‰ shifts. The $\delta^{13}C$ compositions of MCP, CH, MCH, benzene, and toluene can be used as identification parameters for humic and sapropelic condensates. Humic condensates generally have $\delta^{13}C_{MCP} > -25‰$, $\delta^{13}C_{CH} > -24‰$, $\delta^{13}C_{MCH} > -24‰$, $\delta^{13}C_{benzene} > -25‰$, and $\delta^{13}C_{toluene} > -24‰$, whereas sapropelic condensates mainly have $\delta^{13}C_{MCP} < -26‰$, $\delta^{13}C_{CH} < -26‰$, $\delta^{13}C_{MCH} < -24‰$, $\delta^{13}C_{benzene} < -25‰$ and $\delta^{13}C_{toluene} < -24‰$. Moreover, the mixing humic and sapropelic condensates usually show intermediate values.

Keywords: Carbon isotope ratio; Humic condensate; Sapropelic condensate; Oil–oil correlation; Gas washing; Maturity; Distinguishing parameter; Tarim Basin

1. Introduction

The carbon isotopic compositions of individual hydrocarbons are commonly used to characterize oils, correlate and distinguish oils and/or sources, understand processes related to petroleum formation, migration, and trapping, and understand the effects of secondary alteration (biodegradation, gas washing, thermochemical sulfate reduction [TSR], etc) [1–15]. Oils influenced by biodegradation or TSR are enriched in ^{13}C compounds relative to the samples less affected or unaffected by such secondary alteration [6,9,14,16]. Oils from the similar or same sources produce isotopic signatures that are highly correlated [2]. Carbon isotope ratios are less affected by alteration processes than that of molecular concentrations [16]. Molecular concentrations are also consequently more robust parameters for oil–oil correlation [9]. Oils and gases generated by humic source rocks (kerogen type III) are usually more enriched in ^{13}C than

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those originating from sapropelic source rocks (kerogen type I-II) [3,8,11,15], and the carbon isotopic ratios of some individual hydrocarbons may be used to identify the genetic types of those oils or gases.

The Tarim Basin includes condensates of various ages, such as Ordovician, Carboniferous, Triassic, Cretaceous, Eocene, and Neogene, which are formed through the following three processes: (1) gas washing, which is the current most important process in forming condensates in the basin, e.g. the Ordovician condensate in the Lungu oil field and Tazhong gas field [17], as well as the Neogene condensates in the Kekeya gas field [18]; (2) cracking of crude oil, which leads to the Jurassic condensates produced from the Yingnan 2 gas field [19]; (3) and cracking of kerogen, e.g. the Ordovician condensates in the Hetianhe gas field [20,21]. Only a handful of research has been done on the stable carbon isotopic compositions of the individual hydrocarbons of condensates in the Tarim Basin. Moreover, only a few condensates in the basin were analyzed in the previous literature. Zhang et al. studied the carbon isotopic compositions of the individual light hydrocarbons and *n*-alkanes of condensate reservoired in Eogene and Neogene of Well K9 in the Kekeya gas field, and they thought it was the oil mixing together [11]. In this work, we aim to distinguish the oil families of the condensates in the Tarim Basin using the stable carbon isotope signatures in the gasoline-range fraction and *n*-alkanes. The findings will be used to study the effects of gas washing and maturity on the carbon isotopic ratios of the individual hydrocarbons and to determine the carbon isotopic parameters that can be used to identify the condensates' genetic types. This work is expected to improve the current understanding of Tarim Basin's petroleum system and to contribute to petroleum exploration significantly.

2. Geological setting

The geological framework and petroleum system of Tarim Basin have been summarized by numerous authors [22−27]. The Tarim Basin covers an area of approximately 56×10^4 km^2, and it is one of China's most important petroliferous provinces [22]. It is located in Northwest China, it consists of a Paleozoic cratonic basin overlain by a Mesozoic−Cenozoic foreland basin and can be divided into four depressions and three uplifts, i.e. the Kuqa, Northern, Southwest, and South-eastern Depressions, as well as the Northern, Central, and Southern Uplifts [22] (Fig. 1). The Sinian to Cenozoic sedimentary successions are deposited in the basin (Fig. 2), with the Northern Depression having the greatest sedimentary thickness of up to 15,000 m [23]. The Lower Paleozoic strata were deposited in a marine setting, whereas those of the Upper Paleozoic, Mesozoic, and Cenozoic were deposited under mixed marine, transitional, and continental environments.

Five tectonic cycles were recognised during the evolution of the basin, i.e., the Caledonian, Hercynian, Indosinian, Yanshannian, and Himalayan (Fig. 2), with various effects within the basin, such as faulting, folding, uplifting, and erosion [27,31,32], and hence, structural subsidence and uplift (Fig. 2).

Oil and gas reserves in the foreland basin are the highest in the Kuqa and Yecheng depressions, whereas the oil and gas in

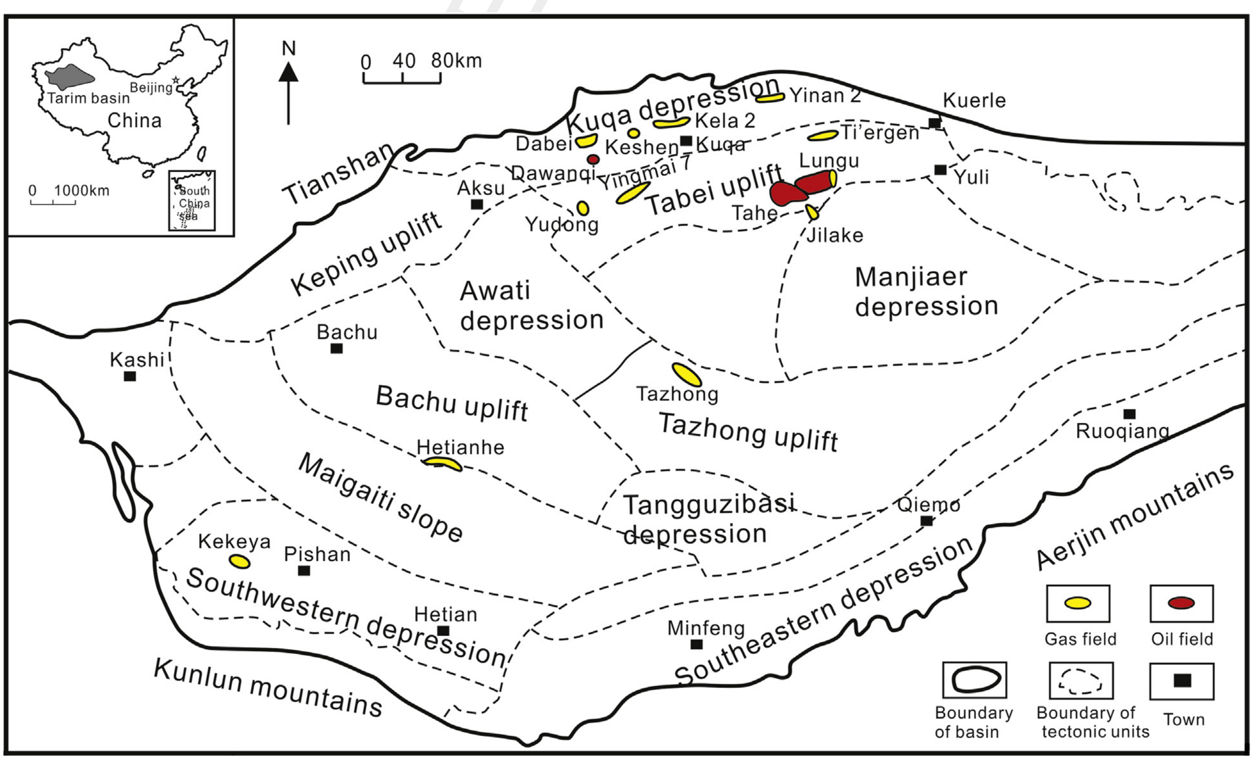

Fig. 1. Generalized map showing the location, distribution of tectonic units, and the oil and gas fields where condensates were collected in the Tarim Basin (modified after Ref. [28]).