CHINESE JOURNAL OF GEOCHEMISTRY: 2006 Vol.25 No.4

DOI: 10.1007/s11631-006-0328-0

Reservoir geochemistry of the Tazhong oilfield in the Tarim Basin, China, Part I. Geochemical characteristics and genetic classification of crude oils*

ZHANG Min (张敏)[1, 2**], HUANG Guanghui (黄光辉)[1, 2], and HU Guoyi (胡国艺)[3]

[1] *Department of Geochemistry, Yangtze University, Jinzhou 434023, China*

[2] *The Key Laboratory of Exploration Technoloies for Oil and Gas Resources, Ministry of Education, Yangtze University, Jinzhou 434023, China*

[3] *Langfang Branch of Research Institution of Petroleum Exploration and Development, PetroChina, Langfang 065007, China*

Reveived May 10, 2006; accepted June 2, 2006

Abstract According to the assemblage characteristics of saturated hydrocarbon biomarkers in crude oils and their geochemical implications, this study has proposed, for the first time, the criteria for the genetic classification of crude oils in the Tazhong area of the Tarim Basin, China. Crude oils from the area studied are classified as three genetic types: Type-I is characterized by the low contents of C_{29} norhopane, extremely abundant contents of gammacerane, low contents of rearranged sterane and relatively high contents of regular C_{28} sterane; the geochemical properties of type-II crude oils are opposite to those of type-I crude oils; the parameters for type-III crude oils are intermediate between type-I and type-II. Results of oil correlation indicated that type-I crude oils were derived from Cambrian-Lower Ordovician hydrocarbon source rocks, type-II curde oils originated from Middle-Upper Ordovician hydrocarbon source rocks and type-III crude oils are of mixed origin.

Key words biomarker; oil correlation; genetic classification of crude oils; Tazhong area; Tarim Basin; China

1 Introduction

Since the 1990's of the 20th century, oil & gas geochemists have shifted their research focus on hydrocarbon source rocks in the past to that on reservoir rocks and oil reservoirs at present; their research field has been expanded from oil & gas exploration to the assessment of oil reservoirs and production & management. Therefore, reservoir geochemistry as a branch disciplinary of organic geochemistry is now attracting great concern of many oil & gas explorers and oilfield engineers. Meanwhile, it is playing a more and more outstanding important role in petroleum industry (England et al., 1987; England, 1990; Larter, 1991; England and Mackenzie, 1989; Hillebrand and Leythaeuser, 1992; Larter and Aplin, 1995). The essential aim of reservoir geochemistry is to characterize the heterogeneity of reservoir fluids and hydrocarbon composition of reservoir rocks and interpret fully and make full use of the geological-geochemical information developed from such heterogeneity so as to apply it in oil/gas exploration and development (Larter and Aplin, 1995; Leythaeuser and Ruckheim, 1989; Horstad et al., 1990; Zhang Min and Zhao Hongjing, 2004). The Tazhong oilfield in the Tarim Basin is one of the major marine oilfields in China, and the genetic types of crude oils from this oilfield, fractionation effects of oil migration and the rules of formation of oil reservoirs still need to be further studied. This paper attempts to propose the criteria for the genetic classification of crude oils in the region of Tazhong on the basis of the theory of oil reservoir geochemistry and the geochemical analyses of crude oils and hydrocarbon source rocks in the Tazhong oilfield, so as to disclose the genetic types of

ISSN 1000-9426

* This research was funded by the State "Tenth Five-Year Plan" Key Science and Technology Program (2004BA616A02-01-01-03).

** Corresponding author, E-mail: zmjpu@163. com

crude oils in the Tazhong oilfield. The results of this study have not only provided the basis for the study of the rules of migration and accumulation of crude oils and the formation of oil reservoirs in the Tazhong region, but also provided new clues to oil/gas exploration and development.

2 Geological background and samples

The Tazhong region is located in the center of the central rise zone of the Tarim Basin, comprising 4 second-ordered tectonic units (Fig. 1): the Tazhong No.1 fault tectonic zone, the Tazhong-10 well tectonic zone, the central fault-uplift, and the Tazhong -1—8 well tectonic zone, covering a total area of 72500 km^2. The exploration of the Tazhong oilfield started in May 1989, and in the same year an important discovery

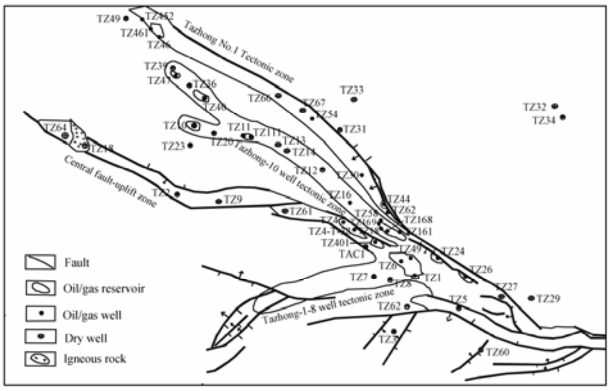

Fig. 1. Sketch map showing the structural framework and well location of the Tazhong region.

was made in Tazhong No.1 well drilled in the Ordovician strata. Since then, the Tazhong region has become an important target for oil/gas exploration in the Tarim Basin. Current exploration results have confirmed that the major target strata in the Tazhong oilfield are Ordovician carbonate rocks, Silurian sandstones and Carboniferous sandstones. And there are two sets of hydrocarbon source rocks, which are Cambrian-Lower Ordovician and Middle-Upper Ordovician carbonate rocks, respectively.

Crude oil samples were taken largely from the various tectonic units in the Tazhong region, of which 17 were collected from the Middle Ordovician strata, 3 from the Silurian strata and 5 from Carboniferous strata. The crude oil samples include condensate oil and light oil samples, as well as normal oil and heavy oil samples. Light hydrocarbon analysis, quantitative chromatographic analysis and quantitative chromato-grammphic- mass spectrometric analysis were conducted on the crude oil samples. Chromatographic analysis was conducted on a Hewlett-Packard 6890/5973 Type chromatograph-mass spectrometer. The chromato- graphic column was an etastic silica capillary column, coated with SE-54 (30 m×0.25 mm×0.25μm). The temperature programming: the samples were heated at the constant temperature of 100 ℃ for one minute, and then the temperature was raised to 220℃ at the rate of 4℃/min, then to the constant temperature of 300℃ at the rate of 2℃/min. The samples were heated at this constant temperature for 20 minutes. The sample inlet temperature was kept at 300℃/min and helium was used as carrier gas. Mass spectrometric analysis condition: +EI/QIMS; the ionization energy of the ion source: 70 eV; and scanning timer interval: 2 s. The quantitative standard sample for the absolute contents of saturated hydrocarbon biomarkers is D4-C29 cholestane.

3 Results and discussion

3.1 Characteristics of saturated hydrocarbon biomarkers in crude oils

The available research results have indicated that tricyclic terpanes, tetracyclic terpanes and hopanes show much similarity, on the whole, in their fingerprint characteristics, but the terpanes either in the Ordovician crude oils or in the Silurian or Carboniferous crude oils in the Tazhong region can be roughly divided into three types in accordance with their distribution characteristics (Fig. 2). One type is represented by crude oils from well-30 (O) and well-452 (O) in the Tazhong oilfield. The crude oils are characterized by the low contents of C_{29} norhopane, and their C_{29} norhopane/C_{29} hopane ratios are 0.41 and 0.61, respectively. In addition, crude oils of this type are extremely abundant in gammacerane, with gammacerane×2/C_{31} norhopane ratio greater than 1.0. Type-II is represented by crude oil samples from well-161 (O), well-168 (O) and well-169 (O) in the Tazhong oilfield, and the characteristics of these crude oils are just in contrast to those of the type-I, as is evidenced by the fact that their gammacerane×2/C_{31} norhopane ratio is less than 0.35 but their C_{29} norhopane/C_{29} hopane ratio is greater than 0.80. The characteristics of terpanes in the type-III crude oils are intermediate between type-I and type-II. The type-III crude oils show the characrteristics of mixed crude oils.

Generally speaking, the distribution character-ristics of sterane compounds are similar to those of terpanes in crude oils from the Tazhong region. The

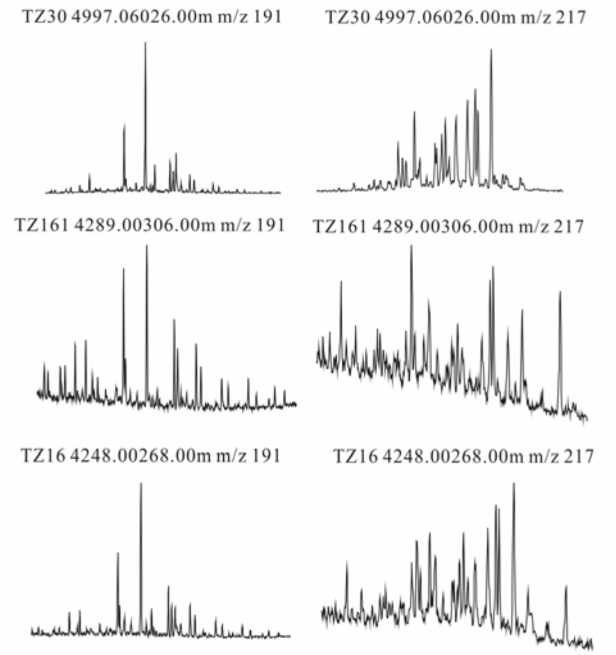

Fig. 2. m/z 191 and m/z 217 mass chromatograms of saturated hydrocarbon fractions in the typical Ordovician crude oils from the Tazhong region.

sterane compounds can also be divided into three types. Type-I is represented by crude oils from well-30(O) and well-452 (O) in the Tazhong region, and those crude oils are characterized by the low contents of rearranged sterane. The ratios of C_{28} rearranged sterane to C_{27} regular sterane are 0.08 and 0.25, respectively. But in the C_{27}-C_{29} steranes, the contents of C_{28} regular sterane are relatively high, being 31.56% and 33.49%, respectively. Type II is represented by crude oils from well-161(O), well-168 (O) and well-169 (O) in the Tazhong oilfield. Crude oils of this type are characterized by high rearranged sterane, C_{27} rearranged sterane/C_{27} regular sterane ratio being greater than 0.50, and C_{28} regular sterane accounting for less than 25% of the C_{27}-C_{29} regular steranes. Type-III is intermediate between type-I and type-II, showing the characteristics of mixed oil.

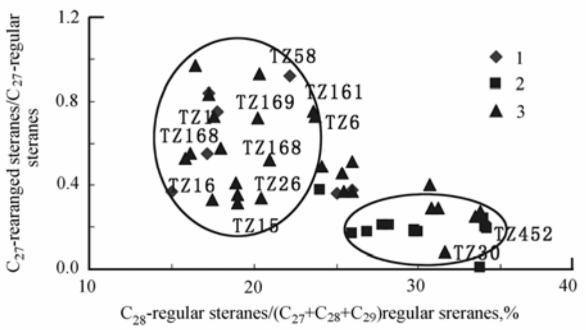

Fig. 3. C_{28} regular sterane/(C_{27}-+C_{28}-+C_{29}-) regular sterane and C_{27} rearranged sterane/C_{27} regular sterane diagrams of crude oils and hydrocarbon source rocks in the Tazhong region. 1. O_{2+3} hydrocarbon source rock; 2. ∈-O_1 hydrocarbon source rock; 3. crude oil.

3.2 Oil correlations and genetic classification of crude oils

On the basis of the molecular geochemical parameters for crude oils and the geochemical characteristics of hydrocarbon source rocks, the authors have established the C_{28} regular sterane/ （C_{27}-+C_{28}-+C_{29}-） regular sterane and C_{27} rearranged sterane/C_{27} regular sterane diagrams (Fig. 3). From Fig.3 it can be seen that crude oils in the Tazhong region can precisely be divided into two categories: one is characterized by the relatively high contents of C_{27} rearranged sterane and the relatively low contents of C_{28} sterane. Crude oils of this category are generally consistent with Middle-Upper Ordovician hydrocarbon source rocks with respect to their distribution characteristics. The other category is characterized by the low contents of C_{27} rearranged sterane and the high abundance of C_{28} sterane. So crude oils of this category are extremely approximate to the Cambrian-Lower Ordovician hydrocarbon source rocks.

Studies have shown that the triaromatic steranes in O_{2+3} and ∈-O_1 hydrocarbon source rocks in the Tazhong region show different distribution characteristics (Fig. 4). It can be seen clearly from Fig.4 that like the distribution characteristics of hydrocarbon source rocks, there may exist two types of triaromatic steranes in crude oils as viewed from their distribution characteristics. Crude oils of one type are closely associated with the Middle-Upper Ordovician hydrocarbon source rocks, and the other type with the Cambrian-Lower Ordovician hydrocarbon source rocks, both of which have good correlations. Obviously, such corresponding relationship also fully reflects their affinities to oil sources.

On the basis of oil correlations, the authors have proposed, for the first time, the criteria for the genetic classification of crude oils in the Tazhong region (Table 1), and in accordance with these criteria they

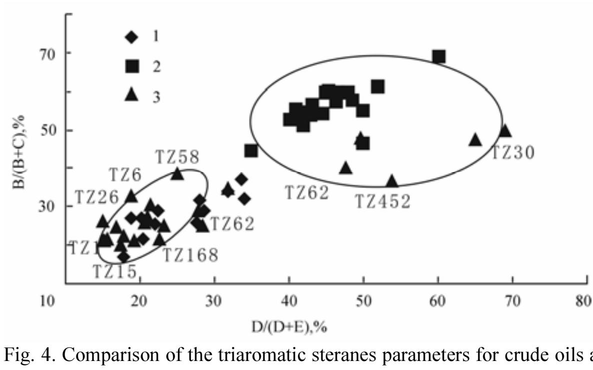

Fig. 4. Comparison of the triaromatic steranes parameters for crude oils and hydrocarbon source rocks in the Tazhong region. 1. O_{2+3} hydrocarbon source rock; 2. ∈-O_1 hydrocarbon source rock; 3. crude oil. B. C_{26}-(R)+C_{27}-(S) triaromatic sterane, C. C_{28}-(S) triaromatic sterane, D. C_{27}-(R) triaromatic sterane, E. C_{28}-(R) triaromatic sterane.

Table 1. Criteria for the genetic classification of crude oils in the Tazhong region

Parameter	Derived from ∈-O_1 hydrocarbon source rocks	Derived from O_{2+3} hydrocarbon source rocks	Mixed origin
Pr/Nc_{17}-Ph/nC_{18}	≥ 0	< 0	Geochemical parameters for crude oils are intermediate between type-I and type-II.
Gammacerane $\times$ 2/C_{31} hopane	> 0.90	< 0.90	
C_{27} rearranged sterane/ C_{27} regular sterane	< 0.30	> 0.30	
C_{28} regular sterane $\times$ 100/C_{27}-C_{29} regular sterane	> 30%	< 30%	
C_{26}-(R)+C_{27}-(S)triaromatic sterane $\times$ 100/C_{26}-(R)+C_{27}-(S)+C_{28}-(S) triaromatic sterane	> 35%	< 35%	
C_{27}-(R) triaromatic sterane $\times$ 100/C_{28}-(R) triaromatic sterane	> 45%	< 45%	

have classified crude oils in the Tazhong region as three types. Crude oils of type-I were derived from Cambrian-Lower Ordovician hydrocarbon source rocks, which are represented by crude oil samples collected from well-30 (O), well-452 (O) and well-62 (O) in the Tazhong region. Crude oils from well-30 (O) in the Tazhong region are believed to be the best preserved ones so far discovered in the Cambrian-Lower-Ordovician hydrocarbon source rocks of the Tarim Basin. Crude oils of this type are characterized mainly by the high abundance of gammacerane, the low contents of C_{27} rearranged sterane and the high contents of C_{28} regular sterane. Crude oils of type-II were derived from the Middle-Upper Ordovician hydrocarbon source rocks, including oil samples collected from well-1 (O), well-161 (O), well-168 (O) and well-169 (O) in the Tazhong region. These crude oils are characterized by the low contents of gammacerane, the high contents of rearranged sterane and terpane, and the low contents of C_{28} regular sterane and terpane, just in contrast to the type-I. Crude oils of type-III are of mixed origin. These crude oils include those from well-15(O), well-16 (O) and well-24 (O) in the Tazhong region. In regard to their geochemical parameters, these crude oils are intermediate between type-I and type-II. Therefore, crude oils of type-III are called mixed oils.

4 Conclusions

(1) On the basis of the detailed analysis and description of the geochemical characteristics of crude oils and hydrocarbon source rocks, the authors have put forward, for the first time, the criteria for the genetic classification of crude oils in Tazhong region.

(2) According to the assemblage characteristics of biomarkers in crude oils and their geochemical implications, crude oils in the Tazhong region can be roughly classified as three types. Crude oils of type-I are characterized by the low contents of C_{29} norhopane, the high abundance of gammacerane, the low contents of re-arrange sterane, and the relatively high contents of C_{28} regular sterane; the geochemical characteristics of type-II are opposite to those of type-I, while those of type-III are intermediate between type-I and type-II.

(3) Results of oil correlations have shown that crude oils of type-I were derived from the Cambrian-Lower Ordovician hydrocarbon source rocks; those of type-II stemmed from the Middle-Upper Ordovician hydrocarbon source rocks; and those of type-III are of mixed derivation.

References

England W.A., Mackenzic A.S., Mann D.M. et al. (1987) The movement and entrapment of petroleum fluids in the subsurface [J]. *Journal of the Geological Society*. **144**, 327-347.

England W.A. (1990) The organic geochemistry of petroleum reservoirs [J]. *Organic Geochemistry*. **16**, 415-425.

England W.A. and Mackenzie A.S. (1989) Geochemistry of petroleum reservoirs [J]. *Geologische Rundschau*. **78**, 214-237.

Hillebrand T. and Leythaeuser D. (1992) Reservoir geochemistry of Stockstadt oilfield: Compositional heterogeneities reflecting accumulation history and multiple source input [J]. *Organic Geochemistry*. **19**, 119-131.

Horstad L., Larter S.R., Dypvik H. et al. (1990) Degradation and maturity controls on oil field petroleum column heterogeneity in the Gullfaks field, Norwegian North Sea [J]. *Organic Geochemistry*. **16**, 497-510.

Larter S.R. (1991) *Determination of Petroleum Accumulation Histories: Examples from the Ula Field, Central Graben, Norwegian North*

Sea, North Sea oil & Gas Reservoirs Ⅱ [M]. pp. 319-330. Graham & Trotman, London.

Larter S.R. and Aplin A.C. (1995) Reservoir geochemistry: Methods, applications, and opportunities. In *The Geochemistry of Reservoirs--Geological Society Special Publications 86* (eds. J.W. Cubitt and W.A. England) [M]. pp.5-32. The Geological Society Publishing House, London.

Leythaeuser D. and Ruckheim J. (1989) Heterogeneity of oil composition within a reservoir as a reflection of accumulation history [J]. *Geochim. Cosmochim. Acta*. **53**, 2119-2123.

Zhang Min and Zhao Hongjing (2004) Reservoir geochemistry of the Kuche petroleum system in the Tarim Basin, China [J]. *Chinese Journal of Geochemistry*. **22**, 163-168.