Geochemical characteristics and identification criteria of effective source rock in Mesozoic Yanchang Formation, southern margin of Ordos Basin

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Abstract: The geochemical characteristics of source rock in Mesozoic Yanchang Formation, southern margin of Ordos Basin have not been introduced in literature. In this study, a number of geochemical experiments were conducted to discuss the geochemical characteristics and to establish the identification criteria. It is shown that source rock in the study area can be divided into five types: A1, A2, A3, A4 and B. Based on the detailed oil source correlation, the source rock types in the study area can be identified as: 1) A1, Chang 7 oil shale, is the excellent source rock with large hydrocarbon-generation potential; 2) A2 and A3, mainly Chang 7 dark mudstone, are the effective source rocks with medium hydrocarbon-generation potential; 3) A4 and B, mainly the thin mudstone or carbonaceous mudstone intervals, are the potential source rock with small hydrocarbon-generation potential. [Received: April 22, 2018; Accepted: May 27, 2018]

1   Introduction

The southern margin of Ordos Basin has been the key exploration area in China, and the exploration area is confined in Zhenjing, Binchang, Dian Yi and Fu Xian (Figure 1). According to the results of Third Round Resources Evaluation, the petroleum resources in this region is 10.71×10^8 t, accounting for 12.45% of the total hydrocarbon resources, indicating the proven rate of 2.36%. The oil and gas are widely distributed within Yanchang Formation, mainly in Chang 2, Chang 4+5, Chang 6, Chang 8 and Chang 9 members. The source rocks in this area are Chang 7 and Chang 9 members. However, the research on the geochemical characteristics of source rock is extremely poor, and the identification criteria for source rock has not been established, resulting in the poor understanding about the distribution of effective source rocks (Duan et al., 2006; Guo et al., 2006; Wang et al., 2007; Ding et al., 2011; Zhang et al., 2012; Zhao et al., 2012; Han et al., 2007). In order to solve the above problems, the author studied the hydrocarbon-generation condition and source quality in Mesozoic Yanchang Formation based on the source rock samples and oil samples in the study area, meanwhile, established the identification criteria using aromatic biomarker parameters, conventional geochemical parameters and logging electrical parameters.

Figure 1   Geographic location and well distribution
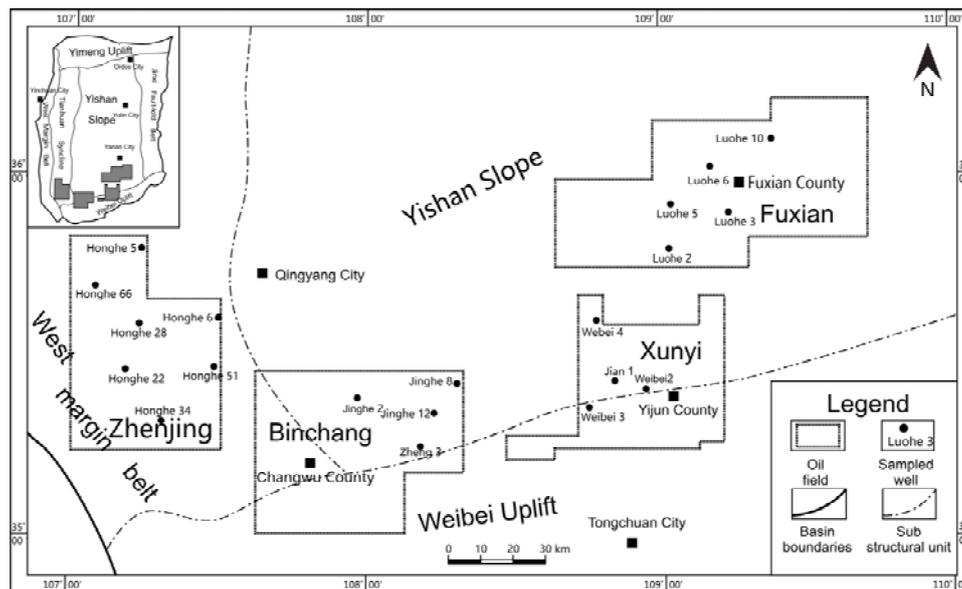
Ordos Basin is a superimposed cratonic basin in China. This basin is bounded by Luliang Mountain on the east, and the Fenwei Mountain on the south, the sub-units includes Shanbei Slope, Yimeng Uplift, Weibei Uplift, Tianhuan Depression, Jinxi Fold Belt and Western Fold-Thrust Belt. The Jurassic is a asymmetric NS-trending rectangular basin with abundant fault-folds in the basin margins. The Yanchang Formation of Jurassic, Ordos Basin is classified into five combinations from bottom to top, i.e., the first one is Chang 10 member (or oil group); the second one includes Chang 9 and Chang 8 members (or oil groups); the third one is Chang 7, Chang 6, and Chang 4+5 members (or oil

groups); the fourth one is Chang 3, and Chang 2 members (or oil groups); the fifth one is Chang 1 member (or oil group) (He, 2003; Wu et al., 2004). The Jurassic paleo-lake began to form during the sedimentary period of Chang 10, the paleo-lake underwent rapid subsidence during the sedimentary period of Chang 9, the paleo-lake was enlarged during the sedimentary period of Chang 8, the paleo-lake reached its largest burial depth during the sedimentary period of Chang 7, the paleo-lake began to shrink during the sedimentary period of Chang 6, the paleo-lake shrinked and disappeared during the sedimentary period of Chang 4+5–Chang 1. Owing to the unbalance tension during the sedimentary period of Chang 7, the area of paleo-lake reached its largest area, and the lake evolved into a deep lake. In the southern part of Ordos Basin, the thickness of Chang 7 can reach up to 30–50 m, indicating a large area of deep lake, and the source provenance came from five directions around the basin, mainly from northeast and southwest. In the north part and west part of the study area, the Jurassic sediments are relatively thick.

2 Samples and experiment

The samples were collected mainly from potential source rocks, including Chang 4+5, Chang 6, Chang 7, Chang 8, and Chang 9 members. The quantity of samples collected from each member is listed in Table 1.

Table 1 Samples collected from source rocks

Types	Classification	Chang 4+5	Chang 6	Chang 7	Chang 8	Chang 9
Rock samples	A1			11		
	A2			8		
	A3		2	5	4	
	A4	4	4	3		5
	B	3		6	9	2
Oil samples	I	3	18	6	14	7
	II		2		1	
	III		1	1		1

The experiments include pyrolysis analysis, TOC measurement, maceral component analysis, Chloroform asphalt 'A' extraction, group component separation and the GC-MS analysis. All the experiments were conducted by the State Key Laboratory of Petroleum Resources and Prospecting, China University of Petroleum-Beijing.

The Rock-Eval Pyrolysis was measured using Rock-Eval equipment, the procedure is as follows:

1 dry the powdered sample for 5 minutes using 90°C nitrogen

2 detect the light hydrocarbon and measure the S0 value

3 increase the temperature to 300°C and keep it for 5 minutes, measure the S1 value

4 increase the temperature to 600°C and keep it for 5 minutes, measure the S2 value.

Total organic carbon was measured using dry combustion weighing method, the procedure is as follows:

1   remove inorganic carbon using diluted HCl (8%)

2   burn the remaining in oxygen flow

3   adsorb burning gas using asbestos

4   calculate TOC content according to the lost weight.

In the GC-MS analysis, the measuring instrument used in this study is TRACE DSQ GC/MS. The measuring conditions are as follows: carrier gas is helium, the inlet temperature is 300°C, temperature of transmission tube is 300°C; the column is HP-5MS elastic capillary column (60 m × 0.25 mm × 0.25 m). The heating was conducted through the following procedures:

1   keep the initial temperature at 50°C for 1 minute

2   increase the temperature to 120°C, with the heating rate of 20°C/min

3   increase the temperature to 250°C, with the heating rate of 4°C/min

4   increase the temperature to 310°C and keep it for 30 minutes, with the heating rate of 3°C/min.

The flow rate of carrier gas is 1 mL/min. In the electron bombardment, the heater current is 100 μA, multiplier voltage is 1,200 eV.

Table 2   Geological parameters of source rocks in different areas

Member	Lithology	$w(TOC)$ (%)	$S1+S2$ ($mg \cdot g^{-1}$)	HI ($mg \cdot g^{-1}$)	RO (%)
Chang 4+5	Dark mudstone	0.80~2.70 / 1.34(7)	0.73~4.20 / 1.62(7)	52~147 / 97(7)	0.88~0.92 / 0.89(3)
Chang 6	Dark mudstone	0.71~4.00 / 1.81(6)	0.43~13.50 / 4.70(6)	39~308 / 170(6)	0.68~0.89 / 0.79(3)
Chang 7	Dark mudstone	0.62~4.90 / 2.92(17)	0.62~17.90 / 9.23(17)	71~318 / 194(17)	0.68~0.76 / 0.72(5)
	Oil shale	3.92~22.50 / 12.90(13)	27.10~120.10 / 76.12(13)	376~727 / 590(13)	0.53~0.76 / 0.62(7)
	Carbonaceous mudstone	4.10~6.80 / 5.13(3)	7.70~16.50 / 11.01(3)	179~236 / 204(3)	0.95~0.95 / 0.95(1)
Chang 8	Dark mudstone	0.59~4.40 / 2.10(13)	0.42~37.84 / 7.81(13)	51~252 / 151(13)	0.71~0.94 / 0.85(7)
Chang 9	Dark mudstone	0.93~2.10 / 1.42(7)	0.91~12.50 / 4.21(7)	67~225 / 157(7)	0.76~0.92 / 0.84(5)

Note: $\dfrac{\text{Minimum} \sim \text{Maximum}}{\text{Average (samples)}}$.

3   Hydrocarbon-generation potential

Geological parameters for source rock in different members are listed in Table 2. The quality of Chang 7 member is excellent source rock, this result is in agreement with previous studies (Wang et al., 2013; Wang et al., 2015; Fan et al., 2017). For the dark mudstone, oil shale and carbonaceous mudstone of Chang 7 member, the average contents of organic carbon are 2.92%, 12.9% and 5.13% respectively; the average contents of hydrocarbon potential are 9.23 mg/g, 76.12 mg/g and 11.01 mg/g respectively; the average contents of hydrogen index are 194 mg/g, 590 mg/g and 204 mg/g respectively. For Chang 7 member, oil shale belongs to good source rock, dark mudstone belongs to medium source rock, carbonaceous mudstone belongs to poor source rock. The mature dark mudstone developed in Chang 4+5, Chang 6, Chang 8 and Chang 9 members, have good abundance of organic matter, and Poor organic types. In contrast, the abundance of organic matter of Chang 6, Chang 8 and Chang 9 are higher than that of Chang 4+5, the types of organic matter of Chang 6, Chang 8 and Chang 9 are higher than that of Chang 4+5.

## 4   Source rocks and crude oils

4.1   Division of source rocks

The commonly used biomarkers are n-alkanes, isomeric alkanes (isomerism, trans-isomerism, acyclic isoprene alkane), dicyclic sesquiterpenes, diterpenes (tricyclic, tetracyclo), pentacyclic triterpene (hopane series, non-hopane series), polyterpene, steroid as well as all kinds of aromatic, oxygenated compounds, and nitrogen compounds. In the north part of Ordos Basin, the above parameters were widely applied to source rock studies. Some researchers have successfully characterised the effective source rock using C30-rearranged hopane (Zhang et al., 2009; Moldowan et al., 1991; Peters and Moldowan, 1993; Philip and Gilbert, 1986; Farrimond and Teln, 1996). In fact, C30-rearranged hopane, Pr/Ph and 8β(H)-drimane can be integrated together to characterise source rocks, for they are interrelated with the abundance of organic matter, TOC, S1+S2 and HI (Tables 2 and 3). Low Pr/Ph and C30-rearranged hopane, high content of 8β(H)-drimane indicate deep lacustrine sedimentation with anoxia environment, which is favourable for forming excellent source rock; high Pr/Ph and C30-rearranged hopane, low content of 8β(H)-drimane indicate semi-deep and shallow lacustrine sedimentation with sub-oxidation environment. Therefore, according to the distribution of Pr/Ph, the source rocks of Yanchang Formation in the southern margin of Ordos Basin can be divided into types A and B. The Pr/Ph of source rock A is larger than 2, and that of source rock B is less than 2. Source rock A can be divided into A1, A2, A3, A4 based on the distribution of C30-rearranged hopane, 8β(H)-drimane and other biomarkers composition. The biomarker composition and geochemical characteristics of source rock types are shown in Figure 2.

Table 3   The characteristics of biomarker and geochemical parameters in different source rocks, Yanchang Formation, southern margin of Ordos Basin

Type	Biomarkers	Effectiveness	TOC (%)	S1+S2 (mg/g)	HI (mg/g)	Lithology
A1	Pr/Ph < 2, low C30-rearranged hopane, C30RH/C30H < 0.3, high content of 8β(H)-drimane, and higher than 8α(H)-drimane, 8β(H)-homodrimane/ 8β(H)-drimane < 2	Excellent	12.9	76.1	590	Oil shale
A2	Pr/Ph < 2, medium C30-rearranged hopane, C30RH/C30H < 0.3, 3 < C30RH/C30H < 0.5, high content of 8β(H)-drimane, lower than 8α(H)-drimane, 8β(H)-homodrimane/ 8β(H)-drimane < 2	Good	3.8	15.7	341	Mudstone
A3	Pr/Ph < 2, highC30-rearranged hopane, C30RH/C30H < 0.3, C30RH/C30H > 0.5, high content of 8α(H)-drimane, lower than 8α(H)-drimane, 8β(H)-homodrimane/ 8β(H)-drimane < 2	Good	3.3	10.1	255	Mudstone
A4	Pr/Ph < 2, low C30-rearranged hopane, C30RH/C30H < 0.3, low content of 8β(H)-drimane, lower than 8α(H)-drimane, 8β(H)-homodrimane/ 8β(H)-drimane > 2	Poor	1.2	1.7	109	Mudstone
B	Pr/Ph > 2, low content of 8β(H)-drimane (but higher than 8α(H)-drimane), 8β(H)-homodrimane/ 8β(H)-drimane > 2	Poor	3.4	8.9	168	Carbonaceous mudstone

Figure 2   The division of source rock types, Yanchang Formation, southern margin of Ordos Basin
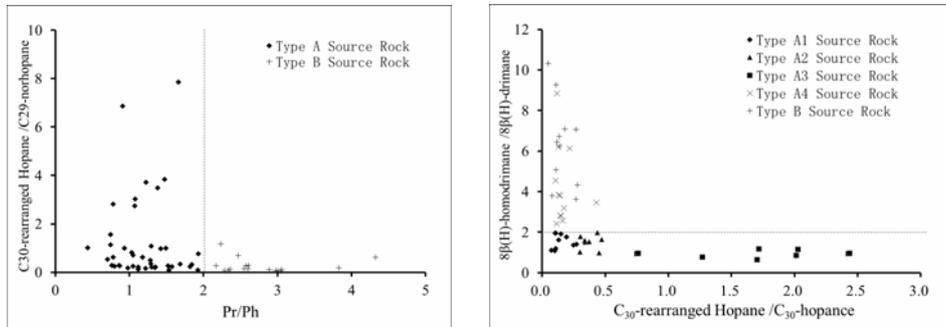
Source rocks with different origins always sediment in different locations, this is also confirmed by this research (Stahl, 1978; Mukhopadhyay et al., 1995). A1 and A2 source rocks mainly distribute within Chang 7 member in Zhenjing, Binchang and Xunyi areas. A3 source rock mainly distributes within Chang 7 and Chang 8 members in Xunyi and Fuxian areas. A1 source rock mainly developed within thick oil shale intervals, whereas A2 and A3 source rocks mainly developed within thick dark mudstone intervals. A4 and B source rocks distribute within the whole Yanchang Formation among the study area, and their lithologies include dark mudstone and carbonaceous mudstone.

4.2   Division of oil types

For Yanchang Formation, the maturity of each member have little difference due to that they are controlled by the same sedimentary environment, resulting in that oil related biomarkers have no difference(Wang and Fan, 2016; Peng et al., 2017). For the oil related biomarker compositions as well as source related biomarker compositions, the difference exists within two parameters, i.e., 8β(H)-drimane and C30-rearranged drimane. Thus, crude oil in the study area can be divided into three types based on the contents of 8β(H)-drimane and C30-rearranged drimane (Figures 3 and 4).

For type I oil, the content of 8β(H)-drimane is relatively high (the content is higher than that of 8α(H)-drimane), the value of 8β(H)-homodrimane/8β(H)-drimane is between 0.69~1.97, with an average value of 1.24; the content of C30-rearranged drimane is very low, the value of C30-rearranged drimane/C30-hopance ranges from 0.02 to 0.35, the value of C30-rearranged drimane/C29-norhopane is between 0.02~0.97, the value of C30-rearranged drimane/C29Ts is between 0.16~0.97, the value of Ts is close to or slightly higher than that of Tm.

For type II oil, the content of 8β(H)-drimane is relatively high (the content is smaller than that of 8α(H)-drimane), the value of 8β(H)-homodrimane/8β(H)-drimane is between 1.01~1.36, with an average value of 1.15; the content of C30-rearranged drimane is secondary large, the value of C30-rearranged drimane/C30-hopance ranges from 0.35~0.47, the value of C30-rearranged drimane/C29-norhopane is between 1.35~4.06, the value of C30-rearranged drimane/C29Ts is between 0.97~1.17, the value of Ts is far higher than that of Tm.

For type III oil, the content of 8β(H)-drimane is relatively low (the content is smaller than that of 8α(H)-drimane), the value of 8β(H)-homodrimane/8β(H)-drimane is between 0.89~1.31, with an average value of 1.02; the content of C30-rearranged drimane is extremely high, the value of C30-rearranged drimane/C30-hopance ranges from 0.63~3.54, the value of C30-rearranged drimane/C29-norhopane is between 1.55~2.86, the value of C30-rearranged drimane/C29Ts is between 1.88~3.02, the value of Ts is higher than that of Tm.

Biomarker parameters of different oil types are shown in Figure 5. For the three oil types, their Pr/Ph values have little difference, with an average value of 1, indicating that the sedimentary environment for forming source rocks belongs to reducing environment. It also shows, type I oil has the largest values on C30-rearranged drimane/C29Ts, C30-rearranged drimane/C30hopane, C30-rearranged drimane/C29norhopane, whereas, type III oil has the smallest values; type III oil has the largest values on 8β(H)-homodrimane/8β(H)-drimane, whereas, type I oil has the smallest values.

Figure 3   C30-rearranged drimane and 8β(H)-drimane characteristics of different oils (see online
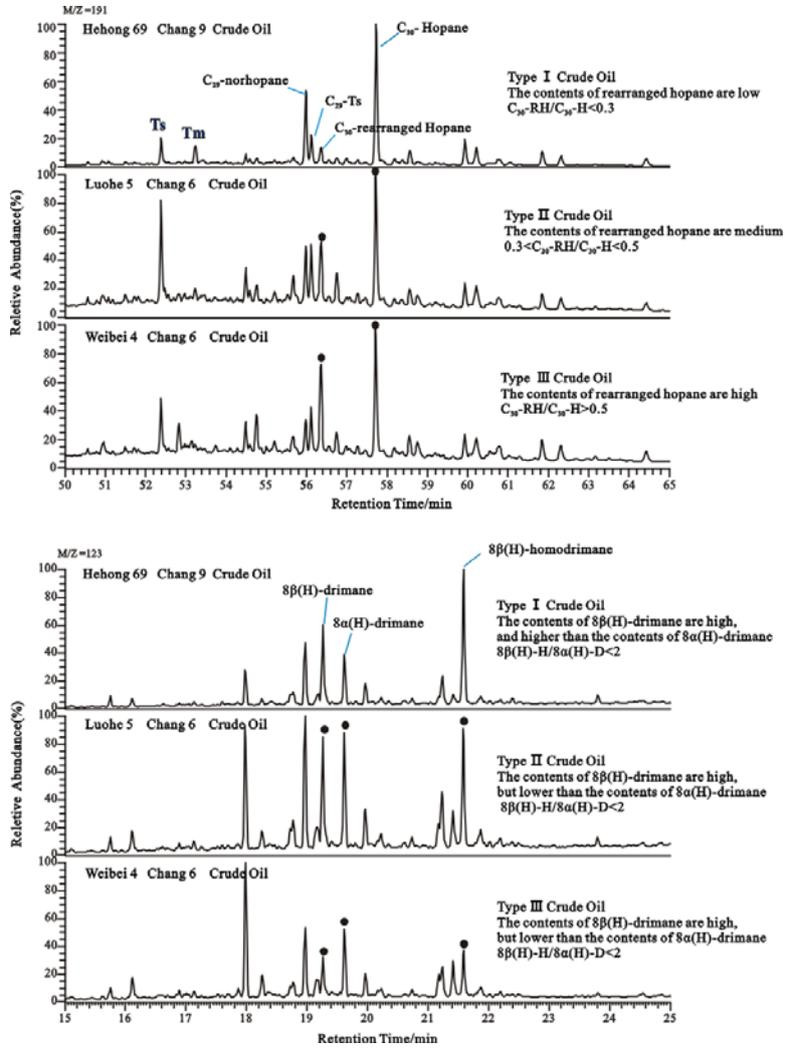version for colours)

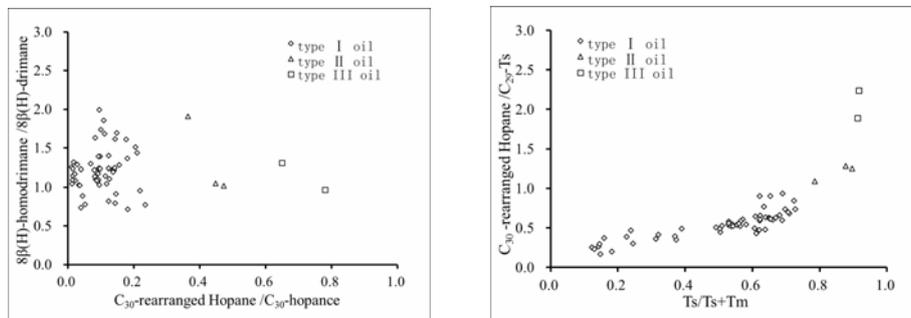**Figure 4**   The division of oil types, Yanchang Formation, southern margin of Ordos Basin

Figure 5 The biomarkers of different oils, Yanchang Formation, southern margin of Ordos Basin (see online version for colours)
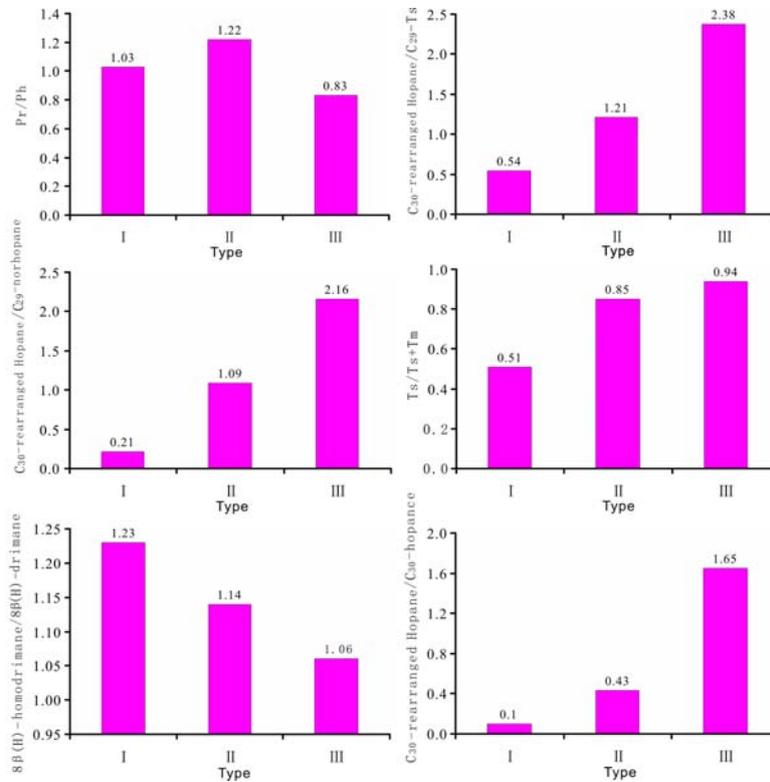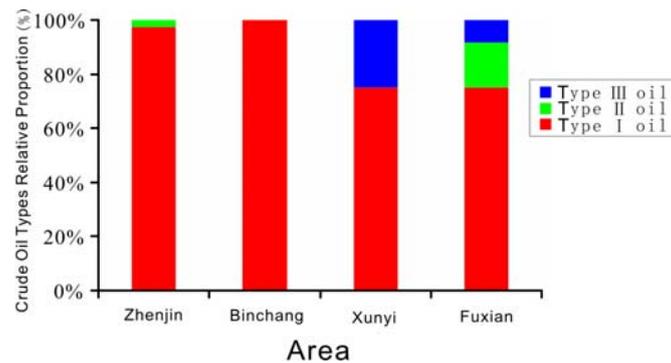

Figure 6 The relative proportions of different crude oils in the different areas (see online version for colours)

Different oil types distribute in different members and areas in the study area. In Zhenjing area, type I oil is widely distributed in Yanan Formation and Yanchang Formation. In Bingchang area, type I oil is widely distributed in Chang 6 to Chang 8

members. In Dianyi area and Fuxian area, type I oil is widely distributed in Chang 7 Member and the overlying members. For type II oil, it is widely distributed in Chang 8 Member in Zhenjing area and Chang 6 Member in Fuxian area. For type III oil, it is widely distributed in Chang 6 and Chang 7 members in Dianyi area, and Chang 9 Member is widely distributed in Fuxian area. Thus, type I oil accounts for a large proportion of the crude oil within Yanchang Formation, southern margin of Ordos Basin, and the proportion of type II and type III oil are very small (Figure 6).

5   Detailed oil-source correlation

Figure 7 presents the relations between C30-rearranged hopane/C29-norhopane and Pr/Ph, as well as 8β(H)-homodrimane/8β(H)-drimane and 8β(H)-drimane/ 8α(H)-drimane. It shows that the Mesozoic crude oil has no relation with type A4 and type B source rocks. Figure 8 presents that the majority of type I, II, III oils have good relation with type A1, A2 and A3 source rocks, showing these oils originated and migrated from A1, A2 and A3 source rocks. In the study area, the dark mudstone of Chang 8 member and a part of Chang 7 member belong to type A3 source rock, the correlation of biomarker distribution (Figure 9) shows that type III oil and dark mudstone of Chang 7 member have high abundance of C30-rearranged hopane, however, their values are lower than that of C30-hopane. The relative abundance of C30-rearranged hopane of dark mudstone of Chang 8 member is obvious higher than that of C30-hopane. The Pr/Ph and sterane characteristics of type III oil are similar to those of Chang 7 dark mudstone, but differ from those of Chang 8 black mudstone. Therefore, it can be inferred that type III oil mainly comes from Chang 7 dark mudstone. The above analysis shows that Chang 7 oil shale and Chang 7 dark mudstone are the effective source rocks in the southern margin of Ordos Basin, and Chang 7 oil shale is the main effective source rock for providing hydrocarbon.

Figure 7   Comparison of biomarkers between mesozoic oil and source rocks, southern margin of Ordos Basin
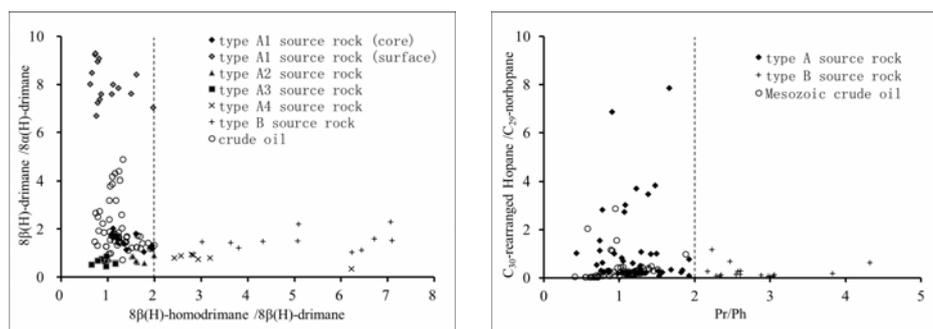
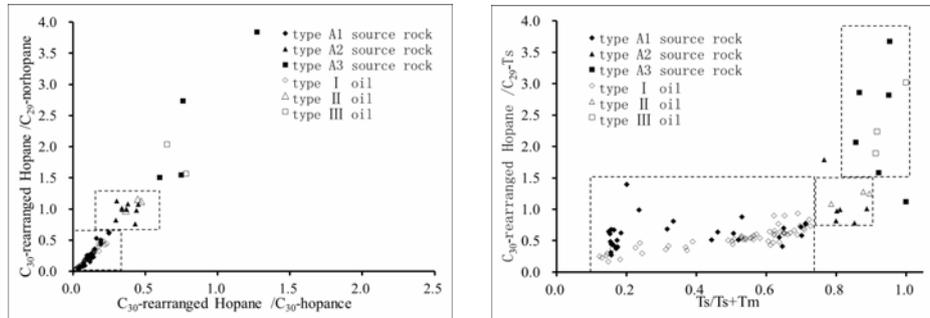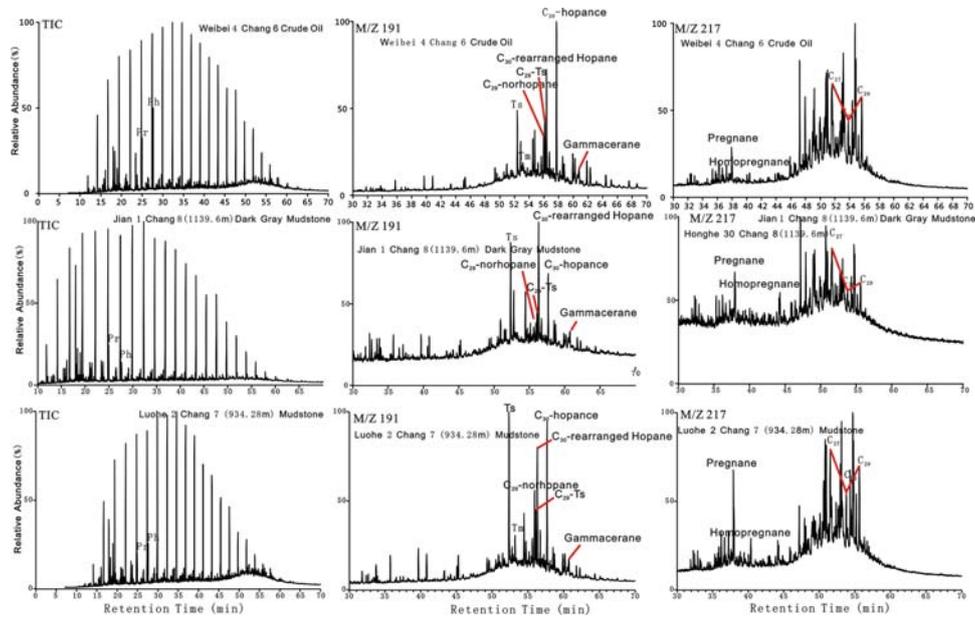**Figure 8** Comparison of biomarkers between different oils and source rocks, southern margin of Ordos Basin

Figure 9 Biomarkers comparison between type III oil and Chang 8 dark mudstone as well as Chang 7 dark mudstone (see online version for colours)

6 The geochemical characteristics and identification criteria of effective source rocks

6.1 The geochemical characteristics of effective source rocks

The hydrocarbon generating ability of different source rocks varies greatly as shown in Table 4. The TOC of Type A1 effective source rock is 3.9%–22.5%, with an average value of 12.9%, the S1+S2 of Type A1 effective source rock is 27.1–120.1 mg/g, with an

average value of 76.1 mg/g, indicating that type A1 is good source rock; The TOC of type A2 effective source rock is 1.8%–5.9%, with an average value of 3.7%, the S1+S2 of type A2 effective source rock is 6.0–32.9 mg/g, with an average value of 16.5 mg/g, indicating that type A2 is the good source rock; The TOC of type A3 effective source rock is 2.1%–4.9%, with an average value of 3.6%, the S1+S2 content in type A3 effective source rocks is 8.1–16.2 mg/g, with an average value of 11.6 mg/g, indicating that type A3 is good source rock. Type A4 and type B also have the capacity of generating hydrocarbon, which are the potential source rock in the study area.

Table 4   Distribution characteristics of organic matter abundance in different source rocks

Types		$w(TOC)$ (%)	S1+S2 (mg·g^{-1})	HI (mg·g^{-1})	w(Chloroform asphalt 'A') (%)	Ro %
Excellent	A1	3.9~22.5	27.1~120.1	376~727	0.19~1.38	0.53~0.76
		12.9(9)	76.1(9)	590(9)	0.88(7)	0.62(7)
Effective	A2	1.8~5.9	6.0~32.9	267~531	0.11~0.69	0.59~1.02
		3.7(5)	16.5(5)	380(5)	0.60(5)	0.78(5)
	A3	2.1~4.9	8.1~16.2	172~481	0.29~0.50	0.73~0.94
		3.6(8)	11.6(8)	261(8)	0.36(4)	0.81(5)
Potential	A4	0.6~2.3	0.4~4.5	39~218	0.04~0.13	0.71~0.92
		1.2(16)	1.7(16)	1.09(16)	0.04(15)	0.87(7)
	B	0.6~8.3	0.4~37.8	51~473	0.05~0.37	0.74~0.95
		3.4(16)	10.2(16)	187(16)	0.14(17)	0.85(7)

Note: $\dfrac{\text{Minimum} \sim \text{Maximum}}{\text{Average (samples)}}$.

Type A1 effective source rock is composed of type I organic matter; type A2 and type A3 effective source rocks are composed of type II1 organic matter (Figure 10). Type A4 and type B effective source rocks are composed of type II2 and type III organic matters. For type A effective source rock, exinite and asphalt-minerals account for at least 70% of all macerals components (Figure 11). Meanwhile, Ro is higher than 0.6%, indicating entering into the hydrocarbon generating stage. For type A4 and type B effective source rocks, exinite and asphalt-minerals account for less than 60% of all maceral components.

The biomarker characteristics of type A effective source rock are as follows (Figure 12): a monomodal n-alkane distribution is observed with a large relative n-alkane concentration in the composition of nC15 or nC16; Pr/Ph is 0.79–1.29; the values of gammacerane and β-carotane are very low, indicating that type A source rock formed in the reducing-weak reducing fresh or mild-saline water environment. The relative content of $\alpha\alpha\alpha$20RC27 sterane, $\alpha\alpha\alpha$20RC28 sterane and $\alpha\alpha\alpha$20RC29 sterane show the shape of 'L' or 'V' patterns, indicating that aquatic organism like alga has great contribution to source rock; the value of rearrange sterane/sterane is 0.05–0.14, the content of C30-hopane is extremely high, the content of C30-rearranged hyopane is extremely low, the content of C29-norhopane is medium-high, the content of Ts is lower or close to that of Tm. The biomarker characteristics show that type A effective source rock formed in the reducing environment, with maturity of low-middle maturation.

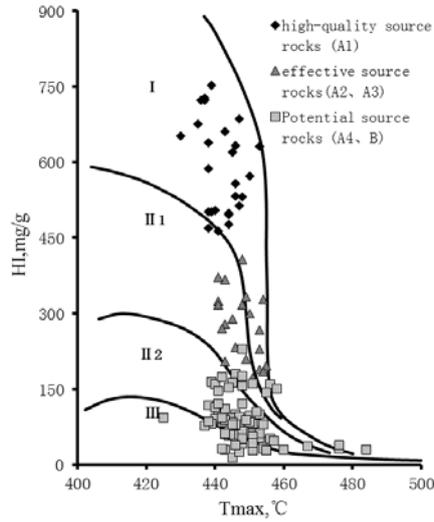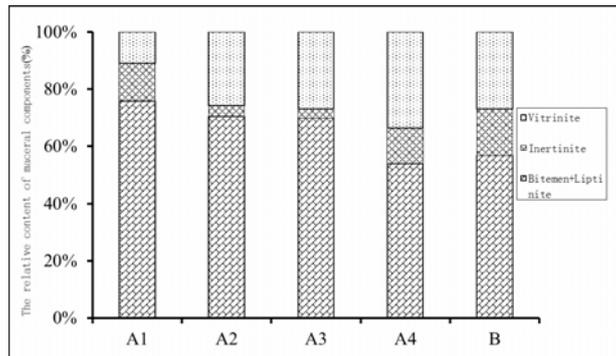**Figure 10**   Organic matter type in different source rocks

Figure 11   Relative content of maceral components in different source rocks

6.2   The identification of source rocks

Different source rocks in Mesozoic Yanchang Formation, southern margin of Ordos Basin can be distinguished using biomarker parameters, i.e., C30-rearranged drimane and 8β(H)-drimane, for they are representatives of different sedimentary environments.

Different source rocks have different hydrocarbon-generation potential. The conventional geochemical parameters such as w(TOC), S1+S2, HI, (S1+S2)/w(TOC) and maceral components can be used to distinguish the different source rocks. The source rocks usually have relatively high gamma ray values and low formation density values than the non-source rocks on well-logging. For the acoustic travel-time differences of kerogen or oil-gas is larger than that of rock skeleton, the acoustic travel-time differences of the formation containing organic matters or oil-gas should be very large. The above properties are the theoretical foundation for identifying the electrical parameters of source rocks (Wang et al., 2002; Zhu et al., 2003; Yan et al., 2009; Zhu et al., 2003).

Figure 12   Saturates mass chromatogram of effective source rocks, southern margin of Ordos Basin (see online version for colours)
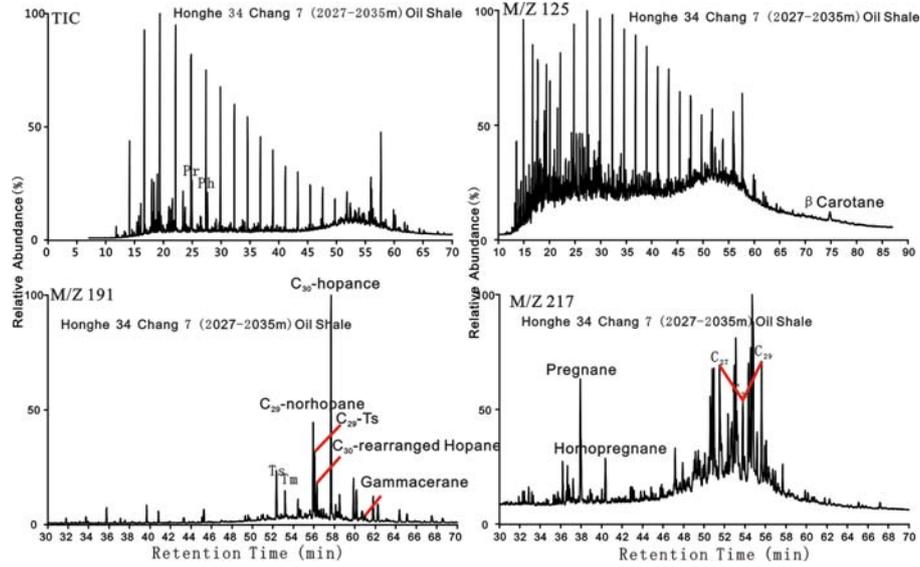
According to the parameters mentioned above, the comprehensive identification criteria for identifying different source rocks can be established. The detailed parameters for identifying different source rocks in the research area are as follows (Table 5, Figure 13), $w(TOC) > 1.6\%$, $S1+S2 > 4$ mg/g, $(S1+S2)/TOC > 20$ 0mg/g, $HI > 170$mg/g; the types of organic matter are mainly type I and type II1, $Ro > 0.6\%$; carbon distribution of n-Alkane has a single peak with $nC15$ or $nC16$ dominating, $Pr/Ph < 1.8$, $\alpha\alpha\alpha20RC27$sterane $\geq$ $C29$sterane, $8\beta(H)$-homodrimane/$8\beta(H)$-drimane < 2; $AC > 260$ us/ft, $RT > 18\Omega\cdot$m, CNL > 25%.

Table 5   Identification of source rocks for Yanchang Formation, southern margin of Ordos Basin

Types	Identification parameters	Excellent source rocks	Effective source rocks	Potential source rocks
Biomarker	$8\beta(H)$-homodrimane/ $8\beta(H)$-drimane	<2	<2	>2
	$8\beta(H)$-drimane/ $8\alpha(H)$-drimane	>1	<1	
Conventional geochemistry	$w(TOC)/\%$	>4	>1.6	
	$S1+S2$ (mg·g^{-1})	>20	>4	<4
	HI (mg·g^{-1})	>450	>170	<170
	$S1+S2/w(TOC)$ (mg·g^{-1})	>500	>200	<200
Well-logging	GR (API)	>170	>120	>100
	AC (us/ft)	>280	>260	<260
	RT (Ω·m)	>15	>15	
	CNL (%)	>25	>25	<25

Figure 13 Correlation diagram of typical parameters in different source rocks
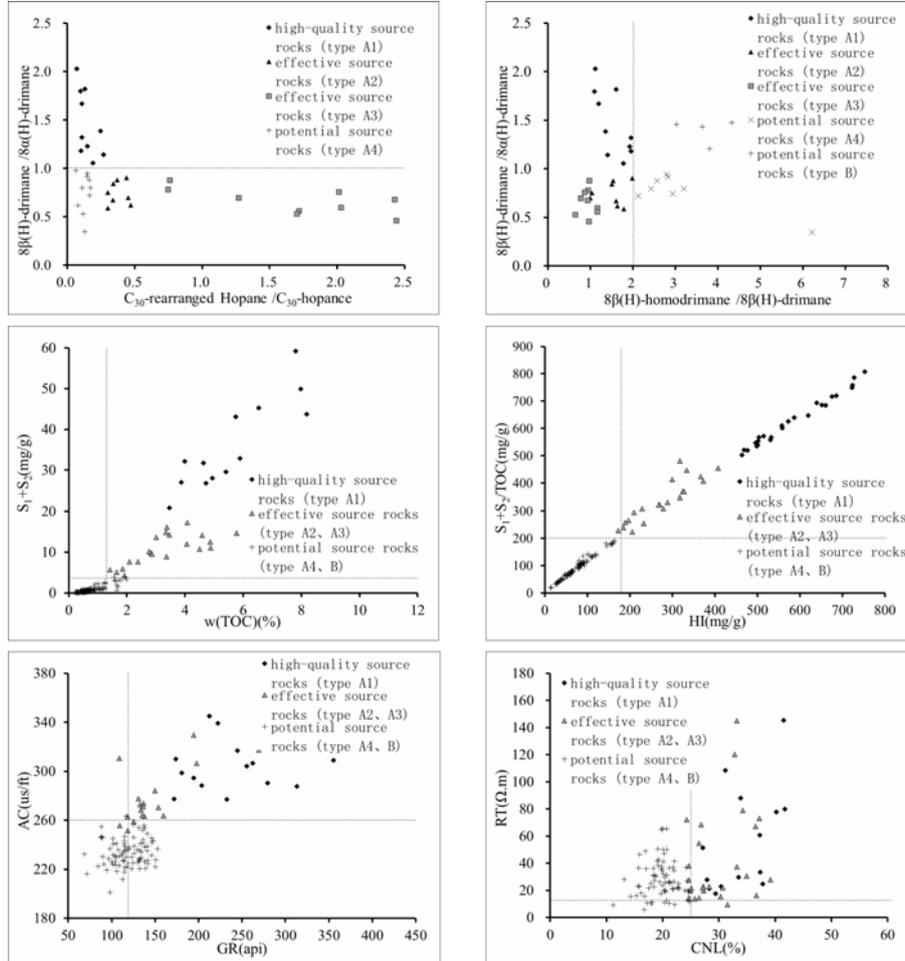
In this study, it is found that the source rocks of Chang 9 member in Zhenjing area are types A4 and B, and that no corresponding oil samples have been found. As the thickness of Chang 9 source rock is excessively thinner than that of Chang 7 source rock, and it distributes partially within the study area, which indicates that Chang 9 source rock only provides a small amount of hydrocarbon, i.e., Chang 9 hydrocarbon in Zhenjing area are mainly provided by Chang 7 oil shale. However, in Fuxian area, Chang 9 source rock probably makes huge contribution to Chang 9 hydrocarbon, for Chang 9 member in this area is the sedimentary centre of source rocks.

7 Conclusions

The drimane, especially the relative content of 8β(H)-drimane as well as hydrocarbon potential is the key factor representing the types of source rock in southern margin of Ordos Basin. The geochemical parameters including 8β(H)-drimane, C30-rearranged drimane are reliable to distinguish the source rock types and oil types.

Type I, II, III oils of Mesozoic Yanchang Formation have good correlations with type A1, A2, A3 source rocks, indicating that the three oils originated and migrated from the three source rocks. Chang 7 oil shale and Chang 7 dark mudstone are effective source rocks, and A1 source rock (Chang 7 oil shale) makes large contribution to hydrocarbon accumulation.

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