Geochemical characteristics of Lower Jurassic source rocks in the Zhongkouzi Basin

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Abstract. Zhongkouzi basin is formed in Mesozoic and Cenozoic and developed on the Hercynian folded belt, the degree of exploration for oil and gas is relatively low hitherto .In order to find out the geochemical characteristics of the source rocks and the potentials for hydrocarbon generation. The research result shows that by analysis the geochemical characteristics of outcrop samples and new core samples in Longfengshan Group, Longfengshan Group are most developed intervals of favorable source rocks. They are formed in depression period of the basin when the sedimentary environments is salt water lacustrine and the water is keeping stable; The organic matter abundance is middle-higher, the main kerogen type is Ⅱ1-Ⅱ2 and few samples act as Ⅲ type, The organic matter maturity is low maturity to medium maturity. The organic matter maturity of the source rock from eastern part of the basin is higher than in the western region. The source rock of Longfengshan Group are in the hydrocarbon generation threshold. The great mass of source rocks are matured and in the peak stage of oil generation.

1. Introduction

Oil and gas exploration in Zhongkouzi basin was began in the middle of 1950s [1, 2], but the former researches in the area are mainly concentrated in the regional geological survey and the analysis of outcrop samples, the study the basic petroleum geological features of the area is not enough. There were some shallow drillings that has low yield oil. For years of petroleum exploration, the Formation in Lower Jurassic and Cretaceous have always been the crucial layers, which have the most favorable hydrocarbon source rocks in them [3-5]. The geochemical characteristics of source rocks in Longfengshan Group are studied in detail, based on the analysis of the distribution characteristics of Cretaceous.

2. Geological background

Zhongkouzi basin is Mesozoic Cenozoic Basin with Hercynian folded basement, located in the northern of Gansu and the southern of Beishan basin. Its tectonic location belongs to the Tianshan and Inner Mongolia geosyncline belt. The basin experienced 3 stages of evolution, including Rift, fault depression and depression.The Formation in Lower Jurassic and Cretaceous overlap each other because of the Strong modification of The Yanshan and Himalayan tectonic movement [2-4].The strata distribution of Lower Jurassic and Cretaceous Formation just like a seesaw. According to the

characters of Residual stratum in basin, the basin are divided into 9 structural units (including 6 depressions, 3 projections), in which the Nanquan sag, Heizhang sag and sag of Xishan coal have always been the main oil and gas exploration areas because of their thickness of residual strata area [5].

The seismic profiles show that the maximum residual thickness of Longfengshan group in Eastern graben is 4700m, the maximum residual thickness in western graben is about 4000m. The field geological profile and drilling (hole) reveals that Longfengshan Group of the lower Jurassic formation is mainly semi-deep to deep lacustrine facies sedimentary, including dark mudstone section thickness is 400 ~ 800m,with the residual mudstone formation area of about 4000Km^2, which was the material basis of development of high quality source rocks [6].

3. Source rock organic geochemistry

3.1. The abundance of organic matter

The Characterization of organic matter abundance index mainly includes the content of organic carbon in source rocks (TOC), chloroform bitumen "A" content (EOM), total hydrocarbon content (HC) and rock pyrolysis hydrocarbon generating potential (S1+S2) [7-8].

The research samples are mainly from Outcrops of basin margin and cores of coalfield drilling and oil drilling, such as Beishan coal mine (Baishan coal mine), Jinmiaojing coal mine, et al.

The test results of more than 100 pieces of research samples in the area show that: the total organic carbon content of dark mudstone is greater than 0.2%, generally between 0.5% and the 1.6%, Part of the test data result is greater than 2%. The chloroform bitumen "A" content is 0.005% ~0.09% generally, some samples is greater than 0.1%. Total hydrocarbon content is (34 ~ 750) * 10^{-6}, some samples is greater than 1000 * 10^{-6} (Table 1).

Analysis of the data showed that the abundance of organic matter of outcrop samples is medium - poor, but the test data from the core samples was significantly higher than that of outcrop samples. The organic matter abundance of Longfengshan source rocks in lower Jurassic formation is generally considered moderate or good, considering the influence of surface strong weathering.

Table 1. Statistical table of organic matter abundance of source rocks in the Zhongkouzi Basin

sampling spot	formation	lithology	the total organic carbon content		The chloroform bitumen "A" content		Total hydrocarbon content		evaluation
			Average (%)	numbers	Average (%)	numbers	Average (10-6)	numbers	
Line-A	J1+2	mudstone	0.75	2	0.012	2	44.77	2	Poor
East Tanyaojing	J3	mudstone	0.5	3	0.0089	3	78.5	2	Poor
	J2	mudstone	0.69	28	0.0247	28	226	6	medium
	J1	mudstone	0.89	13	0.0063	13	58	3	Poor
Beishan coal mine	J1+2	mudstone	1.23	5	0.0044	1			Poor
		Coal			2.6398	1	6038	1	medium
H1	J1	mudstone	1.65	14	0.0218	2	84	2	medium
BSM	J1	mudstone	3.97	10	0.0905	4	77	4	good
J704	J1	mudstone	5.07	20	0.0867	10	172	10	medium
ZK2	J1	mudstone	5.79	17	0.15	7	253	12	good

3.2. Types of organic matter

The type of organic matter is an important indicator of the quality of source rocks. Different types of organic matter have different hydrocarbon generating potential [9]. The Kerogen elemental analysis from outcrop samples and coalfield drilling cores show that H/C value of the source rock in

Longfengshan group is generally between 0.6 and 1.2, O/C value is generally between 0.05 and 0.25. The kerogen type is mainly as II_1- II_2 type, a small part of the outcrop samples for type III.

The use of biomarkers to determine the organic type of source rock, depositional environment and maturity. 20RC27 steranes, C28 sterane and C29 sterane relative composition of organic matter can be used to distinguish the type of parent material.It is generally believed that C29 steroids mainly reflect the contribution of terrestrial plants, and C28 steroids mainly reflect the contribution of algae, and C27 steroids mainly reflect the contribution of plankton[10].The triangular diagram of relative composition of C27-C28-C29 steroids(Figure 1), show that the main source of hydrocarbon source rocks in this region in the main source of organic matter in terrestrial plants, only a few samples with higher plants, plankton and algae mixed source characteristics, the overall contribution of algae and plankton were less than 50%.

Generally in Geochemical research at home and abroad, pristane is always considered formed in the oxidizing environment, the formation of phytane proposed is fromed in the reduced environment [11-13]. Peters pointed that of moldowan samples, high Pr/Ph ratio (greater than 3.0) indicates the terrigenous organic matter input under oxidizing conditions, low Pr/Ph ratio (lower than 0.6) represents hypoxia environment which is usually hypersaline environment [10].Research on Wang Tieguang suggested that the, Pr/C17, Ph/C18 and Pr/Ph diagram is an effective map differentiating sedimentary environment [11].

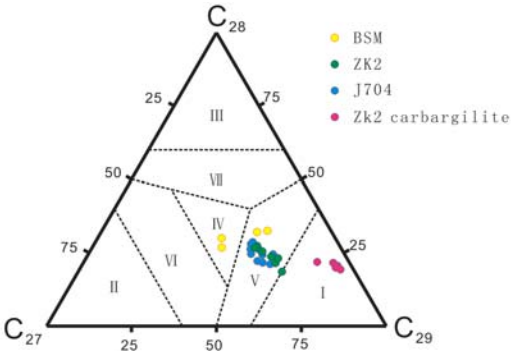

Figure 1. Triangular diagram of C27, C28 and C29 regular sterane of source rock in Zhongkouzi Basin
I - terrestrial plants; II - phytoplankton; III -algae; IV - mixed source; V - terrestrial plant; VI - plankton; VII-algae.

The analysis found that in Pr/C17, Ph/C18 and Pr/Ph relative composition diagrams (Figure 2): most of the extract of source rock samples are distributed in high Ph/C18 value and low Pr/Ph value area, sedimentary characteristics in the western region indicates the hole basin salt lake facies and its regional variation and reveal the above sample analysis the conclusion is roughly the same.

The analysis shows that the half deep lake to deep lake facies, reducing environment salinization and excellent hydrocarbon source rock (type II_1-II_2 kerogen), is in the hole in the early stage of high quality source rocks of hydrocarbon generation and expulsion, mainly due to the formation of low mature oil reservoirs.

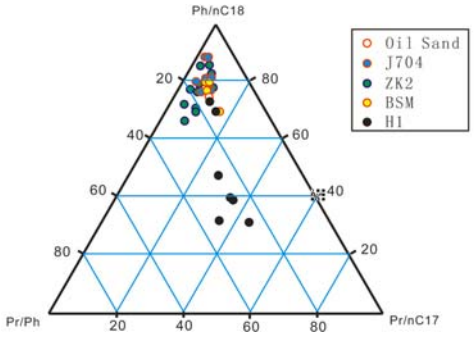

Figure 2. Triangular diagram of Pr/C17, Ph/C18 and Pr/Ph of source rock in Zhongkouzi Basin

3.3. Thermal evolution maturity

The maturity of source rocks and the threshold of hydrocarbon generation and expulsion determine the amount of hydrocarbon expulsion and resource of source rocks [12].

The vitrinite reflectance of organic matter in source rock (Ro) from the Outcrop sample is high on the whole, generally between 0.6% and 1.2%, the pyrolysis peak temperature (Tmax) is generally greater than 435℃ (Table 2). The thermal evolution parameters of core samples is higher than that of outcrop samples. The results showed that the organic matter in the vast majority has entered a mature stage.

The vitrinite reflectance of Jurassic source rocks (Ro) in Heizhangfang sag is generally greater than 1%, the peak temperature of pyrolysis (Tmax) is generally greater than 450℃, which is generally higher than the South sag. The research shows that the source rock thermal evolution degree of Heizhangfang sag is higher than that of Nanquan sag in the western of the basin.

Table 2. Organic matter maturity parameters of source rocks in Zhongkouzi Basin

sampling spot	formation	lithology	Ro	Tmax	evaluation
Line-A	J1+2	mudstone	0.87	465-483	Mature
		Coal	1.36		high mature
East Tanyaojing	J3	mudstone	0.67	450	low-mature
	J2	mudstone	0.77	440	Mature
	J1	mudstone	1.01	503	Mature
Beishan coal mine	J1+2	mudstone	0.79-1.07	450-525	Mature
Youshashan	J1+2	mudstone	1.17	437	Mature
Jinmiaojing	J1+2	mudstone	0.41-0.78	431-478	low-mature or Mature
H1	J1	mudstone	1.2-1.7	450-525	Mature or high mature
BSM	J1	mudstone	1.07-1.17	436-480	Mature
704	J1	mudstone	0.64-0.92	425-437	low-mature or Mature
ZK2	J1	mudstone	0.51-0.79	424-436	low-mature or Mature

OEP (odds ratio CPI (parity) and carbon preference index) is the rock extracts in C23 ~ C34 odd even carbon atom parameters, the relative abundance of alkanes by formula, to estimate the source rock maturity. In sediments, when the source rocks are immature, the alkanes have obvious predominance of odd carbon, and the distributions of OEP is usually greater than 1.2 , CPI distribution is between 2.4 and 5.5. With the increase of maturity, to heat oil and gas phase catalytic pyrolysis of kerogen, produce alkanes, no odd carbon or even carbon advantages of OEP, CPI were less than 1.2; in the main oil generating zone, CPI decreased to about 1 [13, 14].

The parameter analysis results of OEP and CPI show that (Figure 3): Sample OEP and CPI parameters of H1 and BSM in the study area of Eastern Heizhangfang sag showed that the source rock

has reached maturity, and the parameters of J704 and ZK2 sample area of West Nanquan sag showed low mature source rock characteristics, a few samples are immature.The thermal evolution maturity degree of source rock in Heizhangfang sag is higher than that in Nanquan sag, with the consistency of the results of study of Ro and Tmax.

Previous studies showed there were three geological shallow wells in Nanquan sag, and Oil analysis and laboratory data show that the oil content of asphalt in petroleum reached 11.12%[6], so the source rocks in Nanquan sag are mature hydrocarbon generation and oil quality is relatively good. The source rock in Heizhangfang sag is better than that of Nanquan sag, with greater potential of hydrocarbon generation.

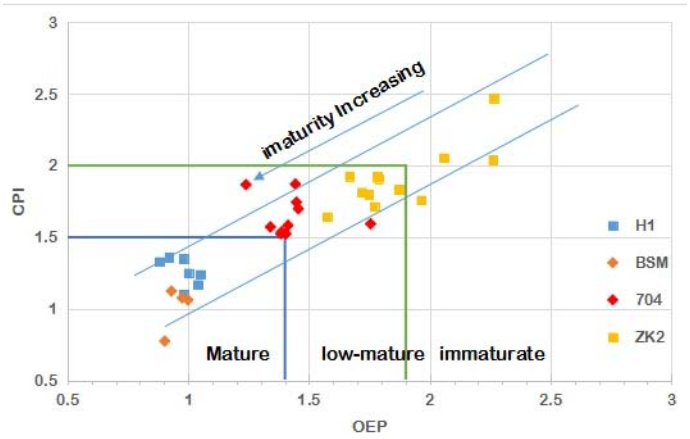

Figure 3. Intersection figure of saturated hydrocarbon CPI and sterane OEP of source rock in Basin

4. Conclusion

The study of geochemical characteristics combined with previous studies show that the source rocks of Longfengshan Group in Lower Jurassic zhongkouzi basin is Saline groundwater lacustrine deposits, sedimentary water stability, abundance of organic matter in source rock were moderate, the kerogen type is mainly II_1- II_2, a small amount of samples for type III kerogen, organic matter maturity is low mature mature stage. Hydrocarbon source rocks in the eastern part of the basin thermal evolution degree is higher than the western region. The main source of hydrocarbon source rocks in this region in the main source of organic matter in terrestrial plants, only a few samples have higher plants, plankton Characteristics of mixed sources of organisms and algae.

Zagegaonao baisn is close to the north of the Zhongkouzi basin. The heavy, magnetic data show that the thickness of Jurassic formation in basin should be large and sedimentary characteristics of Jurassic formation is good consistency with that of zhongkouzi basin. The hydrocarbon source rock condition is superior to that of zhongkouzi basin, considering of its superior cap condition.

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