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Characteristics of the Cretaceous Source Rocks and Prospect Direction, Liupanshan Basin, China

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ABSTRACT

Outcrops, drilling cores and seismic data were used to describe the characteristics of the Cretaceous sources rocks and analyze the organic content, maturity and type. The Naijiahe formation (K_1n), Madongshan formation (K_1m) and Liwaxia formation (K_1l) are the most important source strata in the Cretaceous. K_1n and K_1m which are thinner than K_1l well develop dark mudstone. The organic matter contents are high but the maturity is low. The K_1l has less mudstone ration, low organic matter content but has been mature. Oil-source correlation shows that K_1n, K_1m and K_1l all occurred hydrocarbon generation and migration while the K_1l is the most practical source rock. Based on the analysis, it indicates that oil prospect should focus on the region near the hydrocarbon generation center with proper faults development.

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INTRODUCTION

The Liupanshan Basin is located in the south of ningxia hui autonomous region, with the Ordos block in the east, Helan mountain in the north and north Qilan orogenic belts in the southwest. The area is almost 9000 km2. Previous studies have been conducted on the development characteristics of source rock in Liupanshan Basin, confirming several source rock strata in the Cretaceous (Guan *et al*. 1957, Yang & Hu 2001, Ba *et al*. 2006). By 2014, 8 wells have been drilled into the Cretaceous, among which well C1 and C2 exposed oil patch sandstone. Outcrops of the Cretaceous in the margin of the basin also show many oil seepages, indicating good resource potential (Fig. 1). The prospect of the Basin is still at the primary stage, distribution, quality, burial depth and validity is undefined and systematic research and evaluation is lacked, restricting the advance of hydrocarbon prospect.

Taking geochemical analysis of core and outcrop samples as foundation, development characteristics and resources potential of the Cretaceous is studied and oil and source rock correlation is conducted in the paper. Coupled with drilling analysis, the key factors influencing hydrocarbon accumulation are cleared and prospect targets are identified.

1. Geological setting:

The sedimentary succession of the Liupanshan Basin has experienced four tectonic cycles and now is a complex basin of faulted-depression and depression (Tang *et al*. 2009, Zhao *et al*. 2013). In the Mesozoic, the Basin began to experience extensional rift effect. In the Cretaceous, the powerful extension resulted in a large area faulted-depression, forming the thickest sedimentary succession in the basin (Li 2001). During the Berriasian and Aptian, the deposition is continuous without unconformity, but in the Albian, tectonic movement resulted in the uplift of strata and lack of the whole upper Cretaceous. The widely distributed lower Cretaceous is composed of the Berriasian Sanqiao formation (K_1s), Valanginian Heshangpu formation (K_1h), Hauterivian Liwaxia formation (K_1l), Bashkirian Madongshan formation (K_1m) and Aptian Naijiahe formation (K_1n), ranging in thickness from 3000-5000m (Fig. 2).

During the lower Cretaceous, the lacustrine water was deep, brackish and reductive (Fan & Lin 2003, Lin *et al*. 2006). The drilling of well C1 and C2 proved that many dark shale intervals occurred in the lower Cretaceous, among which K_1n, K_1m and K_1l is the most important source rock strata. Moreover, the Cretaceous source rock outcrops are pervasive in the margin of the basin, facilitating the systematic study.

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2. *Characteristics of the source rock:*

2.1 *Stratigraphy of the source rock:*

Based on field strata section and 2-D seismic data, the distribution of source rock strata was profiled. The K_1n is widely distributed in the Basin with relative thin thickness. The Main depression center is located near the Sikouzi with thickness larger than 1000m. The secondary depression center is located in the east of well PC1 with thickness about 500m. The strata are generally thin in the east of the Madongshan fault. The K_1m's depression center is located along the Madongshan fault in an elongated shape, resulting in an obvious difference in thickness cross the fault. The succession in the west is much thicker with maximum thickness of 1500m, while the thickest area located near the well PC1in the east is about 500m. The K_1l is generally thick in the north of the basin. The biggest depression center is located near the well PC4, where the strata thickness is larger than 2000m, while the thickness is no more than 1700 in the depressions in the south.

Well C1 and C2 are used for the analysis of the vertical development characteristics of the source rock. Form the geological logging section, the K_1n can be divided into four members, in which the lower three members mainly compose of gray mudstone, lime mudstone and mud limestone are the source rock intervals. The K_1n is composed of four members and the second and fourth member is dominated by gray to black mudstone, mud limestone. The middle and upper member of the K_1l are composed of purple mudstone and sandstone while the lower member is dominated by interbedding gray mudstone, gray lime mudstone. The thickness of dark mudstone in the K_1n, K_1m and K_1l is counted in Table 1: K_1m is greatest in cumulative thickness of mudstone and relative thick single layer; K_1n has thinnest cumulative thickness but the single layer is much thicker; K_1m has much thick mudstone, however, the ratio of mudstone is only about 20% compared to the ration of 80% of K_1n and K_1m.

2.2 *Geochemical characteristics of the source rock:*

119 samples from the outcrops and cores were conducted on the TOC measurement Rock-Eval analysis. The results are shown in Figure 3 (a). The TOC values of K_1n range from 0.28% to 4.62% with an arithmetic average of 0.78%. The S_1+S_2 values of K_1n range from 0.05 mg/g to 5.36mg/g with an arithmetic average of 2.87mg/g. The Ro values of K_1n range from 0.47% to 0.75% with an arithmetic average of 0.53%. The Tmax values of K_1n range from 393°C to 444°C with an arithmetic average of 428°C. The arithmetic average of TOC values of K_1m is 1.53%, with minimum and maximum values of 0.25% and 5.27%. The arithmetic average of S_1+S_2 values of K_1m is 9.63 mg/g, with minimum and maximum values of 0.11 mg/g and 42.51 mg/g. The arithmetic average of Ro values of K_1m is 0.59%, with minimum and maximum values of 0.56% and 0.80%. The arithmetic average of Tmax values of K_1m is 436°C, with minimum and maximum values of 428°C and 443°C. The TOC values of K_1l range from 0.20% to 2.33% with an arithmetic average of 0.63%. The S_1+S_2 values of K_1l range from 0.05 mg/g to 10.81mg/g with an arithmetic average of 2.15mg/g. The Ro values of K_1l range from 0.79% to 1.38% with an arithmetic average of 0.96%. The Tmax values of K_1l range from 424°C to 502°C with an arithmetic average of 445°C. At present, the evaluation criterion of the lacustrine source rock is based on the index of Cheng, *et al*. 2008 (Cheng *et al*. 2008, Mu *et al*. 2010, Zhang *et al*. 2010, Liu *et al*. 2012, Lv *et al*. 2012). From Figure 3 (a), K_1m has the best source rock quality followed by K_1n, and K_1l has mediocre quality. The K_1n and K_1m source rocks are low mature while the K_1l have been mature. Cross plot of the I_H and Tmax and microscopic observation of kerogen were used to divide the organic type. As can be seen in Figure 3 (b), kerogen types of K_1m are I and II_1 and kerogen types of K_1n and K_1l are II_2 and III.

Though most outcrop samples from the K_1n and K_1m are low mature, area near the depression center and deep bury could have mature source rock. Base on the present geothermal gradient of 3°C/100m (Cheng *et al*. 2005), the mature source rock should deeper than 2400m. Based on the mudstone ration from wells and strata thickness obtain by 2D-seismic, the contour map dark mudstone thickness of K_1n+m and K_1l were drawn (Figs 4, 5). Area of K_1n+m with mudstone thickness larger than200m is 1900km^2, which shrink to 340km^2 cause by the constrain of bury depth of 2400m. Area of K_1l with mudstone thickness larger than200m is 1280km^2.

2.3 *Oil source correlation:*

Based on the biomarker characteristics analysis, oil source correlation was conducted between asphalt, oil patch and source rock (Table 2). The K_1n and K_1m has similar sedimentary environment and geochemical characteristics, therefore, they can be treated as one source strata. The asphalt samples from Xiaokou and Choushuigou have low Pr/Ph, medium G / C_{30} H, "V" shape of regular steranes C_{27}, C_{28} and C_{29}, indicating the much reductive evolution environment and macerals of coal (Fig. 6). $C_{29}S$ / (R + S), $C_{29}\beta\beta$ / ($\beta\beta$ + $\alpha\alpha$) and Ts / (Tm + Ts) indicate low mature characteristics. It shows that K_1n+m are contributed to the asphalt of outcrops. Compared with the Choushuigou asphalt and K_1m+n, the Xiaokou asphalt samples have high content of diasteranes, indicating that there to some extent may be some source mixing of K_1m+n and K_1l. Samples from well C1 and C2 have relative high $C_{29}S$ / (R + S), $C_{29}\beta\beta$ / ($\beta\beta$ + $\alpha\alpha$) and Ts / (Tm + Ts), "L" shape of regular steranes C_{27}, C_{28} and C_{29},

relative high content of diasteranes (Fig. 6). It indicates that the K_1l is the source of oil in two wells. Until now, no oil path from has been found in drillings, though K_1n+m are contributed to the asphalt in crops, the K_1l is the most practical and guaranteed resource strata. The K_1n+m are still important in the depression center.

Table 1: Development Characteristics of the dark mudstone in the K_1n-K_1l of well C1 and C2.

Well	Formation	Cumulative thickness of dark mudstone [m]	Single layer thickness [m]	Number layer	Ratio of dark mudstone thickness [%]
C1	K_1n	192	0.5-40	64	84.9
C1	K_1m	281	1-30	78	88.5
C1	K_1l	240	0.5-24.5	95	23.4
C2	K_1n	251	0.5-22	92	89.1
C2	K_1m	439	0.5-32	119	92.2
C2	K_1l	352	0.5-7	158	19

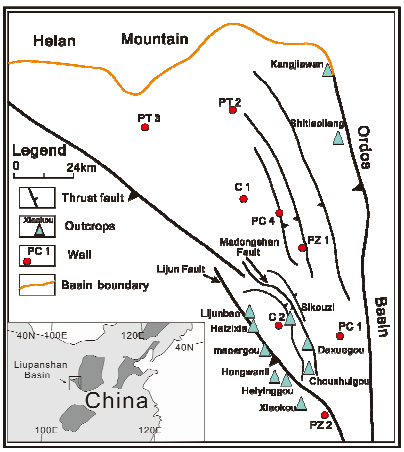

Fig. 1: Structural sketch of the Liupanshan Basin and the location of outcrops.

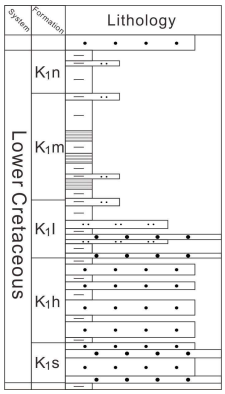

Fig. 2: Lithology section of the Lower Cretaceous, Liupanshan Basin.

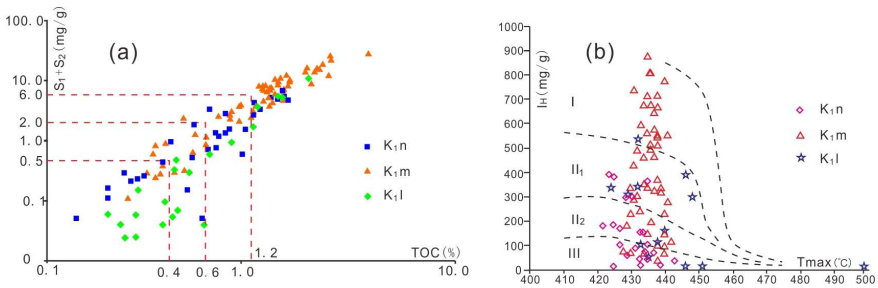

Fig. 3: (a) Cross plot of the TOC and S_1+S_2 of the Cretaceous source rock (Dotted lines divide the kerogen into three classes based on the index of Huang, *et al.*) (b) Cross plot of the hydrogen index and Tmax of the Cretaceous source rock.

3. *The prospect direction:*

In Liupanshan Basin, the Palaeogene has the best reservoir intervals, the Jurassic also has several good reservoirs; but, no good hydrocarbon shows in the strata above the Cretaceous. Oil patches only occur in the thin-bedded sand body with medium reservoir property in the K_1l. It indicates that the migration of hydrocarbon was restricted near the source rock and only accumulated in the isolated thin-bedded sand body. Based on the sedimentary environment analysis, the K_1l lack pervasive thick sand body, so the hydrocarbon expelled from source rock hardly happened effective lateral migration. Thus, the area near the hydrocarbon generation center is the best hydrocarbon enrichment area. Faults formed by tectonic movements are the good pathways of hydrocarbon, but also are the destructors of accumulation, proved by the asphalt of Xiaokou and Choushuigou outcrops. The faults are contributed to the vertical migration of hydrocarbon to the upper good reservoirs, if with proper scale, they can form fault block and anticline traps. Therefore, the prospect of Liupanshan Basin should firstly identify the distribution of effective source rock and evaluate the faults' characteristics and scales. Hydrocarbon enrichment may occur in the good reservoirs above and inside the Cretaceous located in the area near the hydrocarbon generation center with development of faults.

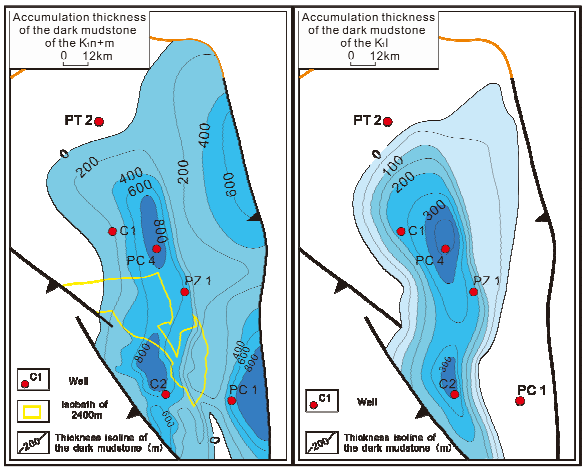

Fig. 4: Isopach map of the cumulative thickness of the dark mudstone in the Cretaceous.

Table 2: Characteristics of the biomarker parameters of the Cretaceous source rock.

Sample source	Form	Pr/Ph	G/C_{30} H
K_1n	Source rock	0.62	0.39
K_1m	Source rock	0.49	0.57
K_1l	Source rock	0.65	0.41
Xiaokou outcrop	asphalt	0.46	0.49
Choushuigou outcrop	asphalt	0.52	0.65
Well C1	Oil patch	0.73	0.72
Well C2	Oil patch	0.33	0.66

Table 2: (continued).

Sample source	C_{29}20S/(R+S)	C_{29}ββ/(ββ+αα)	Ts/(Tm+Ts)
K_1n	0.17	0.23	0.13
K_1m	0.25	0.22	0.11
K_1l	0.37	0.4	0.31
Xiaokou outcrop	0.30	0.29	0.11
Choushuigou outcrop	0.28	0.23	0.14
Well C1	0.34	0.38	0.24
Well C2	0.39	0.45	0.27

4. *Conclusions:*

The K_1n, K_1m, K_1l are the most important source strata of the Cretaceous. The K_1n+m have higher dark mudstone ratio and organic matter abundance with low mature. The K_1l has lower dark mudstone ratio and organic matter abundance with mature. The oil source correlation shows that the Choushuigou asphalt samples are from the K_1n+m source rocks, oil of well C1 and C2 are from the K_1l, Xiaokou asphalt samples are resulted from the mixing of two source rocks.

Drilling data indicate that the hydrocarbon did not experienced long lateral migration. Big faults are adverse for the hydrocarbon accumulation. Hydrocarbon enrichment may occur in the good reservoirs over and inside the Cretaceous located in the region near the hydrocarbon generation center with proper faults development.

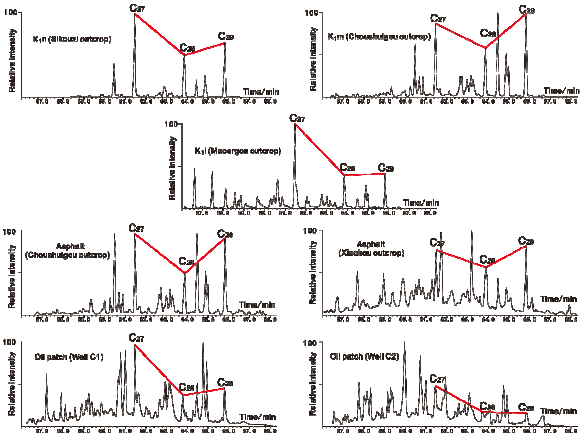

Fig. 5: m/z 217 mass chromatography of the Cretaceous source rock, asphalt and oil samples.

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REFERENCES

Ba, X.E., Y.M. Xu, X.P. He, 2006. The Mesozoic petroleum exploration potential and its direction in Liupanshan basin. *Xinjiang Oil & Gas*, 2(4): 12-16.

Cheng, H.Y., A.L. Li, J.M. Gong, 2008. Terrestrial source rock evaluation parameter analysis. Marine Geology Letters, 24(2): 6-10.

Fan, X.L. S.H. Gao, 2003. The Mesozoic petroleum system and exploration target in the north part of Liupanshan basin. *Petroleum Geology & Experiment*, 25: 532-538.

Guan, S.C., J.Z. Xie, X.M. Xia, 1957. *Geological Survey Introduction of the Gansu Liupanshan area.* Beijing: Geological Publishing House.

Li, D.F., 2001. Characteristic of petroleum geology and prospecting targets in Liupanshan basin. *Xinjiang Petroleum Geology*, 22(1): 27-31.

Lin, X.Y., W.S. Hu, R.J. Xie, 2006. A comparison of reservoiring conditions between Liupanshan and Jiuxi basins. *Natural Gas Industry*, 26(4): 21-23.

Liu, S.P., S.X. Zhou, B.Z. Wang, J. Li, H.K. Zhang S.H. Gong, 2012. Relationship between industrial indexes and source rock evaluation parameters of oil shale. *Natural Gas Geoscience*, 23(3): 561-569.

Lv, S.F., Y.L. Ma, R.C. Cao, J.J. Li, W.M. W.M. Wang, H.G. Li, F.Z. Chen, 2012. Evaluation riteria of high-quality source rocks and its applications: Taking the Wuerxun sag in Hailaer basin as an example. *Earth science Journal of China University of Geosciences*, 37(3): 535-544.

Mu, G.Y., N.N. Zhong, B. Liu, T.C. Yu, Y. Liu, 2010. The quantitative evaluation method of lacustrine mudstone source rock and its application. *Acta Petrolei Sinica*, 31(2): 218-230.

Tang, J.G., L.F. Mei, Q. Li, 2009. Tectonic evolution and its control of hydrocarbon accumulation in Liupanshan basin. *Journal of Oil and Gas Technology*, 31(5): 1-6.

Yang, F.Z., S.R. Hu, 2001. Tectonic evolution and oil-Gas exploration during the Mesozoic and Cenozoic in Liupanshan basin. *Xinjiang Petroleum Geology*, 22(3): 192-195.

Zhang, Z.W., Z.J. Jiang, M.L. Shao, H.T. Xue, 2010. Source rock qualitative evaluation in Binbei area of Songliao basin and determination of hydrocarbon generating threshold. *Journal of Daqing petroleum institute* 34(4): 7-11.

Zhao, H.H., H.Z. Cui, J. Wang, X.B. Hou, J.Q. Ji, X.X. Zhao, 2013. Structural pattern of the southwestern margin in the Liupanshan basin and its significance of petroleum prospecting. *Journal of Northeast Petroleum University*, 37(4): 9-17.

Zheng, D.W., P.Z. Zhang, J.L. Wan, D.Y. Yuan, G.L. Zhang, C.Y. Li, 2005. Apatite fission track evidence for the thermal history of the Liupanshan basin. *Chinese Journal of Geophysics*, 48(1): 157-164.