Study on Geochemical Characteristics of tight sandstone gas accumulation in Linxing area

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Abstract：Based on the comprehensive analysis of the characteristics of tight sandstone gas composition, carbon isotope, light hydrocarbons and source rocks in Linxing area of Ordos Basin, the reservoir-forming model of tight sandstone gas in this area is discussed. The study shows that methane is the main component of tight sandstone gas, with low contents of heavy hydrocarbons and non-hydrocarbons, mainly belonging to dry gas in the Upper Paleozoic in Linxing area. The values of δ13C1, δ13C2 and δ13C3 of natural gas are in the ranges of -45.6‰ ~ -32.9‰, -28.9‰ ~ -22.3‰ and -26.2‰~ -19.1‰, respectively. The carbon isotopic values of alkane gas show a general trend of positive carbon sequence. δ13C1 value is less than -30‰, with typical characteristics of organic genesis. There is a certain similarity in the composition characteristics of light hydrocarbons. The C7 series show the advantage of methylhexane, while the C5-7 series mainly shows the advantage of isoalkane. The tight sandstone gas in this area is mainly composed of mature coal-derived gas, containing a small amount of coal-derived gas and oil-type gas mixture. According to the mode of hydrocarbon generation, diffusion and migration of source rocks in Linxing area, the tight sandstone gas in the study area can be divided into three types of reservoir-forming assemblages: the upper reservoir type of the far-source type (upper Shihezi formation-shiqianfeng formation sandstone reservoir-forming away from source rocks), the upper reservoir type of the near-source type (the Lower Shihezi formation sandstone reservoir-outside the source rock), and the self-storage type of the source type (Shanxi formation-Taiyuan formation source rock internal sand reservoir).

1 Introduction

With the continuous breakthroughs and development of exploration and development technologies, unconventional oil and gas has become a replacement energy source for the stable crude oil production and the rapid growth of natural gas production in China [1-4]. From the perspective of national energy development strategy, entering the field of unconventional oil and gas is an important development strategy of the "13th Five-Year Plan". CNPC, Sinopec and CNOOC are all committed to the rapid development of unconventional oil and gas industries, and have successively established national demonstration projects for tight gas, shale gas and coalbed methane. The Ordos Basin is the second largest petroliferous basin on land in China. Generally, it is a large, asymmetric, north-south, superimposed craton basin with a steep and narrow west flank and a wide east flank [5-6], which contains very rich unconventional oil and gas resources[7-8]. After more than 50 years of exploration and development research, the Sulige, Daniudi, Yulin, Zizhou, Mizhi, Shenmu, Wushenqi, Dongsheng and other large tight sandstone gas fields have been discovered in the basin, which are hundreds of billions of cubic meters

currently discovered in China. The basin with the most large gas fields above the meter level shows that this area has huge natural gas exploration potential [9-11].

Linxing area is located in the eastern margin of the Ordos Basin, rich in oil and gas resources. Drilling gas loggings in this area show that gas is generally contained in the 5th section of Shiqianfeng Formation (Qian5).Taiyuan Formation (P1t), and the thickness of single well drilling gas layer is mainly distributed between 20 and 80m, with an average thickness of 34.6m; The layers are mainly concentrated in the Qian5 Member, upper Shihezi Formation (He 4 Member) ~ Lower Shihezi Formation (He 8 Member), and Taiyuan Formation. The fracturing test shows that some exploration wells have obtained industrial airflow or low-yield airflow, indicating that the study area has good prospects for exploration [12-13]. Due to the relatively low degree of exploration and development of tight sandstone gas in Linxing area, there is no systematic understanding of the tight sandstone gas accumulation model in this area. Especially in the Early Cretaceous, the intrusion of the Zijinshan intrusions in the middle east resulted in the formation of the Zijinshan uplift [14-15]. The effect of the formation of uplift on the migration and accumulation of natural gas is not clear, the

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depth of research restricted and understanding. Therefore, it is necessary to strengthen the analysis and research on the tight sandstone gas accumulation model in Linxing area to provide guidance for the exploration and development of tight gas reservoirs in this area.

2 Geological background

The Linxing area (Figure 1) is mainly located in Linxian and Xingxian on the eastern margin of the Ordos Basin. It is mainly located in the flexure belt in the west of Shanxi. The whole presents the trend of east high and west low [16-18]. According to the comparative observation of field outcrops and the drilling of exploration wells, the Carboniferous-Permian in the study area developed from bottom to top with Benxi Formation (C2b)-Taiyuan Formation (P1t)-Shanxi Formation (P1s)-Shihezi Formation (P2h) -Shi Qianfeng Group (P3sq). Among them, C2b-P1t-P1s mainly developed mudstone and coal as gas source rocks; P2h-Qian5 formation mainly developed sand and mudstone interbeds. At the same time, the thick mudstone of Shiqianfeng Formation can be used as a regional caprock for gas reservoirs and seal Natural gas migrates upwards and forms multiple sets of reservoir-cap combination relationships with underlying reservoirs. Based on core observations, the author used the gas composition, carbon isotopes, light hydrocarbons of 17 wells in Linxing area, and source rock organic carbon, rock pyrolysis, vitrinite reflectivity and other large amounts of geochemistry in the Linxing area. Test data, comprehensively analyze and study the geochemical characteristics, genetic types, gas sources, and hydrocarbon generation potential of the Upper Paleozoic natural gas in the study area, determine the origin and source of tight gas, and clarify the accumulation mode of tight sandstone gas. Provide directional guidance for the expansion of subsequent exploration fields.
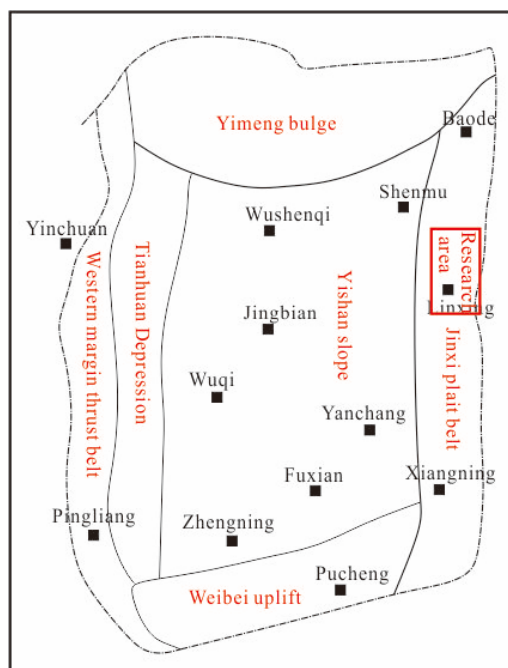

Fig.1. Comprehensive schematic diagram in the study area

3 Sample collection and test analysis methods

In this paper, 17 gas samples from 17 wells in Linxing area were collected for analysis of natural gas composition, carbon isotope and light hydrocarbons; more than 200 samples of mudstone and coal from 35 wells were analyzed for rock pyrolysis, organic carbon content determination, and mirror analysis. The above tests are all done by the Unconventional Experiment Center of CNOOC Energy Development Co., Ltd. Engineering Technology Branch. Among them, natural gas component analysis uses Agilent 7890B gas chromatograph, carbon isotope analysis uses Elementar isoprime vision isotope analyzer, light hydrocarbon uses Agilent 6890A gas chromatograph, rock pyrolysis analysis uses Rock-Eval 6 pyrolysis analyzer, organic carbon content The CS-744 carbon-sulfur analyzer was used for the determination, and the CRAIC 508PV vitrinite reflectance meter was used for the measurement of vitrinite reflectance. The test results of natural gas components, carbon isotopes and light hydrocarbons are shown in Table 1 and Table 2; the statistical results of rock pyrolysis, organic carbon determination and vitrinite reflectance determination of mudstone and coal are shown in Table 3 below.

4 Results and discussion

4.1 Geochemical characteristics of natural gas

4.1.1 Characteristics of composition

The test results of tight sandstone gas components in Linxing area (Table 1) show that the content of CH4 ranges from 90.74% ~ 99.32%, with an average value of 95.29%; the content of C2H6 ranges from 0.12% ~ 6.31%, with an average value of 2.04%; the content of C3H8 ranges from 0~ 1.68%, the average value is 0.42%; the drying coefficient is between 0.924 and 0.998, and the average value is 0.973. Only 3 of the 17 gas samples are wet, and the rest are dry gas. The non-hydrocarbon gases are mainly CO2 and N2. Among them, the carbon dioxide content ranges from 0 ~ 2.1%, with an average value of 0.38%; the nitrogen content ranges from 0 ~ 6.47, with an average value of 1.56%.

Table 1. Gas composition and carbon Isotope of tight sandstone in Linxing area

number	position	constituent content （%）							aridity coefficient	$\delta^{13}C$（‰，VPDB）			Ro[①] （%）
		CH_4	C_2H_6	C_3H_8	iC_4H_{10}	nC_4H_{10}	CO_2	N_2		C_1	C_2	C_3	
1	P_2sq	99.32	0.21	0.00	0.00	0.00	0.40	0.00	0.998	/	/	/	/
2	P_2h	93.06	0.98	0.21	0.04	0.05	0.04	5.54	0.986	-37.7	-25.5	-23.5	0.58
3	P_2h	97.96	1.56	0.28	0.05	0.05	0.00	0.11	0.981	-36	-26.1	-23.5	0.77
4	P_2h	96.82	1.35	0.36	0.06	0.07	0.02	1.2	0.981	-37.3	-27.2	-24.8	0.62
5	P_2h	97.14	1.17	0.20	0.04	0.03	0.03	1.32	0.985	-37.5	-27.1	-24.0	0.6
6	P_2h	91.16	4.69	1.33	0.19	0.26	0.02	1.94	0.934	-34.8	-27.5	-25.3	0.94
7	P_2h	93.93	2.73	0.76	0.13	0.19	0.04	1.76	0.961	-36.4	-26.6	-24.7	0.72
8	P_2h	93.82	1.15	0.32	0.06	0.09	0.01	3.78	0.983	-36.5	-28.9	-26.0	0.71
9	P_2h	98.92	0.84	0.13	0.00	0.00	0.11	0.00	0.990	-32.9	-23.9	-21.6	1.28
10	P_2h	98.00	1.44	0.28	0.05	0.05	0.06	0.11	0.982	-37.2	-26.1	-24.1	0.63
11	P_2h	94.56	3.60	0.90	0.14	0.15	0.08	0.49	0.952	-34.6	-25.9	-24.5	0.97
12	P_1s	90.74	5.20	1.68	0.23	0.32	0.05	1.45	0.924	-33.2	-28.1	-26.2	1.21
13	P_1t	96.04	0.75	0.08	0.02	0.02	2.1	0.97	0.991	-39.8	-24.1	-20.3	0.41
14	P_1t	92.68	6.31	0.28	0.13	0.12	0.15	0.45	0.931	-41.3	-22.3	/	0.32
15	P_1t	93.33	0.12	0.00	0.00	0.00	0.02	6.47	0.990	-40.4	-26.5	-19.1	0.38
16	P_1t	96.53	1.14	0.17	0.03	0.03	1.8	0.25	0.986	-41.1	-24.8	-22.8	0.33
17	P_1t	95.93	1.48	0.23	0.04	0.04	1.58	0.62	0.982	-39.6	-24.6	-22.7	0.43

Note: The formula for calculating the Ro[①] value of natural gas comes from Dai Jinxing[19] （1993）：$\delta^{13}C_1 = 14.12 \lg Ro - 34.39$.

4.1.2 Characteristics of carbon isotope

The carbon isotope test results of tight sandstone gas in Linxing area (Table 1) show that the $\delta13C1$ value is distributed from -41.3~ -32.9‰, with an average value of -37.1‰; the $\delta13C2$ value is distributed from -28.9‰ ~ -20.9‰, with an average value of -25.7‰ ; $\delta13C3$ values

are distributed from -26.2‰ ~ -19.1‰, with an average value of -23.5‰. The $\delta13C1$ value is lighter than the $\delta13C2$ and $\delta13C3$ values. The carbon isotope values of natural gas in the study area show a positive carbon sequence change ($\delta13C1 < \delta13C2 < \delta13C3$) (Table 1), and the $\delta13C1$ values are all less than -30‰, which has typical characteristics of organic gas.
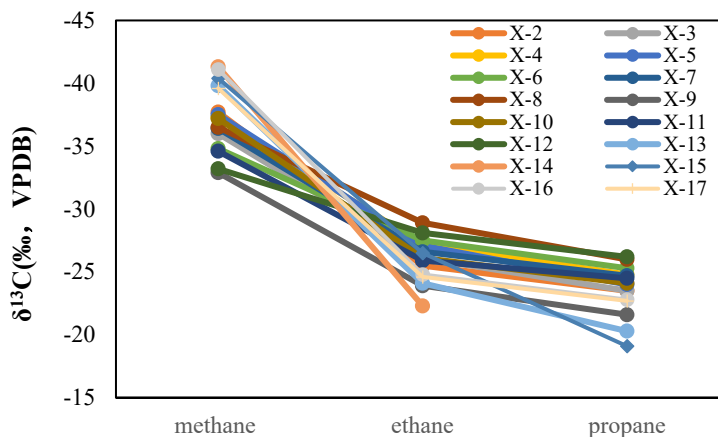

Fig. 2. The characteristics of carbon isotopic distribution of natural gas monomers in Linxing area

4.1.3 Characteristics of light hydrocarbons

The light hydrocarbon parameters of tight sandstone gas

in Linxing area (Table 2) show that the methylcyclohexane index (MCH) of the C_7 series ranges from 52.7% to 69.6%, all greater than 50%, with an average value of 61.9%; Dimethylcyclopentane （Σ DMCP) is distributed in

13.9~21.9%, with an average value of 18.7%; n-heptane (nC_7) is distributed in 12.1~29.1%, all less than 35%, with an average value of 19.4%; C_{5-7} series of n-alkanes are mainly distributed in 13.2%~35.7%, with an average of 23.2%; C_{5-7} alkanes in various configurations are mainly distributed in 26.8~56.5%, with an average of 45.4%; and

cycloalkanes are mainly distributed in 12.6~58.8%, with an average of 31.3%. Comprehensive research suggests that the light hydrocarbon composition of natural gas in the study area is similar, the C_7 series show the advantage of methylcyclohexane, and the main body of the C_{5-7} series show the advantage of isoparaffins.

Table 2. The Light hydrocarbon parameters of tight sandstone gas in Linxing area

number	position	nC_7/%	MCH/%	$\sum$DMCC5/%	C_{5-7} N-alkanes /%	C_{5-7} isoparaffin /%	C_{5-7} cycloalkanes /%
1	P_2h	12.4	65.8	21.9	18.5	55.4	26.1
2	P_2h	24.5	58.2	17.3	30.9	56.5	12.6
3	P_2h	14.9	66.7	18.5	15.3	47.0	37.7
4	P_2h	14.5	65.7	19.8	25.6	52.0	22.4
5	P_2h	26.8	53.5	19.7	30.6	46.5	22.9
6	P_2h	26.6	52.7	20.8	14.4	26.8	58.8
7	P_2h	29.1	57.0	13.9	35.9	43.9	20.2
8	P_1s	22.6	60.6	16.8	33.0	52.3	14.7
9	P_1t	14.4	63.7	21.9	13.2	34.2	52.5
10	P_1t	12.1	69.6	18.3	20.2	44.8	35.0
11	P_1t	15.2	67.8	17.0	18.2	39.7	42.1

4.2 Gas Formation and Source Analysis of Compact Sandstone

4.2.1 Gas Factor Analysis of Compact Sandstone

4.2.1.1 Carbon isotope identification

The carbon isotope sequences of methane and ethane and their homologs are important indicators to determine the origin of natural gas, and are usually used to identify the origin of natural gas. The carbon isotope composition of alkane gas of organic origin gas has a positive carbon sequence ($\delta13C1<\delta13C2<\delta13C3<\delta13C4$). The carbon isotope value of methane is generally less than -30‰, while the inorganic origin gas is the opposite. Different scholars use $\delta13C2$ to distinguish between coal-derived gas and oil-type gas, but the overall difference is not big. Referring to the previous division of coal-derived gas and

oil-type gas by using $\delta13C2$, this paper uses $\delta13C2$ value greater than -28‰ and $\delta13C3$ value greater than -25‰ to identify natural gas as coal-derived gas; $\delta13C2$ value is between -30‰~-28 If between ‰, it is recognized as a mixture of coal-derived gas and oil-type gas; if the $\delta13C2$ value is less than -30‰, it is recognized as oil-type gas. The carbon isotope values of tight sandstone gas in Linxing area show a positive carbon sequence ($\delta13C1<\delta13C2<\delta13C3$) (Table 1, Figure 2), and the $\delta13C1$ values are all less than -30‰, which is of organic origin; $\delta13C2$ values are distributed in -28.9‰~ -22.3‰, the $\delta13C3$ value is distributed from -26.2‰ to -19.1‰, only 2 of the 16 samples the $\delta13C2$ value less than -28‰ and $\delta13C3$ value less than -25‰. The sample points are mainly distributed in the coal-derived gas interval. It belongs to coal-derived gas, with only a few sample points scattered in the mixed gas interval, which is a mixture of coal-derived gas and oil-type gas (Figure 3 and Figure 4)
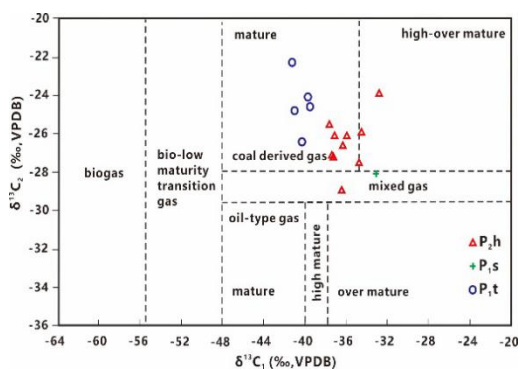
Fig.3. The identification of genetic types of natural gas $\delta^{13}C_2$-$\delta^{13}C_1$ (Sun Pingan et al., 2012)
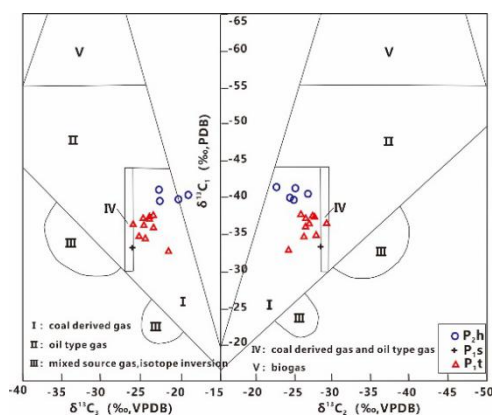

Fig. 4. The identification of genetic types of natural gas $\delta^{13}C_1$-$\delta^{13}C_2$-$\delta^{13}C_3$ (Dai Jinxing et al., 2012)

4.2.1.2 Causes of light hydrocarbon identification

According to previous research results [21-24], the relative content of dimethylcyclopentane (ΣDMCP), n-heptane (nC7) and methylcyclohexane (MCH) in the C7 series of light hydrocarbons , And the relative content of cycloalkanes, n-alkanes and isoalkanes in the C5-7 series to distinguish the types of organic matter. According to the light hydrocarbon test results of the gas samples (Table 2) and the light hydrocarbon distribution triangle map (Figure 5, Figure 6), the analysis shows that the relative content of n-heptane (nC7) in the light hydrocarbon C7 series of tight sandstone gas in the study area is between

12.1 and 29.1 %, both are less than 35%; the relative content of methylcyclohexane (MCH) is between 52.7% and 69.6%, both greater than 50%, and the samples fall within the range of coal-derived gas, which belongs to coal-derived gas. The relative content of C5 -7 n-alkanes in the C5-7 series is between 13.2%~35.7%. Among the 11 light hydrocarbon samples, the relative content of C5 -7 n-alkanes is less than 30%, and most of them The sample points fall within the coal-derived gas range, and only a small part of the samples fall within the oil-type gas range. That is, the Upper Paleozoic natural gas in the study area is mainly coal-derived gas and contains a small amount of oil-type mixed gas. This is the same as the previous carbon isotope analysis research The results are consistent.
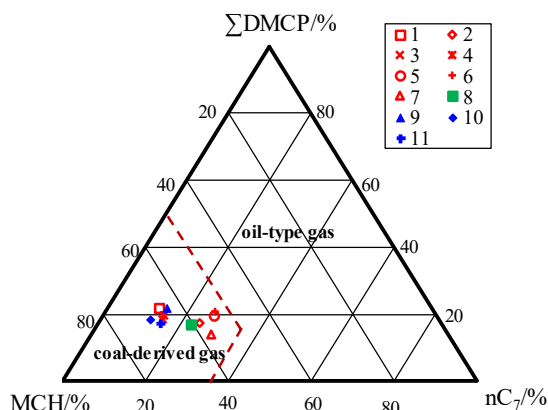

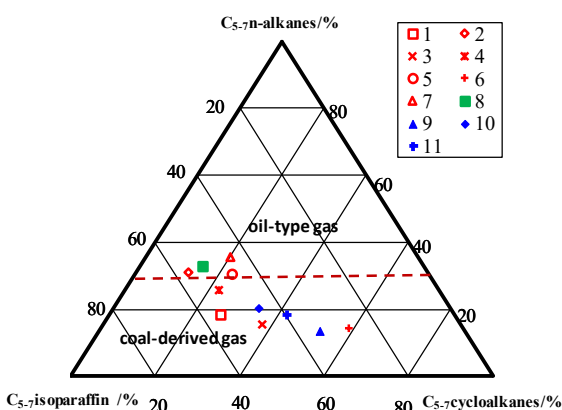**Fig. 5.** The ternary diagram of C7 light hydrocarbon series distribution of natural gas

Fig. 6. The ternary diagram of C5-7 light hydrocarbon series distribution of natural gas

4.2.2 Gas source analysis of tight sandstone

The source rock of the Upper Paleozoic in Linxing area is mainly coal, followed by dark mudstone. Among them, the thickness of coal mainly ranges from 12 to 22 m, with an average value of 16 m; the thickness of dark mudstone mainly ranges from 95 to 115 m, with an average value of 103 m [25]. The test results of coal and dark mudstone in the study area (Table 3) show that the abundance of organic matter is high and belongs to medium-good source

rock; the type of organic matter belongs to type III, mainly gas generation; Ro value is mainly between 0.8% and 1.5%. At the stage of maturity-higher than the maturity stage, entering the stage of massive vitality. Due to the intrusion of the Zijinshan pluton in the east and middle of the study area, the reflectance value of the area around Zijinshan is greater than 2.0%, even reaching 4.2%, which is in the over-mature stage; the gas generation intensity is mainly between (18~32) × 108m3/km2 .It laid a rich material foundation for the accumulation of tight

sandstone gas in the later stage.

Table 3. The Geochemical parameters of Source Rocks in Linxing area

genre		organic carbon（%）	S_1+S_2（mg/g）	Ro（%）	Tmax (°C)
P$_1$s	coal	58.50~74.00 63.82(5)	51.57~167.84 102.91(5)	0.98~1.13 1.07(5)	458.0~463.0 461.0(7)
	Dark mudstone	0.75~21.80 3.28(49)	0.54~71.10 5.03(37)	0.78~1.38 0.98(31)	426.0~480.0 461.0(35)
P$_1$t	coal	45.60~76.10 63.28(16)	45.33~309.37 158.53(13)	0.87~1.45 1.18(9)	447.0~501.0 463.2(23)
	Dark mudstone	0.82~19.20 4.16(22)	0.53~8.81 2.80(17)	0.81~1.42 1.07(24)	442.0~510.0 470.3(20)
C$_2$b	coal	39.60~84.60 64.03(14)	38.67~250.00 118.18(10)	0.93~1.48 1.21(8)	454.0~517.0 485.3(15)
	Dark mudstone	0.78~12.00 3.66(30)	0.58~17.93 3.12(25)	0.89~1.39 1.12(29)	450.0~508.0 482.7(30)

Note: <u>Minimum ~ maximum</u>
Average (number of samples)

The $\delta^{13}C_1$ of natural gas has a good linear relationship with Ro value, which can be used as an effective method for gas source comparison. According to the empirical formula of coal-derived gas established by Dai Jinxing (1993): $\delta^{13}C_1$=14.12lgRo-34.39, the natural gas maturity of the study area is calculated. The calculation results (Table 1) show that the Ro value of P$_1$t natural gas in the study area is mainly between 0.32%~0.43%, and the average value is 0.38%, which is significantly lower than the measured Ro value of coal and dark mudstone; the Ro value of P$_2$h natural gas is mainly between 0.58%~ 1.28%, with an average value of 0.82%, which is lower than the measured Ro value of P$_1$t and P1s source rock maturity. Since the P$_1$t-P1s in the study area belong to the transitional coal-measure strata of the land and sea, the P$_1$s-P$_1$t strata are mainly in the brackish water-salt water sedimentary environment, and the water medium is the key to the natural gas $\delta^{13}C_1$. The saltier the water medium, the lower the $\delta^{13}C_1$ value of natural gas, resulting in the calculated P$_1$s and P$_1$t natural gas maturity lower than the measured Ro. Overall, the P$_1$t tight sandstone gas comes from its own source rock of the Taiyuan Formation, and the P$_2$h tight sandstone gas mainly comes from the P$_1$s source rock in addition to the P$_1$t source rock.

4.3 Gas reservoir model of tight sandstone

Prinzhofer et al. (1995) [26] and Prinzhofer and Pernaton (1997) [27] have shown that the distribution of natural gas ln(C$_1$/C$_2$)-（ $\delta^{13}C_1$-$\delta^{13}C_2$) and $\delta^{13}C_1$-(C2/C1) can be comprehensively reflected The thermal evolution and secondary transformation process experienced by natural gas (mainly the process of migration and accumulation). When natural gas has not undergone the secondary reformation process or the secondary reformation process is weak, the difference in composition and carbon isotope composition is mainly controlled by the maturity of the source rock, and the ln(C$_1$/C$_2$) and $\delta^{13}C_1$-$\delta^{13}C_2$ parameters all follow the source rock As the maturity increases, the $\delta^{13}C_1$ and C$_2$/C$_1$ parameters both decrease as the source rock maturity increases. When natural gas is subjected to diffusion, migration and loss, it is manifested as ln(C$_1$/C$_2$) decreases, and the difference between $\delta^{13}C_1$-$\delta^{13}C_2$ gradually increases; $\delta^{13}C_1$ decreases, and the C$_2$/C$_1$ ratio gradually decreases. The $\delta^{13}C_1$-$\delta^{13}C_2$ difference of P1t tight sandstone gas in Linxing area increases simultaneously with ln(C$_1$/C$_2$), and the ratio of $\delta^{13}C_1$ to C$_2$/C$_1$ decreases simultaneously, reflecting the trend of P1t tight gas change with maturity; P2h tight gas reservoir The difference between $\delta^{13}C_1$-$\delta^{13}C_2$ of natural gas in natural gas gradually increases, ln(C$_1$/C$_2$) gradually decreases, and the ratio of $\delta^{13}C_1$ to C$_2$/C$_1$ increases simultaneously, indicating that the P$_2$h tight sandstone gas has obvious characteristics of diffusion and migration (Figure 7, Figure 8). Comprehensive analysis suggests that the P$_2$h tight sandstone gas reservoir in the study area is mainly from the P$_1$s source rock hydrocarbon generation, pressurized diffusion and migration to near-source or far-source reservoirs to charge and accumulate; the P$_1$t tight sandstone gas reservoir mainly comes from P$_1$t's own hydrocarbon source Rock, self-generating and self-storing in the source rock.
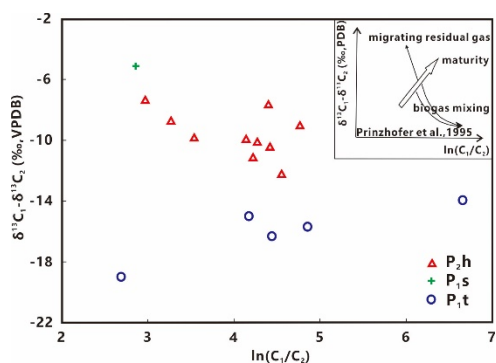
Fig.7. The relationship diagram of tight sandstone gas Ln(C$_1$/C$_2$)- （δ^{13}C$_1$-δ^{13}C$_2$） in Linxing area
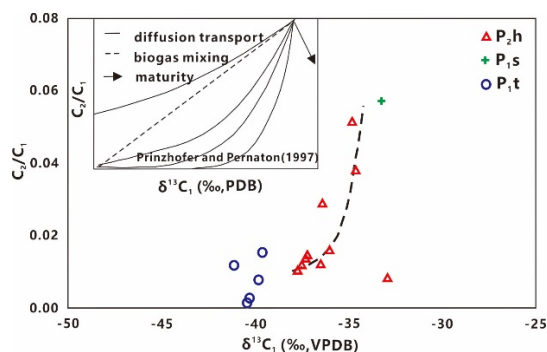

Fig.8. The relationship diagram of tight sandstone gas δ^{13}C$_1$- (C$_2$/C$_1$) in Linxing area

Based on the above analysis of the origin and source of tight sandstone gas in the Linxing area, it is concluded that the tight sandstone gas in the study area can be divided into three accumulation modes (Figure 9): remote source type, lower generation and upper storage type (far away from the source rock) Upper Shihezi Formation-

Shiqianfeng Formation Sandbody Accumulation); Near-source type lower generation and upper storage type (lower Shihezi Formation sand body accumulation outside the source rock); In-source type self-generation and self-storage type (Shanxi Formation-Taiyuan Formation source rock Accumulation of internal sand bodies).
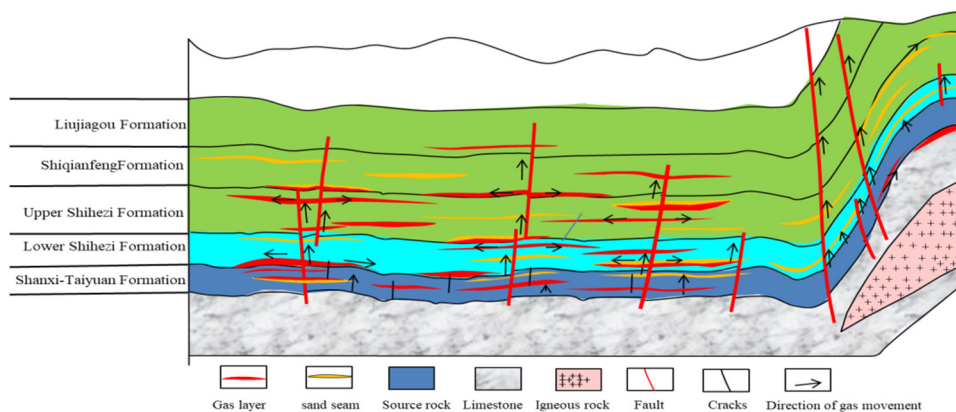

Fig.9. Gas Accumulation model map of tight sandstone in linxing area

5 Conclusions

(1) The tight sandstone gas in Linxing area has high methane content and low heavy hydrocarbon and non-hydrocarbon content; the drying coefficient is between 0.924 and 0.998, which is mainly dry gas; the carbon isotope values generally show a positive carbon sequence change trend. In addition, the δ^{13}C$_1$ values are all less than -30‰, which has the characteristics of typical organic gas; the C$_7$ series of light hydrocarbons show the advantage of methylcyclohexane, and the C$_{5-7}$ series mainly show the advantage of isoparaffins.

(2) The δ13C2 values of tight sandstone gas in Linxing area are mostly greater than -28 ‰ ; the methylcyclohexane index is greater than 50%, the relative content of n-heptane is less than 35%, and the relative content of C5-7 n-alkanes is mostly the same. Less than 30%, mainly coal-derived gas, containing a small amount of mixed gas of coal-derived gas and oil-based gas.

(3) Tight sandstone gas in Linxing area is mainly in the mature stage. P1t natural gas changes with maturity, mainly from P1t's own source rock. P2h natural gas has

obvious characteristics of diffusion and migration, except for P1t source rock. Mainly from P1s source rock.

(4) Tight sandstone gas in Linxing area is divided into three accumulation modes: remote source type, lower generation and upper storage type (upper Shihezi Formation-Shiqianfeng Formation sandbody accumulation away from the source rock); near source type lower generation and upper storage type Reservoir type (Accumulation of sand bodies in the Lower Shihezi Formation outside the source rock); In-source self-generation and self-storage type (Accumulation of sand bodies in the source rock of Shanxi Formation-Taiyuan Formation).

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