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Research Advances

New Way of Predicting Production State by Carbon Isotope Fractionation in the Fuling Shale Gas Field, Southeast Sichuan Basin

LUO Houyong[1, 2], LIU Wenhui[1, *], FAN Ming[2], TAO Cheng[2], WANG Xiaofeng[1], ZHANG Dongdong[1] and HAN Yuanhong[3]

[1] *State Key Laboratory of Continental Dynamics/Department of Geology, Northwest University, Xi'an 710069, Shaanxi, China*

[2] *State Key Laboratory of Shale Oil and Gas Enrichment Mechanisms and Effective Development, Wuxi 214151, Jiangsu, China*

[3] *Key Laboratory of Coal Resources Exploration and Comprehensive Utilization,Ministry of Land and Resources, Xi'an 710021, Shaanxi, China*

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Objective

With the discovery of the Fuling shale gas field and the realization of commercial exploitation, the prediction of shale gas well production state has attracted wide attention of scholars at home and abroad. Although many scholars have put forward the prediction method of shale gas productivity based on numerical simulation, the research on accurately judging the state of shale gas production is still insufficient. Previous studies have neglected the indication significance of carbon isotope fractionation degree of alkane gas to indicate the state of shale gas production. The process of “adsorption-desorption”, “diffusion” and “dissolution” of shale gas will lead to isotope fractionation which is important to judge the state of shale gas production. Carbon isotope of shale gas becomes heavier with time and production decreases in North America, but carbon isotope keeps stable in conventional oil and gas production all over the world. Therefore, carbon isotope fractionation can be used to indicate the state of shale gas production. For the Fuling shale gas field has a short production time, it is impossible to obtain the productivity and isotope data of the whole production cycle at present. Therefore, this work selects the shale core of the Longmaxi Formation to carry out field desorption to obtain the gas production and isotope data, and establishes the relationship between the shale gas production and the carbon isotope of alkane gas in this area, and then takes a preliminary evaluation of shale gas exploitation stage. The research results may provide geochemical reference for further exploration and commercial planning.

Methods

The well gas samples and shale core samples of the Longmaxi Formation were collected from the well JY11-4, and field analysis, gas composition and carbon isotope test were completed in the State Key Laboratory of Shale Oil and Gas Enrichment Mechanisms and Effective Development. Core samples were desorped by gas field instrument to measure desorption shale gas content, and the lost gas content was recovered through the USBM linear regression method. The sum of the determined desorption shale gas and lost gas was the total gas content. Desorption shale gas composition was analyzed by the Agilent 6890N according to GB/T 13610-2003, “Natural Gas Composition Analysis Gas Chromatography”. Desorption shale gas carbon isotope was analyzed by the DELTA Plus XP mass spectrometer according to GB/T 18340.2-2010, “Isolated Mass Spectrometry for the Determination of Stable Carbon Isotopes in Organic Matter”.

Results

The shale gas components of the JY11-4 well are dominated by methane, with the concentration averaging 98.47% in four sampling times. The carbon isotope sequence of alkane gas is completely reversed, with average $\delta^{13}C_1$ value of −30.2‰, average $\delta^{13}C_2$ value of −33.6‰ and average $\delta^{13}C_3$ value of −36.5‰ (Appendix1). The field desorption results of the Longmaxi Formation shale core of JY11-4 well show that the accumulated gas content is 1.91 m^3/t, and the desorption gas components are dominated by methane, with a little of ethane, carbon dioxide and nitrogen.During the desorption process, the methane and nitrogen content gradually decrease, while the ethane and carbon dioxide content gradually increase. The $\delta^{13}C_1$ values vary from −28.6‰ to −11.9‰, $\delta^{13}C_1$ values vary from −37.6‰ to −33.8‰ (Appendix 2). According to the selective adsorption of multi-component gases by organic-rich shale, it is shown that free gases are dominant in the initial stage (first 3 hours) and adsorbed gases are dominant in the later stage of desorption. The

* Corresponding author. E-mail: whliu@nwu.edu.cn

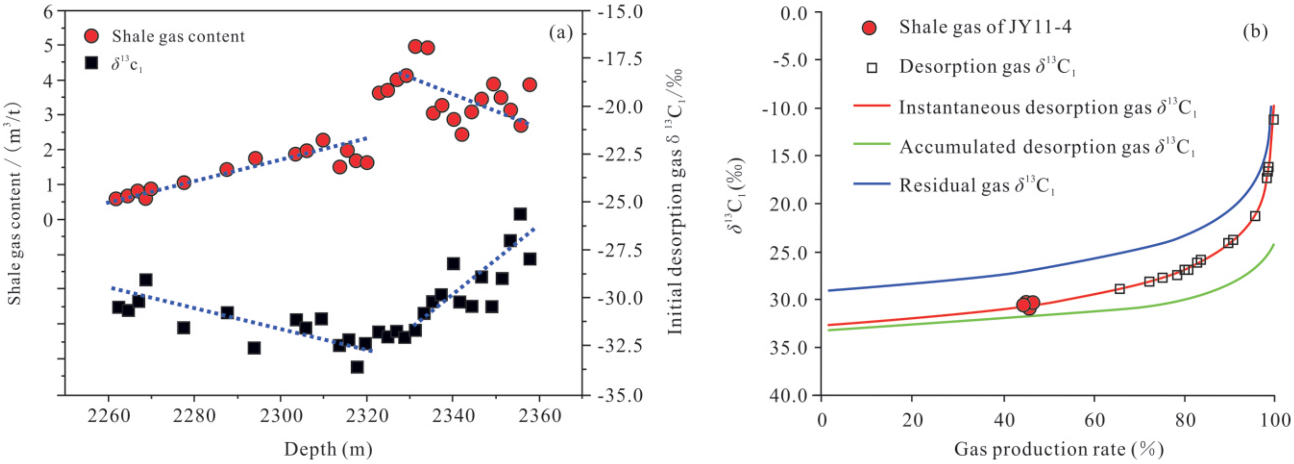

Fig. 1. Relationship of $\delta^{13}C_1$-gas content (a) and $\delta^{13}C_1$-gas production rate (b) in desorbed gas.

$\delta^{13}C$ changes are mainly affected by the mass fractionation effect and the adsorption -desorption process in the diffusion process. The $\delta^{13}C$ of initial desorbed gas from different buried depths are positively correlated with shale gas contents, which could indicate the enrichment and stage of exploitation of shale gas. In conclusion, the shale gas is mainly produced free gas in Fuling area.

Conclusion

The initial $\delta^{13}C$ of desorption gas in Fuling area has a favorable indication effect on the enrichment of shale gas. The occurrence state of shale gas could be qualitatively judged by the desorption gas composition and isotope fractionation degree. Free gas dominates in the initial stage of desorption, and the carbon isotope fractionation is small and mainly affected by the "mass fractionation effect" in the diffusion process. Carbon isotope fractionation during late desorption is significant and mainly affected by the "adsorption-desorption" process. The relationship between $\delta^{13}C_1$ and gas production rate shows that the shale gas is free gas in the early stage of production in Fuling area (Fig. 1). Tracking and monitoring the $\delta^{13}C_1$ during the production process could better evaluate the production state of shale gas in this area.

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References

Hao, Z.G., Fei, H.C., and Liu, L., 2012. China shale gas project started. *Acta Geologica Sinica* (English Edition), 86(4): 1038–1038.

Wang, X.F., Li X.F., Wang, X.Z., Shi, B.G., Luo, X.R., Zhang, L.X., Lei, Y.H., Jiang, C.f., Meng, Q., 2015. Carbon isotopic fractionation by desorption of shale gases. *Marine and Petroleum Geology*, 60: 79–86.

Zhang, T.W., and Krooss, B.M., 2001. Experimental investigation on the carbon isotope fractionation of methane during gas migration by diffusion through sedimentary rocks at elevated temperature and pressure. *Geochimica et Cosmochimica Acta*, 65(16): 2723–2742.

Appendix 1 Shale gas composition and $\delta^{13}C$ of the well JY11-4 in the Sulige gas field

Sampling time	Composition (%)				$\delta^{13}C$ (‰)		
	CH_4	C_2H_6	CO_2	N_2	CH_4	C_2H_6	C_3H_8
2015.12	98.39	0.61	0.54	0.46	−29.7	−34.3	−36.8
2016.11	98.55	0.57	0.47	0.41	−30.4	−33.8	−36.7
2017.09	98.41	0.62	0.54	0.43	−30.6	−33.2	−36.5
2018.06	98.51	0.63	0.48	0.38	−30.2	−33.1	−36.1
Average	98.47	0.61	0.51	0.42	−30.2	−33.6	−36.5

Appendix 2 Desorption gas composition and $\delta^{13}C$ of the well JY11-4 in the Sulige gas field

Sampling time (h)	Composition (%)				$\delta^{13}C$ (‰)		Accumulative gas (m^3/t)	Production rate (%)
	CH_4	C_2H_6	CO_2	N_2	CH_4	C_2H_6		
Loss gas	-	-	-	-	-	-	1.25	65
0	94.47	0.92	0.63	3.98	−28.6	−37.6	1.30	68
0.5	94.89	0.82	0.59	3.70	−27.8	−37.4	1.37	72
1	95.24	0.86	0.58	3.32	−27.5	−37.2	1.44	75
1.5	95.56	0.83	0.47	3.14	−27.4	−37.5	1.48	78
2	95.70	0.87	0.44	2.99	−27.1	−37.3	1.53	80
2.5	95.90	0.85	0.45	2.80	−27.1	−37.2	1.55	81
3	96.09	0.90	0.80	2.21	−26.8	−37.6	1.58	83
3.5	96.47	0.87	0.90	1.76	−26.5	−36.8	1.61	84
4	95.49	1.54	1.34	1.63	−24.3	−37.3	1.72	90
4.5	94.27	2.65	1.76	1.32	−24.1	−37.3	1.75	91
5	93.72	3.21	1.97	1.10	−21.2	−36.9	1.83	96
5.5	93.49	3.42	1.89	1.20	−17.6	−36.5	1.88	99
6	93.44	3.31	1.93	1.32	−17.1	−36.3	1.89	99
6.5	93.53	3.39	1.78	1.30	−16.8	−35.5	1.90	99
7	92.85	3.82	2.05	1.28	−11.9	−33.8	1.91	100