AAPG HEDBERG RESEARCH CONFERENCE
"NATURAL GAS GEOCHEMISTRY: RECENT DEVELOPMENTS, APPLICATIONS, AND TECHNOLOGIES"
MAY 9-12, 2011 — BEIJING, CHINA

Classification and Genetic Discussion of Highly Matured Gas in Paleozoic Ordos Basin

Hua Yang[1,2,3], Wenzheng Zhang[3,4], Chuanli Zan[3,4]

[1]State Key Laboratory of Continental Dynamics, Department of Geology, Northwest University, Xi'an, China
[2]Changqing Oilfield Company, PetroChina Company Limited, Xi'an, China
[3]National Engineering Laboratory for Exploration and Development of Low-Permeability Oil & Gas Fields, Xi'an, China
[4]Institute of Exploration and Development, Changqing Oilfield Company, PetroChina Company Limited, Xi'an, China

By applying Delta^{Plus} XP gas isotope mass spectrometer, on-line carbon isotope testing was performed of C_1-C_5 gas components in 77 gas samples collected from the Upper Paleozoic and Ordovician strata in the Yishan slope area and northern Tianhuan depression in Ordos Basin (excluding Jingbian gas field). Gas sampling was completed either through exhausting or with pressurized cylinder. For all gas samples, $\delta^{13}C_1$ (PDB) ranges between -26.64‰ and -39.26‰, and $\delta^{13}C_2$ (PDB) ranges between -20.19‰ and -37.89‰.

1. Gas classification

Based on carbon isotope compositions of methane and ethane, all gases can be classified into the three types as detailed in Table 1.

Type A: $\delta^{13}C_2$>-29‰. 56 samples belong to this type, which is 72.7% of the total number of all samples for this study. From the point of stratigraphy, 49 samples, i.e., 80.2%, among the total 60 gas samples collected from Upper Paleozoic strata, belong to this type, and 7 samples, i.e., 41.2%, among the 17 gas samples collected from Ordovician strata, belong to this type. This gas type is mainly characterized by large variations in methane carbon isotope composition, as $\delta^{13}C_1$ (PDB) generally ranges between -27.03‰ and -35.29‰, with heavy hydrocarbons showing remarkably positive $\delta^{13}C$, and by positive correlation between $\delta^{13}C_1$ and $\delta^{13}C_2$ (Fig. 1).

Table 1 - Table of carbon isotope data for all typical gas types

Well No.	Horizon	Well depth /m	$\delta^{13}C$(PDB,‰)								Type
			C_1	C_2	C_3	iC_4	nC_4	iC_5	nC_5	C_2-C_1	
Yu69	$P2s^2$	2346-2350	-30.76	-23.94	-23.08	-22.45	-22.43	-22.79		6.82	A
Su190	$P2h^8$	3632-3650.5	-30.45	-24.01	-25.58	-21.93	-23.42	-22.91	-21.61	6.44	
Shan277	$O1mWu_1^3$	3070-3072	-32.43	-25.26	-24.52	-21.05	-21.84			7.17	
Su360	O2w	3981-3989	-33.29	-21.43	-24.51					11.86	
Shan285	C2b	3150-3153	-33.62	-33.92	-33.02	-30.36	-30.02			-0.30	B
Shan302	$P2s^1$	3137.5-3140.5	-27.67	-32.96	-30.82					-5.29	
Shan265	$O1mWu_1^2$	3450-3453	-30.98	-37.32	-32.81	-34.91	-34.26	-33.26	-34.48	-6.34	
Shan281	$P2h^8$, $P2s^2$	3522-3633	-31.26	-35.54	-32.86					-4.28	
Yutan1	O1k		-38.92	-27.17	-25.00					11.75	C
Longtan1	$O1mWu_7$	2832-2837	-39.26	-23.78	-19.72	-19.27	-20.45	-21.96	-22.48	15.48	

Type B: $\delta^{13}C_2$<-29‰. 19 samples belong to this type, among which 11 gas samples were collected from upper Paleozoic strata, while 8 were collected from Ordovician strata. This gas type shows $\delta^{13}C_1$ (PDB) distribution in a scope similar to that for gas type A, with the carbon isotope composition of heavy hydrocarbon components being obviously light (Table 1, Fig. 1). Moreover, this gas type is generally characterized by $\delta^{13}C_2$<$\delta^{13}C_1$.

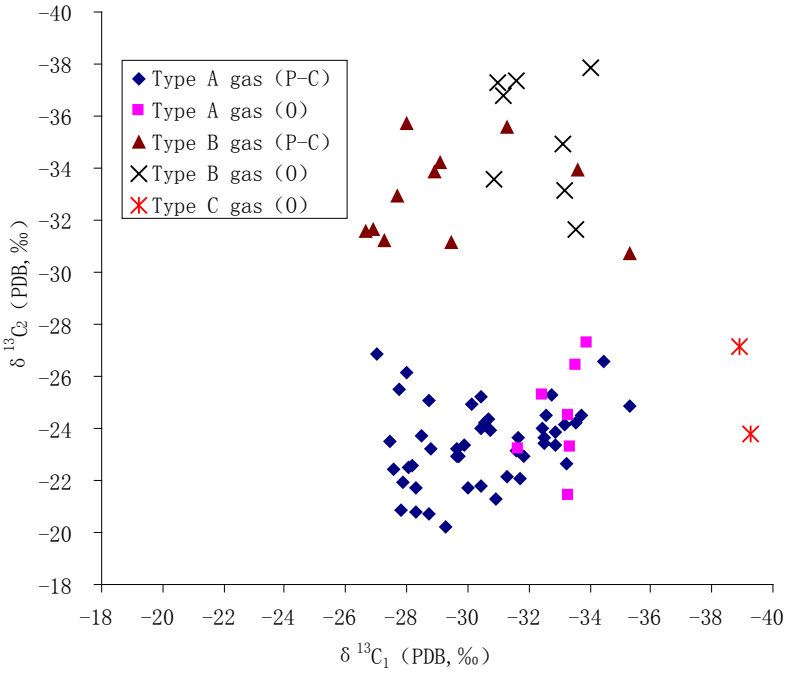

Fig. 1 Diagram showing correlation between $\delta^{13}C_1$ and $\delta^{13}C_2$ for Paleozoic gas.

Type C: 2 samples, with occurrences being far away from the top of the Ordovician strata, belong to this type. Their carbon isotope composition of methane is relatively light, with $\delta^{13}C_1$ (PDB) ranging between -38.92‰ and -39.26‰. However, their carbon isotope composition of heavy hydrocarbon components like ethane is remarkably heavy, which is similar to that for gas type A (Table 1, Fig. 1).

2. Genetic analysis of various gas types

When the results of past geochemical studies of Paleozoic gases are compared (Dai et al., 2005; Yang et al., 2004, 2009; Hu et al., 2007; Fu et al., 2003), it can be found that type A gas shows carbon isotope composition characteristics being consistent with those of upper Paleozoic coal-generated gas, so typically belonging to the type of coal-generated gas.

In regard to type C gas, the gas sample collected from Longtan 1 well occurs in the Yanxia carbonate reservoir in Majiagou Formation of Ordovician System. The sample shows degree of thermal evolution being comparable to the stage of overmatured dry gas. Since the carbon isotope of methane is light in composition, it can be recognized comprehensively that this sample belongs to Ordovician marine facies oil-formed gas type (Yang et al., 2009). The other gas sample was collected from Yutan 1 well located in Tianhuan depression. It occurs in the O_{1k} carbonate karst type reservoir, and is located at 200m+ away from the top of Ordovician System, with the overlying mid-Ordovician strata being mainly comprised of mudstone and argillaceous carbonate rocks. The carbon isotope composition of its methane component is remarkably lighter than that for the upper Paleozoic coal-generated gas in the same area (Yang et al., 2004; Hu et al., 2007). Therefore, a comprehensive judgment can be made that this sample belongs to primary overmatured oil-formed gas of Ordovician marine facies. As a result, it can be concluded that type C gas belongs to marine facies overmatured oil-formed gas based on the carbon isotope characteristics of methane in combination with results of comprehensive geological analysis. The secondary actions are very possibly the dominant factors that result in the obviously heavy carbon isotope composition of methane in gas samples from Longtan 1 well (Yang et al., 2009), while the dynamic fractionation of carbon isotopes as caused by high thermal evolution degree could be used to mainly account for the relatively heavy carbon isotope composition of methane in Yutan 1 well gas samples.

In regard to type B gas, if the carbon isotope indices for heavy hydrocarbon components like ethane are used for genetic discrimination, it can be concluded that type B gas belongs to oil-formed gas type. However, in terms of carbon isotope composition of methane, most type B gas samples show $\delta^{13}C_1$ varying between -27‰ and -34‰, which is consistent with that for type A coal-generated gas occurring in upper Paleozoic strata, but is apparently lighter than that for type C oil-formed gas occurring in Ordovician System. As a result, it would be more reasonable to identify type B gas as coal-generated gas. Obviously, conclusions contradict with each other in genetic discrimination of type B gas by means of carbon isotope indices for methane or carbon isotope indices for heavy hydrocarbon components like ethane. Therefore, a comprehensive study was carried out in regard to the composition characteristics of type B gas, the correlative relationship in carbon isotope composition between methane and heavy hydrocarbon components

like ethane, the dynamic fractionation of carbon isotope of heavy hydrocarbon components like ethane, the geological characteristics for formation of Paleozoic gas reservoirs. Based on the results of this study, it can be concluded that most type B gases genetically belong to coal-generated gas, even though they might be mixed with certain amount of oil-formed gas.

3. Conclusions

The Paleozoic natural gas in Ordos Basin mainly belongs to coal-generated gas type. The Ordovician gas in Yutan 1 well, which is located in the north part of the newly discovered Tianhuan depression in western Ordos Basin, belongs to the over-matured oil-formed gas type. In regard to genetic discrimination of highly evolved dry gas, a comprehensive analysis and judgment shall be made, mainly based upon the characteristics of carbon isotope composition of methane, in combination with other geochemical indices and geological factors for formation of natural gas reservoir.