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Geochemical Characteristics of the Abiogenic Alkane Gases in the Songliao Basin, China

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Although it is found that in many areas there may be alkane gases with abiogenic origin recently, e.g., hydrothermal fluids from the midocean ridges, seepages from the ultramafic rocks, and fluids from the Precambrian shields, there are few reports about commercial abiogenic alkane gas reservoirs. Recently a series of abiogenic alkane gas fields (reservoirs) have been found in the Songliao Basin, Northeast China, which are located east to the paleo-Central Uplift in the eastern Songliao Basin, e.g., Xujiaweizi Fault Depression east to the Daqing Oil Field, Changling Fault Depression in the southern basin and Chaganhua Fault Depression. There are five gas fields with gas reserves over 50×10^8 m^3 including Xingcheng, Shengping, Changde, and Changling-Songnan gas fields. Among them, Xingcheng gas field has been the largest one. Reservoirs of these gas fields mainly consist of the volcanic rocks from the Lower Cretaceous Yingcheng Formation and their distribution is closely related to large faults.

Xingcheng gas field is located in the Xujiaweizi Fault Depression near the Xuzhong Fault (Figure 1). It is a volcanic gas reservoir, with gas-bearing area of 62.6 km^2 and recoverable gas reserves of 24.7×10^9 m^3. Its reservoirs are dominated by tuffs and rhyolites from the first and fourth members of Yingcheng Formation, Lower Cretaceous. Alkane gases account for 94-98% (Table 1) and demonstrate a carbon isotopic reversal trend among C_1-C_4 n-alkanes ($\delta^{13}C_1 > \delta^{13}C_2 > \delta^{13}C_3 > \delta^{13}C_4$).

Both Changde and Shengping gas fields are located in the Xujiaweizi Fault Depression, with proved geological gas reserves of 182×10^8 m^3. In contrast to the Xingcheng, Shengping and Changling gas fields where reservoirs mainly consist of volcanic rocks from Yingcheng Formation, reservoirs of the Changde gas field are dominated by fine sandstones of the Lower Cretaceous Denglouku Formation. Changde gas field is related to the Xuxi Fault (Figure 1), and its gases belong to dry gas, with CH_4 ranging from 92.06 to 95.11% and C_{2+} from 0.89 to 1.87%. In a similar fashion to the Xingcheng gas field, natural gases in the Changde gas field also show a carbon isotopic reversal trend among C_1-C_4 n-alkanes ($\delta^{13}C_1 > \delta^{13}C_2 > \delta^{13}C_3 > \delta^{13}C_4$) (Table 1). Shengping gas field lies north to the Xingcheng gas field, and is also related to the Xuzhong Fault. Its reservoirs mainly consist of rhyolites from the Yingcheng Formation, and its gases belong to dry gas with CH_4 ranging from 92.0 to 94.6 % and C_{2+} from 1.4 to 1.9 %. Natural gases in the

Shengping gas field also show a carbon isotopic reversal trend among C_1-C_4 n-alkanes ($\delta^{13}C_1 > \delta^{13}C_2 > \delta^{13}C_3 > \delta^{13}C_4$) (Table 1).

Changling-Songnan gas field is located in the Chaganhua Fault Depression in the southern Central Fault Depression, Songliao Basin. Proved geological gas reserves are more than 1000×10^8 m^3, and CO_2 are expected to be 257×10^8 m^3. Reservoirs mainly consist of tuffs and rhyolites of Yingcheng and Denglouku formations. Central Fault Depression is characterized by strong tectonic activities, multistage volcanic activities and widespread large faults. In contrast to the low content of CO_2 in the Xingcheng, Shengping and Changde gas field, CO_2 ranges from 10.16% to 98.70% in the Changling-Songnan gas field and shows relatively heavy $\delta^{13}C$ reflecting the abiogenic mantle origin. Similarly, a carbon isotopic reversal trend among C_1-C_4 n-alkanes ($\delta^{13}C_1 > \delta^{13}C_2 > \delta^{13}C_3 > \delta^{13}C_4$) has also been found in this field (Table 1).

Hence, the above four abiogenic alkane gas fields are all characterized by a carbon isotopic reversal trend among C_1-C_4 n-alkanes ($\delta^{13}C_1 > \delta^{13}C_2 > \delta^{13}C_3 > \delta^{13}C_4$) and high R/Ra values. As demonstrated by previous studies, abiogenic gases from the fluid inclusions associated with the Khibiny massif on the Kola peninsula, Russia and Lost City hydrothermal field at 30°N on the Mid-Atlantic Ridge all show a significant depletion in ^{13}C for C_2-C_4 with respect to C_1. The carbon isotopic reversal trend found in these four gas fields also reflects an abiogenic origin. In addition, the associated helium has R/Ra values varying from 0.6 to 3.9 (Table 1) implying the addition of considerable mantle origin ^3He, which indicate that alkane gases in these gas fields are possibly related to abiogenic origin.

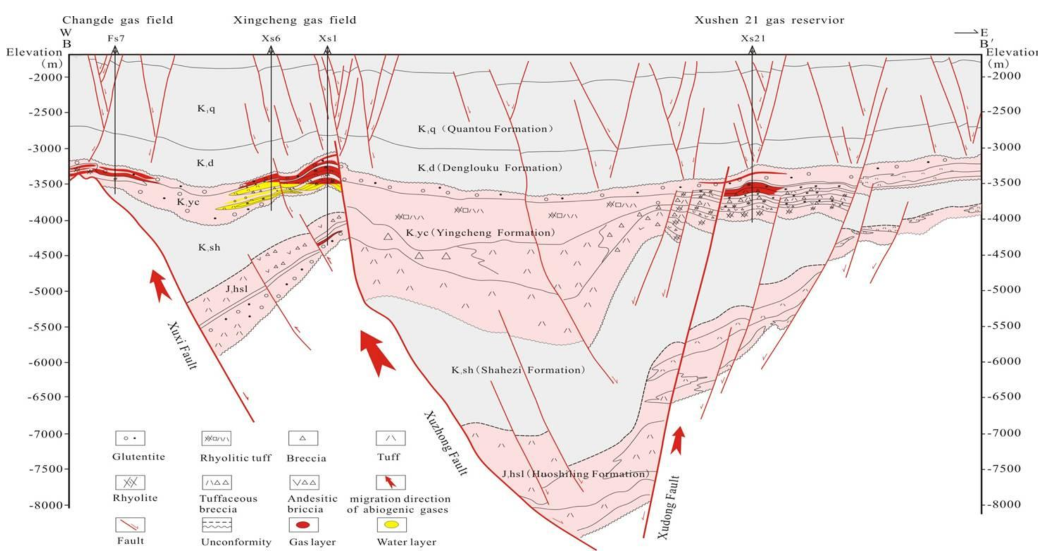

Figure 1 Structural section (B-B') of Xujiaweizi Fault Depression showing gas reservoirs.

Table 1 Main gas composition and isotopic ratios of natural gases from the Xingcheng, Shengping, Changde and Changling-Songnan gas fields

Field	Well	Strata	Depth（m）	Natural gas component（%）						$\delta^{13}C$（‰），PDB					R/Ra
				CH_4	C_2H_6	C_3H_8	C_4H_{10}	CO_2	N_2	CH_4	C_2H_6	C_3H_8	C_4H_{10}	CO_2	
Xingcheng	Xs1	K_1yc	3440-3750	92.62	2.62	0.78	0.26	2.25	1.43	-27.4	-32.3	-33.9	-34.7	-5.0	
	Xs1	J_3hsl	4446-4466	92.66	2.22	0.54	0.10	1.14	1.42	-29.7	-32.9	-34.3	-35.0	-5.9	1.1
	Xs1-1	K_1yc	3416-3424	93.94	2.13	0.40	0.08	1.17	1.86	-28.9	-32.6	-33.3	-34.1	-5.5	1.1
	Xs1-201	K_1yc	3328-3358	94.56	2.13	0.36	0.07	1.53	1.30	-28.6	-32.2	-34.0	-35.1	-7.6	1.2
	Xs1-4	K_1yc	3530-3540	94.46	2.05	0.48	0.23	1.38	1.38	-27.4	-31.8	-33.7	-34.4	-6.8	0.8
	Xs5	K_1yc	3611-3629	91.04	2.33	0.62	0.15	4.09	1.73	-28.6	-33.9	-34.4	-35.2	-5.1	0.9
	Xs6	K_1sh	3629-3637	95.77	2.39	0.49	0.11	0.28	0.86	-28.3	-33.2	-34.3	-34.6	-13.0	1.0
	Xs6-1	K_1yc	3613-3640	94.38	2.45	0.64	0.27	0.32	1.86	-26.9	-33.8	-34.2	-34.6	-8.2	1.2
	Xs6-102	K_1yc	3557-3580	94.46	2.23	0.22	0.11	0.20	0.71	-27.5	-29.3	-31.4	-31.4		
	Xs6-104	K_1yc	3505-3515	95.88	2.20	0.24	0.07	0.30	1.27	-27.9	-31.1	-32.8	-34.9	-15.9	1.3
	Xs6-2	K_1yc	3570-3759	95.41	2.25	0.47	0.10	0.21	1.53	-25.9	-32.4	-33.1	-33.7	-11.1	0.9
	Xs6-208	K_1yc	3542-3550	95.67	2.24	0.22	0.08	0.32	1.33	-28.3	-31.1	-33.5	-35.1	-14.8	1.2
	Xs603	K_1yc	3514-3521	95.48	2.17	0.29	0.08	0.45	1.47	-27.0	-30.4	-32.3	-34.3	-12.3	1.2
Changde	Fs1	K_1d		92.06	1.42	0.13	0.02	0	6.35	-18.9	-22.8	-25.3	-27.6	-18.9	
	Fs2	K_1d		93.87	0.74	0.11	0.04	0.0003	5.03	-17.4	-22.2	-30.5	-31.4	-16.5	0.6
	Fs5	K_1d		95.11	1.54	0.28	0.03	0.46	2.48	-27.1	-28.5	-30.8	-32.2	-16	1.5
Shengping	Shs2	K1d		94.60	1.60	0.30	0.10	0.20	3.30	-27.8	-29.1	-30.6	-30.8		
	Shs2-1	K1yc		92.70	1.50	0.20	0.30	2.60	2.90	-26.8	-29.1	-33.5	-36.5	-14.5	1.8
	Shs2-25	K1yc		92.70	1.40	0.30	0	2.60	2.90	-26.6	-28.8	-32.6	-35.7	-13.2	1.7
	Shsg2	K1yc		92.00	1.40	0.20	0	0.70	3.60	-27.2	-28.1	-32.7	-34.9	-14.8	1.8
Changling No.1	CS1	K1yc	3615	80.46	1.23	0.19	0	10.16	0	-24.2	-26.9	-27.2		-8.2	1.9
	CS1	K1yc	3594	71.40	1.79	0.11	0	22.56	4.14	-23	-26.3	-27.3		-6.8	2.1
	CS1-1	K1yc	3739	75.45	1.91	0.21	0	12.55	5.87	-22.2	-26.9	-27		-7.5	2.3
	CS1-2	K1yc	3697.0-3704	69.44	1.79	0.09	0	21.95	6.73	-24.1	-27.6	-27.2		-8.3	2.1
	CS1-2	K1yc		18.6	0.44			77.80	3.20	-29.9	-23.8	-23.6		-5.8	1.9
	CS2	K1d		4.20	0.40			94.00	1.40	-19.3	-24.6	-24.2		-6.7	
	CS2	K1yc	3791.6-3809	2.25	0.18	0.01	0	96.48	1.08	-17.5	-26.2	-26		-5.0	2.1
	CS6	K1yc		0.40				98.70	0.90	-25.1	-29.6	-30.9		-6.3	3.9
Songnan	YS1	K1yc	3544.4-3574	71.72	1.22	0.05	0.03	20.74	5.83	-23.6	-26.4	-26.4		-7.7	
	YS1	K1yc								-21.2	-26.5	-26.7		-7.9	
	YS101	K1yc	3824.0-3833	71.96	0.84	0	0	21.51	5.59						
	YS101	K1yc	3773.5-3792	69.02		0.05	0	24.75	5.86						

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