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Thermal simulation of basic volcanic fluid influence on different source rocks

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Abstract Based on thermal simulation experiment, interactions between volcanic fluids and source rocks were studied. Gas generations in the dry system and fluid system under different temperatures were analyzed. The results showed that the various types of source rocks are similar in composition, containing gaseous C_1-C_5 hydrocarbons, H_2 and CO_2 whose gas yields increase with increasing temperature. The gas yield of source rocks of type Ⅰ is the highest, followed by type Ⅱ, and that of source rocks of type Ⅲ is the lowest, indicating that the yield of hydrocarbon gases is related to their hydrocarbon generating potential. Although the generating potential of type Ⅲ is the lowest, it can still be regarded as a useful gas source when it is buried deeply enough. The basic volcanic fluid restrains the generation of gaseous hydrocarbons in different types of source rocks, but promotes the generation of inorganic gases.

Key words basic volcanic fluid; source rock; hydrocarbon generation; thermal simulation

1 Introduction

With the exploitation of volcanic reservoirs, influence of volcanic fluids on the hydrocarbon generation of source rocks has become a hot topic. Previous simulation experiments tended to focus on one single factor of volcanic rocks, such as some metallic elements or minerals, but there has been a paucity of research on the influence of entire compositions of volcanic fluids on hydrocarbon generation (Mango, 1992; Jin et al., 2004; Liu et al., 2006; Shi et al., 1994; Zhai, 2003; Jin et al., 2001). Wang (2010) conducted a thermal simulation experimental study on acidic volcanic fluids and source rocks, and reported that the influence of acidic volcanic fluids on the generation of liquid-saturated hydrocarbons was obvious. But there was no influence on the composition of the liquid-saturated hydrocarbons. Currently, only rare simulation experimental research has been conducted on interactions between basic volcanic fluids and various types of source rocks. This study explored the influence of basic volcanic fluids on source rocks and the related mechanism involved, through simulation experiments and the comparison of such characteristics as gas production rates, gas composition, etc. between the dry system and the volcanic fluid system, so as to provide a reference for the exploration of and research on volcanic reservoirs.

2 Sampling

Abundant natural gas resources have been found in volcanic rocks in Northwest China. There are many developing volcanic rocks, such as the Carboniferous volcanic rocks from the Junggar, Turpan-Hami, and Santanghu basins (Fig. 1). Basic systematic geological research has revealed that the volcanic reservoirs are mainly located near the unconformity surface of the Carboniferous strata, which were obviously weathered and leached. The source rocks include the Lower Carboniferous and Upper Carboniferous (Zhao et al., 2009; Hui et al., 1999) rocks. The interbedding relationship between volcanic rocks and mudstones is an ideal choice for exploring the influence of volcanic fluids on hydrocarbon generation in source rocks.

2.1 Source rock samples

We selected T 16 samples of the Harjiahu Formation in the Tiaohu depression of the Santanghu Basin, HSS samples of the Batamayineishan Formation from the Huoshaoshan Carboniferous section in the Junggar Basin, DX8 samples of the Batamayineishan Formation of the Dishui Fountain in the Junggar Basin, and TLF samples of the Tarlang Formation from the Tuepan Carboniferous section in the Turpan-Hami Basin as source rock samples for this experiment. The characteristics of each sample are listed in Table 1.

2.2 Preparation of basic volcanic fluids

We collected andesitic basalt samples from the Haerjiawu Formation of Well 33 in the Sangtanghu Basin as volcanic rock samples. In the fluid system, in addition to the source rocks, deionized water and volcanic samples were also put into the quartz glass tube. The mass ratio of volcanic/source rock samples is 1:1. We firstly measured the inner volume of the quartz glass tube as V_0 and the source rock sample as V_1, and then the amount of added water was calculated [$V_2=(V_0-V_1)\times20\%$].

3 Experimental

Samples were put into numbered quartz glass tubes. Dry system and fluid system experiments were conducted separately. Those tubes were then vacuumed and solder-sealed. Importantly, in fluid system experiment, to prevent water loss during the process of creating a vacuum, it was necessary to place the tubes in the freezer and solder-seal them only after the water was condensed into ice. The applied pressure was 50 MPa. The temperature during the experiment increased from around 300 to 450℃ at an interval of 50℃. These tubes were then held at the initial temperature of 70℃ for 6 minutes. The temperature increased at the rate of 15℃/min to 130℃ and then at 25℃/min to 180℃. A constant temperature of 180℃ was maintained for 4 minutes. The tubes were continuously heated for 72 hours and then cooled down to room temperature. HP6890/Wasson-ECE was applied to determining and analyzing the products.

4 Gaseous products and their characteristics

Gasseous products from the thermal simulation experiment contain organic and inorganic gases. The organic gases include gaseous C_1–C_5 hydrocarbons, and the inorganic gases contain H_2 and CO_2. From Fig. 2 it can be seen that in each simulation experiment, the total amounts of gaseous hydrocarbons and inorganic gases in various types of source rocks tend to increase with the rise of temperature.

In the dry system, the generation of gaseous hydrocarbons in Type Ⅰ is higher, while in Types Ⅱ and Ⅲ the generation of gaseous hydrocarbons is lower. In the fluid system, the generation of gaseous hydrocarbons in type Ⅰ increases obviously. The gaseous hydrocarbon generation of Type Ⅲ is slightly higher than that of Type Ⅱ at 300–350℃, while that of Type Ⅱ is higher than that of Type Ⅲ at 400–450℃. There is no great difference in gaseous hydrocarbon generation between the dry and fluid systems, but the inorganic gas generations are different. In the fluid system, the generation of inorganic gases increases rapidly. In both two systems, gaseous hydrocarbon generation of Type Ⅲ is highest at 300–350℃, and gradually decreases at 400–450℃.

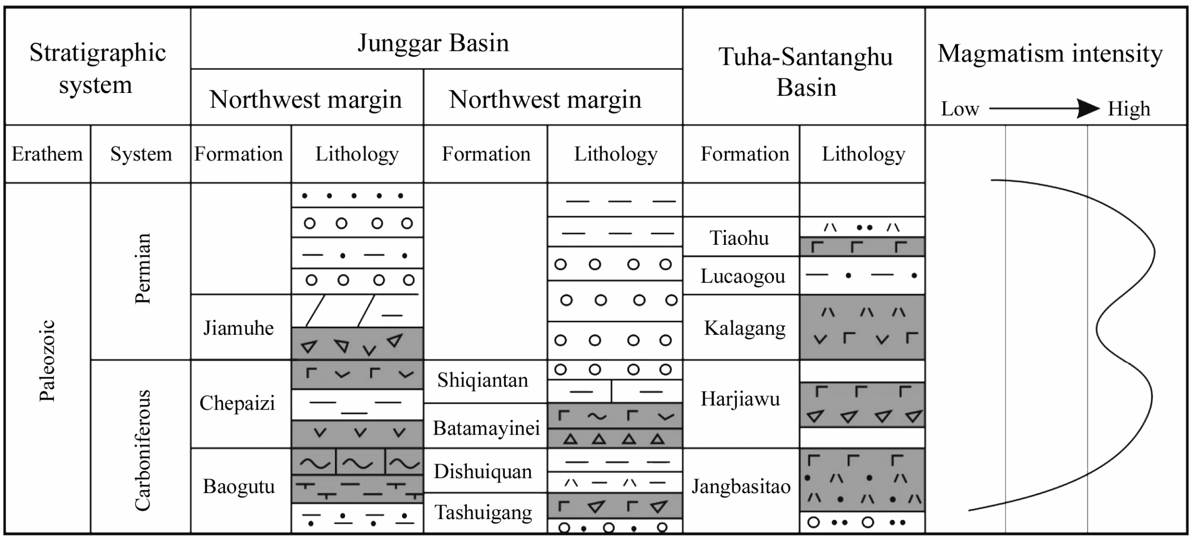

Fig. 1. Comprehensive histogram of the interactions between volcanic rocks and source rocks in western China.

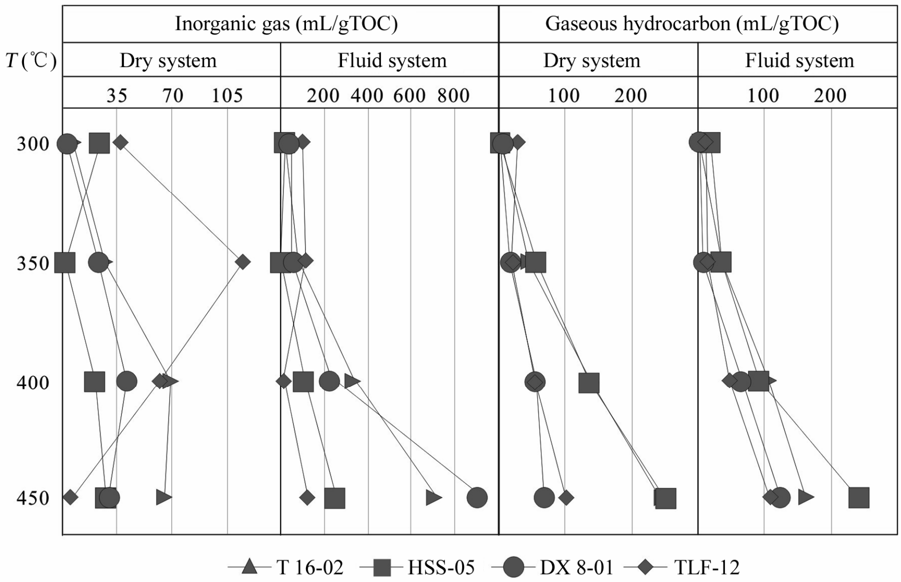

Fig. 2. Map showing the variation trends of the total amounts of gaseous hydrocarbons and inorganic gases.

Table 1 Basic characteristics of the simulation samples

Number	Kerogen type	Stratum	TOC（%）	T_{max}（℃）	S_1+ S_2 (mg/g)	HI (mg/gTOC)	R_o
T 16	Ⅰ	C_2h	5.87	440	30.69	510	0.595
HSS	Ⅰ	C_2b	6.68	444	38.06	562	0.533
DX 8	Ⅱ	C_2b	5.55	447	12.70	201	0.550
TLF	Ⅲ	P_2t	4.01	438	2.12	52	0.814

The gas yield of hydrocarbon gases is related to their hydrocarbon generating potential. The gas yield of source rocks of Type Ⅰ is the highest, that of Type Ⅱ ranks the second, and that of Type Ⅲ is the lowest. But Type Ⅲ can still be regarded as a useful gas source when it is buried deeply enough.

4.1 Characteristic variations in gaseous hydrocarbon composition

In the dry system, the production of C_1 and C_2 increases with increasing temperature, and the amount of C_3 increases at the temperatures within the range of 300–400℃, but decreases with increasing temperature within the range of 400–450℃. In the fluid system, the production of C_1 rises with increasing temperature, and the productions of C_2, C_3, and iC_4–nC_5 show the same variation trend, being steady within the range of 300–400℃ and increasing within the range of 400–450℃. The amount of gaseous hydrocarbons in the fluid system is lower than that in the dry system (Fig. 3).

In the two systems, C_1 generation of Type Ⅰ and Type Ⅲ is higher than that in Type Ⅱ within the range of 300–350℃, while, within the range of 400–450℃, Type I still ranks the first and Type Ⅱ begins to become higher than Type Ⅲ. The production of C_2, C_3, and iC_4-nC_5 shows the same trend, as in the order of Type Ⅰ>Type Ⅱ>Type Ⅲ.

4.2 Characteristic variations in inorganic gas composition

The regularities of inorganic gases are poor, and their production in the fluid system is obviously higher than that in the dry system. The production of H_2 in both systems increases with increasing temperature, as in the order of Type Ⅰ>Type Ⅱ>Type Ⅲ. Within the low temperature range, volcanic fluids make a restraining influence on the generation of H_2, but promote the generation of H_2 within the high temperature range. The production of CO_2 varies irregularly with the rise of temperature (Fig. 4).

5 Conclusions

The various types of source rocks are similar in gas composition, containing gaseous C_1–C_5 hydrocarbons and CO_2 whose gas yields increase with increasing temperature.

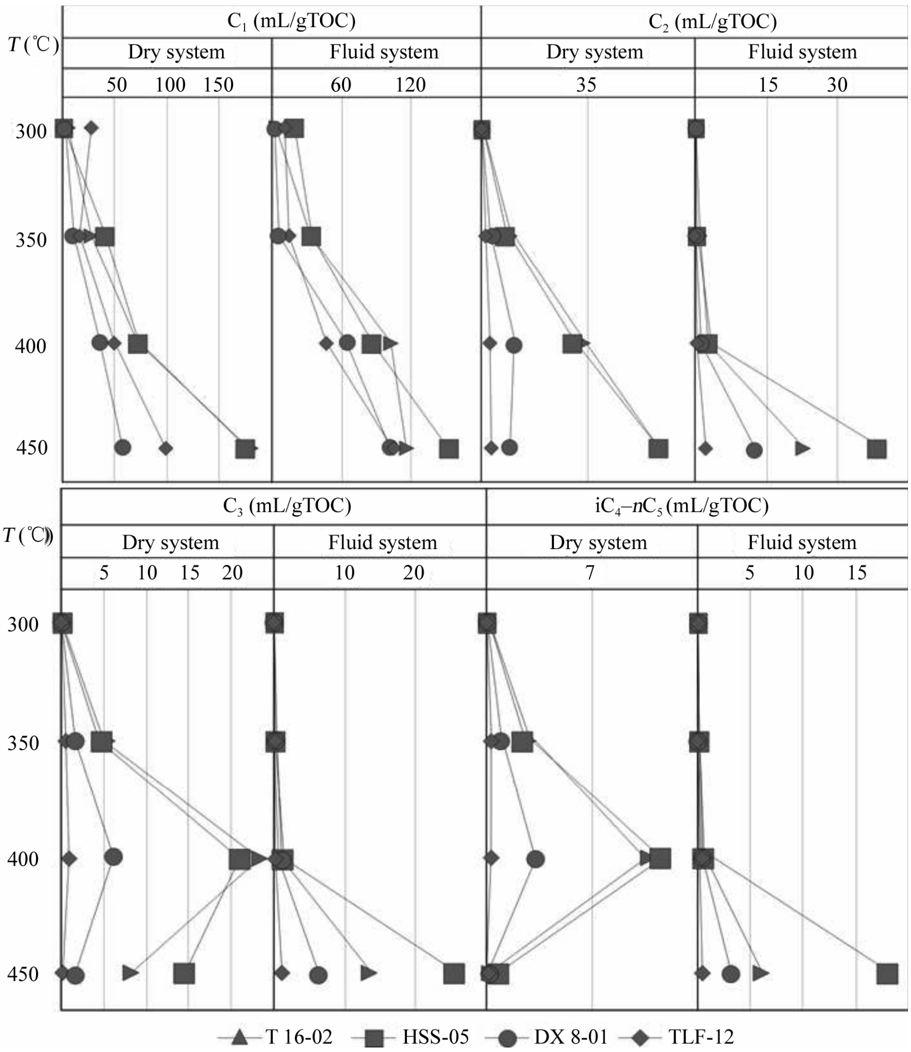

Fig. 3. Map showing the variation trends of gaseous hydrocarbon composition.

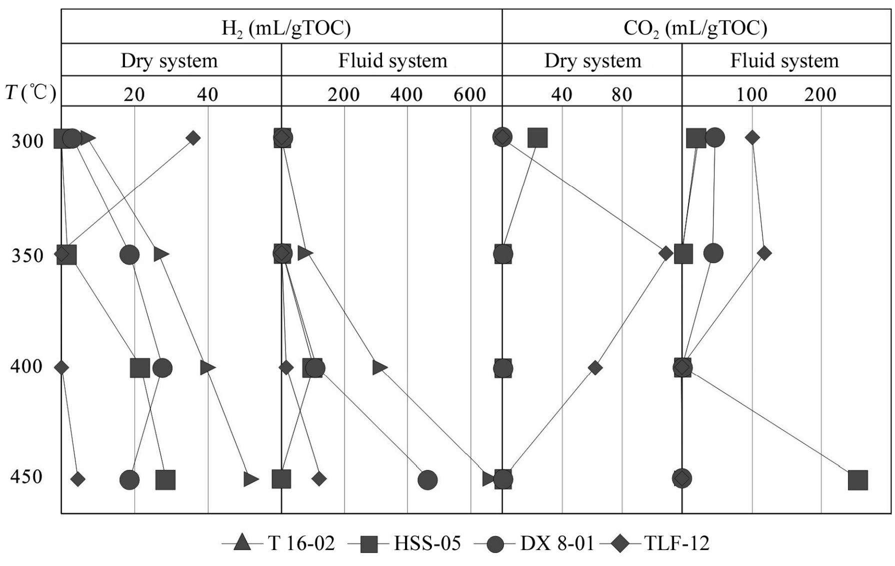

Fig. 4. Map showing the variation trends of inorganic gas composition.

The gas yield of source rocks of type Ⅰ is the highest, followed by Type Ⅱ, and Type Ⅲ, indicating that the yield of hydrocarbon gases is related to their hydrocarbon-generating potentials. Although the hydrocarbon-generating potential of Type Ⅰ is the lowest, it can still be regarded as a useful gas source when it is buried deeply enough.

The volcanic fluids restrain the generation of gaseous hydrocarbons in different types of source rocks, but promote the generation of inorganic gases.

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References

Frank Mango D. (1992) Transition mental catalysis in the generation of petroleum and natural gas [J]. *Geochimica et Cosmochimica Acta*. **56**, 535–555.

Hui Rongyao (1999) Geological characteristics of hydrocarbon generation in major sedimentary basins in western China [J]. *Xinjiang Petroleum Geology*. **20**, 10–14 (in Chinese with English abstract).

Jin Qiang and Wan Congli (2001) Volcanic activities and oil/gas accumulation [J]. *Journal of the University of Petroleum, China*. **25**, 27–29 (in Chinese with English abstract).

Jin Zhijun, Liuping, Yang Lei, and Hu Wenxuan (2004) A preliminary study of mantle-derived fluids and their effects on oil/gas generation in sedimentary basins [J]. *Journal of Petroleum Science and Engineering*. **41**, 45–55 (in Chinese with English abstract).

Liu Quanyong, Liu Wenhui, and Meng Qianxiang (2006) Organic geochemistry of *n*-alkanes from tarim coal with different materials in pyrolysis under closed system [J]. *Natural Gas Geoscience*. **17**, 313–318 (in Chinese with English abstract).

Shan Xuanlong, Li Jiyan, Wang Mingyou, and Chen Guibiao (2013) Thermal simulation of the influence of volcanic fluids on source rock [J]. *Petroleum Science and Technology*. **31**, 1842–1849.

Shi Wei, Guo Shaohui, and Qin Kuangzong (1994) Thermal pressure simulation of the source rock in water medium research. In *The Fifth Session of the National Organic Geochemistry Symposium* [C]. pp.284.

Wang Mingyou (2010) *Simulation Experiments on the Actions Between Volcanic Fluids and Source Rocks in the Songliao Basin* [D]. Jilin University, Changchun (in Chinese with English abstract).

Zhai Qinglong (2003) Effect of volcanic hydrothermal fluid activities on hydrocarbon generation and expulsion from source rocks—Taking Es_3 of the western Dongying sag as example [J]. *Oil & Gas Recovery Technology*. **10**, 11–13 (in Chinese with English abstract).

Zhao Wenzhi (2009) Comparative study on volcanic hydrocarbon accumulations in western and eastern China and its significance [J]. *Petroleum Exploration and Development* **1**, 1–11 (in Chinese with English abstract).