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Enlightenment from Research on Low-mature Gas in the Tuha (Turpan-Hami) and Liaohe Basins of China

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In 1988 Xu Yongchang and Galimov respectively proposed the scientific concept of early bio-thermogenic gas with an attempt to point out that as indicated by the classical theory, at the stage of thermal evolution with R_o ≈0.4%~0.6% and 0.7% organic m atter can not form large-scale natural gas reservoirs, but industrial gas reservoirs. On the basis of the summarization of previous gas data, Liu Wenhui and Xu Yongchang proposed the "humus-type organic matter Ro-$\delta^{13}C_1$ two-stage model". As a result, the upper limit of Ro was made to extend to the range of 0.8%~0.9%. In 2005 China Petroleum and Natural Gas Corporation introduced this concept into the scope of low-mature gas in its look-ahead scientific research program. Our participation in this research program made it granted the concept of low-mature gas.

The proven natural gas in the Tuha Basin is generally assigned to coal-type low-mature gas. The Tuha Basin is an oil-gas region where the proved reserves of natural gas reached about $1000\times10^8m^3$, and, on this basis another complete low-mature gas field was proven in 2010, which is as large as $400\times10^8m^3$ in scale, thus making the proved reserves of low-mature gas reach such a scale as to be $1300\times10^8m^3$. In addition large-scale low-mature gas fields have been also discovered in China. Studies of natural gas from the Liaohe Basin in 2010 showed that in a basin with lacustrine oil generation being dominant, the currently proved reserves of natural gas have reached $2000\times10^8m^3$, of which the fraction of coal-type low-mature gas even has come up to 70% of the total. This suggests that either in a coal-concentrated basin or in a lacustrine oil-generation basin, the formation and reservoiring scale of coal-type low-mature gas is considerable. It is indicated that much attention should be paid to this low-mature gas as a replacement resource of natural gas. Comparisons between the two basins have shown that coal-type low-mature gas has a broad prospect for exploration.

The Tuha Basin is the first, and also the only one large-sized coal-type oil oilfield produced in the Middle-Lower Jurassic coal series source rocks. The currently proved reserves of natural gas have reached $1300\times10^8m^3$. The maturity of source rocks in this region are mainly within the range of R_o≈0.4%~0.9 %. Peak $\delta^{13}C_1$ values of methane vary between −44‰~−39‰

(correspondingly Ro=0.6%~0.8%), and those of ethane are within the range of −29‰~−26‰. As viewed either from its geochemical characteristics or from its geological background, this group of natural gas clearly indicates the predominance of coal-type low-mature gas. The living examples from the Tuha

Basin indicate that at the stage where Ro≈0.4%~0.8% and 0.9% for organic matter present in coal measures there has been formed such a large-scale coal-type low-mature gas resource whose proved reserves of natural gas have reached $1300\times10^8m^3$, and at that stage a complete coal-type low-mature gas field can be formed. This shows a bright prospect for the potentality of low-mature gas resources in Jurassic coal-concentrated basins in Northwest China.

The Liaohe Basin is one of the major oil zones in China, where the proved reserves of petroleum have come up to more than 20×10^8 tons and its oil production has long come the 3rd rank. It is one of the typical examples for terrestrial-facies lacustrine oil-generation. In this basin the proved reserves of natural gas are as much as more than $2000\times10^8m^3$. These natural gases have long being assigned to oil-type gases, except that only in the eastern depression are there nearly $50\times10^8m^3$ of natural gas which are considered to be associated with coal-type low-mature gas. In 2010 Lanzhou Institute of Geology and Liaohe Petroleum Exploration and Development Institution carried out a corporative study on the geochemical characteristics of natural gas in the Liaohe Fault Depression and its resource potential. The results showed that natural gas types are very complicated in the Liaohe Basin, including low-mature, coal-type mature, crude oil-bacterially decomposed and oil-type

Gases. Concretely speaking, crude oil-bacteria decomposed gas accounts for about 6+%; mature coal-type gas, 20%; coal-type low-mature gas, >70%; and oil-type gas, 2-3% only. Listed in Table 1 are their main geochemical characteristic features.

Table 1. Geochemical characteristic features of various types of natural gas in the Liaohe Fault Depression

Natural gas type	C1/C1-5	$\delta^{13}C1$	$\delta^{13}C2$
Crude oil-bacteria decomposed gas	0.98~0.99	-45‰~-55‰	-30‰~-40‰
Low-mature coal-type gas	>0.6	-39‰~-54‰	>-29‰
Mature coal-type gas	0.8~0.95	-30‰~-39‰	>-28‰
Oil-type gas	0.5~0.9	-50‰~-45‰	<-29‰

It is easily understood why natural gas in the Tuha Basin is predominated by coal-type low-mature gas. Why is natural gas in the Liaohe Basin where lacustrine source rocks are dominated is predominated by coal-type gas? It needs to be studied in more detail. On the basis of the available data, it is considered that 1) as for lacustrine oil-generating basins, except that deep-semi-deep lakes are favorable to the formation of sapropelic source rocks, semi-deep lake-facies, delta-facies and offshore-facies are favorable to the formation of humus-type organic matter, whose total amount is generally larger than that of sapropelic organic matter, 2) as viewed from the available data from the Liaohe Basin, a considerable amount of source rocks in this basin seems to be related to humus-type organic matter. And under the direction of such an idea that the focus is put on oil exploration, it is normal to ignore the amount of humus-type

organic matter, 3) On the oil source rock thermal evolution scale, e.g. Ro=1.2%, especially Ro<1.0%, as for the capability of hydrocarbon source rocks to form gaseous hydrocarbons, humus-type organic matter is significantly more capable than sapropelic organic matter, as evidenced by the data in Fig.1.

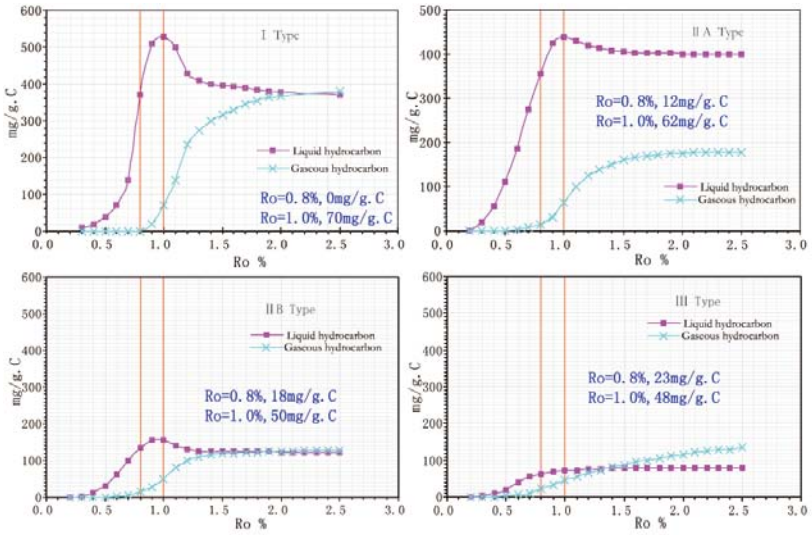

Fig.1. Results of the simulating experiment on hydrocarbon generation of various types of hydrocarbon source rocks in the Liaohe Depression.

The above mentioned reason may be the main one to explain why natural gas formed in the Liaohe Basin where lake-facies oil generation is dominant is predominated by coal-type low-mature gas. That is because the thermal evolution degree of source rocks in this basin is generally designated to the type characterized by Ro<1.2%, and on a larger scale the hydrocarbon source rocks have Ro<1.0%. There are many similarities in thermal evolution extent between the Liaohe Basin and Cenozoic oil zones in the eastern part of China. It can be imagined that in those oil zones coal-type low-mature gas is one of the very important potential resources. According to our available data, at least both in the Huanghua and Jiyang depressions there had occurred the generation and reservoiring of coal-type low-mature gas.

Prospect for the formation of large-scale low-mature gas fields

The discovery of large- and moderate-sized gas fields is a major task for natural gas industry to increase gas production and enhance gas reserves. The economic working effect of achievements of scientific research on coal-generated gas is mainly reflected in the discovary of a batch of large-scale coal-type fields in the coal-concentrated basins of China. The problem is how the prospect would be for the discovery of large- and moderate-scale coal-type low-mature gas fields in China. The fact that a batch of superlarge-scale gas fields as exemplified by the Urengoy gas field discovered in western Siberia belong to the coal-type low-mature gas fields has been more and more accepted by the petroleum geological circles. In 2010 a large-scale low-mature gas field was discovered in the Tuha Basin, providing an important case for search of

large-scale coal-type low-mature gas fields in the coal-concentrated basins in China. Then, how is the prospect for the formation of large- and moderate-scale coal-type low-mature gas fields in lake-facies oil-generation zones? In the following some related data are discussed.

The available data from China's five large-scale oil-type gas fields indicate that the maturity scale of their hydrocarbon source rocks, Ro, is larger than 2%, which is absent in East China's oil zones, but such conditions are not necessary for the formation of large-scale coal-type gas fields by humus-type organic matter.

As for more than 50% of China's ten large-scale coal-type gas fields, their hydrocarbon source rocks have a maturity range of Ro≈0.9%~1.2%. This condition can be always satisfied in the humus-type hydrocarbon source rocks existing in the oil zones. The proved reserves of natural gas in the Qianshan gas field on the Xinglong platform, Liaohe are larger than $200\times10^8m^3$, close to the scale of a large-sized oil field. The hydrocarbon source rock refers to humus-type organic matter. Except for Magu 1, the maturity, Ro, is within the range of ≈0.9%~0.85%. This type is, with no doubt, can serve as breach in natural gas exploration in the Liaohe Basin, and there also is great potential for natural gas resources in oil zones of eastern China.