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Research Advances on the Exploration and Development of Natural Gases in China

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1. Advances of the exploration and development of natural gases

1.1 China becomes one of the countries with largest natural gas reserves

The proved gas reserves in China were only $3.85\times10^8m^3$ in 1949, while by the end of 2009, gas reserves were up to $71424\times10^8m^3$(except Taiwan province). According to the American 'Oil and Gas', the recoverable gas reserves in China were $30299\times10^8m^3$ in 2009, ranking No. 13 in the world.

1.2 Annual gas production in China ranked No. 6 or No. 7 in the world now, which was negligible in the past

Natural gas production in China was only $1117\times10^4m^3$ in 1949, while up to $852\times10^8m^3$ in 2009, which ranked No. 7 in the world. However, according to the American 'Oil and Gas', natural gas production in China was $849\times10^8m^3$ in 2009, which ranked No. 6 in the world. The annual gas production in 2009 was 7628 times of that in 1949, which also demonstrates the great achievements obtained in the past 60 years.

1.3 Recently both proved natural gas reserves and annual production in China have increased fast

The proved natural gas reserves and annual production have increased very fast between 1989 and 2009, and around 10% yearly growth rate has been maintained for the last 10 years. From $100\times10^8m^3$ to $900\times10^8m^3$, it takes around 20, 5, 3, 1.11, 1.06, 0.997, 1.94 and 1.01 years for the every increase of $100\times10^8m^3$.

1.4 Both numbers and sizes of the discovered giant gas fields increased each year

By 1949 only three gas fields have been found in the Sichuan Basin (except Taiwan province), while 231 gas fields had been found by the end of 2009. Among them, 44 were large gas fields with geological reserves more than $300\times10^8m^3$ and 16 were giant gas fields with geological reserves more than $1000\times10^8m^3$(e.g., Sulige, Jingbian, Puguang, Daniudi and Kela2, etc.). Recently more and more giant gas fields with larger reserves have been found each year.

2. Research advances

2.1 The resource evaluation demonstrated great potential of natural gas development in China

The abundance of natural gas resource determines whether a country can be a large gas-producing country or not. The resource evaluation of natural gas in China started in 1981, and the evaluated geological resources of coal-derived gas then were $5.4\times10^{12}m^3$ ~ $6.9\times10^{12}m^3$, however the geological resources of natural gas in China were evaluated to be $52\times10^{12}m^3$ in 2010.

The recoverable resources of natural gas in China increased from $8.28\times10^{12}m^3$ in 1995 to $32.39\times10^{12}m^3$ in 2010.

2.2 Important progresses have been achieved on the identification of natural gas origins

30 years ago, the identification of natural gas in China was limited to few indexes. However, the reliability and accuracy of identification have been significantly improved during the past 30 years, since abundant information of natural gas could be achieved from the gaseous, aqueous (gas condensate) and solid (reservoir bitumen, kerogen) phases, and 37 identification indexes and diagrams as well as the relevant formulas were proposed.

The correlative equations between $\delta^{13}C_1$ and R_o% of coal-derived gas and oil-associated gas were as follows,

coal-derived gas $\delta^{13}C_1=14.13\lg R_o-34.39$ (Dai, 1987)

oil-associated gas $\delta^{13}C_1=15.80\lg R_o-42.21$

2.3 Hydrocarbons generated from coal measures were dominated by gas, with subordinate amounts of oil, opening coal-derived gas as a new exploration target in China

The predominance of gas over oil in the humic coal measures is controlled by the organic source compositions and structures. The gas-prone woody plants initially contain 60-80% cellulose and lignin with low H/C ratios, and the oil-prone protein and lipid with high H/C ratios accounting for only less than 5%. As humic kerogen contains abundant methyl and condensed aromatics, it tends to favor the formation of methane and short chain alkanes and generally lacks the ability to form long chain alkanes that are key components of liquid oils.

Under the direction of coal-derived gas, rapid increase of natural gas geological reserves has been achieved in the past 30 years. The total gas reserves increased from $2264\times10^8m^3$ in 1978 to $71424\times10^{12}m^3$ in 2009. Among them, coal-derived gas reserves increased from $203\times10^8m^3$ before the appearance of coal-derived gas theory to $44309\times10^8m^3$ at present. The occupancy of coal-derived gas of the proved national natural gas increased from 9% to 69%.

2.4 Studies of the main controlling factors on the formation of giant gas fields have effectively guided the exploration and discoveries of giant gas fields in China

In the 30 years from 1959 when the first giant gas field in China was discovered to 1988, only 3 giant gas fields were discovered. After the studies on the quantitative and semi-quantitative controlling factors of the formation of giant gas fields such as large gas

generation intensities, the late-stage accumulation, the low gas potentials, paleo-structures and et al., the rate of discovering giant gas fields increased, and 41 giant gas fields had been discovered from 1989 to 2009. The proven geological reserves of the 44 giant gas fields were $57469\times10^8m^3$, accounted for 80.5% of the total reserves of natural gas in China.

For example, the 8 giant gas fields with proven gas reserves more than $1\ 000\times10^8m^3$ (Kela 2, Dina 2, Jingbian, Sulige, Yulin, Jiuzhou and Daniudi) have been predicted about 5-14 years in advance.

Since the discovery of the first giant gas field in China in 1959, during the 30 years until 1988 only three giant gas fields had been found. Research on the major controlling factors on the formation of giant gas fields (quantitative and semi-quantitative factors such as strong gas-producing intensity, late reservoir formation, low gas potential and paleouplifts) effectively guided and accelerated the discoveries of giant gas fields in China. Since 1989, giant gas fields have been found yearly. By the end of 2009, there were 44 giant gas fields in China, their total reserves accounted for 80.5% of the national gas reserves and the yearly production accounted for 66.4% of the whole country.