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Bohai bay basin Carboniferous - Permian hydrocarbon source rock evaluation method

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Abstract: Bohai bay basin carboniferous - Permian hydrocarbon source rocks mainly include high maturity mudstone, carbonaceous shale and coal, hydrocarbon generation series including the benxi, taiyuan, shanxi group and xiashihezi group, shanxi group and taiyuan group is the major hydrocarbon generating horizon; Benxi group hydrocarbon generating contribution is smaller. Hydrocarbon source rock evaluation methods including organic matter abundance, type, maturity and hydrocarbon generation potential and computing resources.

Key words: *bohai bay basin; hydrocarbon source rocks; hydrocarbon generation potential*

Deep oil and gas exploration in more and more get the attention of the world. On the one hand, because of many areas of shallow oil and gas exploration degree is very high, it is necessary to the exploration of new oil and gas prospects have deep; On the other hand because of deep exists significant reserves of oil and gas fields. Most large oil field buried depth is 1220 ~ 3500m(Tab.1), its reserve accounts for 79% of all major oil reserves, of which more than 3600m depth of big oil and gas reserves accounted for 7.8% and 3.2%[1-4], respectively.

Tab.1 Reserves distribution of large oil and gas fields in depth

depth/m	Major oil reserves/%	Major gas reserves/%
<1200	5.1	25.7
1200-3050	79	46.1
3050-3665	8.1	25
3665-4270	7.6	1.9
>4270	0.2	1.3

I. BOHAI BAY BASIN GEOLOGY BACKGROUND

Bohai bay basin is a Mesozoic, Cenozoic rift basin superimposed in Paleozoic cover layer in the north China platform, located in China's eastern coast of the bohai sea. Bohai bay basin development in the ancient world, in the upper Paleozoic Marine and Cenozoic continental sedimentation, the cumulative formation thickness of more than 33000 meters. Bohai bay basin is the important oil and gas enrichment region in our country. There are many large depression including liaohe, huanghua, jizhong, jiyang, linqing and dongpu[5-6].

II. HYDROCARBON SOURCE ROCK DISTRIBUTION

Deep hydrocarbon source rock in bohai gulf basin contains three sets of sedimentary rock series, one is in more than 3500m depth of the Cenozoic and Mesozoic lacustrine facies mudstone; Second is Neopaleozoic coal mainly in the land and sea; Three is Marine carbonate rocks of lower palaeozoic and medium Neoproterozoic. Oil(gas) rock are lacustrine mudstone, coal and coal shale and carbonate rocks.

Neopaleozoic hydrocarbon source rocks mainly include high maturity, mudstone, carbonaceous shale and coal, the organic carbon content less than 6% for mudstone, organic carbon between 6% ~ 6% for carbonaceous mud shale, organic carbon content is more than 40% for coal[7-8].

Neopaleozoic hydrocarbon generation of the bohai region includes the benxi, taiyuan, shanxi group and xiashihezi group, especially coal and dark mudstone of shanxi group and taiyuan group of

large thickness and high abundance, is the major hydrocarbon - generating horizon; Benxi group formation thickness is smaller and distribution limited, hydrocarbon generating contribution is smaller.

III. HYDROCARBON SOURCE ROCK EVALUATION

3.1 Hydrocarbon source rock organic matter abundance

Organic matter abundance is a important parameter of evaluating hydrocarbon source rocks. The organic matter abundance of the hydrocarbon source rocks ralate to sedimentary environment, organic types and maturity, so it is difficult to establish an evaluation standard which is applicable to any region[9-11]. Cao DaiYong (2001), such as deep hydrocarbon of hydrocarbon source rock condition was studied for the bohai bay, puts forward a set of bohai bay basin Carboniferous - Permian coal measures hydrocarbon source rock evaluation index abundance of organic matter of[12], coal and carbonaceous shale can refer to this standard(Tab.2).

Tab.2 Bohai bay basin carboniferous - Permian organic matter abundance evaluation standard

hydrocarbon source rock types	evaluation parameters	grading evaluation standard			
		good source rock	medium source rock	bad source rock	no source rock
mudstone	TOC/%	>3.0	3.0-1.5	1.5-0.5	<0.5
	"A"/%	>0.1	0.1-0.05	0.05-0.01	<0.01
	S_1+S_2/mg·g^{-1}	>6.0	6.0-2.5	2.5-0.5	<0.5
	HC/10^{-6}	>400	400-200	200-120	<120
carbonaceous mudstone	"A"/%	>0.4	0.4-0.3	0.3-0.2	<0.2
	S_1+S_2/mg·g^{-1}	>35	35-25	25-15	<15
	TOC/%	>20	20-15	15-10	<10
coal	S_1+S_2/mg·g^{-1}	>230	230-160	160-110	<110
	I_H/ mg·g^{-1}(TOC)	>300	300-220	220-150	<150
	E+S/%	>30	15-30	5-15	<5
	"A"/%	>3.5	3.5-3.0	3.0-1.5	<1.5

Evaluation indicators of organic matter abundance include: organic carbon content, the content of chloroform bitumen "A", the hydrocarbon generation potential and total hydrocarbon content[13-14]. The method of evaluation of hydrocarbon source rock organic matter abundance generally has two kinds: one is the direct evaluation method that according to the content of organic carbon (residual carbon) evaluates hydrocarbon source rock organic matter abundance; two is the original organic carbon restoration method, the specific method is to hydrocarbon source rock experiment measured TOC content back to the TOC content of mature stage (near hydrocarbon generation threshold) to evaluation of hydrocarbon source rock organic matter abundance.

3.2 Hydrocarbon source rock organic matter types and maceral composition

Organic matter type is another important parameters of hydrocarbon source rock evaluation, it not only reflects the depositional environment of hydrocarbon source rock, but reflects the input characteristics of maternal. Organic petrology method and organic geochemistry method is now mainly used to study the organic matter type at home and abroad. Organic petrology methods: mainly using the optical principle (transmitted light, reflected light, fluorescence) on experimental instrument identification and statistical kerogen maceral, judge the source of the parent material, using the theory of paleontology, sedimentology and other multi-disciplinary knowledge divided organic types. Geochemical methods: such as kerogen elements analysis, rock pyrolysis of hydrogen, oxygen index, kerogen carbon isotope[15-16].

There are three kinds of method of four points which commonly used by organic matter type division. Ⅰtype - sapropel type, Ⅱtype (Ⅱ$_1$ - humus sapropel type, Ⅱ$_2$ - sapropel humic type) and Ⅲtype - humic type. Three kinds of method of five points: Ⅰtype (Ⅰ$_1$ - sapropel type, Ⅰ$_2$ - containing humic sapropelic type), Ⅱtype - humus sapropel type and Ⅲtype (Ⅲ$_1$ - including sapropel humus type, Ⅲ$_2$ - humic type).

3.3 Hydrocarbon source rock organic matter maturity

The method of evaluation of hydrocarbon source rock organic matter maturity: vitrinite reflectance, kerogen element composition, carbon isotope composition, vitrinite reflectance is the most commonly used indicator of evaluation of organic matter maturity.

According to the vitrinite reflectance, hydrocarbon source rock evolution stage can be

divided into four stages:

Ro<0.5% for diagenetic stage, immature.

Ro is 0.5% ~ 1.3% for plutonic phase, organic matter from low mature to mature, as the main source of phase.

Ro is 1.3% ~ 2.0% for plutonic phase into late stage, high organic matter maturity, mainly produce moisture and gas condensate.

Ro>2.0% is the organic matter metamorphic stage, organic matter maturity, mainly produce dry gas, kerogen tends to form only contains carbon graphite.

IV. THE HYDROCARBON GENERATION POTENTIAL ANALYSIS

At present, the China petroleum and natural gas corporation limited liability companies and research institutions put forward the method of quantitative evaluation of hydrocarbon generation and many of methods are applied. Profile into three categories: chloroform asphalt method, hydrocarbon generation rate method based on the mechanism of hydrocarbon generation, potential of hydrocarbon generation based on the analysis of Rock - Eval. Commonly methods for quantitative evaluation of hydrocarbon expulsion are: material balance method and the hydrocarbon generation potential index method.

Hydrocarbon generation potential index can quantitatively evaluate hydrocarbon generation and expulsion of hydrocarbon source rocks. For the same source rock organic phase, if the hydrocarbon generation potential index $(S_1 + S_2)/(TOC)$ begin with buried depth decreases, and the corresponding hydrocarbon expulsion threshold, reducing the size of the quantitative indicates the size of the hydrocarbon expulsion amount, so as to achieve the quantitative evaluation of hydrocarbon source rock hydrocarbon expulsion amount of purpose. S1 can be applied to solve the residual hydrocarbon and hydrocarbon generation quantity is equal to the amount of residual hydrocarbon and hydrocarbon expulsion, which can realize quantitative evaluation for hydrocarbon of source rock.

V. RESOURCE CALCULATION METHOD

Usually based on the principle of the calculation, resource calculation method can be divided into typical three methods: geologic analogy method, statistical method and genetic method. Genetic method is the most fundamental and most commonly used method. Genetic method includes basin simulation method and pyrolysis method, thermal simulation method.

5.1 Basin simulation method

Basin simulation technology is to modern petroleum geology, oil and gas geology theory as the instruction, using advanced computer technology, integrated application of drilling, well test, logging, geophysical and geochemical analysis, through computer simulation, in the time and space domain quantitatively represent the depositional history of the basin, tectonic history, temperature history, mature organic matter evolution and the basin oil and gas generation, migration and accumulation of quantitative evaluation.

5.2 Prolysis method

The principle of the method is: according to the dynamic response law of thermal degradation of kerogen, raise the temperature to replace geological buried time, simulation of different stages of thermal evolution of hydrocarbon source rocks oil volume, the amount and then multiplied by the coefficient of hydrocarbon expulsion and accumulation coefficient, can be concluded that the total resources of oil and gas.

5.3Thermal simulation method

The formula of thermal simulation computing resource is:

$Q=A\times H\times \rho\times C\times hq\times rec\times dh\times ah\times 10^{-3}$

Formula: Q--resources, 10^8t;

A--the hydrocarbon source rock area, km^2;

H--thickness of hydrocarbon source rocks, km;

ρ--density of hydrocarbon source rock;

C--organic carbon content, f;

hq--unit weight accumulation amount of hydrocarbon generation of organic carbon, mg/g;

rec--organic carbon recovery coefficient;

dh--hydrocarbon expulsion coefficient, f;
ah--gathered coefficient, f.

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