Study on thermal evolution of organic matter simulation of the four basins in the eastern of Songliao Basin

Cunxiao Cui [1, a], Yuanlin Meng [1, b], Xingui Zhou [2, c], Dandan Wang [2, d], Ge Jiang [3, e], Zhen Luo [3, f]

[1]Northeast Petroleum University, Daqing, 163318, China

[2]Strategic research center of oil & gas resources, Ministry of Land and Resources, Beijing, China

[3]No.2 Oil Production Company, Daqing oilfield, Daqing, 163000, China

[a]c119815@163.com, [b]qhdmyl@163.com, [c]xinguizhou100@sina.com, [d]ddwangcn@163.com, [e]734181446@qq.com, [f]532152264@qq.com

Abstract

In order to determine the time of hydrocarbon generation and expulsion in the four typical superimposed basins in the eastern of Songliao Basin in China, figure out the hydrocarbon expulsion threshold and the corresponding Ro value, organic matter abundance and type according to corresponding geochemistry data and hydrocarbon expulsion threshold theory, combined with the basin simulation technology, restore the thermal evolution of organic matter. The following conclusions are obtained. The hydrocarbon source rocks in the lower Cretaceous formations mainly began to hydrocarbon generation at the early-middle of Early Cretaceous, and hydrocarbon expulsion at the end Early Cretaceous, the part of the hydrocarbon source rocks generate and expelled hydrocarbon after the Palaeogene.

Keywords

the eastern of Songliao Basin, thermal evolution of organic matter, the time of hydrocarbon generation and expulsion, basin simulation technology

1. Introduction

Eastern basin of Songliao Basin is refers to the basins in the east of the YiShu fracture, which are mainly superimposed basins. These basins have had low exploration degree, but research shows that they have larger exploration potential according to the present exploration result. In the study of hydrocarbon accumulation periods and genetic types of oil and gas, the most critical is the study of the history of hydrocarbon expulsion in hydrocarbon source rock. Predecessors carried out preliminary discussion for oil and gas accumulation in the eastern basins, but the study of hydrocarbon expulsion period mainly only used the results of the study of hydrocarbon generation characteristics. The author attempts to apply the basin simulation technology, restore the thermal evolution of organic matter, concluding the time of hydrocarbon generation and expulsion in the four typical superimposed basins in the eastern basin group, in order to the eastern basin group of oil and gas accumulation research and exploration deployment provide theoretical basis and practical guidance.

2. Formation and hydrocarbon source rock characteristics

All the basin basement is palaeozoic era, former palaeozoic group metamorphic basement, part associated with each phase of the granite. The sedimentary cover is the Cenozoic and Mesozoic strata.

Sanjiang Basin , Jixi Basin and Boli Basin have mainly the Mesozoic strata, but Hulin Basin have the Cenozoic and Mesozoic strata. in this researching area[1].

Sanjiang Basin develops Didao(K_1dd), Chengzihe(K_1ch), Muling (K_1m) and Dongshan(K_1d) formation in Mesozoic. Hydrocarbon source rocks are mainly located in the K_1ch and K_1m formations.The formations feature is the same as Sangjiang Basin in Jixi Basin and hydrocarbon source rocks are mainly located in the K_1ch and K_1m formations. Boli basin mainly develops Xiayunshan(K_1x), Shangyunshan(K_1s), Zhushangzu(K_1z), Dongshan(K_1d), Houshigou(K_2h) and Hailang(K_2hl), and hydrocarbon source rocks are mainly located in the K_1x and K_1s formations.Hulin Basin is different from the above three basin, whose main exploration formation is in Cenozoic and which have Hulin(E*h)*, Fujin(N*f*) and Daotaiqiao(N*d*) formations in Cenozoic. Hydrocarbon source rocks are mainly located in the E*h* formations.

Thermal evolution of organic matter simulation need combine with hydrocarbon source rocks characteristic. We figure out the hydrocarbon expulsion threshold and the corresponding R_o value, organic matter abundance and type according to corresponding geochemistry data and hydrocarbon expulsion threshold theory [2] (table1).

Table 1 the four basins' hydrocarbon source rocks characteristic

Basin	The formations of hydrocarbon source rocks	Hydrocarbon expulsion threshold (m)	Hydrocarbon expulsion R_o (%)	Organic matter abundance	Organic matter type
Sanjiang	K_1ch,K_1m	880	0.7	medium	II_2
Boli	K_1x,K_1s	780	0.7	poor	III
Hulin	E*h*	940	0.5	good	I
Jixi	K_1ch,K_1m	850	0.7	good	II_1

3. Thermal evolution of organic matter simulation.

3.1 Thermal evolution of organic matter simulation model

Before the recovery of thermal evolution of organic matter, we should restore geologic history and thermal history. The geologic history and thermal history simulation parameters are time of formation, thickness, lithology, mineral composition, denudation amount, ancient land surface temperature, water depth, rock thermal conductivity etc.

Under the premise of in the history of thermal recovery, the author used Easy% R_o method to restore the thermal evolution of organic matter. Easy % R_o method is generally considered the most accurate method for prediction of R_o, which is has been widely used in the word [3-5]. It is established according to the nature of the chemical kinetics which vitrinite generated in the process of the evolution of H_2O, CO_2, CH_4 and other hydrocarbons, and a series of parallel reaction activation energy of the 20 causes the variation of vitrinite of elements and the corresponding growth of vitrinite reflectance. Easy % R_o model is suitable for the large change range of temperature and heating rate, which can more precisely calculate the medium or high heat evolution degree; this chemical reaction can use chemical kinetics model described by the Arrhenius chemical equation:

$$dW_i / dt = -W_i A\exp(-E_i / RT)\,, \tag{1}$$

$$W_i / W_{oi} = \exp\left[-\int_0^i A\exp(-E_i / RT)dt\right], \tag{2}$$

Where W_i is the unreacted concentration for component *i*, E_i is an cativation energy for component *i*, W_{oi} is the initial concentration for component *i*,*A* is a frequency or pre-exponential, *R* is the universal gas constant, *T* is temperature, *t* is time.

The fraction of reactant converted is

$$F = \sum_{i=1}^{20} f_i \left(1 - W_i / W_{oi}\right), \tag{3}$$

Where f_i are stoichiometric, or weighting, coefficients for the parallel reaction. The relationship between F and R_o can be expressed as:

$$R_o = \exp\left(-1.6 + 3.7F_j\right) \; j=1,2,3,\ldots,n \tag{4}$$

F_j is the fraction of reactant converted (vitrinite conversion)in chemical kinetics in the jth buried point of boundary of formation in well, which values range from 0 to 0.85 and the corresponding R_o value of 0.2% ~ 4.7%, so Easy% R_o model is obviously suitable for most of the oil and gas sedimentary basin. We can use this model to restore the history of the organic matter maturity in the study area and it can verify rectify result by using the measured vitrinite reflectance (R_o).

3.2 simulation results

Application of basin simulation technology, on the basis of the burial history and geothermal history of recovery, we can recover organic matter thermal evolution history. The parameters needed in basin mod have time of formation, thickness, lithology, mineral composition, denudation amount, ancient land surface temperature, water depth, rock thermal conductivity, etc., which are taken from our research data and the predecessors' research results [1].

Take Sanjiang basin, for instance. Through single-well simulation of the BC1 well (Fig.1), we concluded,in 125Ma, vitrinite reflectance of the hydrocarbon source rocks reached 0.5% in K1ch formation, it began to hydrocarbon generation. The basin uplifted at the end of the Early Cretaceous (K_1) because of tectonic movement. Then, basin began to decline, the Dongshan formation is rapidly deposited. At the same time, the vitrinite reflectance of the hydrocarbon source rocks reached 0.5% in K_1m formation, it began to hydrocarbon generation. In 113Ma, vitrinite reflectance of the hydrocarbon source rocks reached 0.7% in K_1ch formation, it began to hydrocarbon expulsion Then Sanjiang basin uplifted again, ground temperature is reduced, and the surrounding have no effect on organic matter thermal evolution of the geological factors, such as thermal fluid activity. Therefore, the thermal evolution of organic matter rate slows, vitrinite reflectance of the hydrocarbon source rocks reached 0.7% in K_1m formation at the late of the Late Paleogene (E), it began to hydrocarbon expulsion. The maturated the source rocks with high organic matter abundance K1ch formation in begin to generate a great deal of hydrocarbons the late cretaceous (K_2).

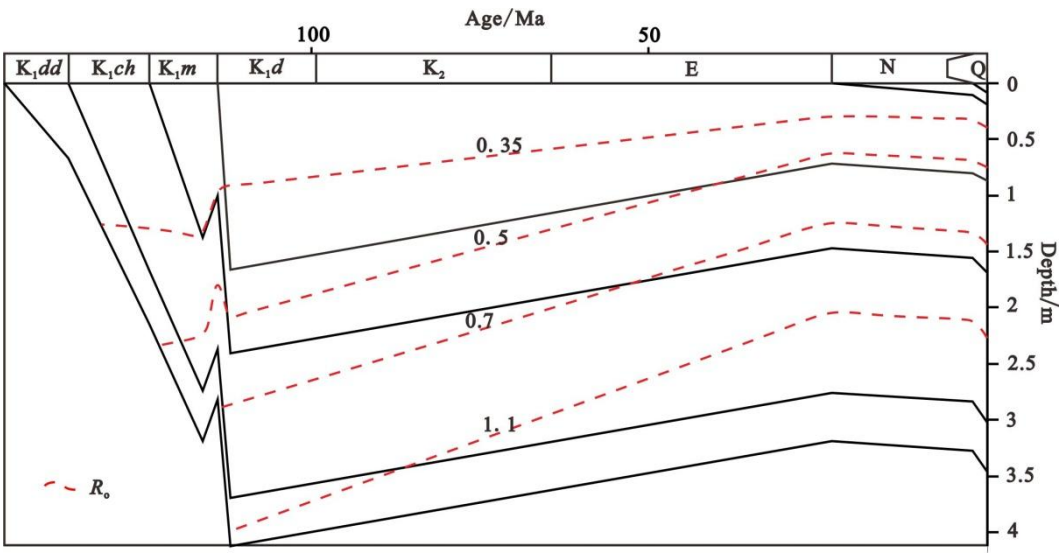

Fig.1. Organic matter thermal evolution history of BC1 well in Sanjiang basin

Application of basin simulation technology, we t recovered thermal evolution of organic matter in the other three basin. As shown in Figure4-7 and Table 2, similar to Sanjiang basin, Jixi basin has

experienced similar tectonic evolution process, the hydrocarbon source rocks in K_1ch formation began to hydrocarbon generation in 130Ma(K_1ch) and hydrocarbon expulsion in 120Ma(K_1d). The hydrocarbon source rocks in K_1m formation began to hydrocarbon generation at the late Early Cretaceous and hydrocarbon expulsion at the early of the Palaeogene. The hydrocarbon source rocks are mainly distributed in Paleogene Hulin formation(E*h*) in Hulin basin, which began to hydrocarbon expulsion in 29Ma(E*h*). Boli basin of the lower cretaceous hydrocarbon source rock mainly began to hydrocarbon generation in 134Ma(K_1s) and hydrocarbon expulsion at the middle-late Early Cretaceous. The source rocks in the Shangyunshan formation reached hydrocarbon generation in 130Ma(K_1z) and hydrocarbon expulsion in 102.7Ma(K_1d).

Table 2 The time of hydrocarbon expulsion in five basins

Basin	Sanjiang	Boli	Hulin	Jixi
The time of hydrocarbon generation (Ma)	125	134	29	130
The time of hydrocarbon expulsion(Ma)	113	102.7	29	120

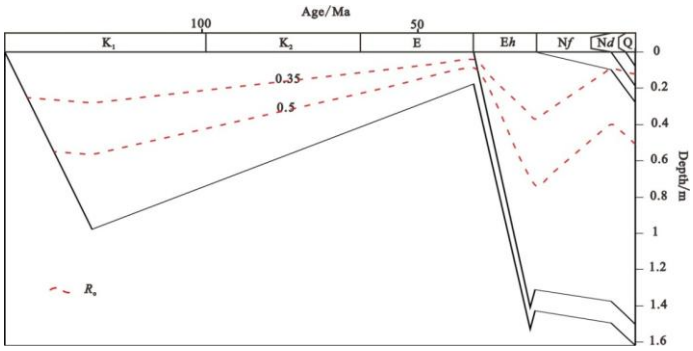

Fig.2. Organic matter thermal evolution history of H2 well in Hulin basin

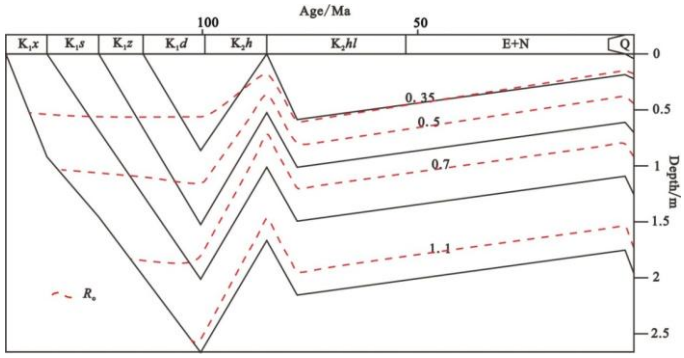

Fig.3. Organic matter thermal evolution history of BC2 well in Boli basin

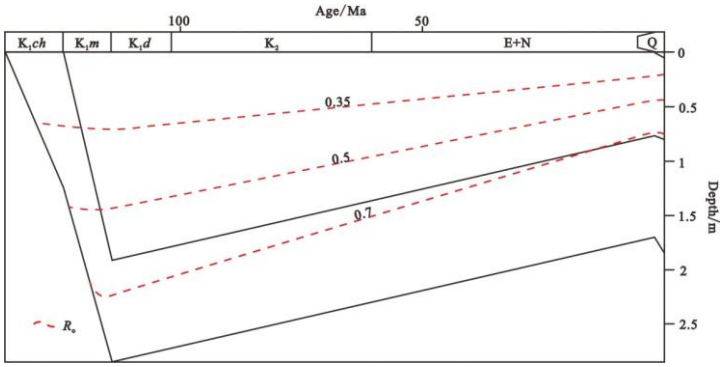

Fig.4. Organic matter thermal evolution history of JC1 well in Jixi basin

4. Conclusion

The hydrocarbon source rocks in the lower Cretaceous formations mainly began to hydrocarbon generation at the early-middle of Early Cretaceous, and hydrocarbon expulsion at the end Early Cretaceous, the part of the hydrocarbon source rocks generate and expelled hydrocarbon after the Palaeogene.

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