Research Advances

A Quantitative Method for Evaluating the Transporting Capacity of Oil-Source Faults in Shallow Formation of Oil-Rich Sags

JIANG Youlu*, ZHAO Kai, LIU Jingdong and LÜ Xueying

School of Geosciences, China University of Petroleum (East China), Qingdao 266580, Shandong, China

Objective

Oil-source faults have an important effect on reservoir formation and distribution in shallow formations with non-hydrocarbon generation in oil-rich fault-related basins (Jiang Youlu et al., 2015). However, the fault transporting capacity cannot be evaluated quantitatively at present. Taking the Zhanhua Sag in the Bohai Bay Basin as an example, this work analyzed the factors influencing the transporting capacity of the oil-source faults and proposed a quantitative method for evaluating their transporting capacity.

Methods

(1) Factors influencing the transporting capacity of the oil-source faults

The main source rocks in the Zhanhua Sag occur in the Paleogene Shahejie Formation, while the oil dominantly accumulated in the Neogene strata. It is found that hydrocarbons generated in Paleogene migrated into Neogene through oil-source faults, and finally accumulated in Neogene strata during the late period of Neogene (Jiang Youlu et al., 2017). This combination of the lower source rocks and upper reservoirs shall be the most important hydrocarbon accumulation model of the Neogene strata in the Bohai Bay Basin.

The fault transporting capacity is mainly constrained by fault static characteristics, hydrocarbon-expulsion intensity of source rocks, and the fault activity during hydrocarbon charge time. First of all, the faults transport more hydrocarbons when they extend longer. With the increasing dip angle of oil-source faults, the buoyancy along fault surface becomes stronger, and so does the driving force of hydrocarbon migration. When the angle between fault strike and principal compressive stress is smaller, the opening degree of fault surface is higher and the oil-source faults will have stronger transporting capacity. Besides, under the same conditions, more hydrocarbons will be transported by faults with the increase of the hydrocarbon-expulsion intensity of source rocks cut by oil-source faults. In addition, it is found that there is a positive correlation between the fault activity and the transporting capacity when the fault activity rate is smaller than 35 m/Ma. However, if the fault activity rate is higher than 35 m/Ma, the fault activity may do harm to the Neogene hydrocarbon accumulation. Due to the late hydrocarbon generation and expulsion periods, the fault transporting capacity will be relatively stronger when the inactive phase of the faults comes later during the main hydrocarbon charge time.

(2) Quantitative evaluation for the transporting capacity of the oil-source faults

Based on the above influential factors, we assigned fuzzy values to each factor and further presented an equation for evaluating the transporting capacity of oil-source faults. It is as follows:

$$FTC=\begin{cases}\sum_{i=1}^{n} L_i\times\cos\theta\times\sin\beta\times E_i\times(\frac{V_i}{35})\times A_i, & V_i\leq 35\text{m/Ma}\\ \sum_{i=1}^{n} L_i\times\cos\theta\times\sin\beta\times E_i\times(\frac{35}{V_i})\times A_i, & V_i>35\text{m/Ma}\end{cases} \tag{1}$$

$$E_i=2E_{Es4}+3E_{Es3}+E_{Es1} \tag{2}$$

$$V_i=1/3\times V_{Ng}+2/3\times V_{Nm} \tag{3}$$

In the above formulae, *FTC* refers to the fault transporting capacity, and a greater *FTC* value indicates a stronger transporting capacity of oil-source faults; L_i, E_i, V_i and A_i are extending length of faults which cut source rocks, expulsion intensity of source rocks, fault activity rate and fault active time during the main hydrocarbon charge time, respectively, corresponding to the units of km, 10^4 t/km^2, m/Ma and Ma, respectively; E_{Es4}, E_{Es3} and E_{Es1} are the expulsion intensity of the fourth, third and first member of Shahejie Formation source rocks, respectively; V_{Ng} and V_{Nm} are the fault activity rates during the Guantao and Minghuazhen periods, respectively; θ stands for the angle between fault strike and principal compressive stress; β is the dip angle of the fault; i is the sequence number of evaluated segmented fault, and n is the total number of fault segments.

* Corresponding author. E-mail: jiangyl@upc.edu.cn

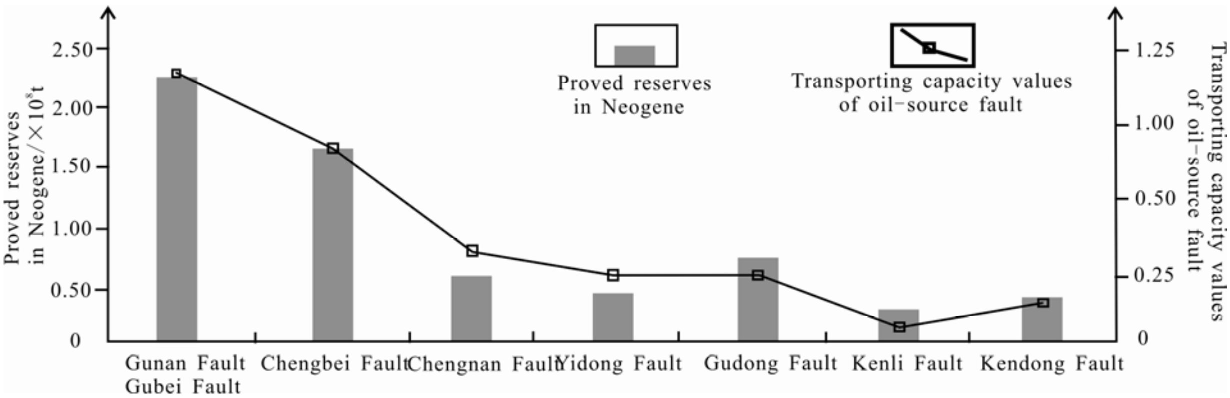

Fig. 1. Relationship between the transporting capacity of oil-source faults and the Neogene proved reserves near faults in the Zhanhua Sag.

Considering the actual complex geological conditions, fault transporting capacity should be calculated for each segment of the fault, and their sum of each segment is the total transporting capacity. For multiple sets of source rocks cut by the oil-source faults, the hydrocarbon-expulsion intensity of source rocks should be assigned and calculated for each set of source rocks. Similarly, the fault activity rate should be assigned and calculated based on the contribution of fault activities in different periods to hydrocarbon accumulation.

Results

This work evaluated the transporting capacity of oil-source faults in the Zhanhua Sag using the new method. It can be found that hydrocarbons are relatively enriched in Neogene strata in those regions controlled by oil-source faults with larger transporting capacity values, whereas hydrocarbons are relatively poor in Neogene in the traps constrained by oil-source faults with smaller transporting capacity values. Therefore, the evaluation results of fault transporting capacity can conform to the real geological characteristics (Fig. 1), and this new quantitative method is effective and feasible.

Conclusion

Based on the influences of fault static characteristics, fault activities during hydrocarbon charge time, and hydrocarbon-expulsion intensity of source rocks on the transporting capacity of oil-source faults, a quantitative equation is established for evaluating the transporting capacity of oil-source faults in shallow formations of oil-rich sags. The results show that the transporting capacity of oil-source faults in the Zhanhua Sag has a positive correlation with hydrocarbon reserves of the favorable accumulation areas. Therefore, this method can be used to effectively evaluate the transporting capacity of oil-source faults and help to predict the extent of hydrocarbon enrichment in shallow layers.

Acknowledgements

This work is granted by the National Natural Science Foundation of China (grant No. 41672131) and Fundamental Research Funds for the Central Universities (grant No. 16CX06045A). Part of this work has been granted national patent (patent No. ZL201510713135.7).

References

Jiang Youlu, Liu Pei, Song Guoqi, Liu Hua, Wang Yongshi and Zhao Kai, 2015. Late Cenozoic faulting activities and their influence upon hydrocarbon accumulations in the Neogene in Bohai Bay Basin. *Oil & Gas Geology*, 36(4): 525–533 (in Chinese with English abstract).

Jiang Youlu, Liu Hua, Song Guoqi, Wang Yongshi, Liu Jingdong and Zhao Kai, 2017. Differential hydrocarbon enrichment and its main controlling factors in depressions of the Bohai Bay Basin. *Acta Geologica Sinica* (English Edition), 91(5): 1855–1872.