EFFECT OF OIL EXPULSION ON THE PETROPHYSICAL PROPERTIES OF LOWER PALEOZOIC SHALES IN NORTHERN GUIZHOU AREA, CHINA

Y.J. Zheng, Y.H. Liao*

Guangzhou Institute of Geochemistry, Chinese Academy of Sciences, PR China
(*Corresponding author: liaoyh@gig.ac.cn)

Introduction

With the development and application of horizontal drilling and hydraulic fracturing technology, unconventional shale oil and gas resources have achieved great success in North America, and shale has been transformed from source rock or caprock in traditional oil and gas theory into a self-contained petroleum system. Because the geological settings of different regions and strata vary greatly, the geological factors restricting shale oil and gas reserves have attracted a lot of attention in recent years. China is the second country to realize commercial exploitation of shale gas after the United States. Shale gas fields in China are mainly distributed in the Sichuan Basin. The main shale-bearing gas intervals are the Lower Paleozoic Cambrian Qiongzhusi Formation and the Silurian Longmaxi Formation. For example, the initial test output of average single well in the Fuling shale gas field (more than 30 wells) is 33.4×10^4 m^3/d (1179.5×10^4 ft^3/d) (Zou et al., 2016). However, according to the current drilling results, the commercial value of the Qiongzhusi shale is far less than that of the Longmaxi shale at present. Only a few shale gas wells currently yield commercial quality of gas from the Qiongzhusi shale. As we know so far, the most productive of all Qiangzhusi shale wells, the Jinye Well #1-HF in the southern Sichuan Basin, only produces 8×10^4 m^3 (283×10^4 ft^3) of gas per day.

Two shallow wells were drilled in Northern Guizhou area, China, to investigate the shale-gas system and the petrophysical property of Niutitang (Qiongzhusi, equivalent strata) shale and Longmaxi shale.

Results

The burial-history reconstruction of Jindingshan-1 well in the Songlin dome trap show that the Niutitang shale has high hydrocarbon expulsion efficiency because of the good matching among the components and processes of petroleum system. However, the Longmaxi shale in Anwen-1 well has low hydrocarbon expulsion efficiency because hydrocarbon expulsion and migration were mostly prevented by the underlying tight limestone.

It is known that an unconventional, continuous petroleum system consists of an accumulation of hydrocarbons that are found in low-matrix-permeability rocks. The Barnett shale is a prodigious shale-gas system because of some specific geologic characteristics, including (1) the Barnett shale-gas system is sealed by limestone above and in some areas below the shale, (2) the retention of abundant petroleum, (3) the hydrocarbon expulsion efficiency of the Barnett shale is lower than conventional source rock (Jarvie et al., 2007). Through pyrolysis experiment, Liu et al. (2017) showed that abundant bitumen can be left in the organic-rich shales if oil expulsion efficiency at the oil window stage is relatively low, subsequently gas generation of the shales at high thermal maturity can be enhanced, and vice versa.

It is a common phenomenon that the Niutitang shale is characerized with undeveloped organic pores, and it only has a porosity about 1/3 to 1/2 of the Longmaxi shale. It is consistent with previous report (Zhao et al., 2016). Through a comparison between less matured shale and highly matured shale, Chen et al. (2016) attributed the smaller pores in the Qiongzhusi shale to a stronger compacting effect. However, although the effect of retained oil on the commercial quality of the self-contained hydrocarbon resource system was demonstrated (Jarvie et al., 2007), little attention has been paid to the effect of oil expulsion efficiency as an essential component of petroleum system on the petrophysical property of shale. The Niutitang shale overlying the carbonate platform has high hydrocarbon expulsion efficiency due to the two unconformities (Tongwan II and III), and also well-developed karst reservoirs in the underlying Dengying Formation and the early traps. The Niutitang shale formed a semi-open (natural) system, while the Longmaxi shale was composed of closed system due to the tight limestone below. The gaseous hydrocarbon yields by bitumen secondary cracking may be significantly reduced due to high oil expulsion efficiency from the source rock (Xiang et al., 2016). Therefore, the undeveloped organic pores and poor commercial quality of shale gas in the Niutitang shale can be attributed to the high hydrocarbon expulsion efficiency.

Conclusions

The lower Paleozoic marine shales are main shale gas exploration targets of the Upper Yangtze region, South China, but they have different petrophysical properties. High openness of the Niutitang shale may have siginificant effect on its petrophysical properties, and also its shale gas potential. Therefore, to precisely evaluate the Niutitang shale-gas system, it is important to consider the specific geological settings of the lower Paleozoic marine shales.

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