Research Advances in Tight Oil and Its Prospect

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Abstract: Tight oil has broad prospects for exploration around the world. There have been achieved success exploration and development of tight oil reservoirs in some foreign basins. China has a large area of unconventional oil and gas resources, of which coalbed methane and shale gas have been well studied, but tight oil is still in its infancy, and its evaluation basis is still weak. By analyzing the control factors of tight oil accumulation, the accumulation process and the accumulation dynamiction, it is believed that the basic theoretical work of tight oil accumulation should be carried out as soon as possible. Especially, there is an urgent need for breakthroughs in the study of the time relationship between tight oil accumulation and reservoir densification and formation mechanism of tight oil reservoir-forming dynamiction.

1. Introduction

The tight oil mainly refers to the petroleum resources accumulated in the tight sandstone and tight carbonate reservoirs which are adjacent to or adjacent to the oil-bearing strata. The reservoir porosity is less than 10%, and the permeability of the overlying matrix is not more than 0.1mD, industrial production can only be obtained under certain technical measures(Clarkson CR, et al., 2011; Chengzao Jia et al., 2012; Caineng Zou, 2012).

Tight oil is another new hot spot for unconventional oil and gas exploration and development after shale gas. From a global perspective, the exploration of tight oil has brought about major changes in the world's oil and gas exploration and development, and is gradually affecting the pattern of world's energy supply and demand. So far, nineteen tight oil basins such as Bakken, Barnett and Eagle Ford have been discovered in North America(Hamed S, et al., 2010; Yongqi Guo et al., 2013; Lian g T, et al., 2013; Caineng Zou et al., 2013; Thomas T, 2015). Fifteen terrestrial tight reservoirs in China such as the Triassic in Ordos basin, the Jurassic in Sichuan Basin, and the Permian in Junggar basin have been identified (Caineng Zou et al., 2013; Jiaoshe Wang et al., 2014; Junfeng Zhang, 2015; Yinghong Zhang, 2015). In addition, a large number of oil spots were observed in the Triassic low-porosity and low-permeability rock formations in Luoyi basin (Mingxi He, 1995; Guilin Qiao, 1997; Sihong Liu, 2003; Fengxun Li et al., 2009; Bin He et al., 2012; Mingde Yu, 2012; Jianbo Du, et al., 2013; Yongxin Yan, 2013; Shaofei Yue et al., 2015; Qinghong Si et al., 2017).

There abundant tight oil reserves in China. They are generally with large-area distribution of effective source rocks (Chengzao Jia, 2011; Senhu Lin, 2011; Caineng Zou, 2013), close contact source-reservoir combination (Peng JW, et al., 2016; Caineng Zou et al., 2011; Shejiao Wang et al., 2014; Weipeng Yan et al., 2014), low-porosity and low-permeability compact rock formations and...
micro-nano-scale pore-throat systems (Law B E., 2002; Caineng Zou et al., 2011; Zhi Yang et al., 2015; Chengzao Jia, 2012) and other typical accumulation characteristics. However, the research on tight oil is still in its infancy, mainly focusing on formation conditions and reservoir characteristics. The research on the theory of hydrocarbon accumulation is relatively weak (Jinli Yao et al., 2013; Shejiao Wang et al., 2014; Yinghong Zhang et al., 2015; Jianhui Zeng et al., 2015).

2. Research progress on controlling factors of tight oil reservoirs

Almost all the areas at home and abroad with significant oil exploration performance have developed good source rocks (Wenzheng Zhang et al., 2008; Huang Wei et al., 2013; Nini Zhang et al., 2013; Zhanli Ren et al., 2014; Laixing Cai et al., 2016). For example, three tight oil high-producing basins in the Williston Basin, the Permian basin, and the Bay basin in North America (Xinshu Zhang, et al., 2016), and if Yanchang formation of Ordos basin and Lucaogou formation of Junggar basin in China (Yanru Guo, et al., 2012; Zhen Qiu, et al., 2016) and much more, have been obviously controlled by high-quality source rocks.

The lithology of tight oil reservoirs is mainly sandstone and carbonate rock (Shijia Chen, et al., 2015; Zhen Qiu, et al., 2016; Qinghong Si et al., 2017). Tight oil accumulation is also obviously controlled by sedimentary facies of reservoir deposition (Yanru Guo, et al., 2012; Liang Cheng et al., 2015).

Domestic and overseas scholars have gradually realized that the flow mechanism of tight oil mainly depends on the microscopic pore structure of tight reservoirs (Caineng Zou et al., 2011). For example, nanoscale pores and throats (radius 50-500 nm) constitute the main reservoir space for tight oils in the middle Permian Lucaogou formation in the Jimusa sag, Junggar basin (Zhen Qiu, et al., 2016).

Generally, there are three closely source-reservoir types of tight oils: source sandwiched in the middle of reservoirs, source-reservoir interbedding and reservoir sandwiched in the middle of sources. The source-reservoir types are important to hydrocarbon expulsion and charging of tight oil (Caineng Zou et al., 2011; Peng JW, et al., 2016; Shejiao Wang, et al., 2014; Weipeng Yan et al., 2014; Tao Song et al., 2014). However, types of source and reservoir combinations for different tight oils may vary. For example, it is found that there are some differences in source and reservoir combinations by comparing Ordos basin to Songliao basin (Wenxue Han et al., 2014). There’s a symbiosis relationship between the source and the reservoir of Chang 7 section in Ordos basin. Because the source rocks of the Fuyu layer in Songliao basin is located above the reservoir, the source-reservoir type belongs to typical “upper source-lower reservoir”, and the tight oil is enriched under the source.

The diagenesis controlling the tight oil accumulation is manifested in two aspects: first, secondary pores formed by the dissolution of minerals such as turbidite (Tao Song, et al., 2016) and limestone (Shijia Chen, et al., 2015). The supplied space of those secondary pores would contribute to the formation of tight oil accumulation. Second, the porosity would be significantly reduced by the influence of cementating the post-production minerals (Yong Zhou, et al., 2016) and the compaction (Mingjie Liu et al., 2014). Then, the reservoir is becoming densify and further obviously controlling over the accumulation of tight oil. In General, different diagenesis may affect the accumulation of tight oil by changing the porosity or degree of densify of reservoirs.

3. Research progress on the dynamiction of tight oil accumulation

Domestic and foreign scholars (Swarbrick RE et al., 1997; Zhongyuan Ma, et al., 2013; Hong Ma et al., 2014; Wenxue Han et al., 2014; Zhi Yang et al., 2015; Hong Ma et al., 2016) consider that the interaction between source hydrocarbon generation and reservoir densification the resulting hydrocarbon generation pressurization is the driving force for the formation of tight oil. In addition, under-compacting effects (Jinli Yao et al., 2014; Shichang Ju et al., 2015) and capillary force (Fuyi Liu, 2015) can also be important sources of tight oil accumulation. The formation of tight oil dynamiction is mainly affected by three aspects: first, the reservoir, its densification process and degree directly affect the pressure transmission mechanism of the source-reservoir binary structure;
second, the source rock, its hydrocarbon generation and discharge process is tight oil accumulation provides hydrocarbons and initial dynamic; third, the Micro-Nano pores, which provide the main space for tight oil reservoirs. In other words, the reservoir densification process, the hydrocarbon source and hydrocarbon expulsion process, and the tight oil enrichment in the microscopic pores determine the dynamic of tight oil accumulation.

Mechanical compaction is the most important cause of dense sand-reducing pores (Mingjie Liu et al., 2014). The effect of strong cementation on the pore-reduction is also an important cause of reservoir densification (Yong Zhou, et al., 2016). In addition, acid substances discharging during the maturity of source rocks (Haibo Yuan et al., 2017) and mineral dissolution (Tao Song, et al., 2016; Shijia Chen, et al., 2015) also affect the physical properties of tight oil reservoirs. This indicates that the reservoir densification process is affected by temperature, pressure and minerals.

The temperature field, pressure field and chemical field are the sources of energy evolution and hydrocarbon migration and accumulation dynamic of hydrocarbon source rocks. The formation temperature is the decisive factor for the evolution of organic matter and hydrocarbon generation in source rocks (Sihong Liu et al., 2003; Yanrong Zou et al., 2012); In addition, there is evidence that the warming effect of volcanic hydrothermal fluids also plays an important role in promoting hydrocarbon generation and hydrocarbon expulsion (Qinglong Zhao, 2003). In addition to temperature and pressure, the hydrocarbon expulsion process of tight oil source rocks is also controlled by many factors such as pore space, formation water, and mineral media (Defan Guan et al., 2012). Therefore, the hydrocarbon expulsion process of tight oil source rocks is also a complex process of integrating rock action, temperature and pressure.

Domestic and foreign scholars recognize the key role of Nano-Idea in studying tight oil accumulation. The development of modern science and technology also provides the possibility to reveal the dense oil enrichment in microscopic pores, especially development of constant-pressure mercury, Nano-CT and high-resolution scanning electron microscope (Cainen Zou, 2011; Bai Bin et al., 2013; Wenxue Han et al., 2014; Zhi Yang et al., 2015), and had a number of achievements in the micro-nano pore flow mechanism (Swanson B F. et al., 1981; Nelson PH, 2009; Chengzao Jia et al., 2012; Jianhui Zeng et al., 2014; Fuyi Liu, 2015; Zhi Yang et al., 2015; Haibo Yuan, 2017; Zhifeng Yang et al., 2018): in the lack under dynamiction conditions, Due to capillary resistance, viscous force and molecular force, the main flow mode is seepage and detention, only then "starting pressure" to trigger displacement.

Regarding the formation of tight oil accumulation, some scholars have carried out a series of studies, and have a certain understanding: Through the diagenesis and fluid inclusion tests, Qiyan Han et al. (2017) judged that the tight oil accumulation period is later than densification period of the Fuyu layer in the Sanzhao sag.

Compaction and cementation are the main factors affecting reservoir compaction. Based on this, through analyzing fluid inclusions, compact history and burial history, Yue Zhao et al. (2018) considered that the tight oil accumulation and densification of Yanchang formation in Ordos basin happen at the same time.

Formation compaction is the main controlling factor of reservoir compaction. Hua Bai (2018) considered that the tight oil accumulation period is earlier than densification period of Lucaogou formation in Jimsar sag of the Junggar basin. Obviously, Different scholars have different opinions on the time series relationship between tight reservoir formation and reservoir densification.

4. Suggestions and prospects
Throughout the previous research results, the main control geological factors of accumulation, the microscopic reservoir space and the lower limit of tight pore filling of tight oil have been studied in depth. However, the current research on the densification of tight oil reservoirs, hydrocarbon-derived hydrocarbon expulsion and micro-pore-tight oil enrichment correlation characteristics, and tight oil accumulation dynamics are weak. At present, there still exist several problems which need to explore:
(1) The source-reservoir types of tight oil may be vary in different regions, and also the reservoir lithology-lithite facies are not exactly the same. What are the similarities or differences among different reservoirs at reservoir densification, hydrocarbon expulsion from source rocks and tight oil enrichment in micro-pores? Do they have similar accumulation dynamitions? All the above are still to be further studied.

(2) Because of different considerations, scholars have different conclusions on the timing relationship between the tight oil accumulation and densification of reservoirs. It is necessary to seek a scientific association point to establish the coupling relationships among reservoir densification, hydrocarbon generation and expulsion from source rocks and the enrichment of tight oil in micro-pore. The above method would provide a universal theoretical basis for the timing relationship between tight oil reservoir formation and reservoir densification.

(3) Revealing the formation mechanism of tight oil accumulation dynamition plays an important role in deeply understanding the laws of migration and accumulation of tight oil. Also, it could be conducive to promote exploration and development of tight oil. At present, domestic and foreign scholars' understanding of tight oil accumulation dynamition is based on the analysis of tight oil accumulation characteristics and its main controlling factors. Few studies have been carried out on reservoir-forming dynamition from the perspective of tight oil accumulation process. There is an urgent need for constructing models to study the formation of reservoir-forming dynamition of tight oil.

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