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Full Length Article

New advances in the assessment of tight oil resource in China

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ABSTRACT

The research on tight oil becomes another hotspot in the field of unconventional oil and gas after the boom of shale gas. The global recoverable resources of tight oil are estimated to be around 47.3×10^9 t. In recent years, significant progress has been made in the technologies of tight oil exploration and development in North America, thus stimulating the dramatic increase of tight oil production. Meanwhile, China has also acquired remarkable achievements in tight oil exploration. Mature assessment methods have been established for tight oil resources by the US, generally dominated by analogy and statistical methods with their own advantages and disadvantages as well as applicable conditions. In China, improvement of resource evaluation techniques becomes an urgent issue in increasing tight oil reserve and production. This study mainly discusses the resource evaluation methods and resource enrichment characteristics of tight oil. Seven kinds of assessment methods in three categories (i.e., analogy, statistical and genetic method) and evaluation parameters have been preliminary established, and are specifically applied in the Sichuan, Ordos, Songliao, Junggar, Bohai Bay and other tight oil basins through the newly hierarchical resource abundance analogy method, the estimated ultimate recovery (EUR) analogy method and the small-cell volumetric method. The preliminary evaluation results reveal that China has great potential in tight oil resource, and the geological resources amount to 20×10^9 t, providing a resource base for large-scale development.

1. Introduction

The world is currently undergoing the third significant energy revolution characterized by the transformation from conventional oil and gas to new energy, in which unconventional oil and gas resources will no doubt be the most practical in future. The research on tight oil has become a hotspot in the field of unconventional oil and gas after the boom of shale gas (Zou et al., 2012a). Hundreds of oil companies in North America have shifted the focus from shale gas to tight oil, thereby contributing to the progress of exploration and development technologies of tight oil as well as rapid increase in production. America first realized the transition from conventional to unconventional resources and now holds a leading position in the field of tight oil exploration and development (Zou et al., 2012a). The tight oil production in America reached 30×10^6 t in 2011 and was up to approximately 70×10^6 t in 2012.

Using the successful experiences in North America as a reference, China has stepped up efforts in tight oil exploitation and development, and made significant achievements in recent years (Liang et al., 2011; Wang et al., 2012; Zhao and Du, 2012; Yang et al., 2013; Jiang et al., 2014). A series of commercial oil flows have been obtained in many tight oil wells in the Ordos, Junggar, Sichuan, Bohai Bay, Songliao and other large-scale hydrocarbon-bearing basins, indicating a favorable exploration situation in China. The scale of tight oil resources is the key in making strategic deployment by some oil companies. The assessment of tight oil resources and technical improvement are thus particularly urgent in increasing tight oil reserves and production in China.

We have carried out a key technological research and development program of unconventional oil and gas assessment. During the course of implementation, the new progress on tight oil exploration and development and the related assessment methods in North America were reviewed and investigated, and China's tight oil enrichment characteristics were analyzed (Jia, 2012; Jia et al., 2012; Pang et al., 2012; Zou et al., 2012b). By learning tight oil assessment methods and the related key parameters in North America, the tight oil assessment methods fitting the geologic features of China were established and applied in some basins. According to the preliminary assessment results, China has great tight oil potential in lacustrine basins and thus possesses a resource base for large-scale development.

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2. Review of tight oil assessment methods

Unconventional resources occupy increasingly important roles in global oil and gas exploration and exploitation, among which tight oil is very important and approachable. The researches on tight oil assessment methods and techniques have attracted extensive attentions in recent years. Based on the theory of "energy triangle", some scholars determined the quantitative relation between conventional and unconventional resources and then made assessments on the unconventional resources using results of conventional resources as a reference (Cheng et al., 2010). However, this evaluation method is somewhat rough. Through investigations on the related literature and academic exchange materials, it was found that several mature assessment methods have been established for tight oil resources overseas, generally dominated by analogy and statistical methods. As listed in Table 1, the analogy methods are represented by the FORSPAN method from the United States Geological Survey (USGS) and the resource grid density method from ExxonMobil Corporation. The statistical methods mainly include the volumetric method, the estimated ultimate recovery (EUR), the stochastic simulation method, the discovery process method and the oil and gas spatial distribution prediction method (Chen et al., 2005; Chen and Osadetz, 2006a, 2006b; Kenneth et al., 2013).

2.1. FORSPAN method

The FORSPAN method is a mainstream method for unconventional resource assessment proposed by USGS (Schmoker, 2005; Dashtgard et al., 2008; Clarkson and Pedersen, 2011). This method was first developed by the John Grace Consulting Company (Gautier, 1995) and then gained a wide application after modification by Schmoker of USGS (Schmoker, 1999, 2002). In recent years, Charpentier and Cook (2010) have made some significant improvements, especially in database, parameter distribution and graphic output standard. Currently, FORSPAN is a sophisticated assessment method, and the 'cell' in the current assessment grid refers to the drainage area controlled by a well. To be specific, in the region with wells, the distributions of some reservoir parameters such as thickness, area, oil saturation, porosity and permeability as well as the single-well recoverable reserves, the single-well controlled area and the recovery ratio, were mainly investigated; in the regions without wells and production data, the assessment parameters are principally acquired through analogy. The FORSPAN method is applicable to assess the remaining resource potential in the developed regions, i.e., the remaining resources in the whole assessment unit are estimated based on the simulation on the parameter distribution and the calculation of resources in each cell.

2.2. EUR analogy method

This method was proposed on the basis of FORSPAN model. Exxon Mobil Corporation established the resource grid density method which can accurately assess the distribution of continuous oil and gas resources by the analogy of EUR in each block (Fig. 1). In 2012, after modification of this method, a multi-prong assessment approach (MPAA) method comes into being. MPAA combines the EUR analogy method and the volumetric method. Through the analogy of EUR in each block and correction with the reservoir volume, the predicted resources will be more reliable. Currently, EUR analogy method has become the most common method for evaluating tight oil resources abroad.

2.3. Stochastic simulation method

Stochastic simulation method is a new method proposed by USGS recently. There were three deficiencies of the traditional analogy methods (Olea et al., 2010): (I) the spatial relationship among the EURs of different assessment units is neglected; (II) the implicit information are not exported fully; (III) the assessment results are somewhat contrary to the spatial distribution regularities. The stochastic simulation method was then proposed for addressing these problems, which differs from analogy method in the following aspects: (I) The development of algorithm from the analogy method to the comprehensive assessment method which the main method is the statistical method supplemented by the analogy method. The stochastic simulation method of the sequential Gaussian simulation algorithm is used in regions with wells, while the analogy method is applied in regions without wells, and the spatial relationship among EURs and the related parameters are acquired through analogy, then the assessment is conducted based on multi-point simulation. (II) The development of geologic modeling. The parameters were previously determined by triangular distribution, and now through the analysis of the relationship among the spatial data, the spatial distribution model of the parameters is established by the geo-statistical method. (III) The development of the simulation cell from the original cell to the earliest grid cell. The area of the new cell is small, or even smaller in

Table 1
Tight oil assessment methods.

Category	Method	Principle and Characteristics	Application conditions	Advantages	Disadvantages
Analogy method	Estimated ultimate recovery (EUR) analogy method, FORSPAN method, resource grid density method	The resource of a target area is evaluated by analogy with the parameters of the known assessment units, and solution is acquired by Monto Carlo stochastic simulation method.	Moderate-and high-exploration regions	Input parameters are less, and the mathematical model is simple	Difficulty in the determination of key parameters and lack of considerations on the spatial correlation of EUR
Statistical method	Single-well reserves estimation method, discovery process method, stochastic simulation method, volumetric method; spatial resources distribution prediction method	In the spatial resources distribution prediction method, based on the statistics of the discovered reservoirs, the oil and gas distribution characteristics are determined for the calculation of resources.	Moderate-and high-exploration regions	By taking the spatial position relationships of parameters into account, the spatial distribution of resources is calculated	A lots of parameters are involved, the distribution of the discovered reserves is required and the calculation process is complex
Genetic method	Pyrolysis analogy method proposed of Humble Geochemical Services, U.S.	The resource is calculated through the basin simulation software.	Moderate-and low-exploration regions	The geological distribution characteristics and accumulation of oil and gas resources are systematically understood	The basin simulation process is complex and the assessment period is long.

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