CSCanada
Advances in Petroleum Exploration and Development
Vol. 8, No. 2, 2014, pp. 37-42
DOI:10.3968/6032

ISSN 1925-542X [Print]
ISSN 1925-5438 [Online]
www.cscanada.net
www.cscanada.org

The Method of Establishing Analogy Reservoir for Low Permeability Sandstone Reservoir

LIU Jiyu[a],*; LI Ze[a], [b]; ZHANG Tianqi[b]; JIA Ziming[c]

[a] Geoscience College of Northeast Petroleum University, Daqing, China.
[b] Daqing Oilfield No.4 Oil Production Company, Daqing, China.
[c] Daqing Oilfield Downhole Service Company, Daqing, China.
* Corresponding author

Received 23 October 2014; accepted 15 December 2014
Published online 29 December 2014

Abstract
Analogy reservoir is accurate or not, related to the reliability of the SEC reserves evaluation. According to the characteristics of Jilin Oilfield low permeability sandstone reservoir, in accordance with SEC new rules and the principle of analogy reservoir establishment, we establish analogy reservoir of low permeability sandstone reservoir by taking the steps of selecting analogy reservoir, calculating geological reserves, evaluating recoverable reserves, and defining analogy recovery. With this method, we set up analogy reservoir sequence of low permeability sandstone reservoir and the sequence provides a reliable basis for SEC reserves evaluation.

Key words: SEC rules; Geological reserves; Recoverable reserves; Analogy reservoir; Recovery efficiency

Liu, J. Y., Li, Z., Zhang, T. Q., & Jia, Z. M. (2014). The method of establishing analogy reservoir for low permeability sandstone reservoir. *Advances in Petroleum Exploration and Development*, *8*(2), 37-42. Available from: URL: http://www.cscanada.net/index.php/aped/article/view/6032
DOI: http://dx.doi.org/10.3968/6032

INTRODUCTION

Since marketing in New York, 1999, oil and gas reserves of PetroChina has been evaluated in accordance with SEC (Securities and Exchange Commission) rules. On December 31th, 2008, the United States SEC issued new rules for the evaluation of oil and gas reserves[1]. On January 1st, 2010, SEC new rules formally implemented and proposed new requirements for SEC reserve evaluation[2]. Through the practice of the evaluation process and the study of the SEC new rules according to the "SEC rules oil and gas reserves Evaluation Guide" (Q/SY182-2006), we find that there is no comprehensive data graph-base for effective dynamic management in the majority of our oil reservoirs, so the reserves evaluation is repeated and inefficient. Therefore, based on the SEC new rules, we make accurate estimates of proved reserves by establishing analogy reservoir of Jilin Oilfield low permeability sandstone reservoirs. It makes both the proved reserves that evaluated in domestic and SEC proved reserves reliable. Meanwhile, it provides an effective basis for determining the recovery efficiency of the expanded and newly discovered reserves.

1. CHARACTERISTICS OF LOW PERMEABILITY SANDSTONE RESERVOIR IN STUDY AREA

Low permeability is a relative concept and has no uniform standards and boundaries[3]. According to the actual situation of China's exploration and development, the low permeability reservoir is defined as $(0.1 - 50)\times10^{-3}$ μm^2 [4].

The type of low permeability reservoir in Jilin Oilfield is generally up dip pinch out reservoir, sandstone lent reservoir and fault lithologic reservoir which duplex controlled by both fault and lithologic characters. The sandstone and mudstone of oil layer obviously intertwined, the thickness of sandstone is instable, and has strong intrastratal heterogeneity between layers. The deeper, the buried depth is, the poorer, the physical properties are, the permeability is less than 50×10^{-3} μm^2 in general and the reservoir gets tight. Tight reservoir has strong intrastratal heterogeneity, complex pore throat, poor communication, low oil saturation and natural productivity.

2. ANALOGY RESERVOIR CONCEPT

In the evaluation of proved reserves, analogy reservoir refers to a reservoir that has the same geological formation (but not necessarily in pressure communication with the target reservoir), the same depositional environment, similar geological structure and the same driving mechanism with target reservoir. However, compared with target reservoir, analogy reservoir has a further development stage[5], and the properties of analogy reservoir must not be as good as target reservoir in general.

3. THE ESTABLISHMENT OF ANALOGY RESERVOIR FOR LOW PERMEABILITY SANDSTONE RESERVOIR

3.1 The Principle of Establishing Analogy Reservoir

Analogy reservoir should choose the reservoir that has basic reliable geological and development data, a certain size of development block, completeness well network, rational water injection mode, a long development time, better regularity and reasonable evaluation of recovery efficiency[1]. It can be an oil field, a reservoir, a development zone, or even a battery of wells.

3.2 The Method and Procedure of Establishing Analogy Reservoir for Low Permeability Sandstone Reservoir

Firstly, we should select an appropriate analogy reservoir according to the principle of establishing analogy reservoir. Analogy reservoir should have the completeness static and dynamic parameters. Static parameters mainly refer to the geological characteristics and dynamic parameters refer to the development characteristics. To establish analogy reservoir of low permeability sandstone reservoir, the following parameters should be considered, including: (a) Petrophysical properties of the reservoir: oil-bearing horizon, depth, pressure, temperature, lithology, effective thickness, aeolotropy, porosity, permeability, structure pattern, the distance of analogy reservoir and target reservoir; (b) Oiliness and fluid property: driving mechanism, oil saturation, reservoir scale, oil density, crude oil viscosity; (c) development program: development mode, well network density, single well deliverability, decline type, decline rate, degree of reserve recovery, recovery efficiency. Based on the above parameters, we can qualitatively and quantitatively compare analogy reservoir with target reservoir under the same economic conditions.

Secondly, calculate or recalculate analogy reservoir geological reserves. Analogy reservoir is used to assess the recovery efficient of target reservoir. To establish analogy reservoir of low permeability sandstone reservoirs, the definite parameters include: (a) Hydrocarbon bearing boundary: combined with production data, the development wells are extrapolated half wells spacing as oil-bearing area boundary in condition of the existing well network. If there is fault at the edge of well network, the fault lines will be taken as oil-bearing area of the boundary; (b) Effective thickness: on the basis of the effective thickness that defined by the development unit that demarcated by recoverable reserves, take the average that based on the re-division of each well in oil-bearing area then obtain the effective thickness by using effective thickness contour weight method; (c) Effective porosity: the average porosity of single well can be determined by effective thickness weight method and then use well point arithmetic average to calculate the average porosity of area; (d) Oil saturation: average oil saturation of single well can be obtained by volume weight method and then use well point arithmetic average to calculate the average saturation of area; (e) Volume factor: use PVT data analysis to determine; (f) Crude oil density: measured by laboratory analysis data.

Thirdly, evaluate ultimate recoverable reserves (ultimate recoverable reserves = cumulative production + proved reserves). The accuracy of ultimate recoverable reserves depends on: whether the development information is accurate and reliable; whether the assessment methods are reasonable; whether the assess results conform to the actual situation of oilfield development. This time, we use dynamic successive subtraction method to calculate recoverable reserves and demarcate recovery efficiency.

Finally, according to the SEC rules, analogy reservoir establishment needs related reservoir basic data figure, drawing structure geological basic map, effective thickness isopach map, permeability histogram, porosity histogram, reservoir cross-section diagram, recovery curve map, evaluation curve map and calculated method, act.

3.3 Example

According to the principle and method steps of analogy reservoir establishment, establish analogy reservoir of low permeability sandstone reservoir in Jilin oilfield. Take block D as an example.

In block D, located in Honggang terrace, the central depression of Songliao basin, the mainly formation of interest is Upper Crataceous Nenjiang three segments, namely Heidimiao, with the stratigraphic thickness of 840 - 980 m. The overall structure of the region is large northwest inclined nosing structure that complicated by faults, with the long axis anticline of general framework, above where fault develop with good block off and the construction formation time matches with the oil and gas maturity time. The average effective thickness of the reservoir is 2.8 m. Under the background of semi-deep lake, the depositional environment belongs to delta sedimentary, whose microfacies are mainly underwater distributary channel (Figures 1 - 3). The lithology is mainly siltstone, followed by sandstone. Particle diameter is generally 0.03 - 0.18 mm. The rock composition of quartz and feldspar content is about 30%. The rock type is feldspathic lithic sandstone. Reservoir porosity is in the range of 19% - 28.6%, with an average porosity of 24.3% (Figure 4). The permeability is in the range of $(0.89\times10^{-3}$ - 26.3×10^{-3} μm^2, with an average permeability of 8.36×10^{-3} μm^2 (Figure 5), which belongs to low porosity and low permeability reservoirs.

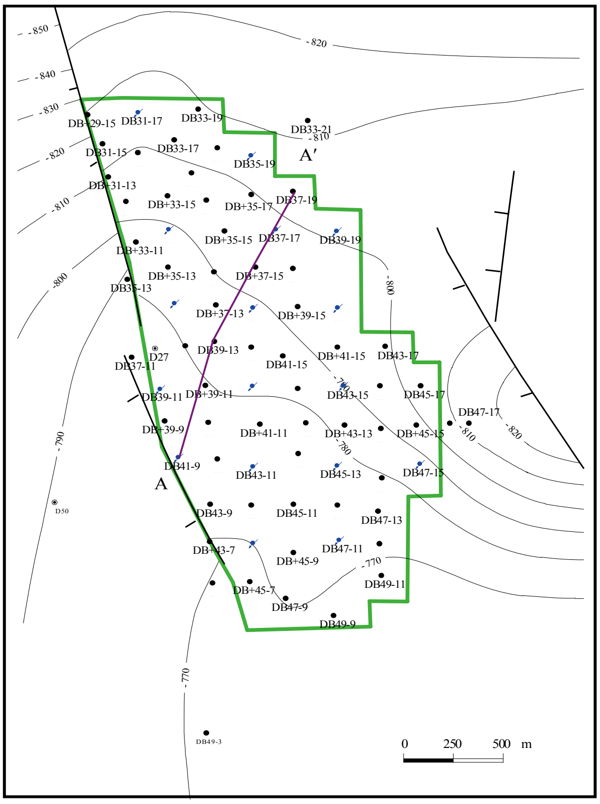

Figure 1
Structure Geological Basic Map of Block D

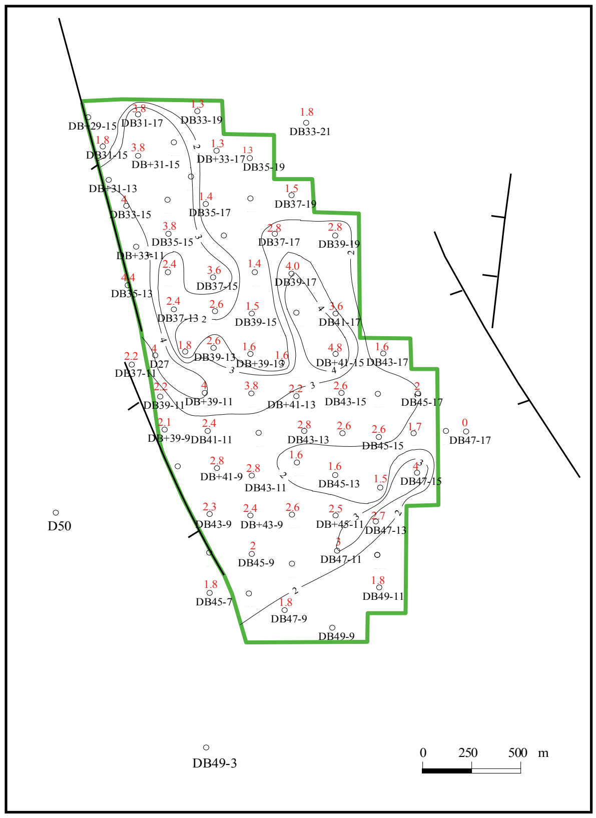

Figure 2
Effective Thickness Isopach Map of Block D

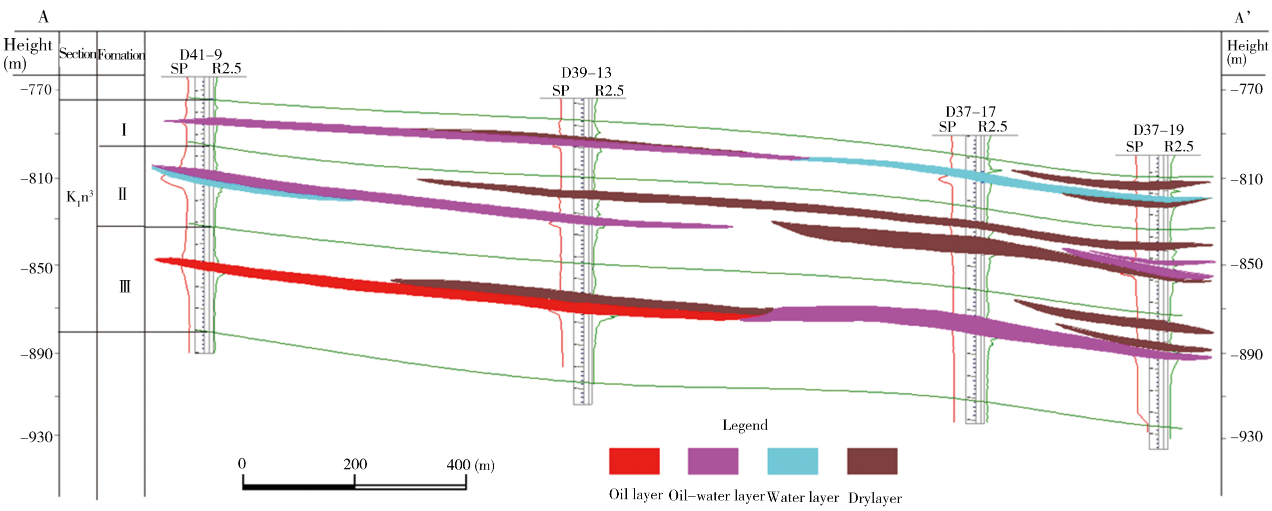

Figure 3
Reservoir Cross-Section of Block D

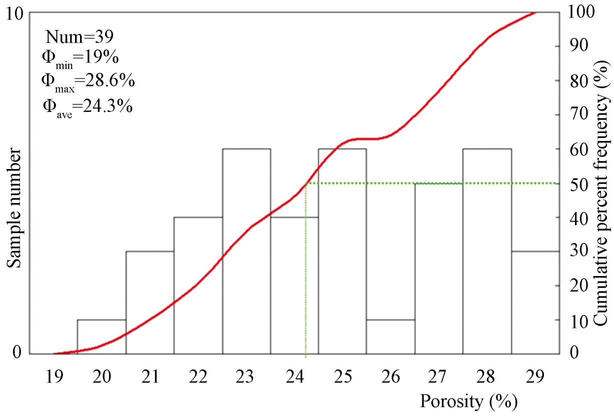

Figure 4
Porosity Histogram of Block D

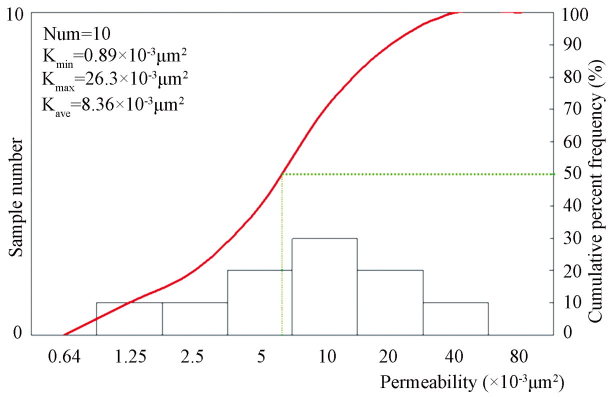

Figure 5
Permeability Histogram of Block D

In October 1996, block D was put fully developed by the water injection method. The pattern shape of well system was reverse 45° 300 m square inverted nine-spot pattern. The first stage is flooding production increased stage (October 1996 - May 1997), in which the number of wells rapidly grew and oil production continued to grow. In May 1997, the peak value reached 2,730 t. At the end of this stage, 29 oil wells and 5 water wells were open. Single well production reached 3.04 t and composite water cut reached 9.0%. The second stage is declining - production exploitation stage (June 1997 - 2002). The block production decreased smaller from June 1997 to December 2000. From 2001 to 2002, the block production decreased quickly and water content increased rapidly. At the end of this stage, 24 oil wells and 8 water wells were open, single well production reached 0.96t, the cumulative oil production reached 10.75×10^4 t, cumulative fluid production reached 12.76×10^4 t and composite water cut reached 39.73%. The third stage is increasing and stable production stage (2003 - October 2008), in which inefficient wells were closed meanwhile encrypt adjustment were taken. Then oil production started to grow. Since 2006, block D had turned into a three-year stable production period, with a production more than 614 t per month. At the end of this stage, 24 oil wells and 10 water wells were open, single well production reached 1.04 t, the cumulative oil production reached 17.39×10^4 t, cumulative fluid production reached 23.78×10^4 t and composite water cut reached 39.73%. The forth stage is encryption adjustment stage (November 2008 - Present), in which the number of oil wells had rapidly grown and the per month production were stable.

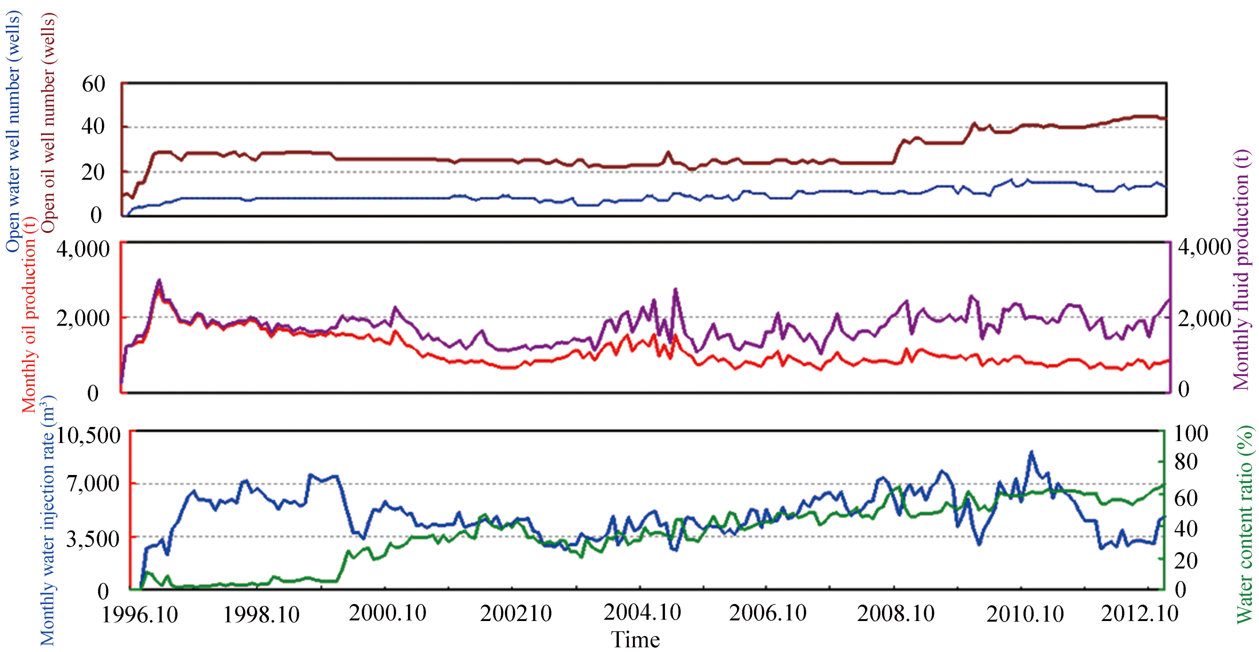

Figure 6
Recovery Curve Map of Block D

Until January 2013, block D had 80 wells, including 63 oil wells, 44 of which were open, and 17 water injection wells, 13 of which were open. Average daily verified oil production per well was 0.62 t and daily fluid production per well was 1.84 t, the cumulative oil production was 21.71×10^4 t，the degree of reserve recovery was 22.79%, composite water cut was 66.20%, oil production rate was 0.96%, the monthly injection-production ratio was 1.34 and cumulative injection-production ratio was 1.91 (Figure 7). According to the dynamic data of production, using the exponential decline method, under the case that initial decline rate is taken as 11.40% ,we can obtain the ultimate recoverable reserves as 29.11×10^4 t.

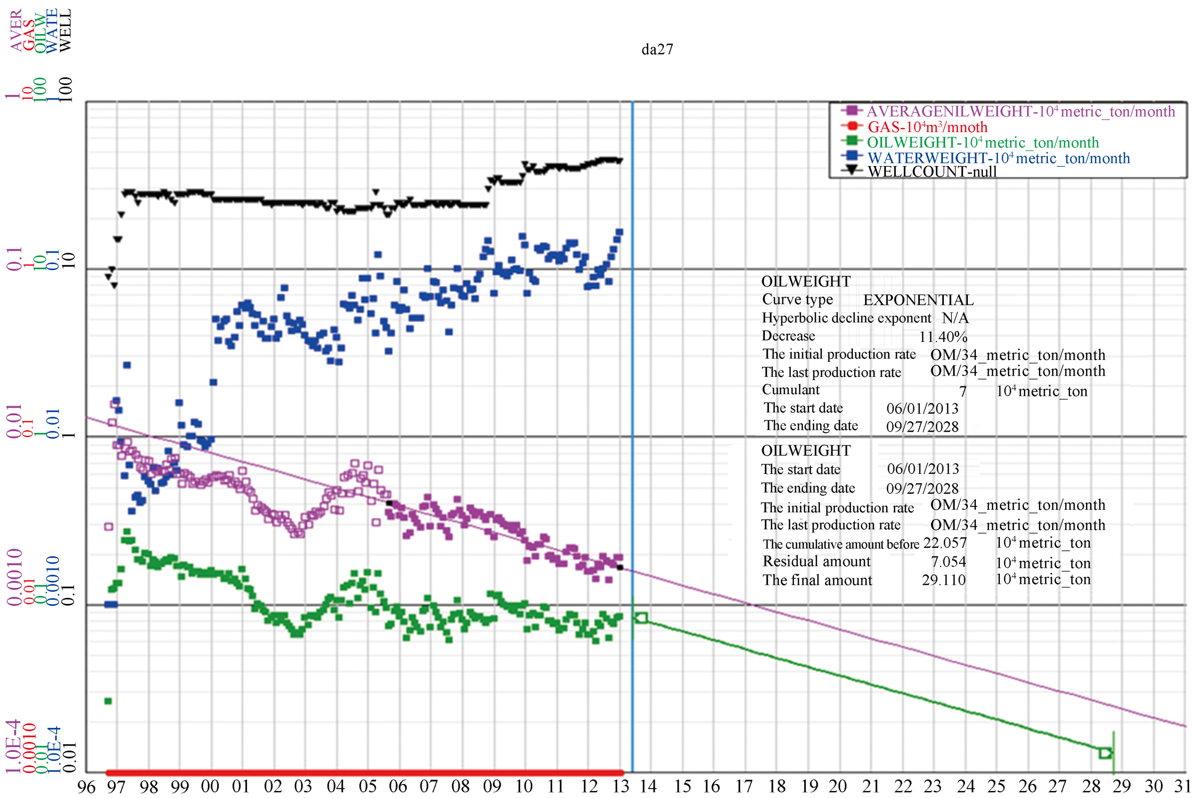

Figure 7
Evaluation Curve Map of Block D

Table 1
Reservoir Basic Data of Block D

	Project	Parameters		Project	Parameters
Basic information	Analogy reservoir name	D	Reserve calculation parameters	Area（km^2）	3.20
	Location	Y		Effective thickness（m)	2.8
	Areal structure	Southern Songliao basin central depression Honggang terraces		Porosity（%）	23.1
	Oil-bearing horizon	K_1n^3		Oil-bearing saturation（%）	60.6
	Reservoir type	Low permeability sandstone reservoir		Oil volume factor	1.119
	Reservoir lithology	Siltstone		Oil density (t/m^3)	0.850
	Reservoir space type	Pore		Geologic reserve ($\times10^4$ t)	95.28
Reservoir fluid property	Atmospheric permeability (mD)	8.4	Operational parameters	Development mode	Water injection
	Permeability variation coefficient	0.76		Well network density(wells/km^2)	17.8
	Depositional environment	Delta front subfacies		Single well initial stable average yield (t/d)	2.1
	Driving mechanism	SGD, elastic drive and water drive		Composite water cut (%)	66.2
	Displacement efficiency (%)	46.5		Composite declining rate (%)	12.88
	Reservoir mid-depth (m)	881	Evaluation parameters	Reserve recovery degree (%)	22.8
	Gas/Oil ratio (m^3/t)	46		Evaluation time (Year)	2013
	Initial formation pressure (MPa)	8.900		Price (CNY/t)/($/Bbl)	4,874/105
	Initial bubble point pressure (MPa)	6.000		Unit operating costs (CNY/t)	1149
	Initial reservoir temperature (°C)	36.00		Total recoverable reserve (10^4 t)	29.11
	Oil viscosity (mPa·s)	5.2		Recovery efficiency (%)	30.6

CONCLUSION

According to the characteristics of Jilin Oilfield low permeability sandstone reservoir, with SEC new rules and the principle of analogy reservoir establishment, the method of establishing analogy reservoir for low permeability sandstone reservoir is created，which has been widely used in Jilin Oilfield. It provides reliable parameters and analogy recovery for SEC reserves evaluation and offers a reliable basis for proved undeveloped reserves evaluation.

REFERENCES

[1] Sun, Q. F., Jiang, X., & Liu, Z. (2011). Establishment of analogous oil and gas reservoirs in the new SEC rule. *Marine Origin Petroleum Geology*, *16*(4), 71-77.

[2] Zhao, H. (2013). Research analogy reservoir sequence of Daqing peripheral oilfield. *Oil and Gas Technology* (*Journal of Jianghan Petroleum Institute*), *35*(2), 56-58.

[3] Li, D. P. (1997). *The development of the low permeability sandstone oilfield*. Beijing, China: Petroleum Industry Press.

[4] Zhu, M. H. (2002). Sedimentary characteristics of Guantao formation in Shuyi area. *Journal of Jianghan Petroleum Institute*, *24*(2), 15-17.

[5] Liu, C. Y., Guo, N., & Yan, X. B. (2009). Oil-gas reserve information disclosure comparison between SEC. *Resources & Industries*, *11*(2), 18-22.