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Influence Factors Analysis of Tight Oil EUR Evaluation

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1 Introduction

The factors that relate to EUR estimation are analyzed from six aspects of decline model combination, economic production, production period, development program, geology and engineering. In this paper, the correlation and coupling between EUR and related factors are further analyzed, and these factors include declined model selection, transition-point of different decline curves, production period, initial maximum production rate, fracturing times and geological key factors (source rock and reservoir).

2 Influence Factors of EUR Evaluation

The improved Arps decline model is used to estimate EUR of more than 800 tight oil wells in Bakken Formation of the Williston Basin, and the EUR plane distribution is established for specific analysis. This paper argues that EUR is mainly dependent on six factors (Table 1). In particular, geology and engineering are the two fundamental factors with relatively high weighting coefficient.

It should be noted that economic production (ultimate production) is the end of production forecast. Its value will certainly affect the estimated EUR. As the oil price increases, the economic production could decrease. The

economic production is assigned at 20 bbls/month in this paper. In addition, the single-well initial production rate, decline rate and other parameters are attributed to development program, which are affected by development plan and completion technology.

Next, the correlation and coupling between EUR and its six influence factors are mainly analyzed in six aspects: decline model selection, transition-point of different decline curves, production period, initial maximum production rate, fracturing times and geological key factors (source rock and reservoir).

2.1 Model selection

The tight oil well performance in the early production stage follows transient flow due to the effect of stimulated reservoir volume (SRV) (Mayerhofer, et al., 2008). The initial transient flow transits to boundary flow in the late production stage due to the effect of flowing boundary and reservoir heterogeneity (Clarkson, 2013). In this paper, an improved Arps decline model is used to simulate the well performance during the transition from transient flow to boundary flow at a certain time point or a specific minimum decline rate.

The estimated EUR is 1587 MBO (as shown in Fig.1a) based on the traditional Arps hyperbolic model. Hyperbolic decline transits to exponential decline when decline rate reaches 10% in the application of the

Table 1 EUR influence factors

Influence Factors	Key Parameters
Decline Models	Arps Decline(Types, D_{swich}), Fetkovich Decline, Blasingame Decline
Economic Production	Economic Monthly Production (the lower limit)
Production Time	Production Months
Development Program	Initial Production, Decline Rate
Geology	Thickness, Generation potential of source rock, Ro, Property of Reservoir, Pressure, Oil Saturation, GOR, Fractures, Structure, Stress, et al
Technology	Well type, Lateral length, Hydraulic Fracturing, Proppant volume & type, Proppant loading, Fluid volume& type, Fluid/proppant ratio, Injection rate, Treatment pressure, Choke size, Plug & performance, Well spacing...

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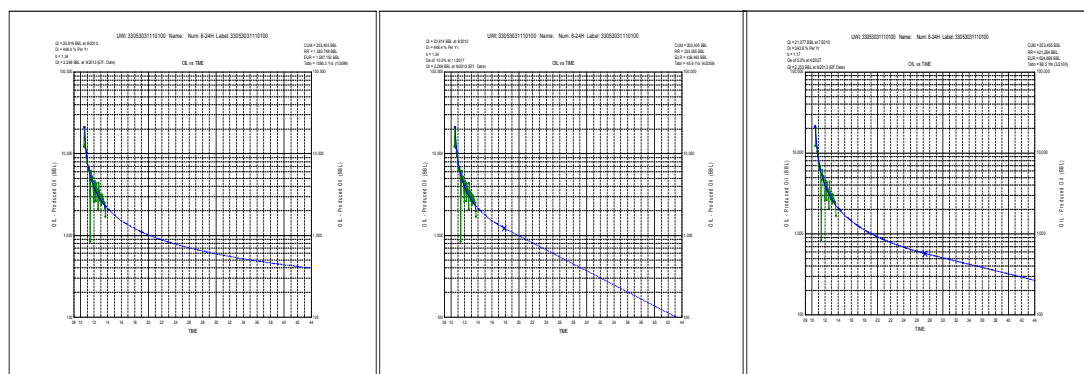


Fig.1. The estimated EUR of tight oil Well 8-24H in Bakken Formation (combination of different decline models and Dswich).

(a), Traditional Arps hyperbolic decline model; (b), Improved Arps decline model hyperbolic + exponential decline (Dswich@10%); (c), Improved Arps decline model hyperbolic + exponential decline (Dswich@5%).

improved Arps decline model. The estimated EUR is 436 MBO based on the improved Arps decline model (as shown in Fig.1b). The contrast shows that traditional Arps decline model will overestimated EUR.

2.2 Terminal decline rate, Dswich

The transition point from transient flow to BDF should be identified for different tight oil plays. In other words, the ultimate (minimum) decline rate should be determined when hyperbolic decline is replaced by exponential decline. The optimum terminal decline rate (Dswich) in Arps decline model varies for different plays, and its value will lead to deviation of EUR. As shown in Fig.1, for the same tight oil well, the estimated EUR is 436 MBO when the terminal decline rate (Dswich) selected as 10%, and 625 MBO when the terminal decline rate (Dswich) is 5%. Clearly, when the terminal decline rate (Dswich) is 5%, the transient flow period increases and the time point of transition to BDF is delayed, which lead to a higher estimated EUR.

2.3 Production period/monthly production data

An optimistic EUR estimation will be obtained in case of a short production period or too few monthly production data. As shown in Fig.2, the estimated EUR is 1986 MBO based on the analysis with 6-month production data. However, the estimated EUR is 436 MBO based on the analysis with 36-month production data under the same combination of decline models and well. Therefore, the latter EUR estimation is more realistic. Study indicates that a stable EUR can be gained when production period exceeds 3 years, because half of EUR has been produced. So, a more realistic estimated EUR can be gained for the well with more than 3-year production period.

2.4 Initial maximum monthly production rate (Qi)

The EUR estimation of more than 800 tight oil wells in Bakken Formation indicates that EUR is well correlated with initial maximum monthly production rate (Q_i) (Fig.3), with the correlation coefficient up to 0.6179 (Eq. (1)).

$$EUR = 18.946 \times Q_i + 69926 \quad (R^2=0.6179) \quad (1)$$

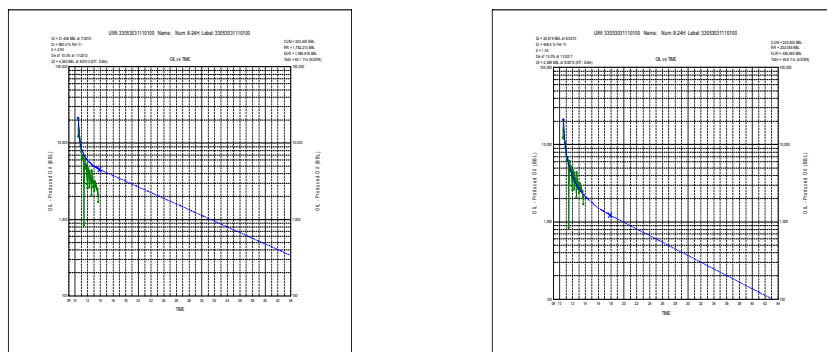


Fig.2. The estimated EUR of tight oil Well 8-24H in Bakken Formation (based on different production periods).

(a), Analysis based on initial 6-month production data; (b), Analysis based on initial 36-month production data.

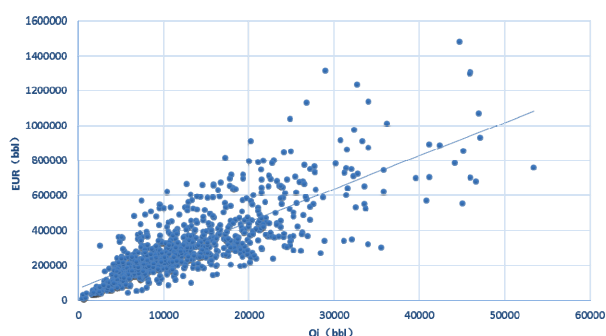


Fig.3. Relationship between EUR and initial maximum monthly production rate.

EUR increases with the initial maximum monthly production rate. Thus, it can be inferred that efficient development plan and completion technology can lead to high initial maximum monthly production rate, which will ultimately enhance single-well EUR.

Based on the above analysis, EUR will be overestimated in case of too few monthly production data, since most of the tight oil wells in China are produced in a relatively short period. Therefore, Eq.(1) can be used for correction in EUR estimation.

2.5 Technology

As mentioned above, efficient completion will enhance single-well EUR. Actually, EUR is dependent on well type, lateral length, times and stages of hydraulic fracturing, proppant volume & type, proppant loading, fluid volume & type, fluid/proppant ratio, injection rate, treatment pressure, choke size, plug & performance, well spacing, etc. (Table 1). The effect of fracturing times on EUR is discussed below. As observed, the estimated EUR is only 147 MBO without re-fracturing treatment. In contrast, the estimated EUR is 167 MBO with a re-fracturing treatment, and the EUR increment is 20 MBO (Fig.4). In addition, the figure also illustrates that the

increments of monthly production rate and EUR will increase with a more efficient re-fracturing treatment.

2.6 Geology

Single-well EUR is related to complex geological parameters, which are listed in Table 1. Tight oil single-well EUR is affected by interest-interval thickness, hydrocarbon generation potential, maturity, physical properties, pressure, oil saturation, GOR, fracture, structure, stress and other geological parameters. Therefore, tight oil reservoirs in Bakken Formation are investigated to identify the key controlling factors.

2.6.1 Multi-parameter correlation analysis

Among the six geological parameters in Table 2, porosity and thickness are two mutually independent parameters, and TOC, HI and TR are three mutually independent source rock parameters. Based on the EUR estimation of more than 800 tight oil wells in Bakken Formation and the extraction of corresponding geologic factors on the Bakken plane map, the correlation between EUR and the six geological parameters are analyzed respectively, suggesting no significant correlation. Similarly, in the multiple regression analysis between EUR and the six geological parameters, the correlation coefficients are lower than 0.2. Accordingly, EUR in tight oil reservoir is dependent on multi-parameter rather than single-parameter due to its complex geology of hydrocarbon accumulation and strong heterogeneity.

2.6.2 Geology coupling analysis

Based on the hydrocarbon migration-accumulation regularities and EUR plane distribution, the key controlling factors are tentatively identified through the correlation between hydrocarbon migration-accumulation geology and EUR. Fig.5 is a superimposed diagram of EUR distribution and structure in Bakken Formation. The colors and shapes of the bubbles are related to EUR value.

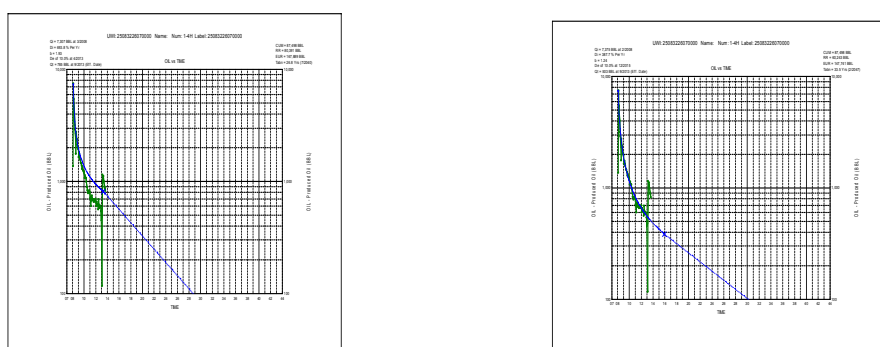


Fig.4. The estimated EUR of tight oil Well 1-4H in Bakken Formation (cases with and without a re-fracturing treatment).

(a), EUR with a re-fracturing treatment; (b), EUR without a re-fracturing treatment.

Table 2 Correlations between EUR and geological parameters in Bakken Formation

	Porosity of Siltstone in Middle Bakken	Middle Bakken Thickness	Lower Bakken- TOC	HI	TR	Hydrocarbon- Generation Amount	Correlation Coef- ficient of Multiple Regression
EUR							0.178
							0.140
							0.032
							0.183
							0.180
							0.181
							0.162
							0.162
						0.113	
Correlation Coefficient of Single Regression	0.035	0.037	0.160	0.164	0.040	0.135	

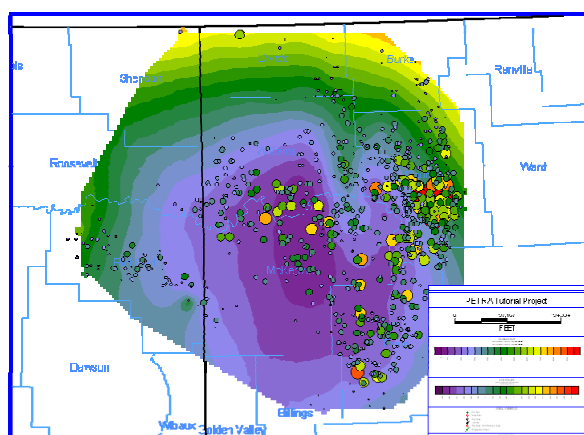


Fig.5. Superimposed diagram of EUR distribution and structure in Bakken Formation, the Williston Basin.

Study shows that EUR is relatively high in structural bulge regions of Sanish, western McKenzie, Williams, etc. These regions are precisely the favorable hydrocarbon

migration-accumulation that is controlled by structural relief high. The figure also presents that EUR is relatively low in the flank of Nesson Anticline. It can be speculated that the anticline flank only serves as hydrocarbon migrating channel. Hydrocarbon passes through anticline flank and migration to the overlying formations and northern region, and little hydrocarbon is accumulated in this region, which results in lower EUR value. In addition, micro-fractures are developed in high-quality source rock region due to the abnormal high pressure generated by high generation-expulsion intensity, which is favorable to reservoir quality and leads to high EUR.

References

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