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RESEARCH PAPER

A method of production profile quick prediction based on typical curves: A case study of the Upper Shale large multi-layered sandstone reservoir, Rumaila Oilfield, Iraq

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Abstract: Combined the advantage of reservoir simulation and conventional reservoir engineering methods, the paper proposes a quick method for production performance prediction, which is based on type curves generated from reservoir simulations of sector model. Fine reservoir simulation is conducted based on the fine geological sector model of the large sandstone reservoir, and type curves of different reservoir type under different development options are generated. Then based on results of reservoir type classification for all layers, well productivity and injectivity evaluation, production profile of the whole field can be predicted. This new method can reflect the impact of reservoir heterogeneity and development option change on reservoir performance. Take a large multi-layered sandstone reservoir Upper Shale reservoir in Rumaila Oilfield for example to illustrate the workflow. The comparison between results of fine reservoir simulation and that of the new method validate reliability of the new method, and the new method consume much shorter time.

Key words: Iraq; Rumaila Oilfield; type curve; production profile; quick prediction; sector model; numerical simulation

1. Introduction

Rumaila oil field located in Basra of southern Iraq, is the biggest oil field in Iraq, and the second biggest oil field in terms of estimated remaining recoverable oil reserves in the world. It is located in a long axis anticline in the south of Mesopotamia Basin (Fig. 1). The interested formation of this paper is Upper Shale reservoir of Zubair Formation in Lower Crataceous, which is a multi-layered sandstone reservoir of delta front deposits from marine transgression. The sand bodies of Upper Shale reservoir are complex in vertical distribution because of the combined effect of river, tide and wave, with sand layers and shale layers interbedded, and are divided into 6 zones and 15 layers (Fig. 2). This reservoir has been produced for nearly 60 years by depletion by the end of 2015, but currently its oil recovery is only around 6%. Currently, the reservoir pressure of some local areas, such as the crest area, is close to the bubble point pressure, so there is a risk of degassing. The annual decline rate of production is above 20%, so water injection is needed to maintain reservoir pressure. With an oil-bearing area of 600 km^2, the Upper Shale reservoir has a basically complete well pattern in the south part with the well spacing of 1 000 m and plenty well logging data. But large in area, complex in vertical and lateral sand body scale and highly variable in reservoir architecture, it is difficult to build a full field fine geological model with high accuracy, and full field reservoir simulation is also difficult and time consuming. Therefore, it is a challenging problem to clearly and accurately characterize reservoir heterogeneity and quickly optimize reservoir development plan and predict development performance.

At present, reservoir performance prediction methods mainly include numerical simulation, production curve prediction method and conventional reservoir engineering method. For large oil and gas fields, upscaling is often used to upscale fine geological model to coarse model in order to improve the calculation speed of numerical simulation, while the coarse model usually cannot characterize the reservoir heterogeneity, therefore, the prediction result will not match with actual reservoir performance. For unconventional reservoirs, production curve method is commonly used in fast prediction of reservoir performance[1–3]. However, not fully considering all affecting factors, this method has low prediction accuracy. Conventional reservoir engineering methods include material balance analysis method[4–6], waterflooding type curve method[7–9], rate transient analysis method[10–15] and pre-

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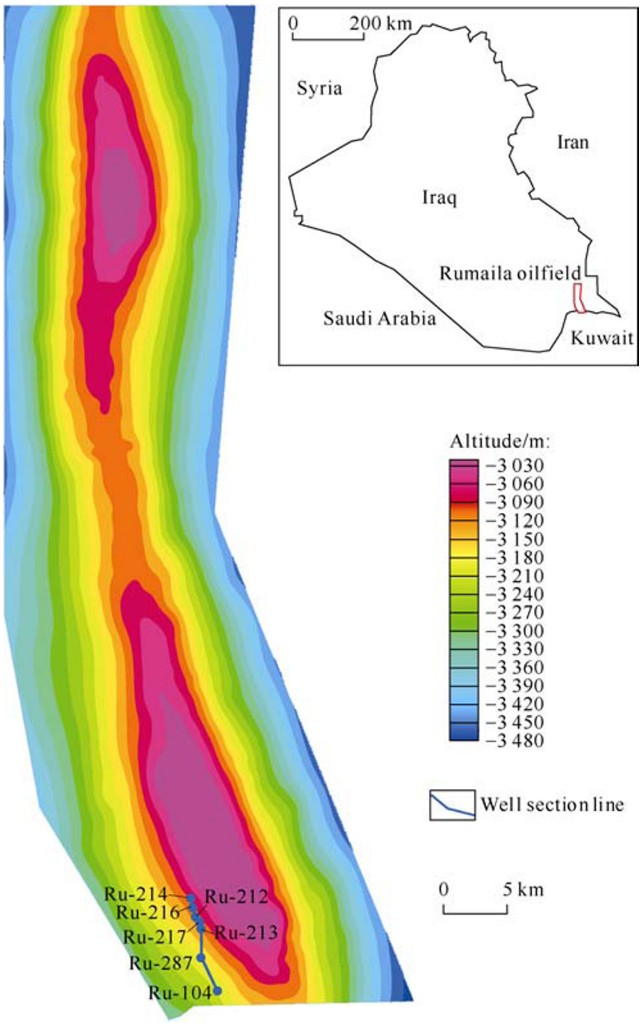

Fig. 1. Reservoir position and structure of Rumaila Oilfield.

diction model method[16–17]. But these methods are also unable to predict reservoir performance of different layers or zones if the development strategy is complex and development measures are adjusted. For multi-layered sandstone reservoirs, well pattern, well spacing and development options often change during the development. Except numerical simulation, other prediction methods limited and one-sided, cannot take all the complex factors in reservoir development into consideration. In this study, a new method combining the advantages of numerical simulation and conventional reservoir engineering method for fast prediction of reservoir performance has been proposed, and the large multi-layered sandstone reservoir Upper Shale reservoir in Rumaila Oilfield has been taken as an example to illustrate the workflow.

2. Principles and workflow of the fast reservoir performance prediction method

In order to ensure the rationality and accuracy of reservoir performance prediction, it needs to minimize the influence of reservoir heterogeneity on prediction. Therefore, the whole reservoir should be divided into as many blocks as possible laterally. Moreover, it is important to match the boundary of each block with well pattern arrangement in order to ensure a balance between injection and production in each block.

The quick method of reservoir performance prediction proposed in this paper is based on type curves generated by fine reservoir simulation of typical blocks. Different reservoir types under different development options use different type curves for reservoir performance prediction, which can reduce the effect of reservoir heterogeneity and development option changes on prediction. The specific prediction workflow includes the following five steps: Firstly, strata correlation, reservoir type classification and evaluation, lateral reservoir properties and reserves distribution of each layer for the whole reservoir should be done. Based on the results, the reservoir is divided into different blocks, during which one principle that each layer in one block is only one reservoir type is followed. Secondly, fine geological model and numerical simulation model are established for representative blocks selected according to reservoir geological features, to generate type curves of reservoir performance (such as water cut vs. recovery, water-oil ratio vs. recovery) through reservoir simulation. Thirdly, the relationship between well production/injection rate and formation flow capacity (Kh) are established based on well inflow-outflow performance relationship method. Based on the relationship, initial production or injection rate for each well in each layer can be calculated. Moreover, the initial production and injection rate of each layer in each block can be calculated by adding up the rate of all wells in the corresponding block. Next, the initial production and injection rate of subsurface condition can be calculated with the volume factor. The minimum value of the initial production and injection rate will be taken as subsurface initial production and injection rate. Fourthly, the time step for performance prediction should be determined. Then based on reservoir type classification results, reserves evaluation, type curves of different reservoir types, recovery of each block for the first step can be calculated with voidage balance assumption and calculation results of the third step. Then based on the established relationship between water cut and oil recovery, the water cut at current oil recovery can be calculated, which will be used for calculation of oil production rate and water production rate for the next time step. Similarly, performance prediction calculation can be done for all time steps, which can generate the production profile and injection profile for each layer in the block. Production and injection of all layers in one block are added to get the total production and injection of the block; then the prediction results of all blocks are added to get the total production and injection of the whole reservoir. Finally, performance curves of recovery, water cut and remaining recoverable reserves of each layer, each block, and the whole reservoir can be generated rapidly based on reserves evaluation results, predicted production and injection rate.