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Study on the Couple of 3D Geological Model and Reservoir Numerical Simulation Results

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Abstract

Taking Dongying Formation, Palaeogene, B Oilfield in Bohai Bay Basin as an example, this paper discusses research on coupling 3D geological model and reservoir numerical simulation results during oilfield development. 3D geological modeling technology and reservoir numerical simulation plays important roles in oilfield development nowadays. 3D geological modeling integrates the static information and data from cores, logs and seismic to approach the reality of reservoir as much as possible. Numerical simulation based on geological models, provides a way to use dynamic data by history matching production. Thus, static data from the subsurface reservoir and dynamic data from production are synthesized with the combination of 3D geological modeling and numerical simulation. At present, except upscaling, which connected these two steps, modeling and simulation are usually discussed and operated separately. This paper tried to find an approach to realize the couple of 3D geological modeling and reservoir numerical simulation, which admits the uncertainty of the geological model and emphases the use of simulation result to adjust geological model. 3D geological modeling provides reservoir numerical simulation with initial reservoir static parameter. With the initial geological knowledge, history matching is conducted to quantitatively describe the flowing rule of oil-water. During the process of matching production history, the changes of reservoir parameters may put insight on corresponding geological knowledge. Based on these updated geological knowledge, these possible changes are coupled to the new geological model. 3D geological model of B oilfield was studied as an example in this paper, how to sufficiently integrate numerical simulation results was researched to improve geological knowledge on the connectivity relationship between well groups, then the 3D geological model was updated.

Key words: Geological modeling; Reservoir numerical simulation; Coupling; History matching; Uncertainty

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INTRODUCTION

The B oilfield locates at Liaodong Bay sea area, Bohai Bay Basin, it is a large scale half-anticline heavy oil reservoir on Liaoxi low uplift. The major productive interval is Dongying Formation, Palaeogene. The oil-bearing area is about 20 km^2, with inter well distance of 350-400 m. The thickness of the productive interval is about 260 m, with 27%-55% of sand and it is mainly composed of fine sandstone and mudstone with different thickness. The main reservoir is composed of fine sandstone and siltstone with high porosity and middle to high permeability. The sedimentary environment of Dongying formation is fluvial-delta system of lacustrine, both delta front and pro-delta are developed in the study area. Sand bodies of distributary channels and mouth bar are the main reservoir in the study interval, with the features of box shape, bell shape and funnel shape in well logs. The distributary channels branch easily due to the gentle slope of the study area and amount of distributary channels formed as a result of the branching. Most of the mouth bars connect with each other and the distribution of reservoirs is sustained laterally under the combined effects of the branching and the reforming of wave.

1. WORKFLOW

3D geological modeling technology and reservoir numerical simulation play important roles in oilfield development nowadays[1-4]. 3D geological modeling integrates the static information and data from cores, logs and seismic to approach the reality of reservoir as much as possible[5-6]. Numerical simulation is especially important in the comprehensive adjustment and well pattern infilling. An effective prediction of remaining oil distribution from numerical simulation is based both on reasonable reservoir models reflecting geological knowledge, and on the knowledge of reservoir performance. 3D geological modeling provides reservoir numerical simulation with reservoir static parameter. With the initial geological knowledge, history matching is conducted to quantitatively describe the flowing rule of oil-water. According to the process of matching production history, the changes of reservoir parameters and the corresponding geological significance are presented. Basing on updated geological knowledge, these possible changes are coupled to the new geological model.

As shown in Figure 1, it is the workflow of geological model and reservoir numerical simulation results coupling. The integrated reservoir geological modeling includes 4 steps, they are detailed geologic correlation, microfacies analysis, establishment of geological knowledge database and facies-constrained geological modeling. The coupling of reservoir numerical simulation results is realized in two steps, firstly analyzing connectivity relationships between well groups, then characterize these geological characteristics in the coarsening reservoir model.

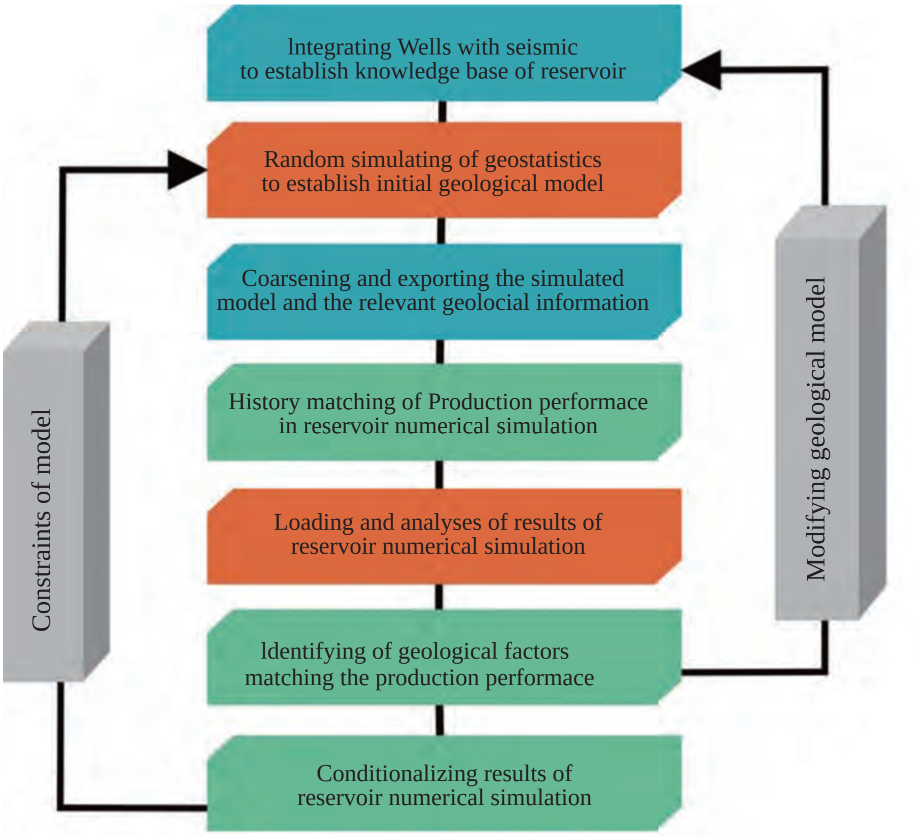

Figure 1
Workflow of Geological Model and Reservoir Numerical Simulation Results Coupling

2. INTEGRATED RESERVOIR GEOLOGICAL MODELING

2.1 Detailed Geologic Correlation

A reasonable stratigraphic correlation, which reflects the geological and statistical features of reservoir, is the base for an effective reservoir geological modeling. Controlled by formation framework and markers based on seismic and wireline logging data, subdivision was carried out according to the following steps.

Firstly, the framework of reservoir groups was built up. The division and interpretation of group boundaries were checked by 3D seismic and logs to ensure a sound framework for the following subdivision. This can be called as the large-scale frame.

Then, within the large-scale frame, detailed subdivision and correlation were done based on logs with some traditional correlation methods, such as morphologic semblance of logs and accordance of heights. The high resolution of logs in vertical direction makes this possible. 3D seismic data can help to avoid wrong correlation of subzones. This can be called as the fine-scale frame.

Lastly, reasonable division of subzones was done. The subdivision based on logs ignores the interwell facies distribution and may be too fine for the incorporation of seismic data considering the limited vertical resolution of seismic. Thus, the fine-scale frame need to be merged to get a proper scale for the integration of seismic and logs, and to get a peculiar feature of facies distribution for each subzone. Seismic slice along the fine-scale frame can provide information about the horizontal distribution of facies. According to the resemblance of horizontal facies distribution in adjacent subzones, the subzones can be merged into less subzones.

2.2 Microfacies Analysis

As the preparation of facies-constrained modeling, microfacies analysis was done, it includes the study on log facies of wells, horizontal distribution of facies and the connectedness among inter well sandbodies. The reservoir of B oilfield can be divided into four microfacies types, they are distributary channel, mouth bar, sheet-like sand and overbank deposits.

A semi-quantitative to quantitative geological knowledge database was established based on the geological analysis with the integration of seismic and log ,it is an important base for geological modeling. Each modeling unit has its particular geological feature of microfacies.

2.3 Geological Modeling

A tow-step modeling method was applied for this study. Firstly, as shown in the above figure of Figure 2, the facies model was built up by using sequential indicator simulation method with the constraints of microfacies distribution. Then the petrophysical parameters (porosity and permeability) were simulated under the constraint of well data and facies model. As shown in the below figure of Figure 1, it is the porosity model, the high value region is mainly distributed in distributary channel and mouth bar microfacies.

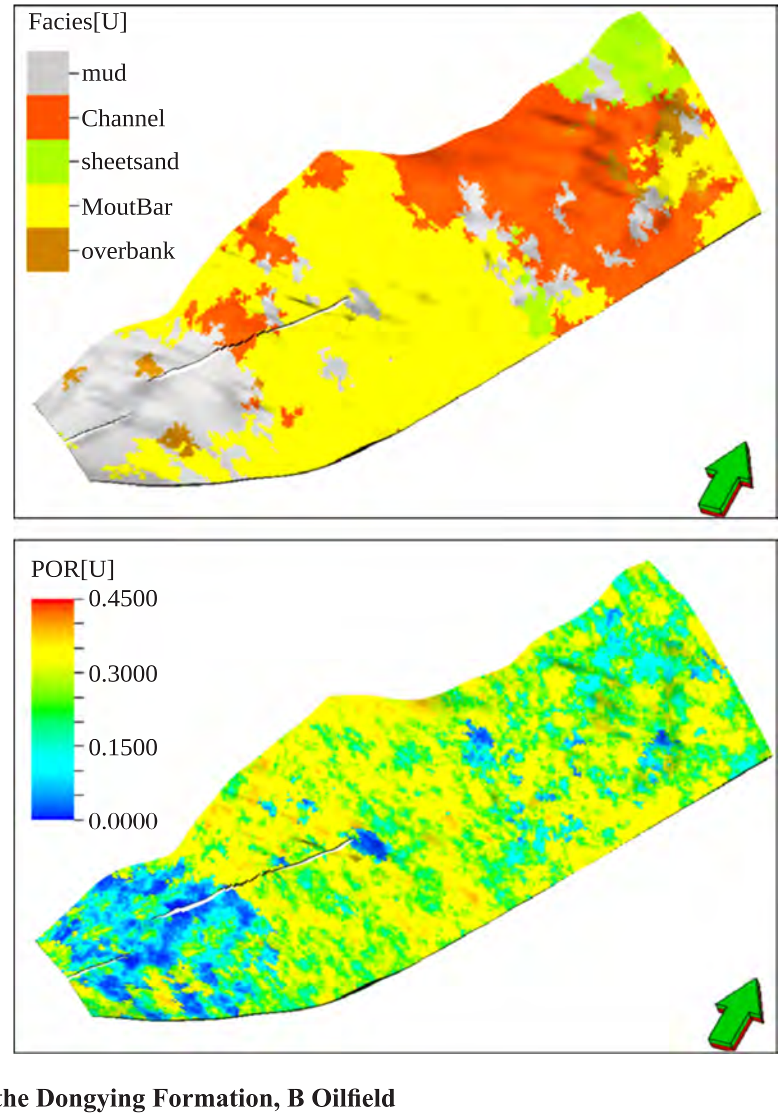

Figure 2
Geological Models of the Dongying Formation, B Oilfield

3. COUPLE OF GEOLOGICAL MODEL AND RESERVOIR NUMERICAL SIMULATION RESULTS

3.1 Variance Analysis of Models

Numerical simulation, based on geological model, provides us a way to use dynamic data by history matching for production. During numerical simulation, in order to get proper result of history matching, the reservoir engineer may edit initial model according to the knowledge about lateral distribution and connectivity of sandbodies from reservoir performance. A permeability variance parameter resulted by the differencing between initial model and edited model was calculated after history matching. It is the research basis for geological factors discriminant and analysis of the dynamic response of reservoir model. As shown in Figure 3, it is the variance parameter of permeability, the main region of variation is around the wells A11 and A10. According to performance analysis, the wells A11 and A10 are well connected. The water breakthroughs in oil well A11 are from the water injector A10.

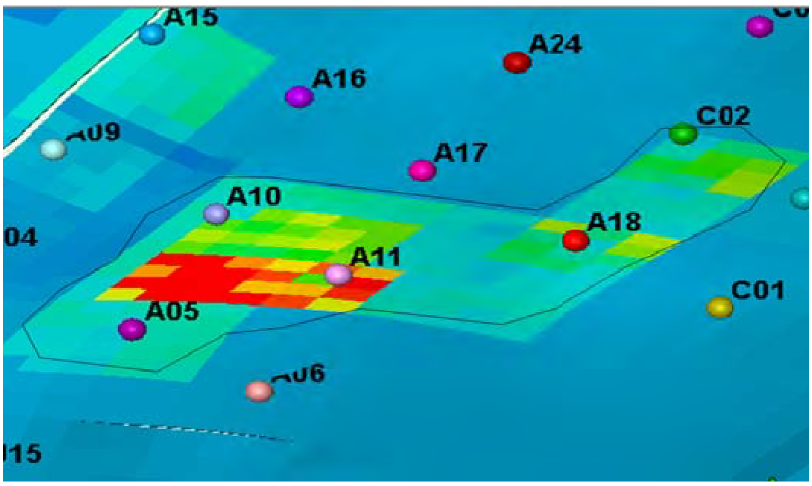

Figure 3
Variance Parameter of Permeability

3.2 Geological Analysis of Performance

In the initial geological model, as shown in the left figure of Figure 4, sandbody in the well C26hfma is defined as mouth bar, different from the distributary channel sands in well A10 and A11. According to reservoir performance, the wells A11, A10 and C26hfma are connected and probably belong to one channel. From the logs shape, the sand on well C26hfma, once was defined as mouth bar, can be defined as stacked channel. Furthermore, the history matching needs the permeability of this area to be aggrandized to 4,200 mD～12,000 mD, which is inside the range of distributary channel permeability (in average 3,446 mD, range from 52 mD to 12,000,mD).Therefore, the change of microfacies of the sand on well C26hfma is reasonable from performance analysis. Thus, as shown in the right figure of Figure 4, microfacies distribution is changed according to this knowledge.

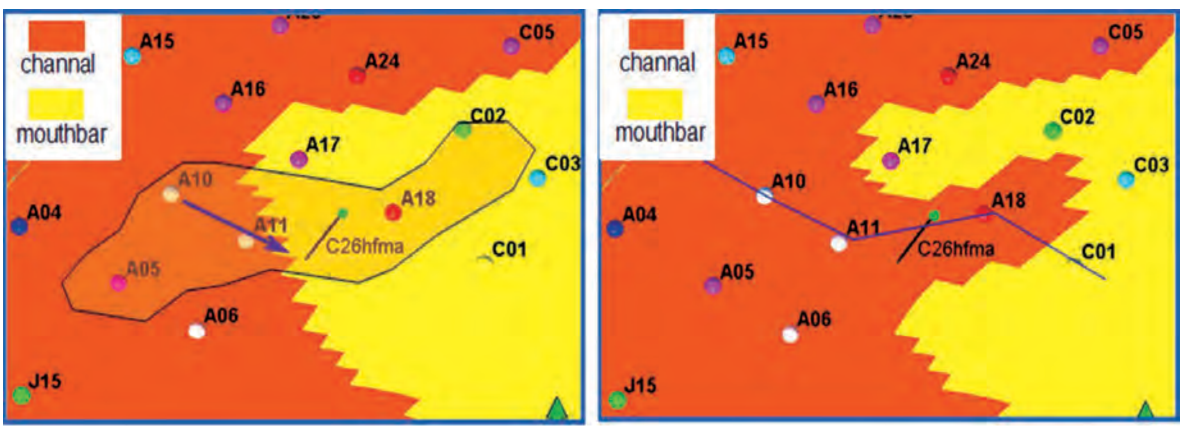

Figure 4
Comparing of Microfaies Map Before and After Coupling

3.3 Updating of Geological Model

Based on the new geological knowledge, the geological model is updated and scaled up for reservoir simulation. Thus, the coupling of geological models and simulation results is realized. As shown in Figure 5, it is the permeability model after coupling. Base on the new model, dynamic production history matching and reservoir numerical simulation were done. The results show that the new model effectively improved the reservoir numerical simulation history matching accuracy, remaining oil distribution prediction precision.

After this round of reservoir numerical simulation, how to keep the reservoir numerical simulation insights in the next round of geological models is challenging, such as the model updating after adjustment wells were implemented. Two methods are summarized in this paper, the first method is to convert the reservoir numerical simulation results into two dimensional trends to constrain the establishment of the property models. The second method is to co-simulate the property parameters of the new model by using the adjusted parameter model after reservoir numerical simulation as the constraint condition.

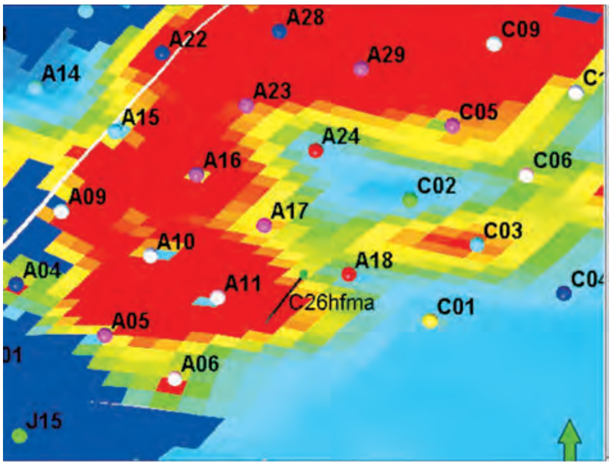

Figure 5
Permiability Model After Coupling

CONCLUSION

(a) Integrated reservoir modeling, incorporating geological data, logs and seismic data, based on reasonable division of modeling units, conditioned under geological knowledge and seismic data, can realize the combination of stochastic simulation method with deterministic condition.

(b) By the couple of geological model and reservoir numerical simulation results, the edition of property models is analysis from geological view. Thus more geological knowledge about the reservoir are get. In this way, a more reasonable model is assured by the integration of static data from well and the static data from production.

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