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Establishment of Geological Knowledge Database for Meandering River Reservoirs in Offshore Oilfields With Large Well Spacing

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Abstract

Based on quantitative logging microfacies identification, seismic constraint facies map compilation and horizontal wells architecture analysis, the reservoir geologic knowledge database of different grades configuration unit was established for meandering river reservoirs of Lower Minghuazhen Formation in Q oilfield. The results show that the average point bar sand body width is 360-783 m, the average sand body thickness is 4.0-8.5 m, the ratio of width to thickness mainly distributed in 40-100. Average lateral accretion layers dip is 5.7°, lateral accretion layers horizontal interval mainly distributed in 70-200 m. On the basis of reservoir geological knowledge database, a fine geological model was established together with sequential indicator method and equivalent characterization method. Base on the reservoir geologic knowledge database and geological modeling results, 130 adjustment wells were successfully deployed and implemented at the comprehensive adjustment process of Q oilfield, these wells made an obvious oil production increase effect.

Key words: Geological knowledge database; Offshore oilfield; Meandering river; Large well spacing; Reservoir architecture; Geological modeling

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INTRODUCTION

The establishment of reservoir geologic knowledge database is a very important basic work of reservoir characterization, the results can be directly as input parameters of reservoir modeling[1-2]. The establishment methods mainly include field outcrop data, modern deposition (including deposit investigation and observation satellite images), sedimentary simulation experiment method (including tank simulation and computer simulations) and dense well pattern anatomical method[3]. Dense well pattern anatomical method is mainly used for the establishment of the underground reservoir geologic knowledge database. Due to the restriction of the high cost of development, offshore oilfield has the characteristics of large well spacing, dilute well pattern, relatively little information, it difficult to do fine reservoir characterization, so research in building a quantitative geological knowledge base in offshore oilfields is too little.

Q oilfield in bohai sea area was studied as an example in this paper, reservoir geological knowledge database of different grades configuration unit was established by fully using of high resolution seismic data and a large number of horizontal well data in offshore oilfield. Lastly, fine geological model was established to provide support for oilfield adjustment and remaining oil exploration based on the geological knowledge database results.

1. OVERVIEW OF THE STUDY AREA

Q oilfield is a large meandering river oilfield located in the central bohai sea, Lower Minghuazhen Formation is the major hydrocarbon containing target zone, it is also the interest interval of the study. As the oilfield developed into the middle-latter period, a contradiction of injection-production become serious, there is an urgent need to develop fine reservoir research.

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2. ESTABLISHMENT OF RESERVOIR GEOLOGICAL KNOWLEDGE DATABASE

2.1 Establishment of the Microfacies Scale Geological Knowledge Database

Firstly, single well sedimentary microfacies was quantitative identificated by log curve. Then sand body boundary was depicted by comprehensive application of well and seismic data, plane microfacies map of each layer was compiled combining with sand body thickness distribution and single well microfacies. Lastly, measurement and statistics of microfacies sandbody size of each layer were done based on the plane microfacies map to establish the microfacies sand body scale reservoir geological knowledge database.

2.1.1 Quantitative Logging Microfacies Identification

Based on core analysis and logging facies characteristics, the meandering river reservoir of Lower Minghuazhen Formation in Q oilfield was divided into four kinds of microfacies, they are point bar, abandoned channel, crevasse splay, levee and flood plain. Based on coring well statistics, as shown in Figure 1, it is concluded that the deep lateral resistivity value of point bar is generally greater than 15Ω·m, the GR value is less than 73 API. The deep lateral resistivity value of abandoned channel is generally between 5 and 15Ω·m, the GR value is between 70 and 80 API. The deep lateral resistivity value of crevasse splay is generally between 2 and 6Ω·m, the GR value is between 70 and 80 API. The deep lateral resistivity value of levee is generally between 2 and 4Ω·m, the GR value is between 76 and 82 API. The deep lateral resistivity value of flood plain is generally less than 4Ω·m, the GR value is greater than 82 API.

As shown in Figure 1, the microfacies identification boundary of point bar and abandoned channel is clear. There is a certain boundary overlap of crevasse splay and levee, but it still can be used as the basis for the microfacies identification. Firstly, single well microfacies type was quantitatively divided by the deep lateral resistivity and GR curve, then correction was done based on the curve shape and depositional model for part of the wells. Lastly, the microfacies division of each single well was finished.

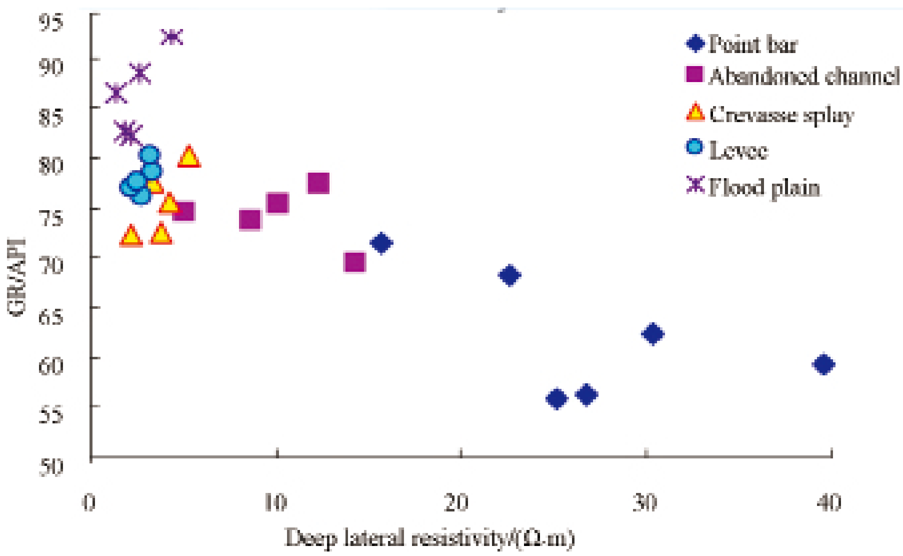

Figure 1
Quantitative Logging Microfacies Identification

2.1.2 Seismic Constraint Facies Map Compilation

The average well spacing of Q oilfield is between 300 to 400 meters, the predicted result of the plane sedimentary microfacies distribution based on the sedimentary pattern and sand body thickness distribution has greater uncertainty. Due to the buried depth of the field is relatively shallow, seismic data resolution is higher, it was concluded by analysis that microfacies types have good correlation with relative acoustic impedance. The relative acoustic impedance value of point bar is low, the value of the abandoned channel and crevasse splay is big, the value of the flood plain is the biggest, the result is shown in Figure 2. Therefore, sand body boundary was depicted by comprehensive application of well and seismic data, plane microfacies types of no well area were identified by relative acoustic impedance distribution. Based on the sand body boundary depicted by seismic data, the plane distribution form of the sand body and meandering river abandoned mode was studied together with the sedimentary pattern and sand body thickness distribution. Lastly, plane microfacies map of each layer was compiled under the control of a single well microfacies, the result is shown in Figure 2.

2.1.3 Microfacies Sand Body Geometry

Measurement of microfacies sandbody size of each layer was done based on the plane microfacies map, mainly

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includes the geometric parameters such as thickness, width and length. Statistics show that the size of the different microfacies sandbodies has a certain difference in Lower Minghuazhen Formation reservoir of Q oilfield. The width of point bar sand body is the biggest, in an average of 360 to 783 meters, the average thickness is between 4 and 8.5 meters. The ratio of width to thickness of sand body is an important geometric parameters to predict the distribution of sand body. Based on the study of the ratio of width to thickness of point bar sand body in Lower Minghuazhen Formation reservoir of Q oilfield, it was concluded that the value is distributed from 19.8 to 310.5, mainly distributed from 40 to 100, the average value is 77.

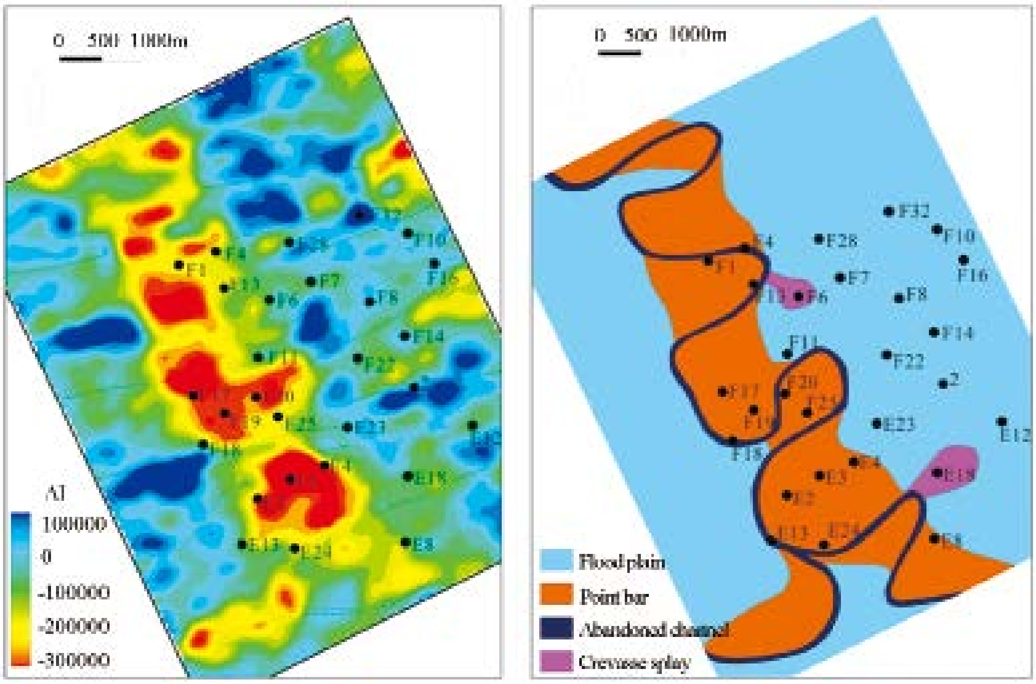

Figure 2
Acoustic Impedance (Left) and Microfacies (Right) Distribution

2.2 Establishment of the Reservoir Fine Configuration Scale Geological Knowledge Database

Sand body internal configuration study is an important research subject that has played a great effect in the process of oilfield comprehensive adjustment and remaining oil potential，now it has become a research focus in the oil industry[4]. This paper established the reservoir of fine configuration scale geological knowledge database based on the anatomy of the typical single sand body of Q oilfield.

2.2.1 Lateral Accretion Layers Division of Single Well

Core observation shows that the lithology of the regional common lateral accretion layers mainly includes silty mudstone, siltstone and argillaceous siltstone. The thickness of lateral accretion layers is mainly 20-30 centimeters, the thickest is 1 meter. Through the configuration analysis of the core, the logging curve characteristics of the lateral accretion layer and lateral accretion body were identified, it provided the basis for the realization of the logging curve configuration analysis.

2.2.2 Attitude of Lateral Accretion Layer and Horizontal Width of Lateral Accretion Body

The dip of 31 lateral accretion layers was calculated according to lots of horizontal wells and directional wells data in this area, and well deviation and stratigraphic dip correction were done to the calculated values. The results show that the lateral accretion layers dip in this area is distributed in 3.7°-8.5° , the average dip is 5.7°, it is close to other oilfields in China.

Alternate change of lateral accretion layer and lateral accretion body is reflected in the change of electrical curve when point bar sand body is researched by horizontal well data. As shown in Figure 3,the GR value get higher at each flood period in the horizontal direction, it represents the evolution from lateral accretion body to lateral accretion layer, the GR value of lateral accretion layer is generally 10-20 API bigger than lateral accretion body. Based on the analysis of 4 horizontal wells, it concluded that lateral accretion layers horizontal interval is distributed in 70-200 meters, mainly in 80 meters. When the well spacing is 300 meters, 3-4 lateral accretion bodies could be found between two wells on the lateral accretion direction

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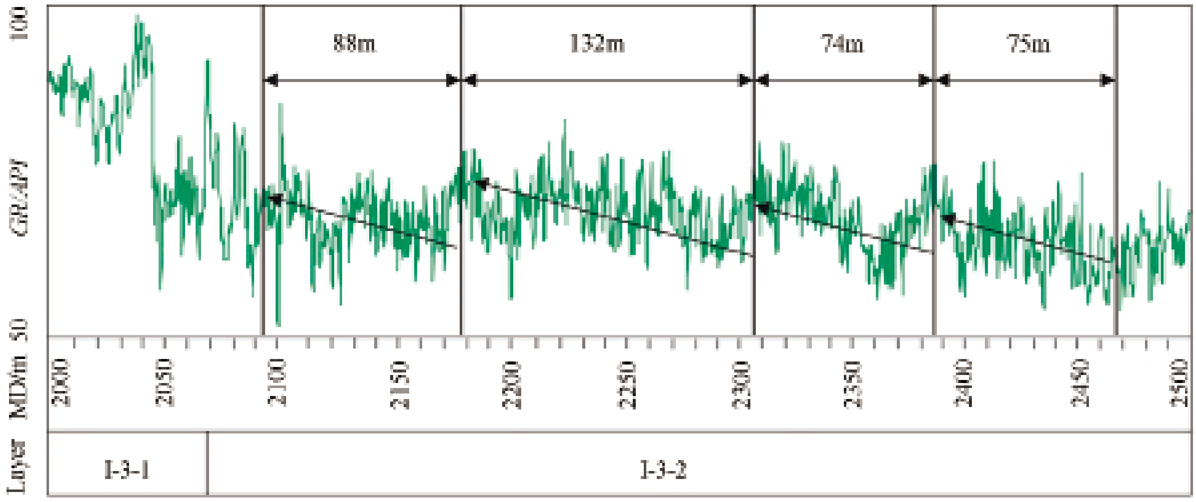

Figure 3
Horizontal Section Analysis of B26H

Based on the reservoir geologic knowledge database of different grades configuration unit, quantitative relation of lateral accretion body horizontal width and point bar width was studied. The correlation formula is: $w = 0.158W-41.524$, in which w is lateral accretion body horizontal width, W is point bar width, the unit is meter, the correlation coefficient is 0.901. The results show that there is a good positive correlation between the lateral accretion body horizontal width and point bar width. Therefore, by utilizing the regression formula, lateral accretion body horizontal width could be calculated by point bar width in the area there is no horizontal well.

3. APPLICATION OF RESEARCH RESULT

3.1 Establishment of the Geological Model

3.1.1 Establishment of the Microfacies Level Geological Model

Based on the establishment of the microfacies scale geological knowledge database, firstly, the microfacies sandbodies mainstream line direction were described by plane microfacies map, it could be used as the direction constraints of different microfacies in microfacies and properties simulation. Then the variogram of each microfacies of each layers was calculated based on the microfacies sand body geometry parameters. Lastly, microfacies model was established based on the above constraints, porosity and permeability models were established under the constraint of the microfacies model.

3.1.2 Equivalent Characterization of Lateral Accretion Layer

The scale of lateral accretion layer is small, the number and size are uncertain, and the distribution is also not stable, so it is difficult to characterize in a reservoir model, but it has important effect on fluid flow because of its poor permeability. In recent years, a lot of research have been done to characterize the lateral accretion layer in the reservoir model. These research is mainly done by local grid refinement[5]. But the distribution of lateral accretion layer is very wide in the meandering river sedimentary, this will lead to too many grids need to be refined, it often causes inconvenience because the grid size is far too much difference.

This paper proposes an equivalent method to characterize the lateral accretion layer in the coarsening reservoir model. The effect of fluid seepage affected by lateral accretion layer is characterized by adjusting the grid lateral conductivity. The geometric parameters of lateral accretion layer have not been characterized into the model, so the limitation of the grid size has been break[6].

In the equivalent characterization process of lateral accretion layer in Q oilfield, firstly, lateral accretion layer surfaces were generated in the microfacies level geological model by using the results of reservoir fine configuration scale geological knowledge database(such as attitude of lateral accretion layer and horizontal width of lateral accretion body). Then the lateral accretion layer surfaces were put into the coarsening geological model, grid system intersection operation and surfaces serrulation were done. Lastly, grid lateral conductivity multiplier data card on both sides of the lateral accretion layer surfaces was extracted.The grid lateral conductivity multiplier data card contains the location information of lateral accretion layer surfaces in the coarsening reservoir model, the effect of fluid seepage affected by lateral accretion layer was characterized in the model by adjusting the conductivity multiplier specific values.

3.2 Application Effect

Base on the reservoir geologic knowledge database and geological modeling results, dynamic production history matching and reservoir numerical simulation were done. The results show that the new model established based

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on fine geological knowledge database and equivalent characterization method effectively improved the reservoir numerical simulation history matching accuracy, remaining oil distribution prediction precision and the accuracy of logging interpretation of the water flooded layers.

Through the statistics results of the history matching of 44 well, it is concluded that there is 40 wells whose history matching error of single well moisture content is less than 10% in the new model, the coincidence rate is 91%. Through the statistics of 44 main sand bodies of 12 new drilling adjustment wells, the result is shown in Table 1, it is concluded that the coincidence rate of the water flooded degree predicted by new model and log interpretation after drilling is more than 90%. From 2013 to 2015, a batch of remaining oil enrichment region were effectively predicted base on the reservoir geologic knowledge database and geological modeling results in Q oilfield, 130 adjustment wells were successfully deployed and implemented at the comprehensive adjustment process of Q oilfield, these wells made an obvious oil production increase effect.

Table 1
Results Contrast Table of Model Prediction and Log Interpretation After Drilling

Layer	Number of the water-out layers of actually measured well logging interpretation	Number of the layers model prediction results in accordance with well logging interpretation	Coincidence rate /%
0-11	9	7	78
Ⅰ-3	12	11	92
Ⅱ-3	10	9	90
Ⅲ-2	7	7	100
Ⅳ-1	6	6	100
Total	44	40	91

CONCLUSION

(a) Due to the buried depth of the meandering river reservoirs in offshore oilfields is relatively shallow, seismic data resolution is higher, it brings unique benefits that compensate for the data restrictions caused by relatively small well spacing density. Under the guidance of the sedimentary model, the microfacies sand body scale reservoir geological knowledge database could be effectively established by comprehensive utilization of core, logging and seismic data.

(b) At the advantage of lots of horizontal wells in offshore oilfields, the reservoir fine configuration scale geological knowledge database could be established accurately.

(c) The reservoir geologic knowledge database of different grades configuration unit was established by comprehensive utilization of various data for meandering river reservoirs of Lower Minghuazhen Formation in Q oilfield. On the basis of reservoir geological knowledge database, a fine geological model was established, it has the achieved a good effect in actual application.

(d) It could provide a reference for reservoir fine characterization of the other similar offshore fluvial facies oilfields through utilization of the reservoir geologic knowledge database results in Q oilfield, especially for the parameters selection of reservoir modeling.

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