Effects of Architecture Modeling on the Distribution of Remaining Oil

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ABSTRACT

Considering the influence of architecture on the distribution of remaining oil, few studies have been done. geological models with architecture (Block A and B) and without architecture are established in this paper, as well as the corresponding simulation models. It can be summed up that saturation, porosity and permeability of the main river with regard to architecture are higher than these without regard to architecture .Through the linear row-shaped injection-production well pattern, the development of the model was simulated for 30 years, the parameters such as the liquid production, degree of reserve recovery, water cut and the three-dimensional model were compared after producing the same time .Through comprehensive analysis, the conclusion can be obtained that the models considering the geological architecture or not show great difference on the forming and distribution of the remaining oil in the simulation process. It is shown that whether considering the architecture in simulation or not has a significant influence on the prediction of the production of remaining oil, the analysis of underground fluid flow pattern and the development of oil field.

KEYWORDS: architecture; numerical simulation; remaining oil

INTRODUCTION

Reservoir architecture refers to the patterns, scales, directions of the units from different reservoir layers and their superimposed associations[1][2][3].In the petroleum-gas exploration and development industry, the study of underground reservoir architecture is mainly used for oil-gas field development .Under current conditions of economy and technology, nearly 70% of oil-gas source still remains untapped, about 35% of which is untapped because of the heterogeneity within the reservoirs[4] .At present, two-dimensional flat section is the major method adapted in the research of remaining oil[5] .As a result, it is impossible to simulate oil and water movement of reservoirs, and hard to see what effect controls reservoir architecture will impose on the remaining oil[6][7].Currently, scientists used to adapt Semi-quantitative Analysis, such as method of dynamic analysis, in order to know more about remaining oil in delta reservoir architecture, however, they pay little attention to three-dimensional numerical modeling about oil reservoir[8] [9].

To improve the study, an experiment of two model simulations about one oilfield has been carried in this article. one of our two models is under architecture, while the other is not .The study analyzed the differences between these two models .At the same time, we also studied the differences in the form of remaining oil, as well as in forming regions of the two models. Later we try to find out how architecture will influence the oilfield model simulations, and we manage to quantify the differences above so that the results would be more straight forward .The experiment has great significance for the research in remaining oil, especially to the new blocks with little data to study.

GEOLOGIC RESERVOIR DESCRIPTION

The oilfield lies in the southwestern Ordos Basin, annular depression to the west, Yishan slope to the east and Weibei uplift to the south .The oilfield just locates in the Annular depression .Terrains studied have an overall characteristic of higher in the southwest and lower in the northeast.

Main productive layers in this field are Member 3 and 8 of Yanchang Formation .In Member8, mean permeability is $0.5\times10^{-3}\,\mu m^2$, 66% of which is low-permeability reservoirs while the rest 32% is compacted reservoirs .So the strata in oilfield typically has low permeability. Our target reservoir is Paleogene 4th upper submember of Shahejie Formation in Dujiatai reservoir .The reservoir is 1200-1475 m in depth underground. Architecture distribution map of A block is shown below (Fig1).

According to the data, A block's and B block's producing position can be divided into 10 layers. A block's main productivity layers are 2, 4,7,8, while B block's are 3,4,5,6.

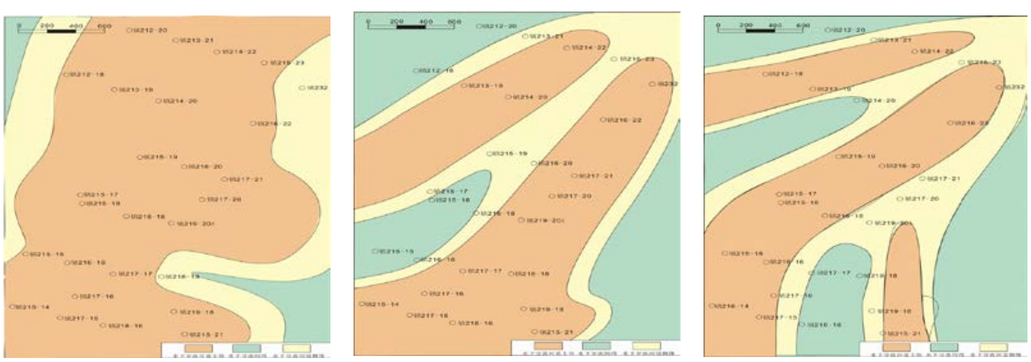


Figure 1: Architecture distribution map of A block.

NUMERICAL RESERVOIR SIMULATION

On the basis of data in oilfield and seismic log, the software, Petrol, is used to model the two geologic models :one takes the architecture into account, while the other is not .In the latter model, the one without architecture, finite differences are chosen to process the oilfield data, and then we build the geologic model .As the researched region adapts water flood development, two-phase movement of oil and water is the main motion mode in oil layers, so we choose Eclipse, a black-oil model, as the simulator.Figure2 is Three dimensional geological numerical simulation of A and B blocks.

Table 1 shows the statistics of the parameters in numerical simulation .From the present oil well's data, scientific data on maximum injection ability and production ability of oil-water wells were collected in the two models, the production and distribution of oil wells and water wells are controlled within this value, and the injection-production balance and pressure level are maintained during the development. The two models are water driven for the same time .A/B block are both in direct line drive flooding pattern.

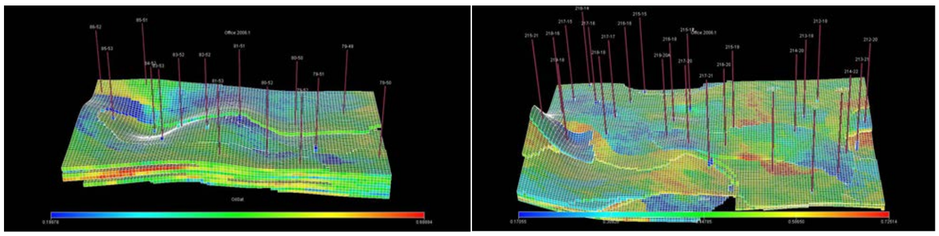


Figure 2: Three dimensional geological numerical simulation of A and B blocks

Table 1: The statistics of the parameters in numerical simulation

Item	value	Item	value
initial reservoir pressure /MPa	16.50	crude oil density /(g . cm^{-3})	0.89
initial bubble point pressure /MPa	5.78	natural gas density /(kg . cm^{-3})	1.10
formation crude oil viscosity/（mPa . s）	23.47	formation water density (g . cm^{-3})	1.00
ground crude oil viscosity /（mPa . s）	161.4	initial steam/oil ratio /(m^{-3} . t^{-1})	20.40
bottom water viscosity /（mPa . s）	0.50	crude oil compressibility /(10^{-4}MPa)	16.90
formation oil volume factor	1.10	formation water compressibility /(10^{-4}MPa)	4.50
formation water volume factor	1.00	rock compressibility /(10^{-3}MPa)	4.00

CONTRASTIVE STUDIES OF DIFFERENCES IN GEOLOGIC MODELS

Difference in Permeability

The coefficients of variation of permeability, heterogeneity coefficient and grade of each main reservoir in Block A and B are calculated (table 2).

From Table 2, a conclusion can be drawn that the three coefficients involved above are lower in the model with architecture than that without .That is to say, the former model has a stronger heterogeneity .In the Fig3, A2 means layer 2 in A block, and so on for each layer. With Eclipse, A/B block have been divided into several layers and established a definite numerical model of permeability plane distribution.Fig3 and Fig4 show a concrete analysis .The chart in the left is under architecture, and the right one is not.

It can be concluded from Fig3 that whether under architecture or not, permeability plane figures of A7 have the same form, although there are some differences in distribution range .When it comes to the model under architecture, it has a generally high permeability in main part of subaqueous distributary channel .Meanwhile, the permeability tends to be lower in the margin of channels .However, when not using architecture, we cannot find distinct distribution patterns of permeability because of its large distribution range .Just as it shows in Fig3,the high permeability tends to locate in upper-left as well as the bottom right .So It can be realized that the permeability distribution will be much different whether the experiment is under architecture or not, though the study is based on the very same oilfield data.

Fig. 4 also tells us that there is no permeability in the pinch-out side with the application of architecture, that is to say no mobile fluids .But the permeability in the pinch-out side can be measured when the study is not considering architecture, which is not consistent with facts .Besides, due to the existence of the pinch-out, the plane figure under architecture is smaller than that without architecture .The former figure has a more distinct distribution pattern of permeability and stronger anisotropy.

Table 2: The contrast of correlation coefficient of permeability of A/B block’s main layers

layers	coefficient of variation		coefficient of anisotropy		permeability contrast	
	not consider	consider	not consider	consider	not consider	consider
A 2	1.17	1.21	4.22	4.77	141.65	168.37
A 4	1.13	1.00	3.78	3.83	34.20	14.76
A 7	0.93	0.95	3.09	3.21	21.90	24.70
A 8	0.87	0.86	2.72	2.69	245.70	193.58
B 3	0.17	0.20	1.19	1.22	6.70	9.80
B 4	0.35	0.36	1.45	1.46	2.96	2.55
B 5	0.99	1.05	4.38	4.44	58.93	76.22
B 6	1.07	1.24	5.45	6.63	542.91	753.00

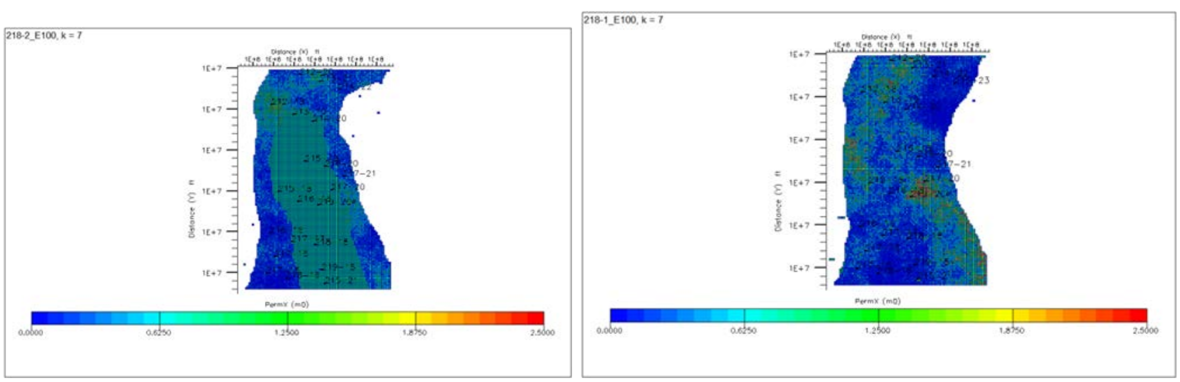


Figure 3: The contrast of permeability of seventh layer in A block

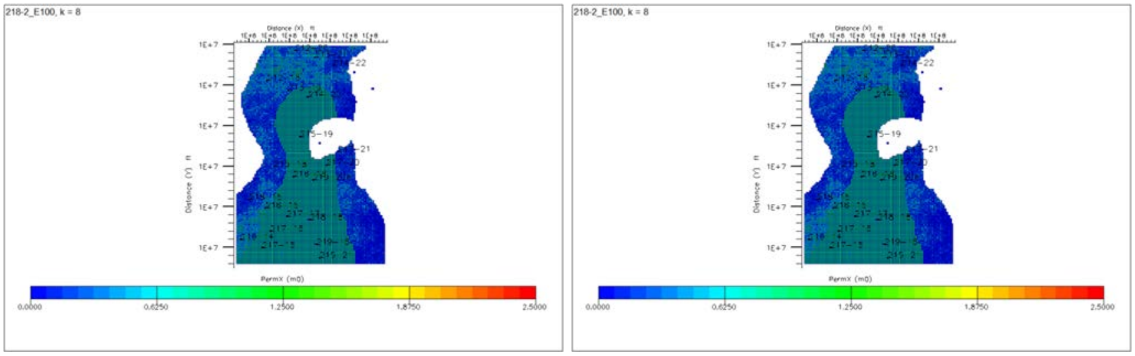


Figure 4: The contrast of permeability of eighth layer in A block

Difference in Porosity

The same methods was used to draw a distribution map of porosity .Take B4, A4 as examples, the data was analyzed in details.

As it shows in the contrast of porosity of fourth layer in A/B block(Fig5 and Fig6),it is obvious that porosity distribution areas are much different in two models .In the model under architecture, porosity in the drainage line is markedly higher, in the form of sheets, having a clear boundary against low-porosity area .However, in the other model, porosity distribution is less regular . Since the model without architecture based on discrete difference method, the porosity of the model tends to homogenize.

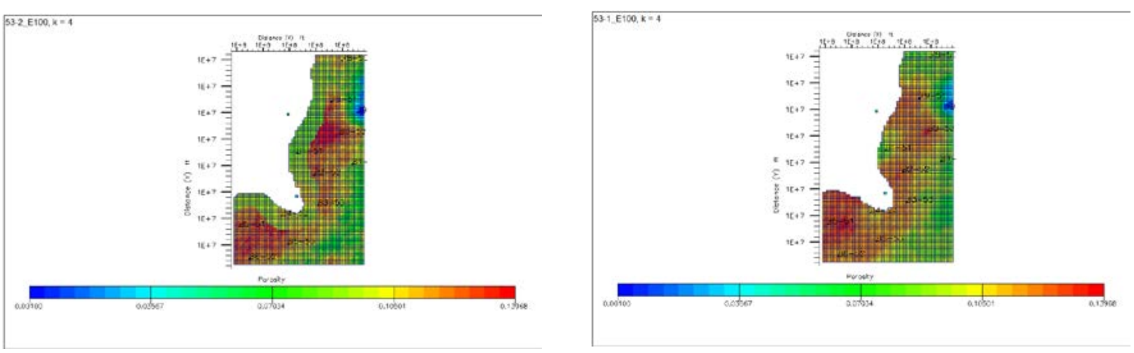


Figure 5: The contrast of porosity of fourth layer in B block

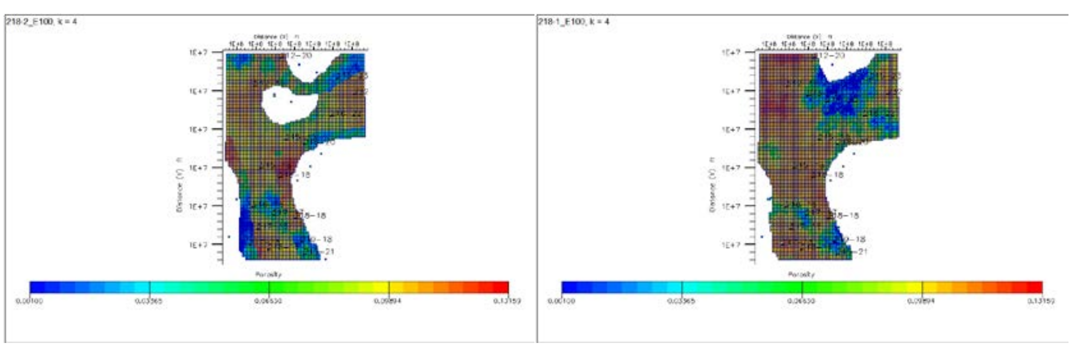


Figure 6: The contrast of porosity of fourth layer in A block

Difference in Saturation

In the same way, a distribution map of saturation was also drawn .Take A7, A8 as examples, the data was analyzed in details(Fig7 and Fig8).The left one has taken architecture into consideration, while the right is not.

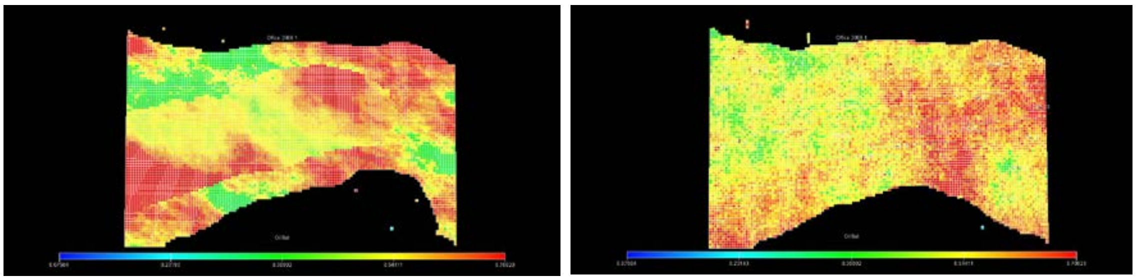


Figure 7: The contrast of saturation of seventh layer in A block

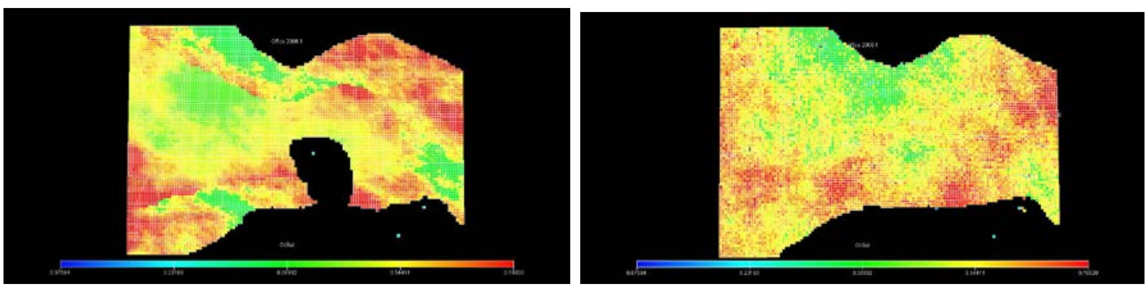


Figure 8: The contrast of saturation of eighth layer in A block

From the figure above, when the study has been done with architecture, It can be known that the crude oil is in the obviously centralized distribution, in the form of sheets, and concentrates in the top area .But we cannot come to such a rule in the study without architecture, because the oil tends to have a dispersed distribution, like a pile of sand .In the same way, the existing of pinch-out side has great influence on the saturation.

THE STUDY OF ARCHITECTURE'S INFLUENCE ON RESIDUAL OIL DISTRIBUTION

Parametric Variation in the Exploitation of Reservoirs

In the study, the same flooding well network is used for the two kinds of numerical simulations, by developing the same period of time, and the useful data have been acquired, such as degree of reserve recovery, water cut and accumulated oil production rate .In this way, the conclusion could tell whether architecture would have influence on the field development and what influence it is.

Take A block as an example (Fig 9):With the 30 years' oil recovery, the simulated data have some differences in the model under architecture and the one without architecture .The degree of reserve recovery turns to be 2.3% higher in the former model, water cut turns to be 6.1% lower, and the oil production is $0.54*10^5m^3$ in the latter model. So architecture constraint plays an important role in the simulation .As is shown in Chapter3 that porosity, saturation and permeability all have great effects on the research .That is just why the architecture study is more scientific.

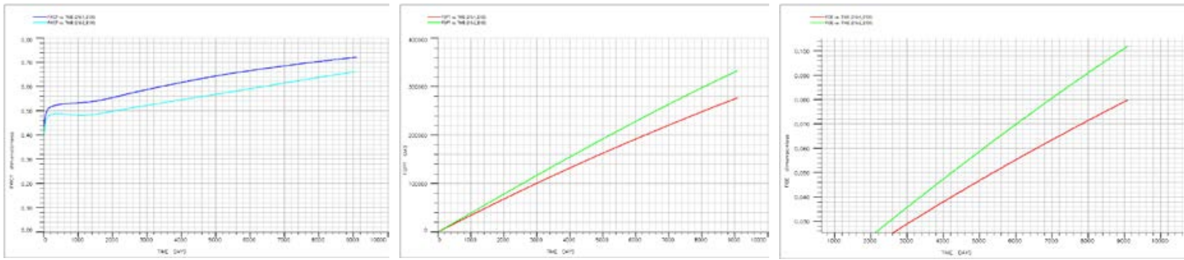
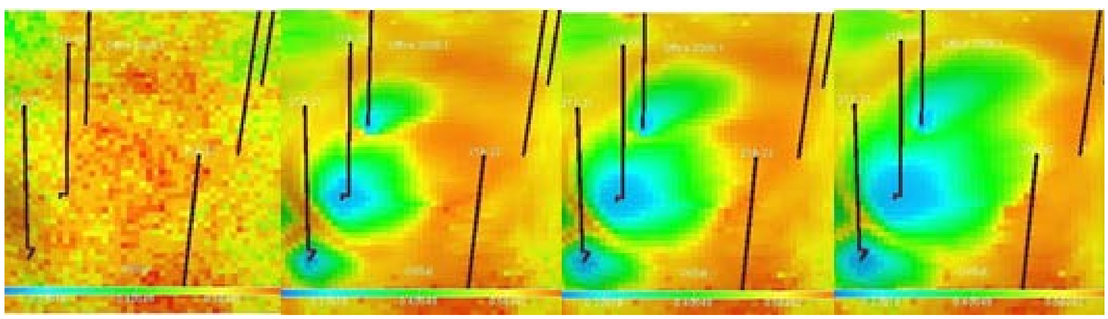


Figure 9: The compared of water cut, oil production and degree of reserve recovery in A block

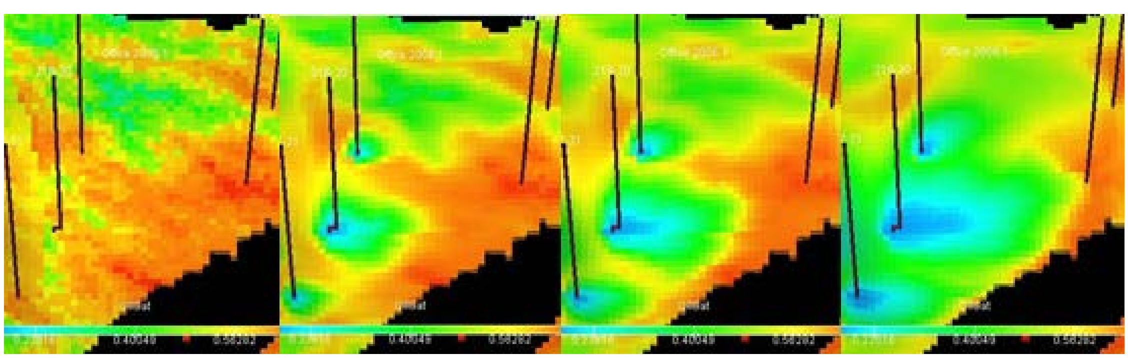
Difference in the forming process of remaining oil

In the research considered architecture, there is a strong fingering phenomenon (as it is shown in Fig10). Water breakthrough time is short in production wells .In the drainage line, water could flow into the production well, along the shortest channel from injection well to production well .After the channel comes into being, the water would meet less resistance, which is in favor of the movement of water .Then there would be more remaining oil because of the low sweep efficiency .Water close to the injection well has an elliptical shape, tilting to the production well .As for the model unconsidered architecture(Fig11),there is a low water displacement efficiency as well as no evident macro fingering phenomenon, and the Water breakthrough time turns to be longer. Water near the injection well has a slightly round shape.



Time:0 Time:10years Time:20years Time:30years

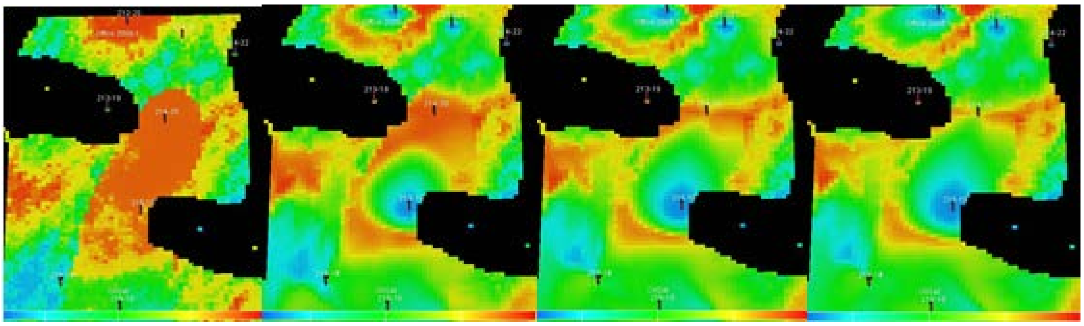
Figure 10: The performance history of fifth layer in A block unconsidered architecture



Time:0 Time:10years Time:20years Time:30years

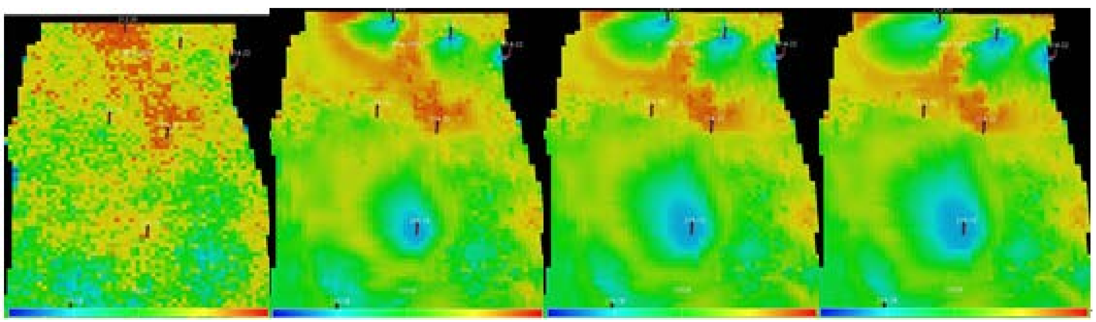
Figure 11: The performance history of fifth layer in A block considered architecture

In the research considered architecture, pinch out could be found easily (as it is shown in Fig12). It is hard for the injected water to flow, but Darcy velocity turns to be high in drainage line .However, in the study unconsidered architecture, the seepage can still be found in pinch-out side, and the porosity, saturation and permeability could still be measured out, which is no scientific .If the data is reasonable, a judgment could be made that water would flow into the pinch out through the rock cracks(Fig13),which means that there were remaining oil in the pinch out .And it is impossible .So the study considered architecture is consistent with fact.



Time:0 Time:10years Time:20years Time:30years

Figure 12: The performance history of ninth layer in A block unconsidered architecture



Time:0 Time:10years Time:20years Time:30years

Figure 13: The performance history of ninth layer in A block considered architecture

Difference in The Remaining Oil's Distribution Area

To find out architecture' influence on the remaining oil's distribution area, two factors, one is the existence of pinch out, the other is well pattern, were mainly analyzed.

(1) The pinch-out influence :In Fig14,from the data unconsidered architecture, there is remaining oil in A214-20 area, while in the other picture, the one considered architecture, the pinch out exists in the A214-20 with no remaining oil .So if the petroleum workers choose the unconsidered architecture model, they would likely fail to find oil in A214-20 zone .That is, the oil pumping operation in this area is meaningless, but a waste of money and time . An identical conclusion in Fig15 can be drawn.

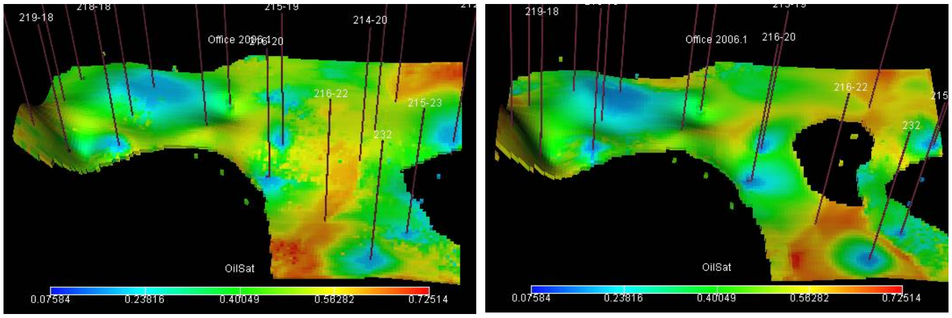


Figure 14: The comparison of remaining oil's lebensraum of the fourth layer in A block

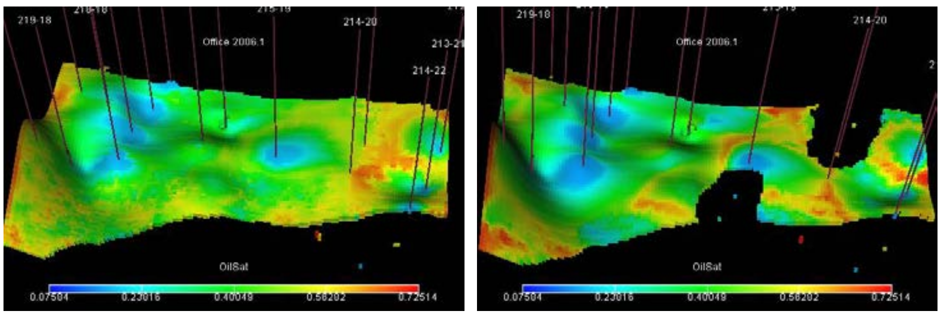


Figure 15: The comparison of remaining oil's lebensraum of the ninth layer in A block

(2) In the layers that have low permeability and poor physical property, a number of remaining oil may be missed in the imperfect region of the well pattern .In Fig16 and Fig17, workers are likely to believe that there is few oil in A212-18 when they have seen the model unconsidered architecture .But the reality is that there are plenty of remaining oil as it is shown in the study considered architecture .When it comes to the field operation, workers may hold a view that it is unnecessary to drill in A212-18, which is definitely wrong .In a word, all the factors should be taken into consideration in order to make the best judgment.

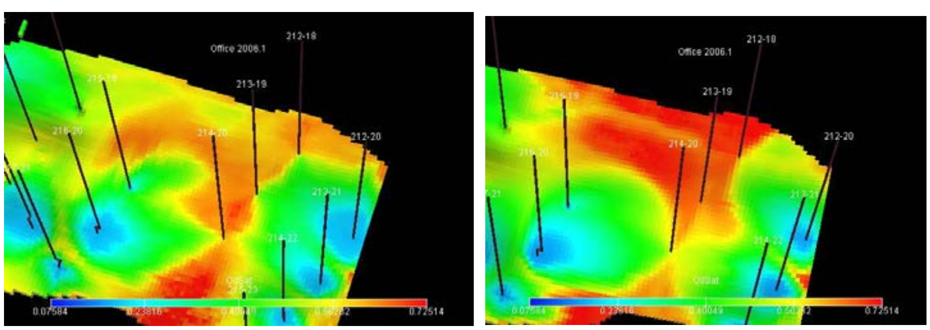


Figure 16: The comparison of remaining oil's lebensraum of the ninth layer in A block

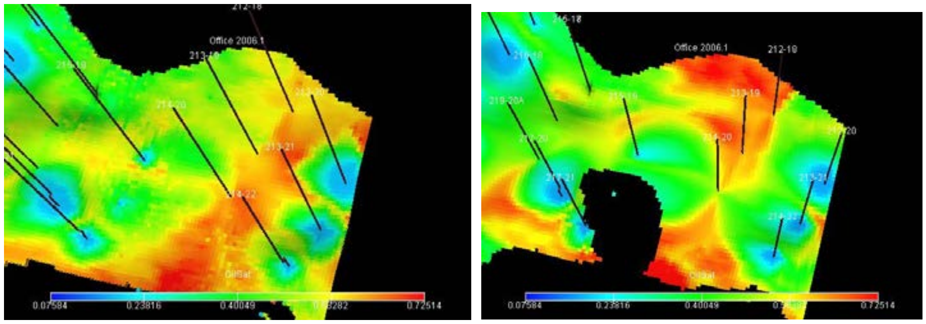


Figure 17: The comparison of remaining oil's lebensraum of the eighth layer in A block

CONCLUSIONS

(1) In the geologic model considered architecture, permeability and porosity turn to be higher in the main body of distributary channel, lower in the margin sediment channel .Oil concentrates in the high position with sheet distributions .Compared with the model unconsidered architecture, it has stronger anisotropy .And in the latter model, reasonable regularities of distribution of permeability, saturation and porosity can be hardly found, and the crude oil show as the scatter of points.

(2) From the data, such as water cut, oil production and degree of reserve recovery in the block, it can be found out that architecture have a strong impact on the design of recovery scheme .Because of fingering phenomenon, the study considered architecture conforms with the movement laws of fluids underground .And the pinch-out side also has strong influence on the formation of remaining oil . The conclusion has been drawn that the pinch out and the incomplete flood pattern result in the difference in oil's distribution area.

Above all, in the numerical reservoir simulation, whether the architecture is taken into consideration will have a significant effect on field development, such as the production forecast, placing of well in later development process, as well as the study on fluxion pattern of underground fluids .That is why we need to pay more attention to the architecture.

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