Application of new geological modeling technology in secondary development in Daqing oil field

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Abstract. The reconfiguration on underground geology system is one of the key techniques for secondary development in Daqing oil field. The geological modeling is the unique method to characterize new knowledge system of reservoir. The development history of maturing field is long. The structure of maturing field is complex and the distribution of oil remaining is highly scattered. The difficulty of adjustment and potential tapping is great. In viewing of demand for secondary development, the strategies and methods of geological modeling are proposed. According to the characteristics that many faults crosscut each other, the clue of fractional simulation—key horizon controlling—overall structural modeling is carried out to accurately and effectively build fine structural models. In order to approximate the real microfacies simulation effect, microfacies modeling technology of multiple iterations and geology tendency under vertical and lateral geology tendency constraint is used. And the attribute models could approximate the real parametric distribution. Moreover, in viewing of the key and potential reservoir sand, the countermeasure on configuration modeling by different stochastic simulation methods and step simulation is proposed to rapidly build geologic models. The geologic models are scientific and feasible. The above-mentioned countermeasures and methods have been used in secondary development of Daqing oilfield and the effect was well. This new technology presents directive sense.

1. Introduction
Because of the increasingly severe development situation, most of maturing land fields have been at later stake of high water cut and high degree of reserve recovery [1-3]. Yet, contribution of production and reserves of these oil fields is still greater. The potential tapping of remaining and recoverable reserves is still the essential measure for maturing field. Because of this, the secondary development idea is proposed—the new development system of maturing field is rebuilt using new technologies and methods and idea, in order to greatly raise the final recovery rate [4].

Rebuilding underground knowledge system is one of the key technologies for secondary development. In order to deepen oil remaining distribution regularities, three-dimensional geological modeling is the unique method to research oil remaining by using the three-dimensional seismic structure describe and distributing feature of reservoir. For geologic feature of maturing field with complex blocks and demands of secondary development, the corresponding countermeasures of...
triaxial geological modeling technology are proposed to meet demands of secondary development [5-6].

2. **Countermeasures on structure modeling technology in complex blocks**

Structural modeling that is the carrier of attribute models, could ascertain the spatial position of geologic model and contact relation of interlamination. Therefore, building feasible geologic models is the base of triaxial geological modeling [7-8] and it is the triaxial visualization of achievements on previous structural knowledge. Multitude faults and complex collocation connection are the classic geology features of maturing field. It is difficult to match the research report of geology with structure. In order to meet demands of secondary development, the study scale of geology should be more refined [9-10]. In addition, the study scale of geology should be research from reservoir to layer, until to several meters single sand body. It is well known that the completely presentation of feature of thin-numerou layers is difficult for modeling.

The Daqing oilfield, with a long development history, has been at later stake of high water cut and high degree of reserve recovery. Take Pubei area for example, the fault system is complex and the blocks are fracture (Figure 1).

![Diagram of some fault types](image_url)

**Figure 1.** Diagram of some fault types.

In viewing of difficulty and complexity of faults and layers, the technology countermeasures on structural modeling are proposed: fractional simulation, key horizon controlling, overall structural modeling. Structural model is composed with fault model and bedding model. As an important part structural model, effectiveness and accuracy of fault model affect particularity of subsequent modeling. Bedding model is the three-dimensional distribution of depositional interface. For the structural model of maturing field subdivided to single sand body, because of the multitude beds and thin sand body and different type fault, the fault model is established firstly, then bedding model is established.

Fault system is divide into3 levels as the scale. The development time of second level fault is long, the fault throw is large, propagation range is long. The third level fault performs control functions for local structure and oil/gas distribution. The other is the forth level fault with short development time and small fault throw. The research is constructed form different hierarchies. First of all, the second
and third level faults with stability development are simulated, in order to obtain the fault model that controls structure format. In addition, the obtained fault model could carry out quality supervision of the fault parameters and reciprocally crosscutting relationship between faults. Based on these, combining with analysis on local microtectonics, the fault model is established by mutual analysis and quality supervision. Bedded plane model reflects the superimposed form of sedimentary association. Because of the maturing field with multitude single sand bed and complex faults, it is hard to match layers and fault system. In consequence, based on fault model, the key single sand beds are built firstly to control layer stratigraphic framework and are use as restraint to build bedded plane of others single sand bed. The references on optimizing single sand bed are as follows: (1) Overall structure could be essentially controlled and bedding separation is not too large. (2) Fault framework of key bedding should present representativeness and could essentially express fault alteration. (3) The single sand bed essentially stand for oil horizon system. The optimized key horizons are initially simulated and mutually edited in order to accord with the knowledge on actual geology and be well fitted with fault model. Base on horizon model of key single sand horizon, building entire structural model of single sand bed could minimize the amount of work on beds system modeling and is easy to carry out quality control. The model is made to correspond in structure.

3. Countermeasures on modeling technique of sedimentary microfacies
Using multi scientific information, sedimentary microfacies modeling characterizes distribution of sedimentary microfacies [11]. As research and development of modeling technique, it is an inevitable tendency to truly reflect the subsurface reservoir feature. Structural models are the base of modeling and the attribute models are the attribute models manifestation. At first, the facies model that is built by using interpolation as algorithm tendency using well logging data is used for restraint on facies control. However, as the development of exploratory development technique, the knowledge of reservoir is deeper. Now, various methods are used to restrict predication on reservoir attribute [12-13]. The knowledge of sand and mudstone could not meet the necessaries of fine fine structural models or the secondary development of maturing field. Hence, precipitation facies are used. Because different precipitation facies have different distribution features of physical property data and. Under the restraint by precipitation facies, the attribute models come into real parametric distribution of geology (Figure 2-3). Thus precipitation facies models affect accuracy of attribute models and accuracy of subsequent numerical reservoir simulation.

![Figure 2. Attribute model without restraint](image)
Based on the method of sequential indicating simulation, microfacies models are built by using the restraint method of vertical and lateral geology tendency. According to subdivision result of microfacies in wells, traditional microfacies modeling using variation function analysis to interpolate on plane is not exact to reflect the cognitive achievements of geology. In addition, the antecedent fine geology achievement could not be used in microfacies modelling [14].

Except for restraint method of vertical and lateral geology tendency, the method of multiple iteration of geologic body are used in simulating process. In order to adjust simulation result to geology tendency, this method is used to achieve automatic contraction and effects on denoising. The simulation effect of denoising and convergence of geologic body attribute after iteration is better than the simulation effect with iteration (Figure 4). However, it is not the more iterate frequency, the better simulation effect. The simulation effect is also affected by coincidence degree of trend surface and thickness of microfacies classified by well point.

4. **Fine modeling of internal structure of key single sand body**

The redevelopment of the maturing fields is on the basis of rebuilding geologic model and reservoir model to form the new underground cognizing system, and according to the accurate geological research to find the potential oil sand body. Especially to the “double high” field, that reservoir mainly is fluvial sedimentary facies, remaining oil distribution in the “border, finely laminated, poor” parts of sand body or structure, need us take focus on the research of some “small and fat” sand body, depict to its internal structure and translate into geologic model, supply numerical simulation to subtly anticipate remaining oil distribution and find important breakthrough area of remaining oil “dessert”. Geologic model become the important vinculum to link geological research achievements and numerical reservoir simulation.
The key to single sand body internal structure detailed modeling is description of point bar internal lateral accretion layer, and the difficulty is how to use suitable means to translate the tectonics understanding into model. Using different stochastic simulation method nested technology in the modeling process, stepwise simulate spatial distribution of meandering river point bar and lateral accretion layer. Means on the basis of structural model combine with microfacies research achievement, first using seismic sedimentary facies simulation method to build river channel and point bar model, then using multipoint geostatistics method to simulate lateral accretion layer, put lateral accretion layer model embed into facies model and get configuration model.

Seismic sedimentary facies simulation is on the basis of seismic sedimentology, using high resolution 3D seismic data and manifold technology to delicate depict sedimentation system. Commonly used strata slice, well-log and seismic integration technique to predict sand body boundary and thickness trend, geological cognition restrictive revision to build channel and point bar model. Point bar internal configuration simulation is the key point of refined modelling, but the precondition is that make fine dissection of point bar internal configuration, which is the only way of old oil field redevelopment geologic research. After deeply analyze point bar internal configuration, have comprehensive comprehension about point bar internal lateral accretion layer’s parameters (curvature, trend, dip angle), reserve quantitative knowledge base to configuration simulation. The configuration is simulated by marked point process simulation algorithm and using multi-point geological statistics random simulation. Select the multipoint geostatistics for two main reasons: ① the multiple-point statistics colligates the advantage of method based on target and pixel; ② fine geological research of secondary development provides operability for training images. Due to the side product layer is thin, the simulation results’ non-convergence is easy to produce with grid precision simulation model of facies model. So a suitable grid size must be explored by continuous cross-validation before the simulation. That is to ensure the precision of configuration model by the way of secondary encryption.

After determining the grid size of configuration simulation, establish the training image of the side product layer. The establishment of the training image is based on the configuration study quantitative knowledge base, then build up training images(Fig.5) of the side product layer by using software, according to some determined parameters including side product layer’s curvature, trend. The training images reflect quantitative distribution pattern of lateral accretion layers. And simulation results(Fig.6) are approximate to the research achievement of geology of microfacies sand body.

Figure 5. Training image of lateral accretion layers
5. Conclusion

- In view of the structure modeling of the complex fault block old oilfields' secondary development, puts forward the technical countermeasure of the key layer controlling-distributed simulation-the overall modeling. Effectively solves the difficult problem of many single sand layers, complex fault and well-seismic matching and forms a quick and accurate modeling thinking.

- Sedimentary microfacies simulation puts forward a double geological trend constraint method including plane trend and vertical trend. At the same time, taking multiple iterations in the simulation process achieves a result of denoising, smooth, making full use of geological results and having high goodness of fit with geological trend and provides a good reference for microfacies simulation.

- In view of the "small-fat" oil-rich single sand body of the secondary development, focusing on dissecting, establishing internal configuration model, putting forward using different random simulation method nested using technologies to simulate microfacies-configurations gradually. Multipoint geostatistics method is applied to simulate configurations and can make the simulation results fine and reliable.

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