# 3D Geological Modeling in Digital Basin

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***Abstract*—3D geological model, including structure model and attribute model, is the basis of building a 3D digital basin. This paper analyzed the models and their applicated model types involved in digital basins construction. In digital basins structure model is expressed by TIN surface, and attribute model is expressed by voxels. Divided the level of model and its expression range in digital basin. Taking into account the construction of digital basins, detailed the 3D geological modeling flow of oil and gas reservoir, and focused on the structure modeling of the process.**

***Keywords- digital basin; classification of geological models; 3D geological models of oil and gas reservoir; 3D geological modeling; 3D structure modeling***

## I. INTRODUCTION

In China, after tectonic studies, basin analysis and basin simulation, the research on oil and gas basin has entered the digital basin stage [1]. The 3D digital basin actually takes the basin research way from 2D to 3D space, from the plane slicing into 3D with 3D visualization technique [1,2,3]. Research and construction of digital basin started from geological field and was based on the geological field. At the same time, along with the extension and cross of geology and engineering in oil and gas field development, development project occurred in digital basin. The 3D digital basin bases on 3D geological model, combines the information of oil and gas exploration and development, with which geological research, evaluation and analysis, numerical simulation, pattern arrangement, fracturing simulation are developed, and provides the support for the exploration and development of oil and gas resources management.

The base of construction of 3D digital basin system is construction and visualization of 3D geological model of the oil and gas reservoirs, [4,5]. Geological model itself contains structure model and attribute model. Each kind of model has different applications in the digital basin. Two kinds of models complement each other, and meet the requirements of application about 3D digital basin coming from the management and production enterprises.

## II. 3D GEOLOGICAL MODEL IN DIGITAL BASIN

In the process of researching geological model of oil and gas reservoir, many scholars put forward different model concept, [6, 7, 8]. For example, divided by the structure level, size, coverage, there are the formulation of trap structure model, tectonic geological model, geological model of reservoir and flow unit model; and classified by different geological attribute, there are the formulation of fluid distribution model, face model, porosity model, permeability model and saturation model.

In the 3D digital oil and gas basin, D geological model is divided into two categories according to its characterizing content: 3D structure model and 3D attribute model. Oil and gas reservoir type, shape, size, internal structure can be attributed to the oil gas reservoir structure category known as 3D structure model; oil and gas reservoir parameters, fluid distribution, stress field can be classified into oil and gas reservoirs geological attribute category, and 3D geological model characterizing these properties is called 3D attribute model.

3D structure model can express many content and each level objects in digital basin, such as basin model, depression model, trap model, reservoir model and sand body mode. For a wide range entities, such as basin, depression and trap, researchers pay close attention to the overall distribution, not the internal property, so surface model is suitable,[3]. For small entities, such as reservoir, sand body, surface model and voxel model are both suitable. The classification is shown in Fig.1.

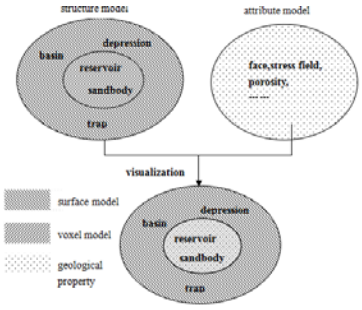


FIGURE I. CLASSIFICATION OF 3D GEOLOGICAL MODEL IN DIGITAL BASIN.

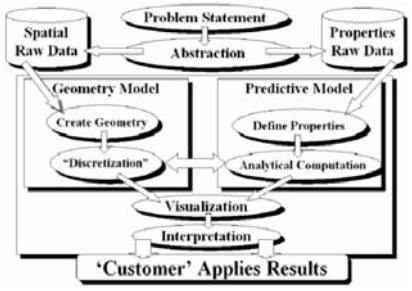


FIGURE II. BASIC FLOW OF 3D GEOLOGICAL MODELING[10,11].

The use of 3D geological model is closely related with 3D visualization technology, must visualize before you can really show in front of users. From Fig.1, structure model can be visualized directly, while attribute model must rely on the element, attribute in each voxel to voxel values, and be shown.

## III. THE HIERARCHY DIVISION OF GEOLOGICAL MODEL IN DIGITAL BASIN

From the scale and performance of the content, models in 3D digital basin can be divided into three levels. Because of different data involved in different levels, the specific modeling method is changed accordingly.

The first level of model is the whole basin model, which is called the first-order structure model in this paper. This level of model is a 3D digital model of an oil and gas basin reflecting the overall "trap" in the basin. In this paper,the "trap" stands for the small structure of the basin, collectively known as the second level structure.

The second level of model is the local trap model, which reflects the structural form of traps (i.e. second level structure), including faults, morphology of fault blocks, and distribution,oil and gas range, thickness of the reservoir, etc.

The third level of model is the fine reservoir model, which reflects the fine distribution of reservoir in small oil and gas block, including various petrophysical characteristics, the stress characteristics, distribution of oil and gas wells and well track of reservoir in this block .

According to three levels of the model hierarchy, every level of models express different information. At basin level, the main role of structure models is showing the overall appearance of a basin, mainly related to the geographic information (such as topography, DEM), the global structure information (such as the trap distribution). Oil region partition and other information can be attached to the model, and basin evolution can be behaved with it. At the trap level, the main role of structure models is showing local structure, mainly involving the stratum information, reservoir distribution, additional well distribution, ground facilities, production statistics, reserves estimation and other information, and structure evolution process can be presented. At the reservoir level,[12], the main role of structure models is showing the structure and properties of the reservoir, mainly related to rock properties, mechanical parameters, stress, cracks. Wells can be attached to the model, and the result of reservoir numerical simulation can be presented.

## IV. 3D GEOLOGICAL MODELING IN OIL AND GAS RESERVOIR

### A. *The Basic Process of 3D Geological Modeling*

The 3D geological modeling are divided into two categories, one is to build spatial geometry model, the other is to build spatial property model (i.e. predictive model), A. Keith Turner of Colorado Mining University proposed a typical 3D geological modeling process, as shown in Fig.2, [10].Corresponding to the two kinds of modeling process, the original data are divided into spatial data and property data. After processing, the original spatial data are used to establish the geometry model to reflect spatial form of geological body; the original attribute data is used to establish the predictive model to reflect the distribution of geological property in a geological body space.

### B. *3D Geological Modeling in Digital Basin*

*1) The overall process of 3D geological modeling in digital basin.* From throughout the basin into individual reservoirs, 3D digital basin construction contains the information of all levels of entities with different particle size. 3D digital basin need not only 3D geological model to express characteristics of a small range of reservoir, but also 3D structure model to express a wide range of structural feature in an oil and gas basin.

Through the data generated in oil and gas exploration and production and the reservoir modeling requirements in digital basin, this paper put forward a refined 3D geological modeling process applied to oil and gas industry, shown in Fig. 3.

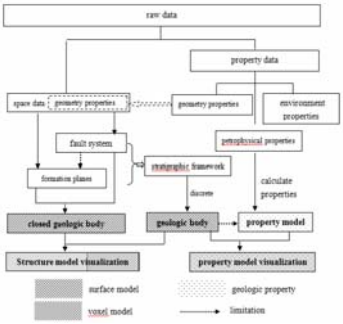


FIGURE III. THE 3D GEOLOGICAL MODELINGFLOW IN DIGITAL BASIN.

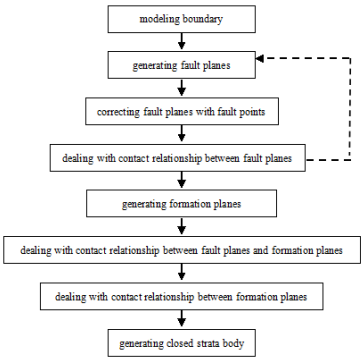


FIGURE IV. FLOW CHART OF 3D STRUCTURE MODELING.

As shown in Fig.3, consistent with Turner's, the overall workflow of 3D geological modeling process divided into structure modeling and property modeling. The modeling results are structure model and property model (i.e. predictive model), and the modeling data is also divided into two parts, spatial data and property data.

*2) 3D structure modelling.* In the structure modeling process, the original data used to modeling includes both spatial data and geometry property data, referred to as spatial data here. 1) To establish the fault system by generating fault surface with spatial data. 2) To establish formation planes with spatial data and fault system. 3) To generate closed geological body with the fault system and formation planes. Then structure model has been established and can be display to the user. This process is surface modeling and the result is surface model.

The system consisted of fault system and formation planes is called stratigraphic framework in oil and gas field, and controls the boundary for discretizing the internal region to voxels, such as hexahedron and then can be display to the user. This process is voxel modeling and the result is voxel model. Generally oil and gas geological researchers call stratigraphic framework as geological structure model, and call the discrete model as formation entity model, [12, 13].

3D structure model mainly focus on the structure interface, such as the fault plane, formation plane and unconformity plane, [14]. So it is possible to drive the modeling process with planes as the core, [10, 11], as shown in fig.4. The key technologies of 3D structure modeling mainly include: 1) building a reasonable data model to manage geological data; 2) constructing reasonable geological interface with geological constraints; 3)processing contact relationship between geological interfaces (such as fault and fault, fault and formation, formation and formation); 4) extracting geological unit block and sealing to form a body. Under the condition sparse original data, it is difficult to establish geological models, then it is necessary to import expert experience into the modeling process by interaction and adding auxiliary explanation data.

*3) 3D property modelling.* Property data in oil and gas reservoir can be divided into geometric properties data, rock property data and environmental property data. Geometric properties data is attributed to spatial data, and generally environmental property data is not considered. The main purpose is to predict and express the rock properties in property modeling. For a specific property, to make calculation rules and calculate the property values of each voxel generated in structure modeling, and then attribute model has been established. At last to complete the visualization of property model based on voxel model with color and display to the user.

## V. CONCLUSION

As a visual way, 3D geological model has been widely applied in oil and gas reservoir exploration and development and the information construction. The reasonability of 3D geological modeling method directly affects the correctness of geological study. Effective use of 3D geological model can greatly promote the understanding of oil and gas geology, improve the way of developing oil and gas, perfect oil and gas field development plan,and promote the overall progress in exploration and development of oil and gas field. Take advantage of 3D structure model of control, and apply 3D structure model to study of oil and gas field development, rather than as an intermediate result of property modeling, it will promote the use of 3D geological model.

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