Application of Corner Point Grid for the Generation of 3D Geological Models for Drilling Purposes

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ABSTRACT: Due to its extreme applicability, 3D geological modeling gains more and more space in the oil industry, being today indispensable in the process of geological and geomechanical characterization of the subsurface. The objective of this paper is to present a workflow for structural modeling using a structured grid of Corner Point Grid geometry, exposing the possible gains in quality and robustness in the final volume of a model specially built to characterize the overburden. Through the interpretation of seismic data and well logs, the initial data to start building the model were obtained, extensive quality control processes were carried out to ensure the resolution of possible errors in the mesh due to the non-verticality of the faults. As a result, it was obtained a grid where the structural geology was honored, making it possible that distributions of properties carried out on it will be much more consistent with the reality of the oil fields modeled.

KEYWORDS: Geological modeling, structured grid, corner point grid, structural geology, post salt.

1 Introduction

The development of subsurface 3D geological models are today of extreme importance for the characterization of reservoirs, exploration geophysics and production, analyzes that are indispensable in the oil industry. A quality model should always honor the structural geology and stratigraphy identified in the seismic and well data applied in its generation (Wu, 2017).

Structural modeling, more specifically, is a means of generating information capable of implementing, through visualization and comparison, the model under development, it also has a data-provoking character capable of supporting numerical models referring to more complex phenomena (Caumon et al., 2009).

Based on this assumption, the structural models are vital to the development of projects that aim beyond a robust geological characterization also analyzes focused on well engineering, where structural geology is applied as a prerogative in many of the circumstances addressed. As an example, Caumon et al. (2009) emphasize in his work the importance of 3D structural models in solving geomechanical, geological and geophysical problems. Cerveny et al. (2005) and Andreoletti et al. (2009), highlight as an example, the complexity of failure analysis in certain oil fields, which can represent extreme scenarios, both a barrier and a path for the fluids flow.
The workflow developed in this article aims to present the possible gains in quality and greater robustness in a geological model, initially developed in a simple grid, through the insertion of structural geology applied to a structured grid of corner point grid geometry. This geometry presents hexahedral cells where they will have their geometries modified in the places close to the faults, the vertices will be “pulled”, to insert them in the model under construction. This type of grid is characterized by the existence of cells with different increments and considered by the bibliography as the closest to reality (Zakrevsky, 2011).

2 Metodologia e Resultados

To develop the methodology that will be presented below, a smaller scale area of a given offshore field previously modeled in a simple grid was delimited. The previous geological and structural study focused on the overburden portion of the field under study, the grid generated and presented during this work was developed for the post-salt portion of the field.

The workflow chart generated for the construction of the structural geological model can be previously observed in Figure 1. The procedures and results will be presented in more detail in the course of the paper.

Figure 1. Proposed flowchart for making a structural geological model for drilling purposes.
2.1 Preparation of the input data

In the elaboration of a 3D structural model, the input data can be diverse as already suggested by Wu (2017), Kaufmann & Martin (2008), Caumon et al. (2009), Fernández et al. (2004). For the development of this work, 20 wells were used as well as a 3D seismic cube, six previously mapped surfaces and fourteen faults classified as having large displacement.

Effectively, the first step in making the structural model is the definition of an area limit for it and the quality control of the faults and mapped horizons. The faults are visualized in a 3D window so that it is possible to ensure, when existing, the correct relations between them. It should also be checked if there was a duplication of faults during the interpretation and incoherences of structures with the seismic. Horizons are also analyzed in 3D, their interpretation must be checked so that possible inconsistencies (spikes) are eliminated.

In the data package used no inconsistencies were found in the horizons and they did not need to be smoothed either, this process had already been carried out in a previous workflow developed with the same horizons. The fault data package required several interventions, spikes (interpretation errors) were initially deleted and very small scale faults were removed from the project, as the analyzes do not aim at such a scale. An initial approach in the process of standardizing the surfaces of the faults and checking with the seismic image was also carried out.

After the first quality control of the data, it is necessary to define an interval of uncertainty between the fault plane and the mapped horizon, so that during the generation of the grid there is no overlap of data, which could result in errors in the final result of the model. This uncertainty can be reworked later in the flow, if necessary. After this first approach, a fault model must be created to start the grid construction.

2.2 Fault Model

In this step, the interpreted faults are converted into faults plans, consisting of pillars, belonging to a newly created model. For this conversion, the column and fault type must be defined. New revision work is then implemented on the faults in the model. The previously identified relationships, in the quality control and pre-processing stage, are now defined through operations that affect the type of truncation between the structures.

A process of smoothness is performed on the pillars to make the failure plane as homogeneous as possible, establishing fixed distances between the pillars, smooth gradation in height and so on. The intention is to reduce the possibility of errors generated by cell distortion during the generation of the grid skeleton.

2.3 Structured Grid - Corner Point Grid

It is through the generation of the top, middle and bottom skeletons that the corner point grid is effectively started. To do so, it is initially necessary to define the increment of the grid mesh, followed by the classification of the faults according to trends I and J.

A cell increment of 100x100 was defined, so that was the possibility of communication between this grid and the previous model grids (simple grid).

Fault trends were automatically set using the 22.5 ° angle, given by the software as the default. In the 2D window, all trends of the faults were checked and corrected when necessary.

At this point in the process the faults of the model are used as the basis for starting the 3D grid, where the three skeletons, top, middle and bottom, connect to the top, middle and bottom nodes of the fault pillars. An example can be seen in Figure 2.
Careful quality control was carried out at this stage, to ensure the quality of the mesh generated in the three skeletons. Figure 2 shows the final result, after their quality control.

![Figure 2](image)

Figure 2. The three previous skeletons of the 3D grid presented together with the faults used in the process of the model construction.

### 2.3.1 Horizon Modeling

One of the problems faced in the modeling process is the distortion of the cells due to the non-verticality of the faults. To solve this problem during the creation of horizons, and also taking into account the faults already present, the Volume Based Model (VBM) algorithm developed by Mallet (2004 *apud* Gringarten *et al.*, 2008) is applied. Through it, an iso-stratigraphic property is calculated for the area, being continuous in the entire area that is being modeled and discontinuous through the faults, thus decreasing the variations in inclination (dip) and thickness.

In this stage, the spacing between the fault and horizon must be checked again, for the model under construction the value of 50 meters of spacing was defined. Another quality control required in this step is the calculation of the fault displacements. Each fault must be checked and adjusted individually, ensuring that the fault nodes and horizons of the model are correctly adjusted, only then will the calculation of the displacements be done correctly.

For the model under construction, the chronostratigraphic horizons of the Miocene, Eocene, Cretaceous, and Cenomanian were used, as well as the horizons referring to the bottom of the sea and the top of the salt. All faults were reviewed, but not all faults x horizon relationships needed correction.

### 2.3.2 Vertical Resolution

The last step refers to the definition of a vertical resolution for the model, a step also known as layering. The definition of this resolution took into account the final objective of the study, which consists of a discretized 3D model for drilling wells. For this reason, the average value of Z along the pillars, referring to the zones created in the modeling of the horizons, was divided by two, which resulted in an average thickness of two meters for the cells.

At the end of this process, the final grid was generated (Figure 3). Besides, quality control is performed on the volume, for this purpose the Cell Volume and Cell Inside Out calculations were applied. No negative cell volume value was found, which points to the success in making the volume.
Figure 3. Cross section of the structured grid created at the end of the workflow.

2.4 Comparison between grids

A comparative analysis between the structured grid (corner point grid) generated through the workflow and the simple grid was performed, as can be seen in Figure 4. Although the morphology is honored in a simple grid (without inserting faults) the movement of the strata is only honored when using the structured grid in it, the horizons are shifted based on the movement of the structure inserted in the grid. Through this result, it is possible to analyze the interference of the structures in the analyzed area.

Figure 4. a) limits of zones presented in a simple grid b) limit of zones presented in a structured grid of corner point grid geometry, in black there is one of the structures taken into account in the construction of the volume.

3 Final Considerations

The pre-processing and quality control of the data was fundamental for a more fluid development of the proposed flow. As several steps require punctual quality control, the time required at work would be much greater if the data had not been previously worked on.

The definition of adequate spacing between fault and horizon was essential in reducing errors in the skeletons of the grid, as well as the need for simplifications of certain structures.
The quality control related to the displacement of the faults was the stage that demanded the most time in the process of elaborating the grid, because it required individual checking between the horizons and faults nodes, which was already expected.

Through the results obtained, it is observed that geology tends to be better represented when the structural of the area is taken into account, by calculating the displacement of the structures the contact relationships between lithologies can be better represented after the distribution of facies and population of other properties on the grid.

Despite adding more time to the workflow comparing to the generation of a simple grid model, it is believed that the gains in the use of a structured grid, in the short and long term, have much to add in a 3D geological model making it possible that the properties once distributed in the same are much more consistent with the geological reality of the fields worked.

It is recommended as a next step that quality tests related to the distribution of properties, already analyzed by this research group, be developed. From the application of this methodology, it will be possible to develop directly integrated analyzes with well engineering.

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REFERENCES


