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New workflow of Stratigraphic Grid building from Relative Geological Time Model

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Summary

Seismic interpretation and cellular gridding are traditionally performed independently. A one-way approach also aims at using a few horizons to generate the grid. At this point, options of getting back to the input horizons edition are limited and the most of the refinement has to be laboriously performed in the cellular grid environment. This paper shows an interactive two-way workflow enabling to connect the Relative Geological Time modeling method (Pauget et al, 2009) with a stratigraphic grid creation process. The interpreter dynamically defines the geological correlations, unit boundaries and bedset terminations within the RGT model. He has the control to adapt the cell pattern of each stratigraphic unit according to the seismic quality. The synergy between seismic interpretation and geomodelling is thus optimized in order to offer new perspectives for static and dynamic simulations that can be performed at various stages either during the exploration or the development phase.

Introduction

From the exploration task to the reservoir modelling process, the traditional approach consists in splitting the workflow in two fields of expertise with a one-way path between them: the seismic interpretation, a key step to define geochronological relationships between stratigraphic and structural units; followed by the geo-cellular grid creation, where rock properties coming from the well data are estimated for each cell.

The most recent methods aim to flatten the stratigraphic units from the seismic volume into a geological domain in order to remove the deformations and simplify the relations between horizons and faults (Mallet et al, 2004; Poudret et al, 2012). These methods are used for geostatistical simulation across the geological model of rock properties from well log data (Rainaud et al, 2015). Some other techniques aim to compute stratigraphic ages thanks to an implicit function in an unstructured tetrahedral mesh (Lepage et al, 2014) or a watertight model (Pauget et al, 2017).

In this paper, a stratigraphic grid is directly computed from an input Relative Geological Time (RGT) model using a dense grid of seismic horizon patches. Any change made to stratigraphic or structural units within the RGT model can be directly applied to the grid. The objective is to reduce the time between seismic interpretation and stratigraphic gridding in order to improve the simulation of rock physics properties correlated with seismic facies.

Description of the Method

The method aims at building a stratigraphic grid from a RGT model thanks to a three-step workflow.

First, the RGT model is obtained using a dense grid made of numerous horizon patches called Model Grid. The Model Grid stands as the framework for seismic interpretation. This grid is computed from the seismic volume using the method described in Pauget et al (2009). Its spatial resolution depends on the seismic bin size whereas its vertical resolution relies on the seismic trace extrema. A patch linking process determines vertically the stratigraphic ordering and spatially by comparing correlation factors between the centers of the horizon patches. The interpreter can manually edit the links, by merging or splitting them, to get a stratigraphically and structurally consistent grid.

The continuous RGT model is then derived from the Model-Grid by interpolating vertically the RGT values between consecutive patches. In this way, one horizon in the RGT model corresponds to one single geological age materialized by one value in the implicit function. By respecting this method, even the tiniest seismic event is taken in consideration within the process of RGT modelling (1st step of the workflow, Figure 1).

An unlimited number of continuous surfaces can afterwards be extracted from the RGT model by delineating any stratigraphic boundary. Based on this feature, stratigraphic units of interest are chosen by the interpreter with a sub seismic sample control (2nd step of the workflow, Figure 1). For each stratigraphic unit, the cell architecture has afterwards to be parametrized: vertical resolution (or number of sublayers), and method of layering pattern creation. The spatial resolution of the grid (through the spatial cell size) is comprehensively defined.

A regular 3D corner point gridding process creates the cells by horizontally sampling the corners at regular intervals in the survey directions. The vertical distribution of the corners points is performed according to two constraints: first the stratigraphic unit boundaries and then the sub layering pattern (3rd step of the workflow, Figure 1). This process can be realized for each interval according to different patterns. Either the seismic information is relevant and the cells geometries are computed directly from the RGT model to maximize the resolution, or the seismic quality is too poor and it therefore uses classical patterns (isoproportional, parallel to top or bottom).

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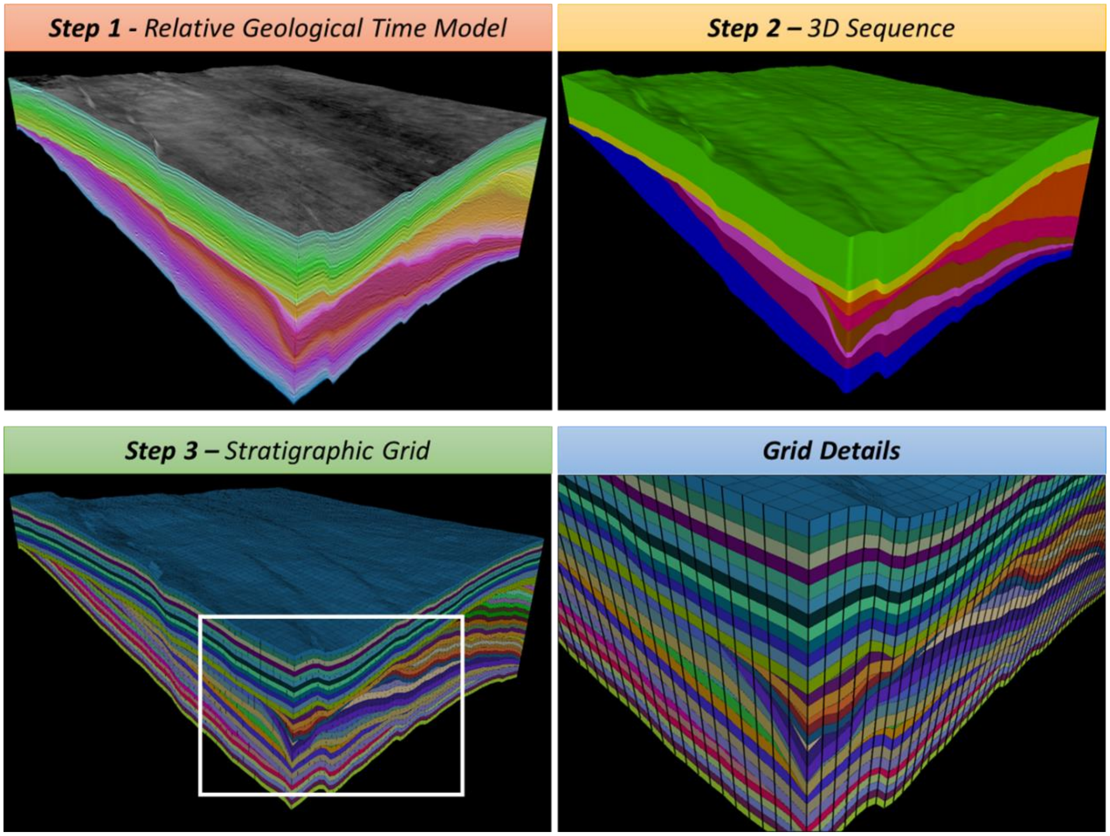

Figure 1: Workflow of the Stratigraphic Grid from Relative Geological Time (RGT) model method. Step 1 – Creation of a RGT model from automatic tracking of horizons. Step 2 – Creation of a real time 3D sequence from RGT model including bedset terminations. Step 3 – Creation of a Stratigraphic Corner Point Grid from a 3D sequence, and architecture details.

At the end, this process delivers a high-resolution stratigraphic grid (regular grid with curvilinear geometry), where geometries of the cells can be directly controlled by the RGT model.

Case study example

The studied zone is located offshore New Zealand in the Maui High, and represents the Northern horst of the Central Graben. Cretaceous and Paleogene periods consist in a rifting stage linked to a transgression leading to a thin terrestrial to shallow marine deposits. A regional post-rift subsidence occurred during the Paleocene – Eocene epochs, where transgressive sequences can be observed. A subsidence allowed the deposition of the coarse shelf carbonates during the Oligocene epoch. Finally, through the Neogene period, marine and terrigenous rocks were deposited during a regressive propagation of the shelf across the basin (Durot et al, 2017).

Boundaries of the main stratigraphic units are delineated in order to constrain the 3D sequence (Figure 2, thick black and red boundaries). Since the RGT model physically links the 3D seismic cube with the stratigraphic grid, any 3D volume coming from the seismic data or the RGT model can be used as background image during the tasks of sequence modelling then stratigraphic gridding. Thus, the stratigraphic grid is designed according to the modification of the RGT model and its sequencing, back and forth. Any real time stratigraphic and structural inconsistency that is emphasized within the grid (3rd step of the workflow) can be iteratively refined upstream within the 3D sequence (2nd step of the workflow) and even in the RGT model (1st step of the workflow).

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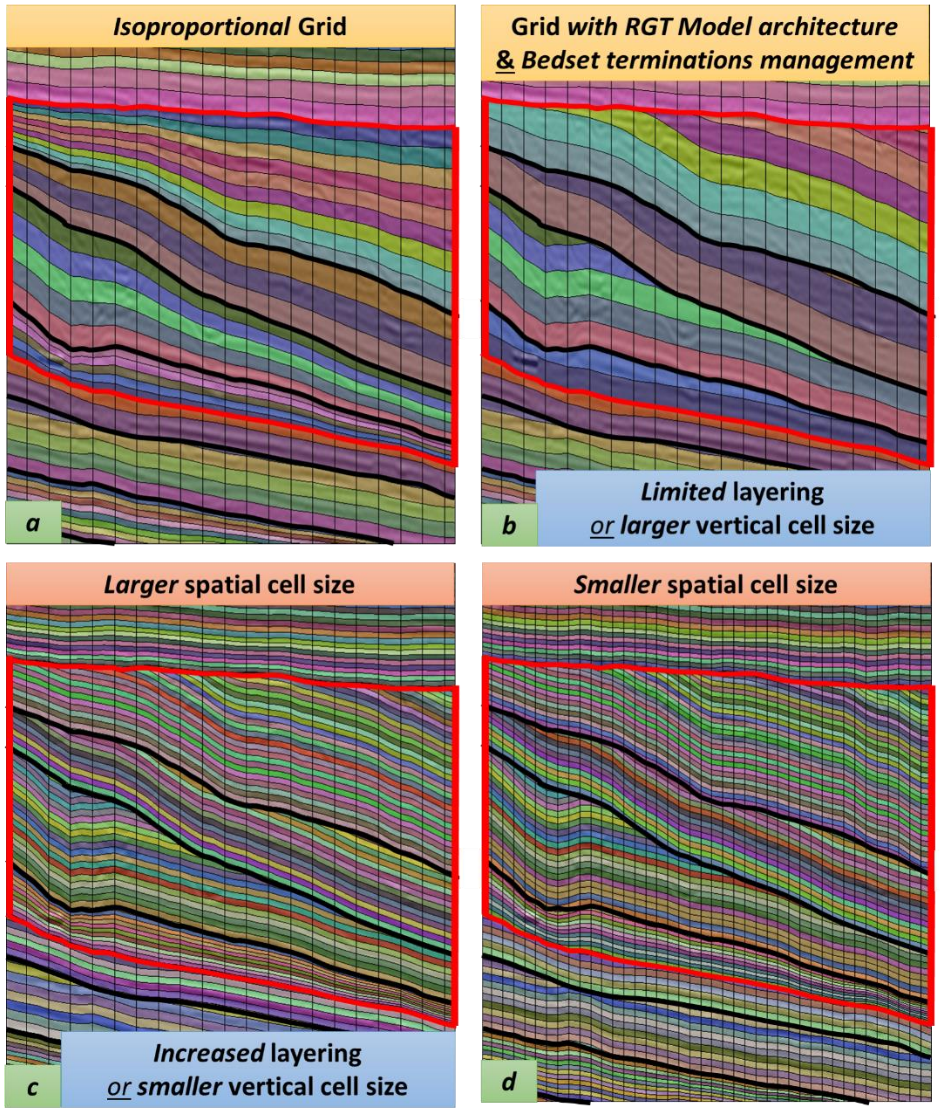

Figure 2: Main options of the Stratigraphic Gridding method. [a] Isoproportional vs. [b] Initial RGT model based on seismic signal with bedset terminations management. [b] & [c] Vertical gridding resolution based on either the intra layering of each stratigraphic unit or the vertical cell size. Spatial gridding resolution based on the seismic bin size: downscaling [c] and upscaling [d].

The Miocene clinothems could have been gridded thanks to an isoproportional distribution of the sub-layers within each stratigraphic unit (Figure 2 [a]). For an optimum stratigraphic consistency, the initial RGT model architecture is kept with intra unit bedset terminations management (Figure 2 [b], the four units in between the red boundaries).
The grid's vertical resolution is controlled according to either the number of sub-layers or the vertical cell size (Figure 2 [b] and [c]). The layering can be increased or the vertical cell size decreased in order to get more stratigraphic details. The resulting overlayering enables to reach an optimum vertical resolution fitting the well log scale (Figure 2 [c]).
Additionally to that, the spatial cell size can be decreased to improve the spatial sampling of the structures (Figure 2 [d]). The goal is to discriminate the spatial variation of the geological structures at a relatively higher resolution. This spatial resolution is computed from the seismic bin size. To perform basin modelling with high resolution, an upscaling is possible through a combined decreasing of both the vertical and spatial cell size.

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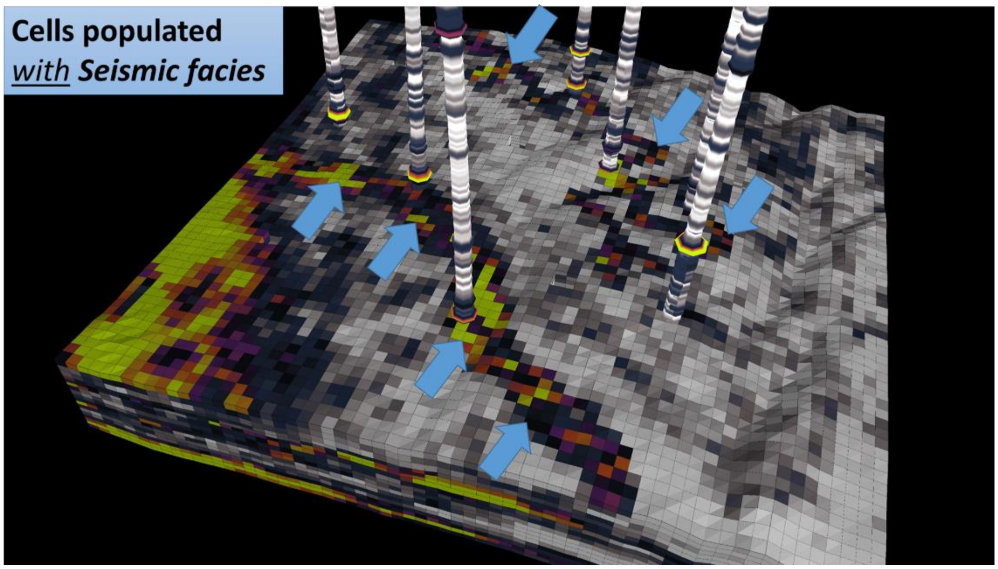

Figure 3: Stratigraphic grid populated with seismic facies (Envelope of the seismic traces) enabling Cretaceous turbidite channels modelling.

Facies Modelling

The grid's cells are finally populated (4th step of the workflow, Figure 3) with voxel information coming from any 3D cube: facies derived from seismic traces (e.g. amplitudes, seismic inversion, spectral decomposition, classification), stratigraphic and structural features computed from the RGT model (e.g. unconformity and fault attributes), or well log rock physics modelled thanks to geostatistics. As an example, Cretaceous turbidite channels can finally be modelled within the grid according to seismic facies (Envelope of the seismic traces). The consistency of the facies distribution can be controlled thanks to the previous steps, from the seismic interpretation and RGT modelling to the stratigraphic grid creation.

The resolution of the stratigraphic grid controls the level of details. If we need to synthetically bring out the spatial and vertical extension of the turbidite deposits at a basin scale, the grid resolution could be decreased and anomalies of amplitude coming from larger vertical window size of voxel analysis could be computed. On the other hand, for further understanding of the sedimentary structures representing the waning of turbidity current, the stratigraphic divisions of those deposits should be discriminated thanks to a higher grid resolution. Such a strategy should also be combined with fine scale properties coming from either well logs or high resolution seismic facies.

Conclusion

Pauget et al (2009) RGT modelling method is used as input for a regular 3D corner point gridding process. The output is a stratigraphic grid of whose units, resolution and architecture are iteratively controlled by the interpreter thanks to the RGT model. As a consequence, the interpreter dynamically defines the stratigraphic unit boundaries and the sub-layering pattern in a 3D environment connecting the original 3D seismic data and the stratigraphic grid. The seismic interpretation (RGT modelling) and stratigraphic gridding are thus parts of a single, continuous and two-way workflow, which reduces structural and stratigraphic uncertainties of the resulting grid. Therefore, this method allows creating a geo-cellular grid directly from the seismic and proposes a better definition of the cell geometry, compared to classical techniques based on a few horizons and faults. Furthermore, it shows a better synergy between seismic interpretation and geomodelling and offers new perspectives for static and dynamic simulations, which can be performed at a various scale either during the exploration or the development phase.

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