

FROM SEISMIC INTERPRETATION TO PROPERTY FILLED GRIDDING USING THE RELATIVE GEOLOGICAL MODEL

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Summary

This paper presents a new workflow from seismic interpretation to property filled gridding. The use of a relative geological time model resulting from a comprehensive seismic interpretation simplifies classical processes and helps to quality check the results. To calibrate well logs and seismic data, the model can be used to preview properties modeling during the seismic-well tie process. The creation of the low-frequency model for model-based inversion is improved. Compared to standard methods based on several key horizons, the propagation of acoustic impedance logs is guided by the iso values of the relative geological time model. The inverted impedances and the rock physics estimation are then better consistent with the geology. After a stratigraphic interpretation, a geo-cellular grid is computed based on the geological model and then filled with the rock properties.

Introduction

The reservoir workflows traditionally vary with the input data, the complexity of the geology, the objectives of the geoscientists and their methods of interpretation. In all cases, checking first the validity and the quality of the input data carries a proper start for all the next modelling steps. In order to simplify processes, to better quality check the results at each stage and to avoid a loss of resolution from the beginning to the end of the reservoir workflow, having a geological model as consistent as possible is crucial.

Description of the method

The following workflow (Figure 1) compiles all steps from seismic interpretation to reservoir modelling using a Relative Geological Time (RGT) model (Pauget et al., 2009). This model helps for each process to interpret the data, reduce uncertainties and estimate rock physics to finally create output models for reservoir gridding processes.

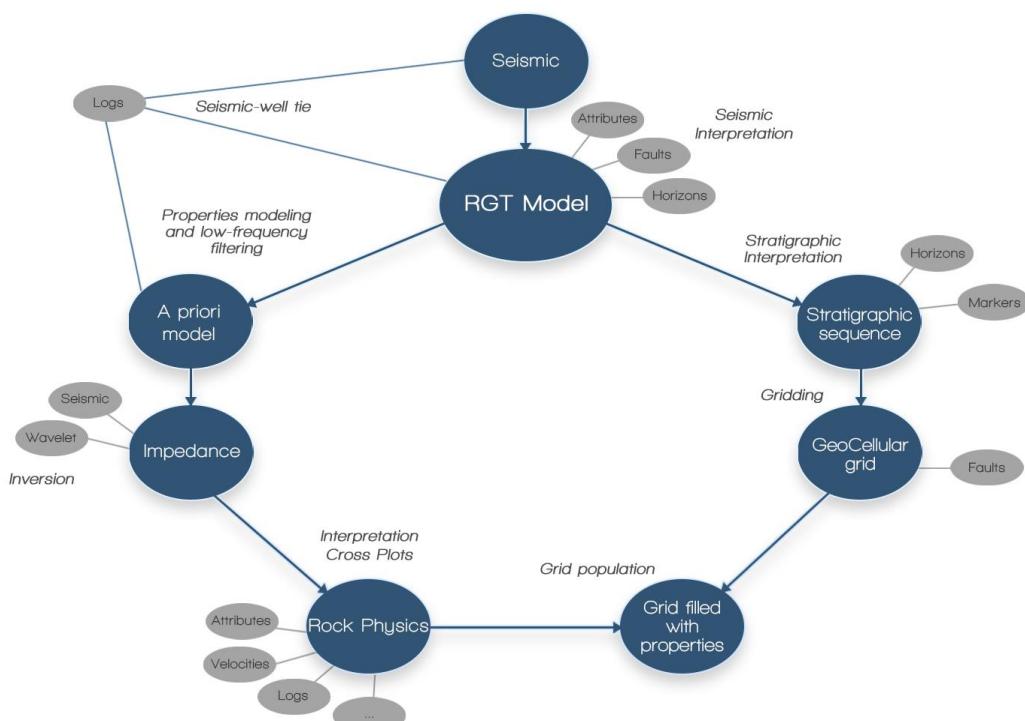


Figure 1 Proposed workflow from seismic interpretation to property filled gridding using the Relative Geological Time model.

- Creation of the Relative Geological Time model

The Relative Geological Time model (Pauget et al., 2009) comes from a comprehensive seismic interpretation method. First, a grid of horizon patches is computed on each polarity of the seismic volume. They are then automatically linked using the minimization of a cost function and a chrono-stratigraphic sorting is performed to assign relative geological ages to all horizons. Then the interpreter edits the relationships between horizons and updates the model in real time to obtain the optimum solution. The grid can integrate faults and seismic features. The output model mainly aims at providing a virtual unlimited number of depositional time surfaces.

- Calibration of the well logs with the seismic interpretation

The seismic-well tie is a critical process. Before propagating the values of wells logs along horizons, these data have to match together in order to properly interpret the stratigraphic layers. The calibration has to be done by applying simple time shifts and then by avoiding any stretch and squeeze operation

as far as possible. The RGT model can be used to propagate the computed acoustic impedance and other logs during the seismic-well tie process to preview the future a priori model of acoustic impedance (Cubizolle et al., 2015) (Figure 2). The wells already tied can also be used as constraints for previewing the resulted impedance model in the entire volume.

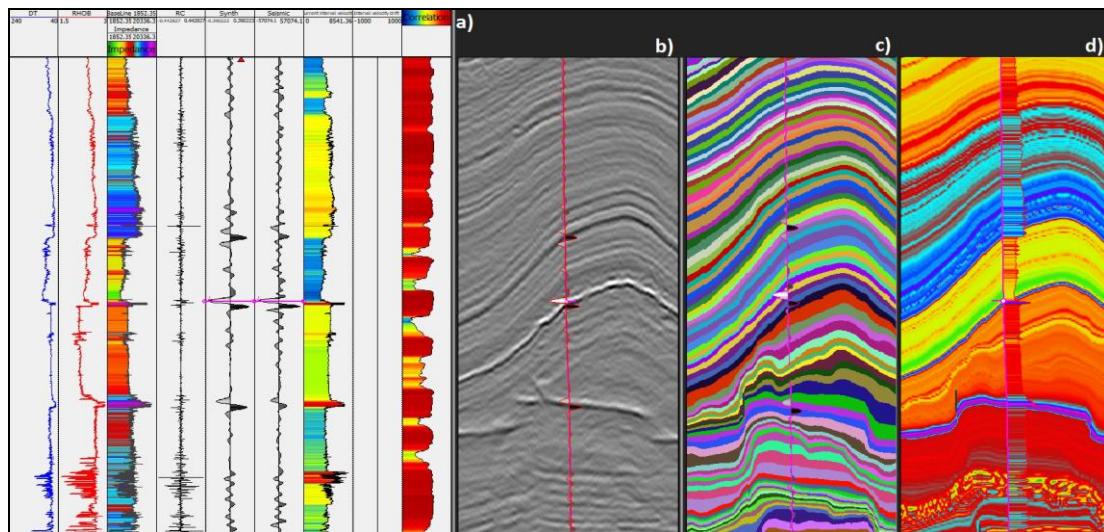


Figure 2 Global seismic-well tie. a) Logs viewer, b) seismic view with the synthetic trace, c) RGT model with the synthetic trace and d) impedance log propagated in the RGT model during process.

- Estimation of the a priori model for inversion

The inversion techniques are widely used to estimate relative or absolute impedances and then locate hydrocarbon reservoirs, with their benefits and constraints (Russel, 1988; Veeken and Da Silva, 2004). The creation of the low-frequency model is one of the most delicate step. To get absolute values, the band-limited seismic data needs to be constrained by a model which includes the structural framework and the low-frequency content of rock properties. All of the iso values of the RGT model are used to guide the propagation. Thus, the a priori model is obtained by interpolating acoustic impedance logs from several wells within the RGT model (Figure 3) using one of these methods: inverse distance weighting, kriging or co-kriging (Luquet et al., 2016). Then a low-pass frequency filtering is applied to the new impedance volume. The quality of this model depends on the interpretation of the seismic and logs data but also on the wells' distribution. Compared to standard vertical and spatial interpolations between some horizons (Huck et al., 2010), the propagation along the isotime values of the model enhances the main trend of impedances that honours the geology.

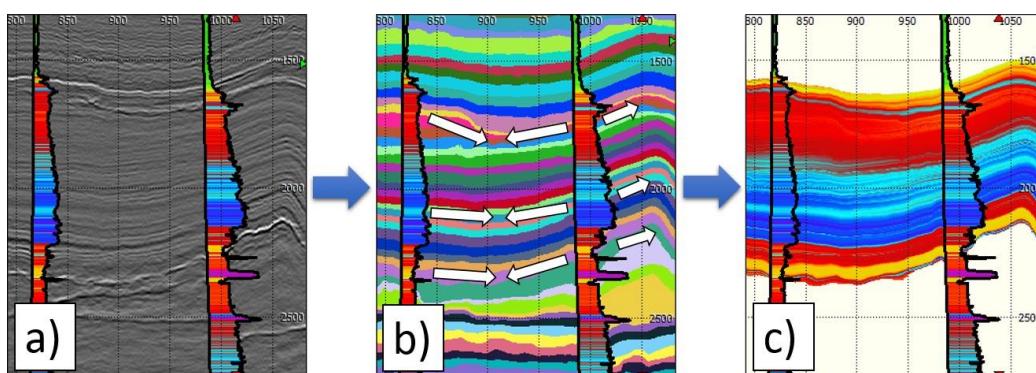


Figure 3 Propagation of well logs data guided by the RGT model (from Luquet et al., 2015).
a) Acoustic impedance logs displayed over the seismic amplitude volume. b) The corresponding RGT model. c) Acoustic impedance volume which will be used as a priori model for inversion after low-frequency filtering.

Using this low-frequency model and a wisely chosen wavelet, a model-based seismic inversion can be applied. By iterations, the differences between real and synthetic data are reduced to get a final impedance model. The computed impedance values are then consistent with the structural geology, such as horizons, faults and seismic features. Based on rock property relationships obtained from a log-log cross-plot, it could be possible to use the inverted seismic attributes to estimate other rock properties such as porosity from acoustic impedance towards filling a cellular grid.

- Building of the geo-cellular grid filled with rock properties

The last step of this workflow consists in building a geo-cellular grid which will be populated by rock properties. The method described by Lacaze et al. (2019) allows creating a geo-cellular grid directly from the seismic and proposes a better definition of the cell geometry. From the RGT model, stratigraphic sequences are picked to define geological layers. Then, a tailor made sub-layering defines the vertical resolution of the future grid up to log resolution. Finally, volumes of rock properties are used to fill the grid generating a strong link between seismic interpretation and geo-modelling. The control of the cell size is very useful to adjust the display of results: it quickly avoids the loss of significant information from the properties distribution.

Application to North Sea data

The previous workflow has been applied to the K05-block in the North Sea. A RGT model was obtained from Carboniferous to Paleogene (Daynac et al., 2014). The area is mainly characterized by a complex fault system underneath the Zechstein Salt (Late Permian), where the Upper Rotliegend Group containing a known reservoir formation is present. The available wells were tied to the seismic using the previous global method, which allowed the preview of the impedance a priori model (Figure 2). This one has been computed using the inverse distance weighting method from several wells using the RGT model (Figure 3) and a low-pass Hann-filter. The a priori model was then used as input for a post-stack model-based inversion. From the estimated absolute acoustic impedance values, several other rock physics can be computed such as porosity, using cross plotting focused on reservoir intervals. Stratigraphic sequences have been picked according to the geological interpretation in order to build the geo-cellular grid. Thanks to the previous computed properties volumes, geo-modelling of porosity and others can be populated within the grid (Figure 4). The reservoir layer is quite complex, the assumption of a decrease of porosity and granulometry from base to top of the layer is yet validated (Daynac et al., 2014). Thus, this method brings new opportunities and less uncertainties before going further in the geo-modelling workflow.

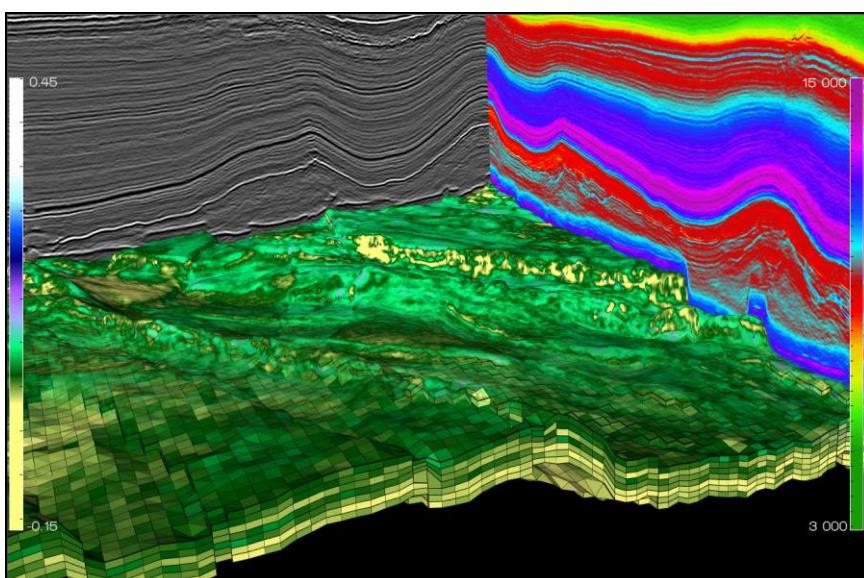


Figure 4 3D display of the porosity values on geo-cellular grid on foreground and on a surface of the reservoir on background, with a seismic line on the left and the inverted impedances on right.

Conclusions

This abstract introduces an original workflow from seismic interpretation to geo-modelling based on the use of a Relative Geological Time model. This model allows at each step of the process reducing errors, uncertainties and keeping a link with the real geology. This method has been applied to a real dataset in the North Sea, showing interesting results in a quick and robust way. The use of the RGT model during the building of the low-frequency model strongly improved the seismic inversion accuracy. The geo-cellular grid also permits to quickly synthetize the properties distribution to highlight reservoir features. This method could also be adapted to depth domain: the depth conversion of the RGT model, from a layer-cake velocity model created using the propagation of velocity logs for example, can integrate the workflow in replacement of the seismic-well tie process. Alternatively, other techniques of inversion, stochastic for example, and different rock properties or dataset such as velocities, could be used to complete and improve results of this workflow.

Acknowledgements

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