Meshless Geological Model from Seismic Data

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Summary

Although geological models represent a simplified vision of the earth, their obtention arises from a complex process based on a few horizons and faults during the seismic interpretation phase. A novel method to generate meshless geologic model from a grid of horizons automatically picked. This approach consists in computing relative geological time model from key selected horizons to reduce the dependency on the seismic data and its associated artefacts, related to acquisition and processing limitations. Fault surfaces are then used as stratigraphic breaks, in a global minimization of the geological time variations. Each fault block can be computed independently and therefore complex geometries can be modelled such as reverse faults. Compare to other approaches requiring a transformation into a depositional space, the geological model is directly computed in the seismic domain. This model being at the same resolution as the seismic, a stair step effect is observed at the fault location. This effect is removed by a bilinear interpolation with structural constraints, which generates a meshless watertight model, where complex geometries are such as reverse faults can be managed. It can be used for various applications such as structural maps as well as cellular grid generation for static geological modelling.

Introduction

The obtention of geological models have progressively represented a major process for the understanding of reservoirs in the oil and gas as well as other industries. Although those models represent a simplified vision of the earth, at various scales, their obtention arises from a complex process based on a few horizons and faults during the seismic interpretation phase.

Over the past decades, novel methods have been proposed to exploit the three dimensionality of the seismic data to reconcile seismic data and geology. Some of these methods are based on the classification of the reflector extrema (Borgos et al, 2003), horizon cube (de Groot et al, 2010) or chronostratigraphic models (Labrunye, 2013).

The global approach, proposed by Pauget el al (2009), where a Relative Geological Time (RGT) model is generated, by using a grid of auto-tracked elementary horizons patches, allows to interpret quickly and more accurately the full seismic volume for prospect lead assessment. However, the close relationships with the seismic and its associated artefacts does not allow the RGT model to be used as an input for geological modelling.

In this paper, we present a method to generate geological model, derived from the RGT grid, where the dependency on the seismic limitations can be fully controlled.

Limitations of the RGT Method

The Relative Geological Time (RGT) model generation relies on a semi-automatic process, which tracks every horizon within the seismic volume, where a relative geological time is computed for every point. The main task of the seismic interpreter is then focused on refining the model by modifying relationships between points inside a grid of elementary horizon patches, until an optimum solution is obtained. Continuous geological times can be computed and are consistent with the seismic image.

This approach reduces the time cycle and improves the quality of prospect leads generation. However, as the RGT model is computed from the entire grid of horizon patches, it cannot be used directly for geological modeling due to the high level of dependency with the seismic. Indeed, even though the seismic image is the best input to understand geology, it has some limitations related to the acquisition or the processing (low signal to noise ratio, multiples, etc), which must be removed to obtain a proper geological model. When the data quality is poor, it becomes difficult to generate stratigraphic model, sequence termination (on-lap, top-lap, down lap, etc.). Moreover, in the RGT volume, a fault corresponds to a no-value (Figure 1.b). Although fault displacement attribute such as throw and heave can be calculated, complex structural geometries as well as fault sealing properties cannot be managed.

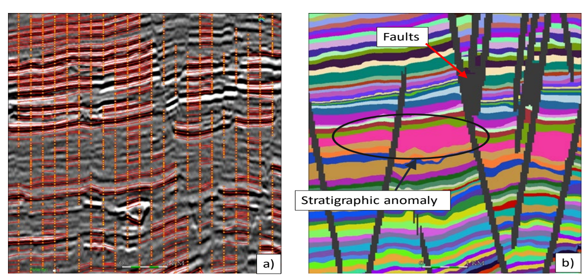

Figure 1: *Limitation of the RGT grid for geological modelling. (a) Grid of horizons is generated on every seismic polarity. (b) RGT values are assigned to every seismic sample, faults represent discontinuity constraints with no value.*

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Model based on Key Horizons

The following method aims to adapt the RGT value computation with a reduction of the seismic dependency and more control on the geometry of the model.

By using the same initial grid of patches, where a stratigraphic ordering is already performed, new RGT values are computed from selected key horizons. Vertically, a simple interpolation is performed between horizons, whereas values are extrapolated spatially by using the RGT variations (Figure 2.b).

Consequently, the RGT model is strictly consistent with the selected key seismic horizons. Besides, by reducing the dependency to the full horizon grid and, to some extent to the seismic, it becomes possible to produce a clean geological model (Figure 2.c), with a better control by the interpreter.

Stratigraphic models for reservoir characterization can be generated in complex zones, even with a poor seismic quality. Thanks to this novel method, the RGT model is cleaner and does not show strong thickness variations. It becomes a perfect input for stratigraphic modelling and cellular grid generation (Lacaze et al, 2019).

The method was applied to a 1,000 km^2 3D seismic dataset (HCA2000A) located along the north-western Australian margin in the Exmouth sub-basin, part of the North Canarvon Basin. The Neogene upper interval, characterized by a passive margin carbonate shelf, made of transgressive and regressive regimes, is properly modelled.

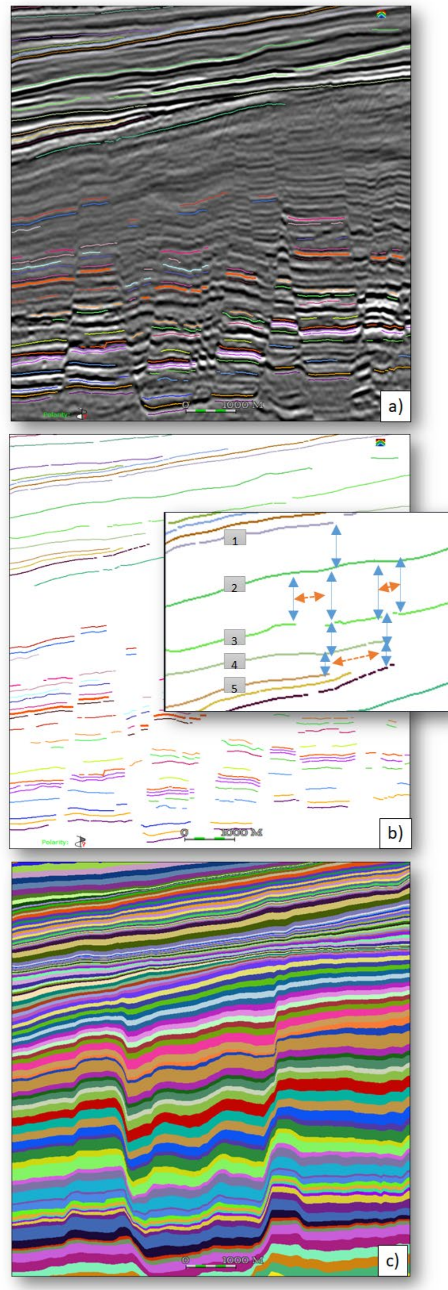

Figure 2: *Method to compute RGT values from key horizons only. (a) Horizons a selected from a grid of auto-tracked horizons in the entire seismic volume. (b) RGT values are interpolated vertically. Spatially the extrapolation is based on the geologic time difference. (c) The new RGT model is cleaner and does not show strong thickness variations.*

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RGT modelling with Fault Constraint

Despite the method with selected key horizons produces relevant results to reveal stratigraphic units, an approximation is made at the fault location due to the vertical interpolation between horizons. This effect can be seen in the lower Jurassic and Cretaceous intervals, where a complex normal fault system, related to a rifting phase, remains difficult to enhance (Figure 2.c).

A difference can be observed between the fault break point of the model and the actual interpreted fault surface (Figure 3.a). To overcome this issue, fault constraints are inserted as stratigraphic breaks in the global minimization of the geological time variations. RGT values can be computed independently for each fault block, while honouring the structural constraint. The overlap of the RGT values for a same spatial position can then be managed. This way, complex geological models are generated such as reverse fault systems (Figure 3.b), with great dip angle.

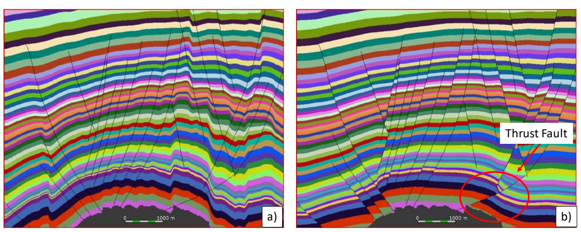

Figure 3: *RGT modelling with fault constraint. (a) Overlapping of interpreted faults with RGT model obtained from the selected key horizons. (b) RGT model using the fault constraint as stratigraphic break, enabling the modelling of reverse fault systems.*

As RGT values are computed at the resolution of the seismic, a stair step effect is observed along the fault surface corresponding to each voxel. A bilinear interpolation, constrained by the structural discontinuities, is then performed to convert the pixelized model into a watertight meshless geological model (Figure 4).

This model manages the contact between iso-geologic time surfaces and faults and therefore becomes watertight (Pauget et al, 2017). Compared to other approaches, which require a transformation in a depositional space (Mallet et al, 2004; Lepage et al, 2014), this method is directly applied in the seismic domain. Such as other meshless methods (Renaudeau et al, 2019), it can be used for various geological applications such as fault polygon extraction, structural mapping as well as fault seal analysis.

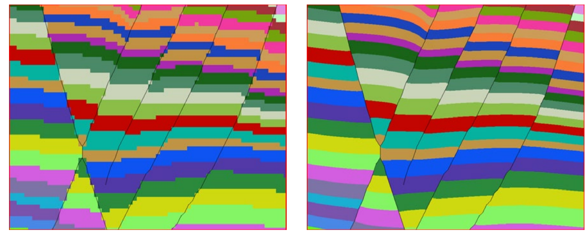

Figure 4: *RGT modelling with fault constraint. (a) Overlapping of interpreted faults with RGT model obtained from the selected key horizons. (b) RGT model using the fault constraint as stratigraphic break.*

Conclusion

In this paper, we have presented a novel method to generate meshless geologic model from a grid of horizons automatically picked. This approach consists in computing relative geological time from key selected horizons to reduce the dependency on the seismic data and its associated artefacts, due to acquisition and processing limitations. Fault surfaces are then used as stratigraphic breaks, in a global minimization of the geological time variations. Each fault block can be computed independently and therefore complex geometries can be modelled such as reverse faults. Compared to other approaches requiring a transformation into a depositional space, the geological model is directly computed in the seismic domain. The relative geological time being at the same resolution as the seismic, a stair step effect is observed at the fault location. This effect can be removed by a bilinear interpolation with structural constraints, which generates a meshless watertight model, where the contact between iso-geologic time and faults is perfectly managed. This meshless geologic model is then directly controlled by the seismic and can handle complex geometries such as reverse faults. It can be used for various applications such as structural maps generation, fault polygons extraction as well as generation of a cellular grid for static geological modelling.

Acknowledgments

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