Comprehensive Method for a Multi 2D Seismic Interpretation

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Summary

Structural interpretation from 2D seismic line sets is common in the hydrocarbon exploration process. Generally, this process consists in the interpretation of several key horizons on the several seismic lines available, which is time-demanding. Furthermore, as the seismic lines are often processed differently, misties are frequently observed between the lines, which may lead to cumbersome interpretation.

In this paper, we introduce a method aiming at providing an efficient 2D line seismic interpretation answering the need of obtaining early 3D geological model during reservoir exploration.

Introduction

Traditional 2D seismic interpretation is generally a complex and time-consuming task which relies on 2D auto-tracking and the manual picking of a few stratigraphic events on every line. At the regional scale, interpreters have to consolidate multiple lines, often contending with varying resolutions, amplitude ranges and misties. These issues largely stem from working with 2D lines with varying acquisition and processing histories. As a result, defining the initial stratigraphic geometries from 2D seismic before moving on to higher-resolution 3D seismic may be an undesirable prospect.

To improve this process, we propose an innovative method which aims to build a global geological model from a multiple 2D line set. This method utilises more of the information contained within the 2D seismic data to produce a 3D geological model, and gives a better understanding of the stratigraphy at a very early stage in the exploration process.

Single Line Interpretation

The first objective of this methodology is to transform a single 2D seismic line into a 2D Relative Geological Time (RGT) model. This is achieved by adapting the method of Pauget et al. (2009), originally designed for 3D seismic data. In summary, the method consists of a semi-automatic process, where the seismic data are converted into a grid of horizon patches, regularly sampled spatially and propagated on every seismic polarity (peak, trough, zero crossings). An automatic solution automatically links the patches by using a minimization process based on the seismic correlation. This grid is then converted into a RGT model, using a stratigraphic sorting algorithm. The links between the patches can be refined at any time during the interpretation to update the model (Lacaze et al, 2011).

To adapt this method in two dimensions, a 2D horizon patch grid is created and the links between the patches are automatically established by using the same method as in 3D. Although the workflows are similar until this stage between 2D and 3D, the quality of the resulting 2D RGT model is not as accurate as in 3D. As there are fewer connections between the patches in 2D seismic, the RGT model is more sensitive to the noise effects and seismic artefacts, generally more important in 2D acquisitions.

To overcome this issue, the 2D RGT model is built from a seismic-based grid (Figure 1a) on which the user interprets or “marks” a certain number of events (Figure 1b). RGT values are first computed only on the “marked” horizons, using the same chronostratigraphic algorithm. This way, the RGT values strictly honour the marked horizons, which is essential in order for the model to be conformable with stratigraphic discontinuities. Intermediate RGT values are then calculated on the remaining patches of the grid by using a thickness optimisation method.

Even though the size and distribution of the marked horizons are variable, the 2D RGT model always shows a consistent trend as the algorithm manages crossing effects and lateral variations using the underlying grid. In this new technique, the quality of the 2D RGT model is consistent with stratigraphic boundaries and unaffected by the noise in the full 2D line. Moreover, it can be easily updated by adding or refining marked horizons. It shows a drastic improvement compared to classical strata slicing methods based on a simple vertical interpolation between horizons (e.g. Zeng et al, 1998), without handling crossings, faults and spatial heterogeneities.

We applied this workflow on a single line from the Northern Carnarvon basin (NCB) of Australia’s North-West Shelf. The NCB contains numerous sub-basins (e.g. the Barrow, Dampier and Beagle Sub-basins) which form deep (up to ~10 km thick), NE trending depocentres containing Late Paleozoic to modern day sediment fill (Bradshaw et al, 1988). Stratigraphic units include the Triassic Mungaroo Formation and the Cretaceous Barrow

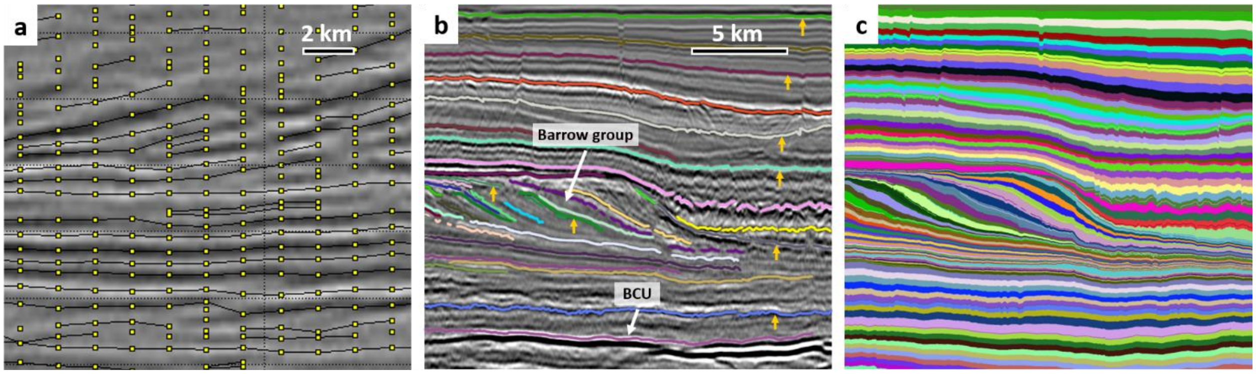

Figure 1: 2D global interpretation on one seismic line. (a) Generation of seismic-based grid (b) Horizons marked by the interpreter (yellow arrows) on a single 2D line in the Northern Carnarvon basin (off-shore Australia). (c) 2D RGT model, where RGT values strictly honor the marked horizons.

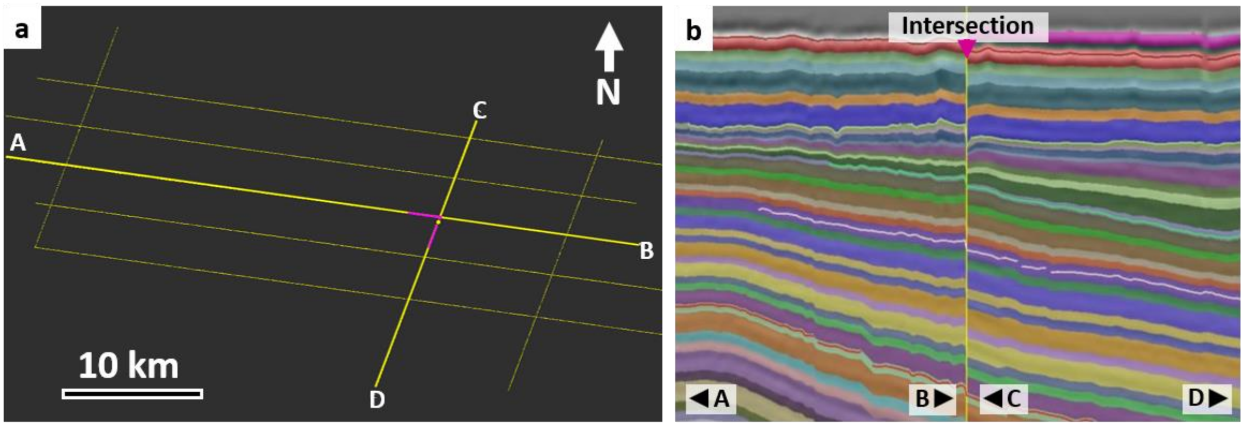

Figure 2: Multiple line interpretation. (a) Survey map showing the crossing lines AB and CD. (b) Intersection of the two crossing lines AB and CD (pink sections on (a)) with the RGT models obtained independently on the two lines.

Group, both of which host significant hydrocarbon accumulations in the NCB (Longley et al, 2002). These units are overlain by a thick succession of Late Cretaceous to recent carbonates deposited during post-rift thermal subsidence (Apthorpe, 1988).

A 2D grid was computed from a line whose extension is about 27 km long. The grid computation accounts for every peak, trough, and zero crossing, and is made of approximately 90 thousand patches. An automatic solution was first computed and a number of horizons were marked and refined from the sea floor down to the mid Triassic. Despite the geological complexity present in the sequence, only a few scattered marked 2D horizons were required to obtain a relevant RGT model (Figure 1b).

Multiple Line Interpretation

Traditionally, problems have arisen when combining 2D lines of multiple vintages and processing histories, with the most problematic being variations in amplitude range and misties between lines. To reduce the impact of such differences, an amplitude normalization is performed on each line within the line set. This normalises the amplitude range across the set as a whole, creating more consistent amplitude values. The main challenge then consists of managing the misties between the lines. Misties often occur between lines from different acquisitions. The line misties are clearly highlighted at their intersection on both seismic and in RGT values (Figure 2).

To overcome the mistie effects between lines, the grid is calculated on the entire line set. 2D RGT models obtained on single lines are synchronized by connecting the marked horizons at their intersection (Figure 3a and b). The misties are then minimized by correcting the vertical differences of the RGT values for each marked horizon at their intersection (Figure 3c and d). In this way, variable trace shifts are obtained for each intersection between the lines.

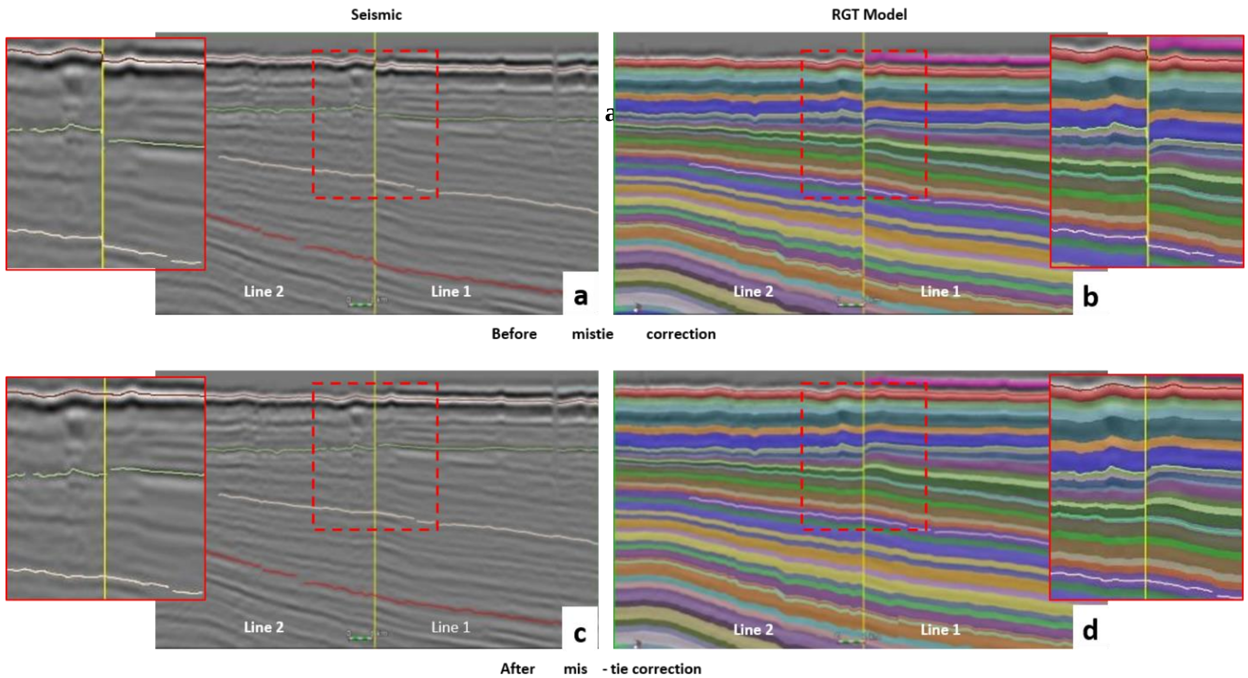

Figure 3: Mistie management between crossing lines. (a & b) Seismic lines and RGT models showing the mistie between the lines. (c & d) Seismic and RGT model after mistie compensation using a variable shift calculated from the connected marked horizons.

When applied to the multiple line interpretation, the problem becomes more complex. As the number of lines and intersections can be numerous, the variable shifts computed at each line intersection are interpolated on each respective line. Therefore, a vertical shift is assigned to each seismic sample allowing the global minimization of the misties for the entire line set (Figure 2a and 4a).

Upon generation of the 2D RGT model (Figure 4a), a multitude of 2D horizons (2D horizon stack), representing iso-geological times, can then be extracted to explore continuously the multiple line set. By using interpolation techniques, such as kriging or inverse distance, the 2D horizons can be converted to 3D surfaces. In this way a 3D horizon stack can be produced to gain an initial understanding of the stratigraphic architecture of the studied area (Figure 4b). The 3D horizon stack can then be converted into a 3D RGT model by using the same stratigraphic sorting algorithm as used in the initial patch grid. We thereby obtain a 3D model showing the main stratigraphic trends at a regional scale (Figure 4c and 4d) from a multiple 2D line interpretation.

Conclusions

This work represents a new and innovative method to generate Relative Geological Time (RGT) models from 2D seismic data. Single line RGT models are generated from an adaptation of the 3D method developed by Pauget et al. (2009). A 2D horizon patch grid is first computed on each seismic polarity and the links are automatically established by way of a minimization process. Some adaptation of the 3D RGT model calculation was required due to the lower level of links in the 2D grids when compared to 3D. The RGT values are first assigned to the horizons marked by the interpreter. The intermediate values are then calculated on the remaining patches by using a thickness optimisation method. This new technique produces a more consistent 2D RGT model, noise-independent and strictly honouring the stratigraphic discontinuities. When applied to a multiple line set, the misties between seismic lines are compensated by computing a variable shift at the intersection based on the connection between the marked horizons. Therefore, the 2D RGT models obtained for each line can be synchronized and converted into a 3D RGT model by simple interpolation. From an interpretation perspective, it allows a “2.5D” interpretation with a comprehensive understanding of the stratigraphic geometries at an early stage of the exploration workflow. Moreover, by co-kriging seismic amplitude values, this innovative methodology would enable the computation of pseudo 3D seismic cubes from 2D interpreted lines.

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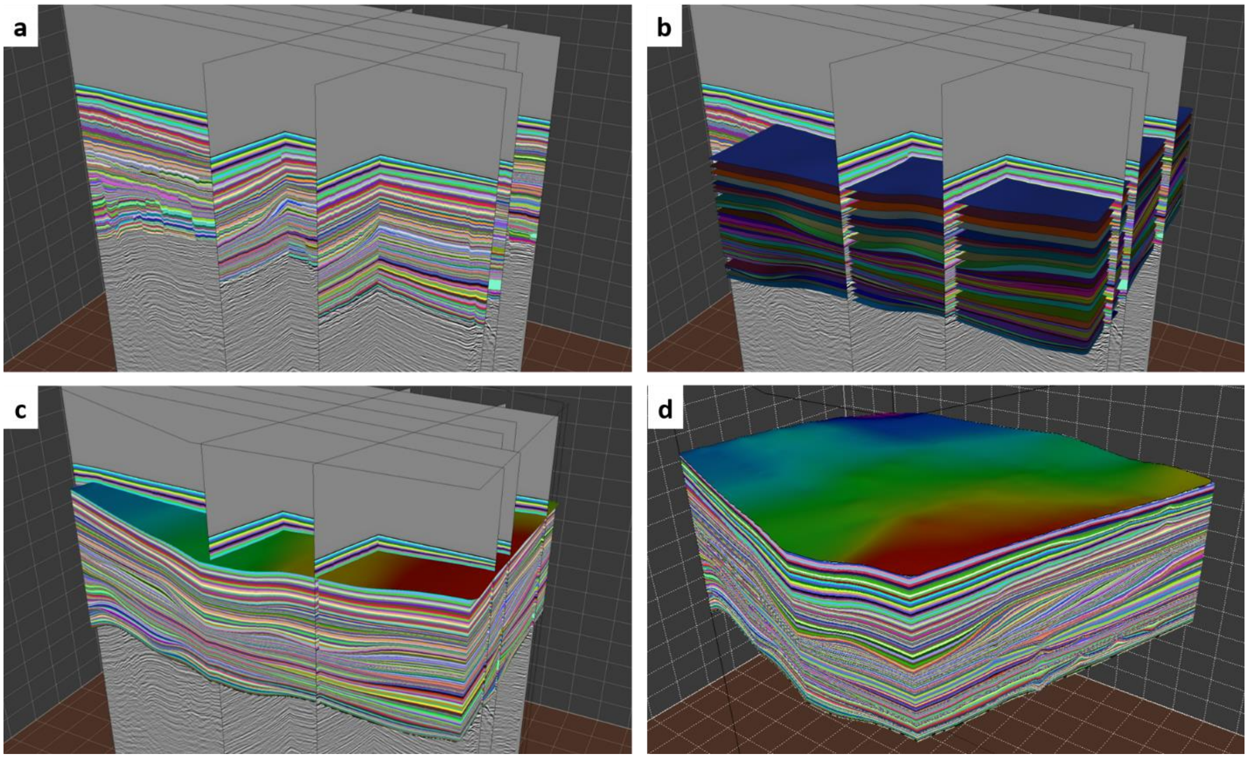

Figure 4: From 2D to 3D RGT model. (a) 2D multiple line set RGT model (b) 3D Horizon stack extrapolated from 2D horizon stack. (c) and (d) 3D RGT model generated from the 3D horizon stack.

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