Spectral Decomposition combined with geo-model interpretation: Creating new workflows by integrating advanced technologies for seismic imaging and interpretation.

Ingelise Schmidt (Maersk Oil), Sebastien Lacaze (Eliis), Gaynor Paton (ffa),

Introduction

Identifying geomorphological features from seismic has been the aim and the challenge since the first seismic was recorded. Although the quality and resolution has improved beyond expectations from those early days, improvement of imaging and interpretation techniques are continuously on-going and new and enhanced tools are regularly presented, with potentials that are not always evident at first glance. This paper will present how integration of a novel interpretation technology using a Relative Geological Time (RGT) model and spectral decomposition imaging can be combined into a powerful workflow for interpreting and imaging geomorphological features from seismic data which are not readily resolved using conventional techniques. Geo-bodies can then easily be extracted within a stratigraphic framework established using the thickness attribute cube derived from the RGT model. The workflow will be demonstrated and supported through case studies.

Full Volume Interpretation with a Relative Geological Time Model

The method consists of a computer aided three-step workflow to build a Relative Geological Time (RGT) model (Pauget *et al.* 2009) directly from the seismic. A grid is computed, where each node is an elementary horizon patch with a constant size. The patch size defines the spatial step, whereas a node is created vertically every peak, trough or zero crossing. The linking of the nodes is done automatically by propagation of the horizon patches. This way numerous links are created between nodes inside the grid. The propagation process is gradually constrained by the increasing number of links inside the grid. This process consists in minimizing a cost function, which depends on the similarity of the horizon patches.
A relative geological time is then computed for every node of the grid and by interpolation populated continuously in the entire seismic volume. The seismic interpreter checks relationships between horizons to refine the links between the nodes inside the grid until an optimum solution is obtained. Such approach has been already demonstrated on various case studies (Gupta *et al.* 2008; Lemaire *et al.* 2010; Schmidt *et al.* 2010; Beller *et al.* 2012; Vidalie *et al.* 2012).
When the RGT model is completed horizons can be extracted from the model covering the full area of the volume. Effectively an unlimited number of horizons become available which can scrolled through like a seismic volume following the interpreted stratigraphy. Any kind of attribute can be displayed on each horizon and displayed simultaneously.

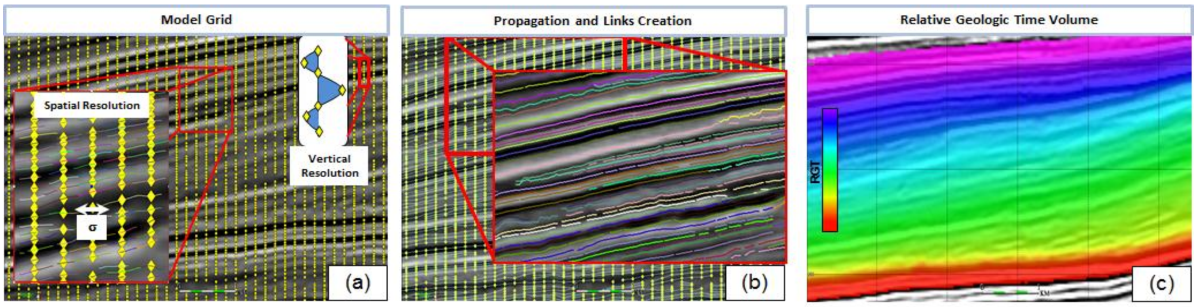


Figure 1– Method for modeling the Relative Geological Time –RGT- (Pauget et al, 2009). (a) Creation of the grid, where a node represents a small horizon patch with a limited size. The patch size defines the spatial distribution of the nodes. Vertically, a patch can be computed every peak, trough or zero-crossing. (b) After propagation, links are established between nodes; the volume is composed of horizons with various sizes. (c) Based on these relationships between the nodes, a 3D continuous Relative Geological Time (RGT) model is computed in the entire seismic volume.

Detection of thinning zones

By computing the vertical derivatives of the relative geological time model, also called the "*Thickness*" cube, it reveals the instantaneous variations of the geological layers in the volume on each seismic voxel (*Figure 2*). Like other methods analysing the thinning of seismic reflection packages at a large scale (van Hoek, *et al*. 2010; Lacaze *et al*. 2012), the “thickness cube” is sensitive to the convergence and divergence of the geological horizons and therefore appears to be particularly well adapted to reveal traps, seal, spatial distribution of reservoirs as well as assisting sequence stratigraphic analysis and interpretation of depositional environment evolution (Schmidt *et al.* 2012; Vidalie *et al.* 2012)

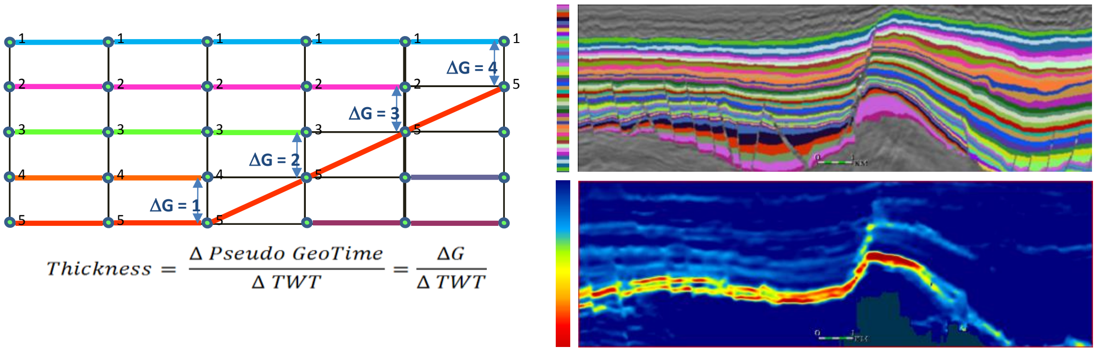
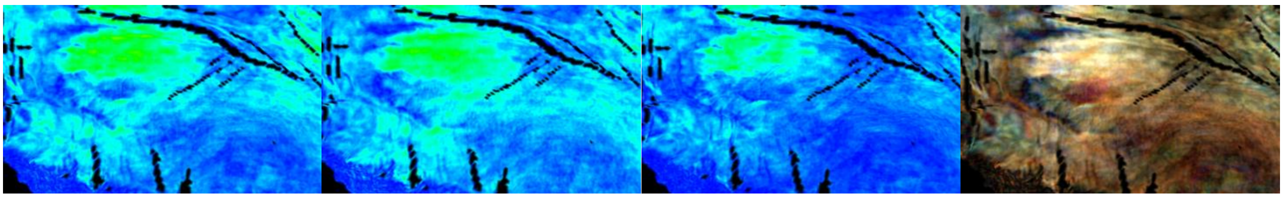


Figure 2– Definition of the “thickness” attribute. (a) A value of thickness corresponds to the vertical derivative of the relative geological time model computed for every seismic voxel. (b) and (c) the thickness attribute enhances stratigraphic discontinuities, after Lacaze et al. 2012.

Spectral Decomposition

Spectral Decomposition and RGB blending have become established methods of identifying stratigraphic geometries within seismic data, especially in areas where subtle changes in the seismic expression can indicate significant changes in the stratigraphy. Visualising each frequency response independently reveals a very limited amount of information, however when three frequency magnitude responses are combined using a three dimensional RGB (Red-Green-Blue) colour bar, the interplay between different frequency responses becomes apparent (Henderson *et al.* 2007). This provides a more sensitive method of analysing the amplitude variation within the data. Specifically, the colour balance within the RGB blend relates to geometrical (thickness) variations, via the sensitivity of each frequency band to tuning effects, and also to frequency dispersion caused by fluids (McArdle & Ackers, 2012). RGB blends often starkly highlight geological features and can be used both to focus interpretation and to image geological elements including those at or just below the limit of seismic resolution.

The frequency decomposition workflow in the software is based on the convolution of Gabor wavelets with the seismic trace. The wavelets have a defined central frequency and bandwidth, and a number of different responses are created prior to the RGB blending. The RGB blending workflow consists of assigning a different frequency magnitude response to each of the three colour channels; low frequency in the Red channel, mid frequency in the Green channel and high frequency in the Blue channel. The resulting colour blend provides high resolution colour visualisation of the three volumes and the strength of their response relative to each other (Figure 3).



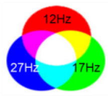


Figure 3 – Three frequency magnitude response volumes and the composite RGB blend displayed along a regional horizon. The RGB display defines the extent and internal variations of a fan in more detail than the individual frequency response volumes.

Combining technologies

The spectral decomposition colour blend is projected onto a 1D scale to be transferred as an attribute volume to the RGT model. The unlimited number of stratigraphically consistent horizons of the RGT model can be used to explore and interpret the geomorphological elements in the volume. Furthermore, one targets of interest are identified, RGT horizons can be transferred to the spectral decomposition environment, where high resolution displays, using the full 3D colour blend, can be generated. Geobody interpretation on the colour blend volume enables accurate extraction of the geological features constrained by both the RGT stratigraphy and the seismic expression.

Case Study

An RGT model is constructed with detailed interpretation of the seismic reflectivity data with assistance from frequency enhanced volumes to improve the vertical resolution. From this model the thickness attribute cube is calculated which is used in combination with the horizons from the RGT model to delineate the stratigraphic intervals to constrain the geo-body extraction (Figure 4). The spectral decomposition volume is an excellent attribute volume for geo-body interpretation and Figure 5 show how subtle geometries can be interpreted and extracted as geo-bodies. The extraction can be constrained by the sequence stratigraphic framework and hence the depositional evolution of the sequences can be illustrated.

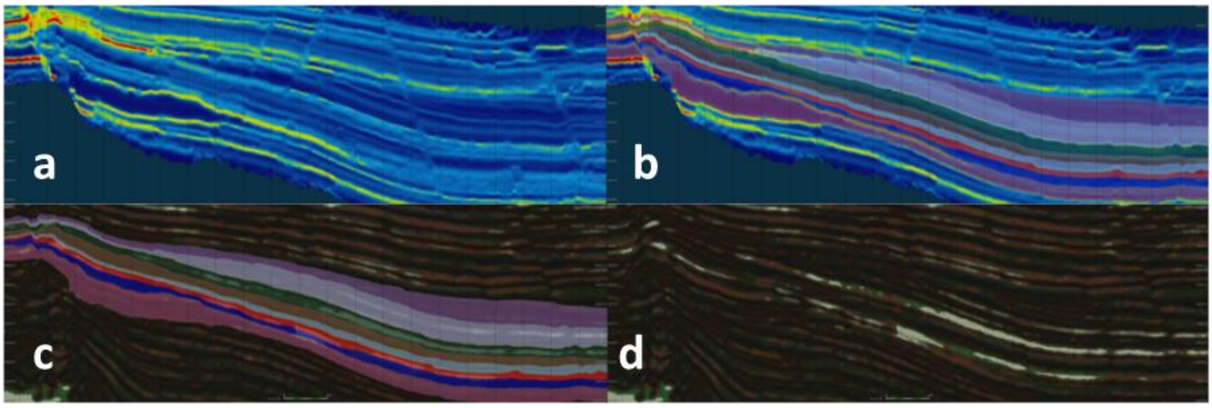


Figure 4 – (a) and (b) thickness attribute for definition of stratigraphic intervals without and with the intervals. (c) and (d) spectral decomposition volume with and without stratigraphic layers

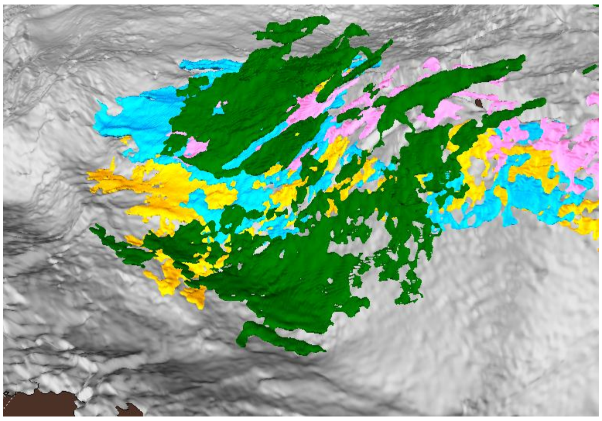


Figure 5 – Geo-bodies extracted from spectral decomposition, within stratigraphic layers

Conclusions

A new workflow based on full volume seismic interpretations techniques combined with spectral decomposition imaging technology is established and demonstrated through a case study. A derived detailed sequence stratigraphic interpretation forms the framework for the geo-body extraction, from spectral decomposition cubes, which can then be used to establish and interpret the depositional environment.

References

Beller, M., Lacaze, S., Pauget, F. and Mangue, M. Fast Leveraging of Seismic Information over Large Areas – A Central North Sea Case Study. EAGE Extended Abstract, June 2012.

Gupta, R., Cheret, T., Pauget, F. and Lacaze, S. Automated Geomodelling a Nigeria Case Study. EAGE Extended Abstracts, B020, June 2008.

Henderson, J., Purves, S. J., Leppard,C. (2007) Automated delineation of geological elements from 3D seismic data through analysis of multi-channel volumetric spectral decomposition data. *First Break*, **25**, 87-93.

Lemaire R., Pauget F., Lacaze S., Cheret T., Mangue M. & Horno Kort C. A Multi Scale Approach on Large Seismic Volumes – Tunisia Case Study. EAGE Extended abstracts, 72nd EAGE Conference & Exhibition, June 2010.

Lacaze, S; Pauget, F; Lopez, M; Gay, A;. Mangue, M, 2012.High Resolution Fault and Seals Imaging from Geological Model - A North Sea Case Study, EAGE Fault and Top Seals Conference Extended Abstract, C12, October 2012.

McArdle, N.J. and Ackers, M.A. (2012) Understanding seismic thin-bed responses using frequency decomposition and RGB Blending. *First Break*, **30**, 57-65.

Schmidt, I., Docherty, M., Pauget, F. and Lacaze, S. Improved 3D seismic interpretation and reservoir model construction using PaleoScan technology, AAPG, Abstract, April 2010.

Schmidt, I., Hansen, H.P., Stanbrook, S., Kiely, Mukund, S., Turbidite Play Interpretation with Elastic Invesion, Sedimentology, Sequence Stratigraphy and Seismic Geomodelling Technology. EAGE Extended Abstract, June 2012.

Vilalie, M., van Buchem, Frans., Schmidt, I., Uldall, A., Seismic Stratigraphy of the lower Cretaceous Valhall Fromation (Danish Graben, North Sea) – evidence for eustatic and local tectonic control. EAGE Extended Abstract, June 2012.

Van Hoek T., Gesbert S. and Pickens J. Geometric Attributes for Seismic Stratigraphic Interpretation, The Leading Edge, Vol 30, no.1,1056-1065, January 2011.