G. DE BRUIN[1], H. LIGTENBERG[1*], N. HEMSTRA[1], K. TINGDAHL[2]
[1] dGB Earth Sciences BV, Nijverheidstraat 11-2, 7511 JM Enschede, The Netherlands
* Current addres: Shell International E&P – NAM, Schepersmaat 2, Assen, The Netherlands
[2] dGB-USA,1 Sugar Creek Center Blvd. Suite 935 Sugar Land, TX 77478 USA

Synchronized sequence stratigraphic interpretation in the structural and chrono-stratigraphic (Wheeler transformed) domain

Introduction

Chrono-stratigraphic horizon tracking, Wheeler transforms and system tracts interpretations are unique 3D seismic interpretation capabilities that are supported in OpendTect SSIS, dGB's new Sequence Stratigraphic Interpretation System. In SSIS, seismic interpreters are offered new ways of visualizing and analyzing seismic data, which leads to better insights of sediment deposition, erosion and timing. In combination with OpendTect's attributes and neural networks plugin, users can follow up with advanced analysis of the data and study the resulting patterns and bodies, and their spatial distribution, in both the structural and chrono-stratigraphic (Wheeler transformed) domain.

OpendTect SSIS Workflow

The OpendTect SSIS workflow is an iterative process that consists of four basic steps. First, major bounding surfaces are interactively mapped with horizon trackers. Next, all possible intermediate horizons are auto-tracked with sub-sample accuracy. Each intermediate horizon corresponds to a geological time line, i.e. a chrono-stratigraphic event (Figure 1). Two auto-track modes are supported: model driven and data driven. In the model driven approach, chrono-stratigraphy is calculated by interpolation or by adding horizons parallel to upper or lower bounding surfaces. In the data-driven mode, seismic horizons are auto-tracked by following the local dip and azimuth of the seismic events. This mode requires a pre-calculated steering cube that contains the local dip and azimuth information.

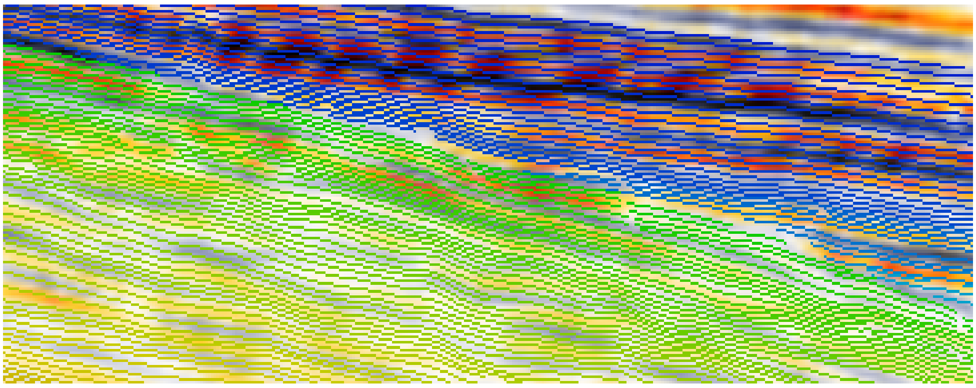

Figure 1: Chrono-stratigraphic horizons are auto-tracked while honouring hiatuses.

The third step in the process is the actual Wheeler transform. Basically, this is a flattening of the seismic data (or derived attributes) along the auto-tracked horizons, that honours truncations and erosional / depositional hiatuses (figure 2). Studying the data in the Wheeler transformed domain increases our understanding of the spatial distribution and timing of sediment deposition. The fourth step in the SSIS workflow is the synchronized analysis of the seismic data in both the structural and normal domain.

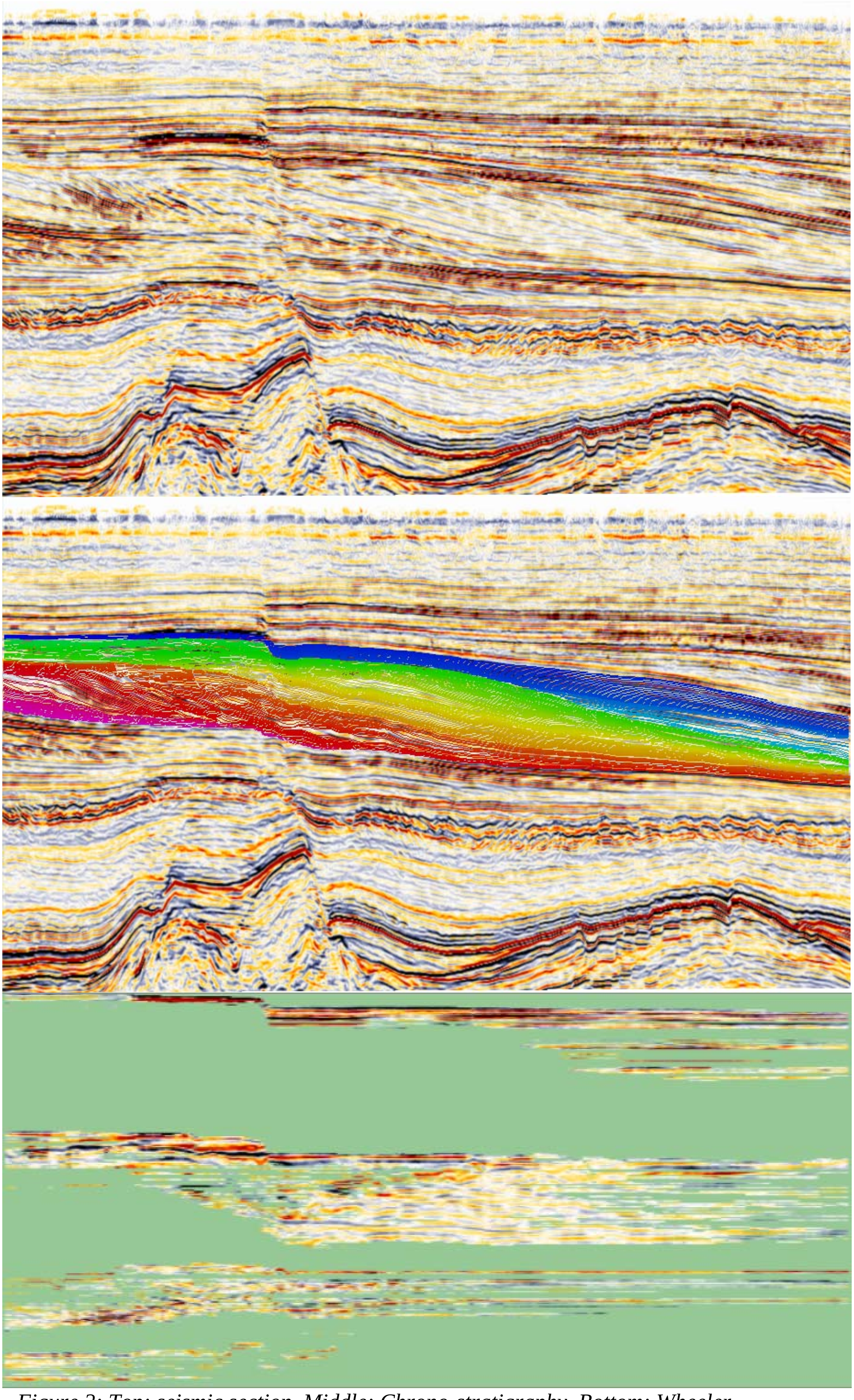

Figure 2: Top: seismic section. Middle: Chrono-stratigraphy. Bottom: Wheeler transformed seismic data

Data analysis in both the structural and Wheeler transformed domain

The first step in our synchronized analysis in both domains is to make a systems tracts interpretation by subdivision of the sequences. Inspecting the spatial distribution of the sequences and lap-out patterns of seismic events, in both the structural and the Wheeler transformed domain, enables the user to identify systems tracts and to specify them per chrono-stratigraphic range (figure 3).

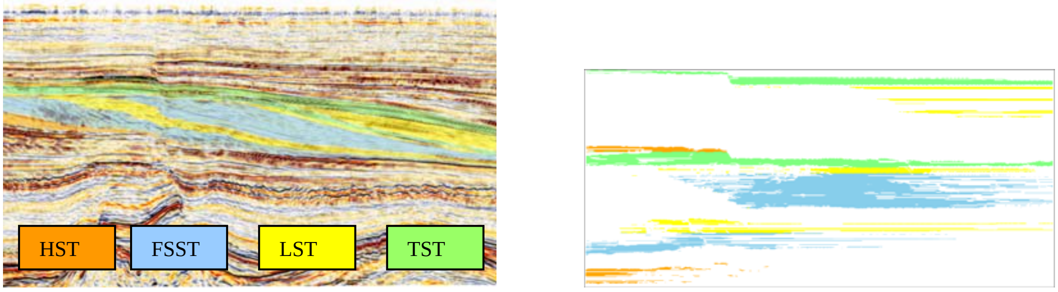

Fig 3: Systems tracts interpretation in the structural and Wheeler transformed domain

Similarly, supervised neural network outputs can be analyzed in both domains. For instance seismic information can be converted to porosity by way of neural network inversion. The neural network is trained to establish the (possibly non-linear) relationship between seismic response and porosity. When analyzing the result solely in the structural domain, trends in time and space are difficult to interpret, but while using the Wheeler transformed domain these trends are very obvious (Figure 4). The two lower sequences shows a clear regressive trend while the upper sequence shows a transgressive trend. When linking the porosity data to facies, or even lithology, an interpreter can make a rough estimation of the facies or lithology distribution in time and space.

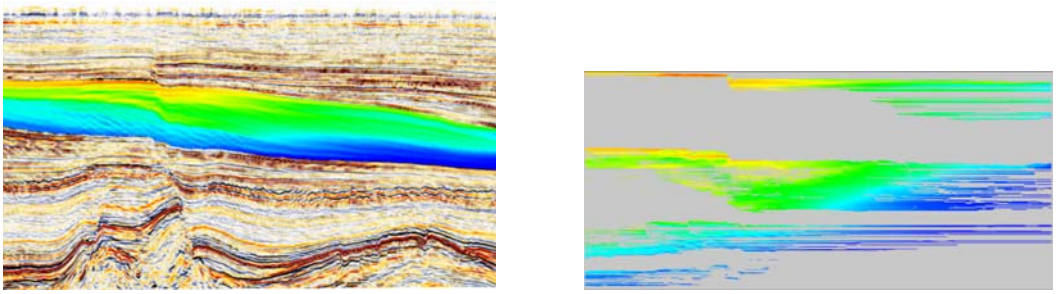

Figure4: Porosity in the structural and Wheeler transformed domain

Advanced seismic facies analysis is possible by means of a neural network. Waveform segmentation along any chrono-stratigraphic horizon is a simple, straightforward approach for visualizing seismic patterns per stratigraphic event. Similarly, seismic attributes can be clustered by a neural network to reveal 3D bodies. When analyzing these results in both domains it becomes apparent that the seismic facies are closely linked to depositional position, and shifts in facies is shown as expected (Figure 5). Similar patterns can be observed when analyzing single attributes in both domains, as for instance spectral decomposition (Figure 6).

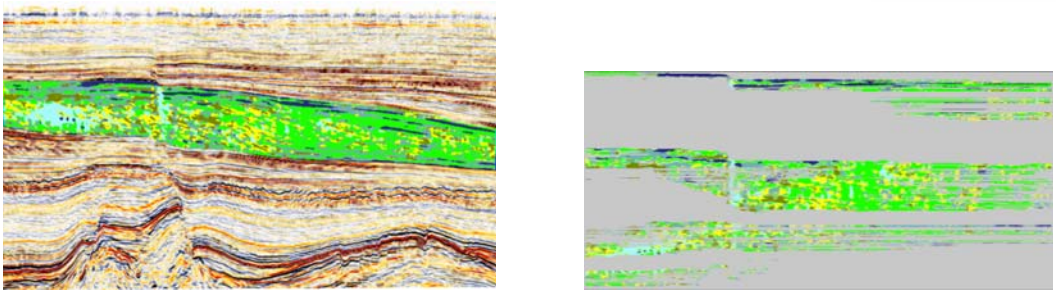

Figure 5: A 3D seismic facies clustering based on waveform in the structural and Wheeler transformed domain

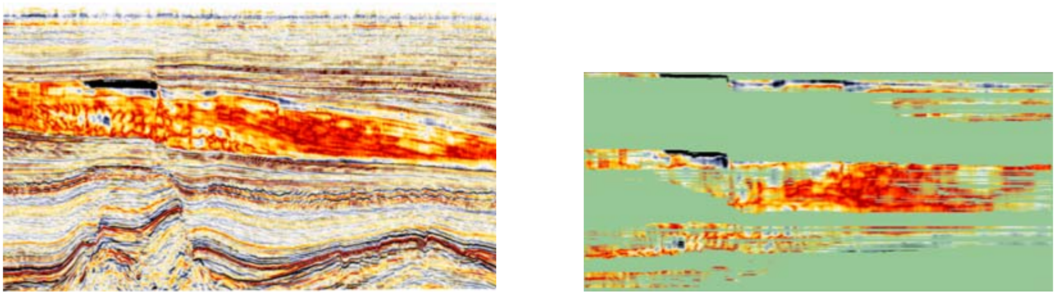

Figure 6: Spectral decomposition(30 Hz) in the structural and Wheeler transformed domain

Incorporating Chrono-stratigraphic results in different disciplines

All seismic (sub) events are mapped (figure 1) and can be extracted as individual 3D grids. Additional seismic attribute and neural network analysis can be applied to individual sequences or isochrones. These individual isochrones can also be used as input for basin modelling, for stratigraphic modelling and to improve your reservoir model with additional accurate internal layering.

Possible extensions of the sequence stratigraphic analysis

The sequence stratigraphic analysis could be improved further by incorporating well data and core data. Wells have a much higher vertical resolution, but lack the lateral resolution of seismic data. Possibilities are to incorporate biostratigraphy in the chrono-stratigraphy calculation, to improve the geological time assignment. Vice versa, the chrono-stratigraphy can be used to assist in the correlation between wells.

Facies predictions, derived from the Wheeler transform, could be used as an input to improve lithology predictions, since facies type and lithology are closely linked. Facies type could be used as an extra input during a supervised neural network prediction.

Conclusions

The analysis of data in both the structural and Wheeler transformed domain provides a far better insight in the data and reveals geometries and patterns that would otherwise be difficult to interpret in the structural domain alone.

References

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