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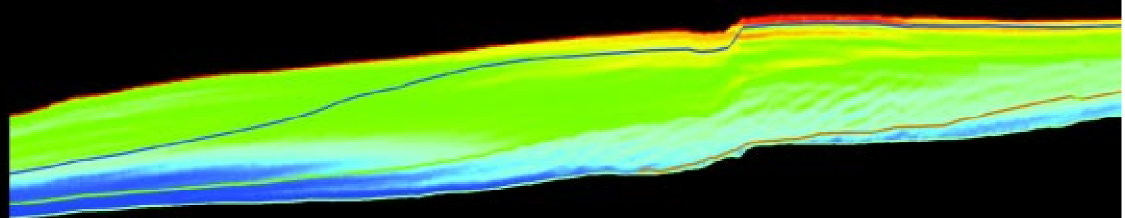

OpendTect SSIS

Sequence Stratigraphic Interpretation System

Sequence Stratigraphic Interpretation System (SSIS) is a new plugin of OpendTect, the open source seismic interpretation software. In OpendTect SSIS, seismic interpreters are offered new ways of visualizing and analyzing seismic data, which leads to better insights of sediment deposition, erosion and timing.

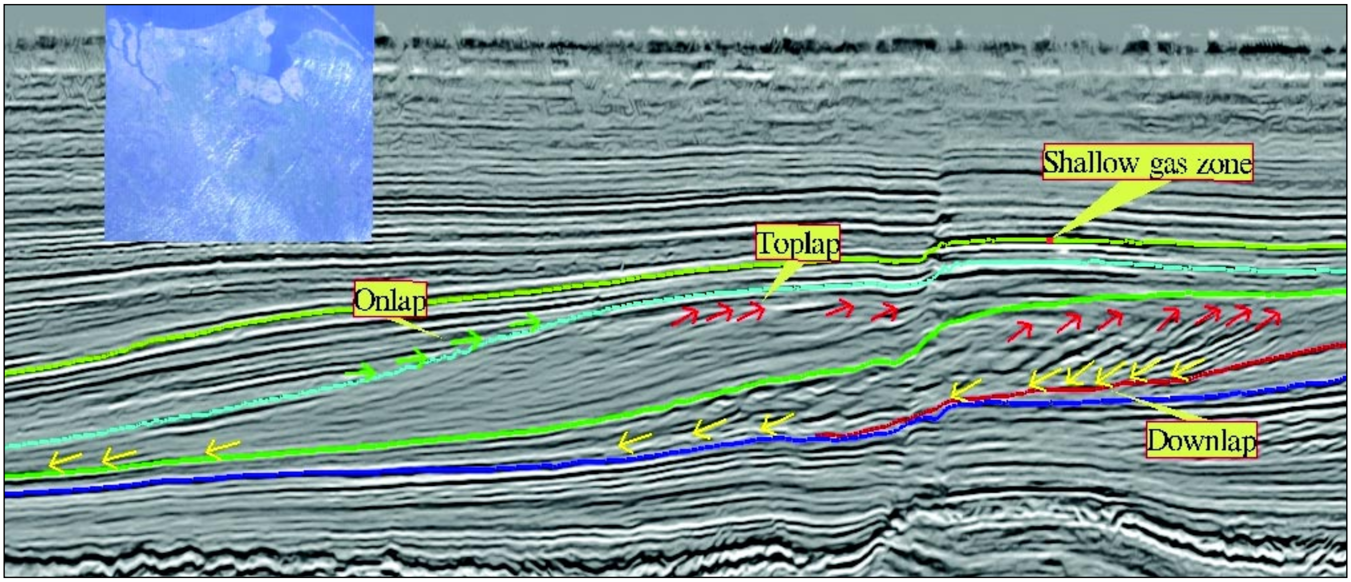

Figure 1: Example of some typical sequence stratigraphic annotations made in OpendTect Base, the open source part of the system.

OpendTect SSIS

Sequence Stratigraphic Interpretation System

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Summary

This article describes a new software system for sequence stratigraphic interpretation of 3D seismic data. SSIS is a new plugin of OpendTect, the open source seismic interpretation software that was described in the January 2006 issue of DEW. In OpendTect SSIS, seismic interpreters are offered new ways of visualizing and analyzing seismic data, which leads to better insights of sediment deposition, erosion and timing. Unique capabilities in SSIS are: automated tracking at sub-seismic resolution of chrono-stratigraphic horizons, Wheeler transformations (i.e. flattening) of 3D seismic data, and systems tracts interpretations. In combination with OpendTect's attributes and neural networks plugins, 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.

Introduction

Sequence Stratigraphy, the method that originated from the study of seismic patterns in the 1970's, considerably improved our insight in the accumulation and preservation of sediments in sedimentary basins (for an excellent introduction to Sequence Stratigraphy, see Catuneanu, 2002). The technique is widely used as a highly successful hydrocarbon exploration tool for predicting stratigraphic traps. With the trend in hydrocarbon exploration shifting towards complex structural traps and subtle stratigraphic traps, the need for Sequence Stratigraphy is bound to grow further. Against this background it is distinctly odd that no software tools exist on the market to assist geoscientists with a sequence stratigraphic interpretation. Most of the work is still done on 2D seismic paper sections using color pencils.

With the introduction of OpendTect SSIS this practice may change. OpendTect Base (the open source part of the system) now supports annotations of arrows, text labels and images. Fig.1 gives an example of arrows indicating downlap, toplap and onlap terminations, text labels highlighting features of interest and a linked satellite image showing the location. In addition to the extensions of the base system the new SSIS plugin

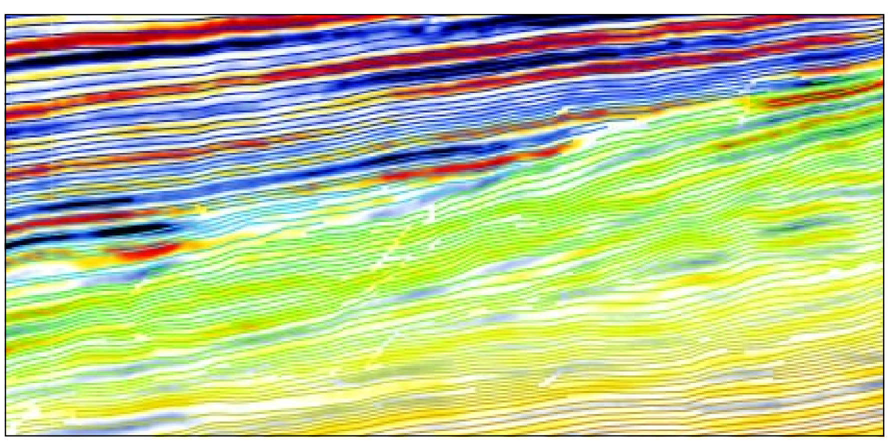
Fig. 2:Auto-tracked chrono-stratigraphic horizons terminate against each other thus highlighting unconformities.

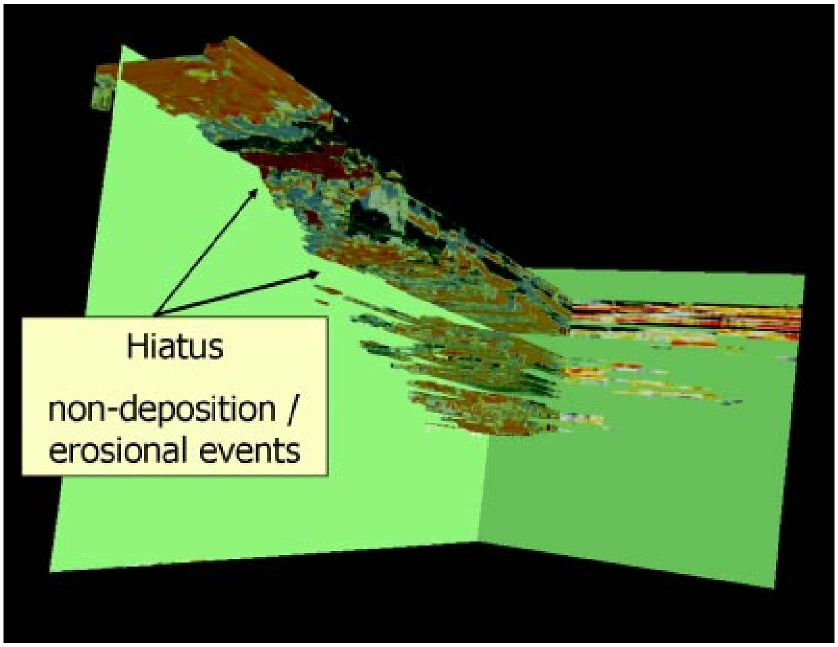

Fig. 3: 3D Wheeler transformed seismic data. The vertical axis represents relative geologic time.

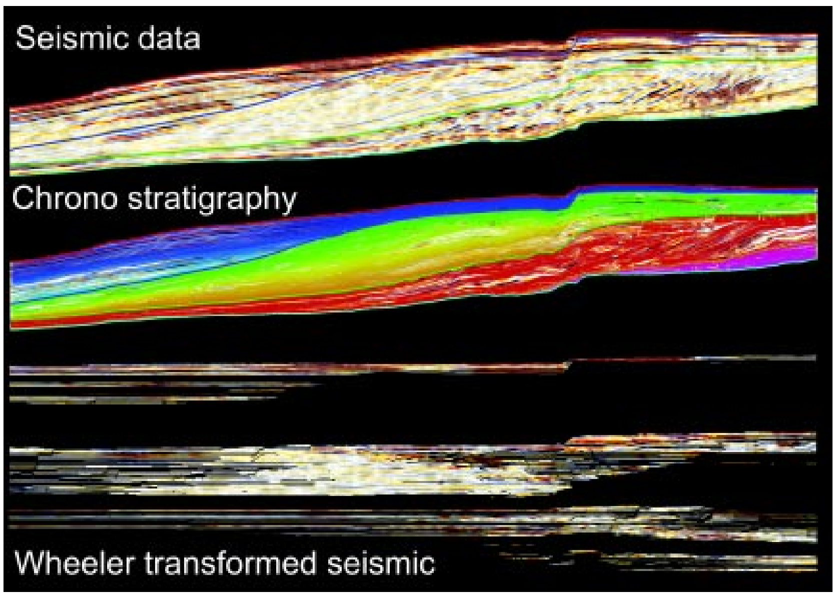

Fig. 4:Seismic line (top) with auto-tracked chrono-stratigaphic horizons overlain (middle) and Wheeler-transformed result (bottom).

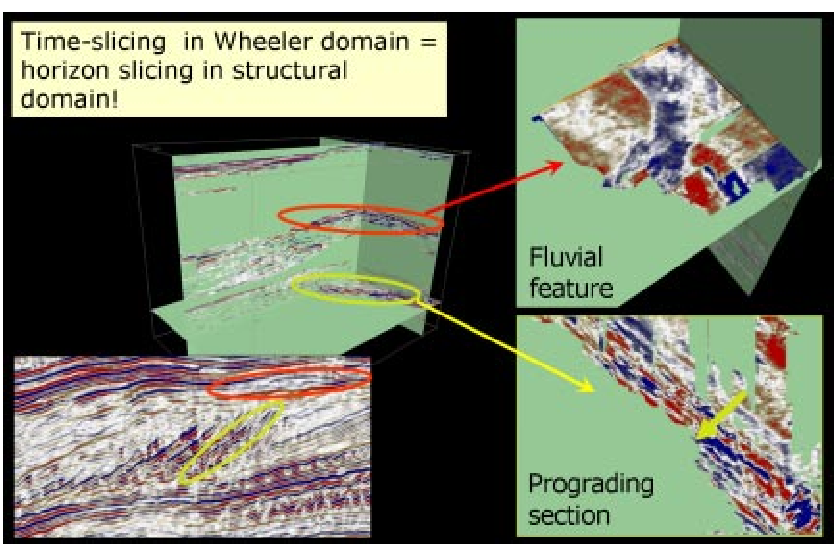

Fig. 5:Sedimentary feature on a time-slice from the Wheeler-transformed seismic data.

supports unique capabilities for studying and visualizing seismic data for sequence stratigraphic purposes. SSIS allows data to be studied in two synchronized domains. The structural domain is the normal seismic domain in which the vertical axis represents two-way travel time, or depth as the case may be. The chrono-stratigraphic domain is the Wheeler-transformed (flattened) domain. The vertical axis in this domain is relative geologic time.

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. This work is either done in OpendTect base, or the horizons are imported from other interpretation systems. Next, intermediate horizons spaced roughly one seismic sample apart 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 (de Groot et.al., 2006). This mode requires a pre-calculated steering cube that contains the local dip and azimuth information.

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 3). 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 Wheeler domain (de Bruin et.al., 2006).

Example

The example is from offshore The Netherlands where we analyze a deltaic package comprising sands and shales. Within the package large scale sigmoidal bedding with downlap, toplap, onlap and truncation structures are readily observed. Bright-spots are also clearly visible, and are caused by biogenic gas pockets. Fig. 4 (top) shows one inline through the 3D volume. The interpreted lines are horizons that were mapped in the conventional way using auto-trackers and manual interpretation techniques. These horizons represent major bounding surfaces between which chrono-stratigraphic horizons are auto-tracked (Fig. 4 middle). The Wheeler transformed data is shown in Fig. 4 bottom. In this domain it is easier to recognize hiatuses and erosional effects. Moreover, time-slices in the Wheeler-transformed domain correspond to horizon slices in the structural domain. Consequently time-slices in the Wheeler domain reveal sedimentary features that are not distorted by structural effects. Fig. 5 gives an example.

Wheeler transforms are not restricted to seismic data. In principle any seismic volume or attribute can be transformed and studied in the Wheeler domain. Fig. 6 shows the transformation of a porosity volume. This volume was created within OpendTect from an acoustic impedance volume by a neural network that was trained on well logs and AI extracted along the well tracks. Note the text-book quality porosity progradation in the Wheeler transformed domain. This porosity/facies trend is not, or at least much more difficult to pick up in the structural domain.

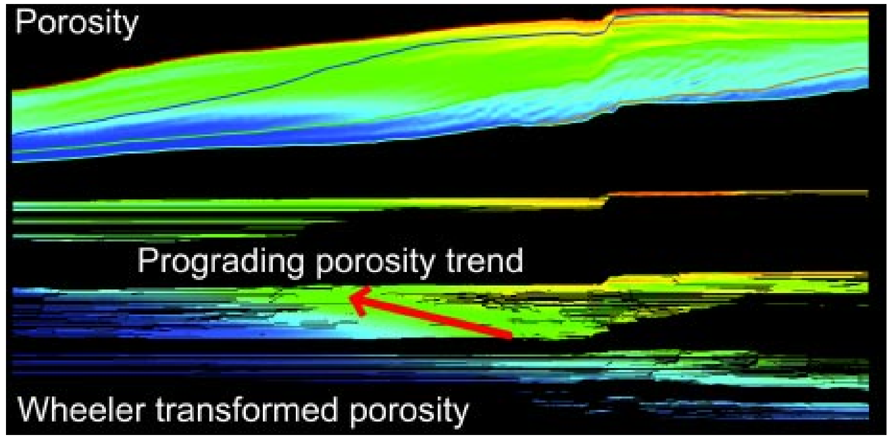

Fig. 6:Seismic predicted porosity in the structural domain (a) and the Wheeler-transformed domain (b). Note the prograding porosity trend that stands out in the Wheeler-transformed domain.

Next, we show the results of a seismic facies clustering (Fig. 7). This result was generated with an unsupervised neural network that was aimed to cluster the seismic data into 6 different clusters based on differences in attribute response. To obtain realistic clusters the attributes were extracted along chrono-stratigraphic lines (dip-steered attribute extraction and smoothing). The upper left image in Fig. 7 shows the clustered result in the structural domain. The Wheeler transformed result of a few lines is shown. It was observed that one of the seismic objects (red colour) corresponded to bright-spots in the seismic data. Using simple logical (IF … THEN … ELSE …) and mathematical operations supported within OpendTect Base the red bodies in the upper-most

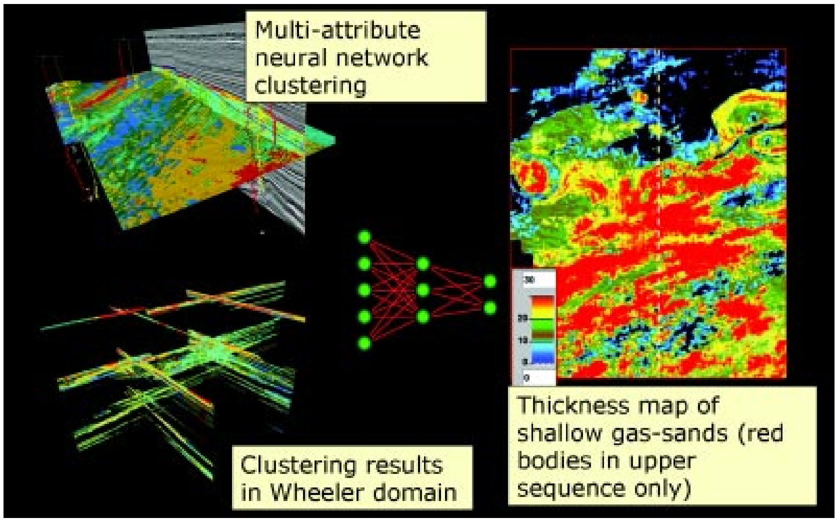

Fig. 7:Neural network clustering of attributes reveals seismic bodies that can be further analyzed and manipulated to create e.g. thickness maps.

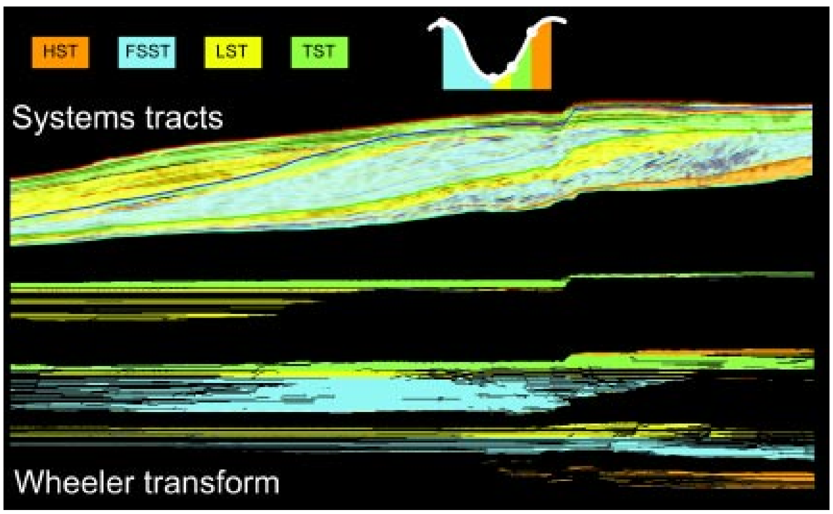

Fig. 8:Systems tracts interpretation.

sequence were then isolated and a thickness map was produced. This map shows the thickness of the biogenic gas-pockets in the upper sequence.

An important step in any sequence stratigraphic interpretation is to perform a systems tracts interpretation by subdivision of the identified sequences. Inspecting the spatial distribution of the sequences and lap-out patterns of seismic events, in both the structural and the Wheeler transformed domains enables the user to identify systems tracts and to specify these per chrono-stratigraphic range (figure 8).

Conclusions

Auto-tracking horizons that are spaced roughly one seismic sample apart opens a completely new way of analyzing and visualizing seismic data. Viewing chrono-stratigraphic horizons in the structural domain highlights unconformities, helps decomposing packages into (sub-) sequences and assists in systems tracts interpretation. Chrono-stratigraphy is also instrumental in transforming the data to the Wheeler domain. Studying the data in this domain leads to better insight of sediment deposition, erosion and timing.

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ABOUT THE AUTHORS

Paul de Groot is Managing Director of dGB. He worked ten years for Shell where he served in various technical and management positions. Paul subsequently worked four years as a senior research geophysicist for TNO Institute of Applied Geosciences before co-founding dGB in 1995. He has authored many papers covering a wide range of geophysical topics and co-authored a patent on seismic object detection. Paul holds MSc and PhD degrees in geophysics from Delft University of Technology.

Geert de Bruin is a Geoscientist, working for dGB since 2004. He is primarily involved in seismic object detection and interpretation studies. Furthermore, he is providing the SSIS (Sequence Stratigraphic Interpretation System) development project with geological guidance and he is conducting the sequence stratigraphic analyses. Geert holds a MSc in sedimentary Geology from the Free University of Amsterdam, where he specialized in carbonate geology.

Kirstin McBeath obtained a BSc in geology from the University of Aberdeen. She is currently finalizing her MSc in geophsyics with Leeds University on a sequence stratigraphic interpretation project with dGB Earth Sciences. From Sep. 2006 Kirstin will be employed by BP.