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Maximizing the Value of Seismic Data Through the Increased Mapping of Horizons

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Summary

Conventional interpretation workflows today require a limited number of key horizons to be mapped to construct generalized geologic models. The result is that gigabytes of data are often reduced to just a few kilobytes of interpreted data on which key economic decisions are made. An improvement in interpretation can be achieved by greatly increasing the number of mapped horizons. This can increase the potential of high resolution seismic in reservoir characterization, leading to improved quantitative rock property estimation, an enhanced definition of stratigraphic traps, and more accurate and robust geological models.

In this paper, we introduce a 'step-change' in seismic interpretation where, through a series of semi-automated techniques, a high density set of mapped horizons (known as HorizonCubes) are created. The paper will demonstrate the application of this new technique through a real-life data.

Introduction

One of the single biggest challenges in seismic interpretation today is maximizing the value of geological data. While seismic interpretation technologies have improved dramatically over the last few years in their ability to predict rock types (sand, shale, carbonate, salt), rock properties (porosity) and fluid types (oil, gas, water) and develop geologically consistent 3D representations of the subsurface, too often operators remain dependent on highly generalized geological models as an input into their economic decision-making.

One of the key reasons for the limitations of a conventional workflow is that only a few key horizons are mapped. To meet these challenges, we introduce a new approach for increasing the number and density of mapped horizons and for maximizing value from existing seismic data.

The HorizonCube – An Overview

The HorizonCube we have developed consists of two steps. First, a (dip) 'steering Cube' is generated which calculates local dip and azimuth values of the seismic reflectors. The steering cube is then used to generate the horizon cube using a 3D auto-tracker algorithm that tracks the dip/azimuth field to generate a dense 'cube' of horizons throughout the 3D seismic volume. The HorizonCube consists of a dense set of correlated 3D stratigraphic surfaces that are assigned a relative geological age. Figure 1 illustrates the HorizonCube and some of its various applications, such as well correlation, sequence stratigraphic interpretation, and to build detailed geologic models.

A key advantage of the HorizonCube is that dip fields are more continuous than amplitude fields. This is as opposed to conventional auto-trackers that pick amplitudes and which lead to a set of patchy horizons rather than a set of continuous, chronologically consistent horizons. This is demonstrated in Figure 2 where the horizons are accurately tracked through a rather patchy section of delta foresets - note the 'stair-like' appearance caused by small-scale slumping in the sediments.

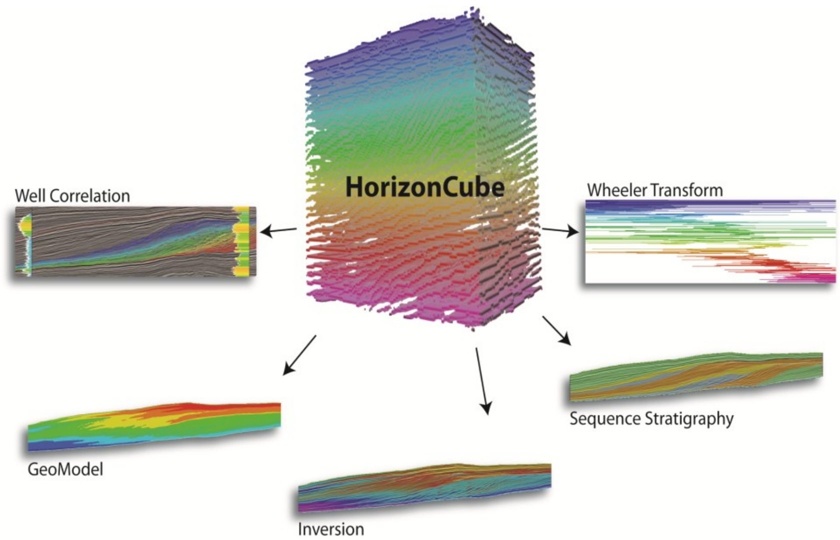

Figure 1: HorizonCube and its downstream applications.

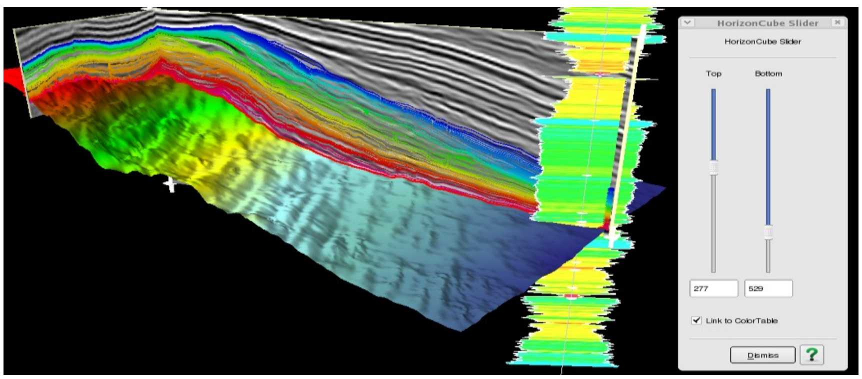

Figure 2: Section cut through the horizon cube, with one horizon fully displayed.

With HorizonCube, users can interactively reconstruct the depositional history in geological time using the HorizonCube slider, flatten seismic data in the Wheeler domain, and make full system tracts interpretations with automatic stratigraphic surface identification and base-level reconstruction.

Applications

The 3D data set we use to demonstrate the HorizonCube shows a typically deltaic progression from older shelf sediments to younger coastal sediments. While the shelf and coastal sediments are relative easy to map, the intermediate sigmoidal shape foreset beds are not. The paper will demonstrate how the HorizonCube can be applied in this environment to enhance different tasks of the geological interpretation of the seismic dataset - tasks such as well correlation, sequence stratigraphy, geomorpholigical analysis and inversion/geologic model building within this data set.

Well correlation can be enhanced with the seismic interpreter able to view in detail how events are correlated between the wells and how rock properties vary laterally. This enables the interpreter to reveal the spatial evolution of the sedimentary succession by visually moving forwards and backwards in geological time. The well correlation example is demonstrated in figure 2, highlighting in detail how events are correlated and how HorizonCube aids in the understanding of how rock properties vary laterally. To facilitate correlation, a section through one or more wells is created from the 3D volume, and the horizons from the HorizonCube are displayed on this section. The color coding indicates relative geologic age and an interactive slider on the right is used to correlate chronostratigraphic sequences of interest to the well logs. In the example, the shaly, toe-of-slope facies in the well correlates with the sandy shelf-edge facies updip (well not shown in image).

Geological model building. The data set examines the HorizonCube's application for inversion/geologic model building. Acoustic Impedance (AI) inversion for quantitative rock property estimation form a crucial stage in reservoir characterization. The greater the number of horizons, the greater accuracy in the AI inversion results, a fact demonstrated in figure 3 The simple model uses only top and bottom horizons to guide the well interpolations *(a).* The detailed model uses 19 additional horizons *(d).* The simple low-frequency model *(b)* does not fully honor the seismic while the detailed model does. The inverted results which are driven by the input models reflect these differences *(c & f).* The difference in detail between the conventional workflow and HorizonCube is significant.

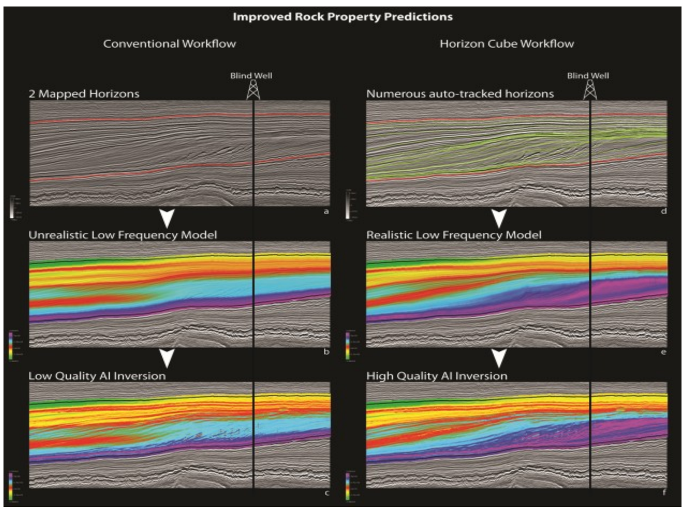

Figure 3: Benchmark test of low frequency models using conventional and HorizonCube workflow.

Seismic Sequence stratigraphic interpretation is illustrated in figure 4, where a workflow is applied to analyze 3D data sets. The resulting dense set of horizons is grouped by the interpreter into genetically related units or systems tracts with the user sub-dividing the sequence into packages with similar depositional characteristics revealed by the densely tracked horizons. The interpreter is aided by interactive visualization tools, such as the chronostrat slider and displays in the Wheeler domain.

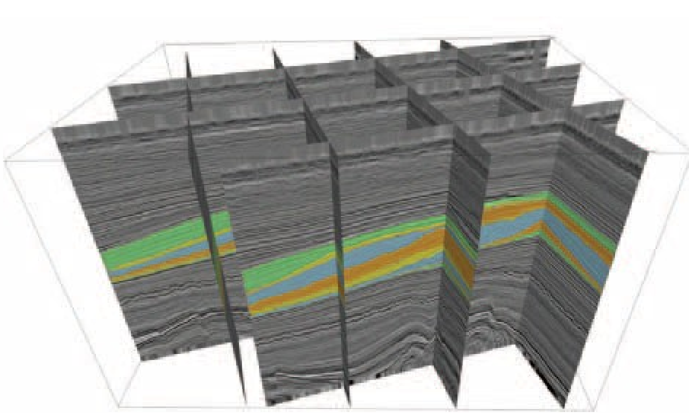

Figure 4: Seismic Sequence Stratigraphic interpretation using the HorizonCube

Geomorphological interpretation is shown in Figure 5, using a blended display of structure (color) and discontinuities (grey scales) where from top left, clockwise, we slice through: 1) bottomsets with turbidite channels sourced from the paleo-high; 2) prodelta lobe showing slumped foresets and continuous shelf deposits deeper in the basin; 3) progradation of the foresets deeper into the basin, showing topset landward (not the incisions at the steep cliff in the upper left corner!); and 4) a tidal-flat environment showing reworked coastline and channels. The HorizonCube allows the interpreter to geoslice the sigmoidal foresets, which are notoriously hard to map using conventional methods, at arbitrary geological chrono-consistent surfaces. Combining sequence stratigraphic interpretation and geomorphological interpretation leads to a very accurate 3D prediction of sedimentary facies for source rock, reservoir rock and seal rock.

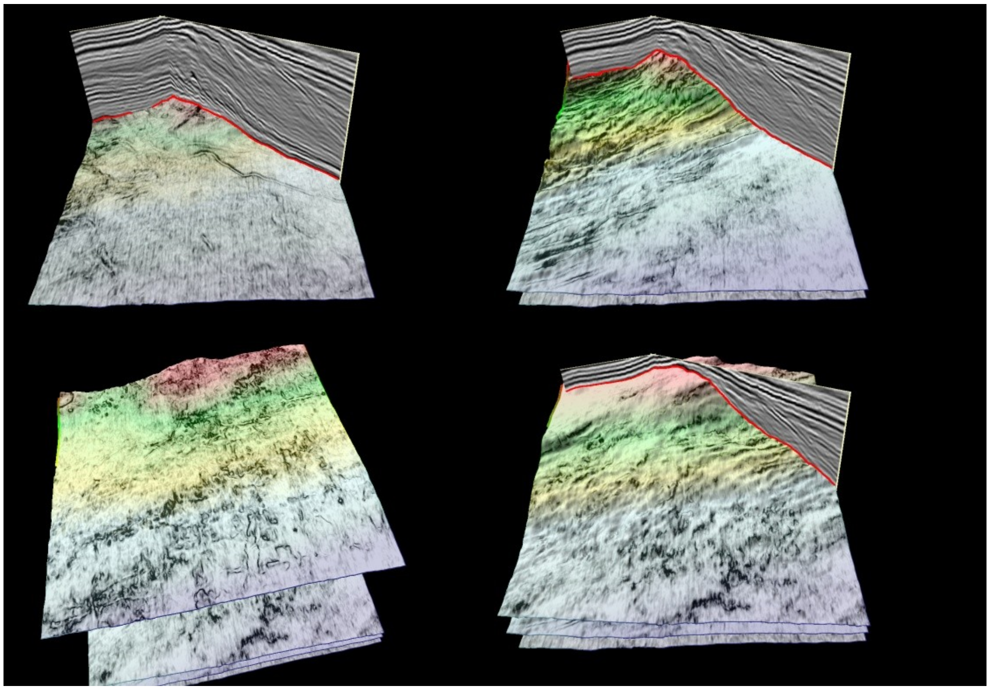

Figure 5: Geoslicing through the delta sequences showing structure (color) and seismic discontinuity (grey scale).

Conclusions

This abstract demonstrates that densely tracked horizon mapping enables seismic interpreters to extract more information from their high resolution data and meet this goal. The potential benefits of improved well correlation, facies mapping and sequence stratigraphy, and rock property estimation are illustrated in this paper.

Acknowledgements

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