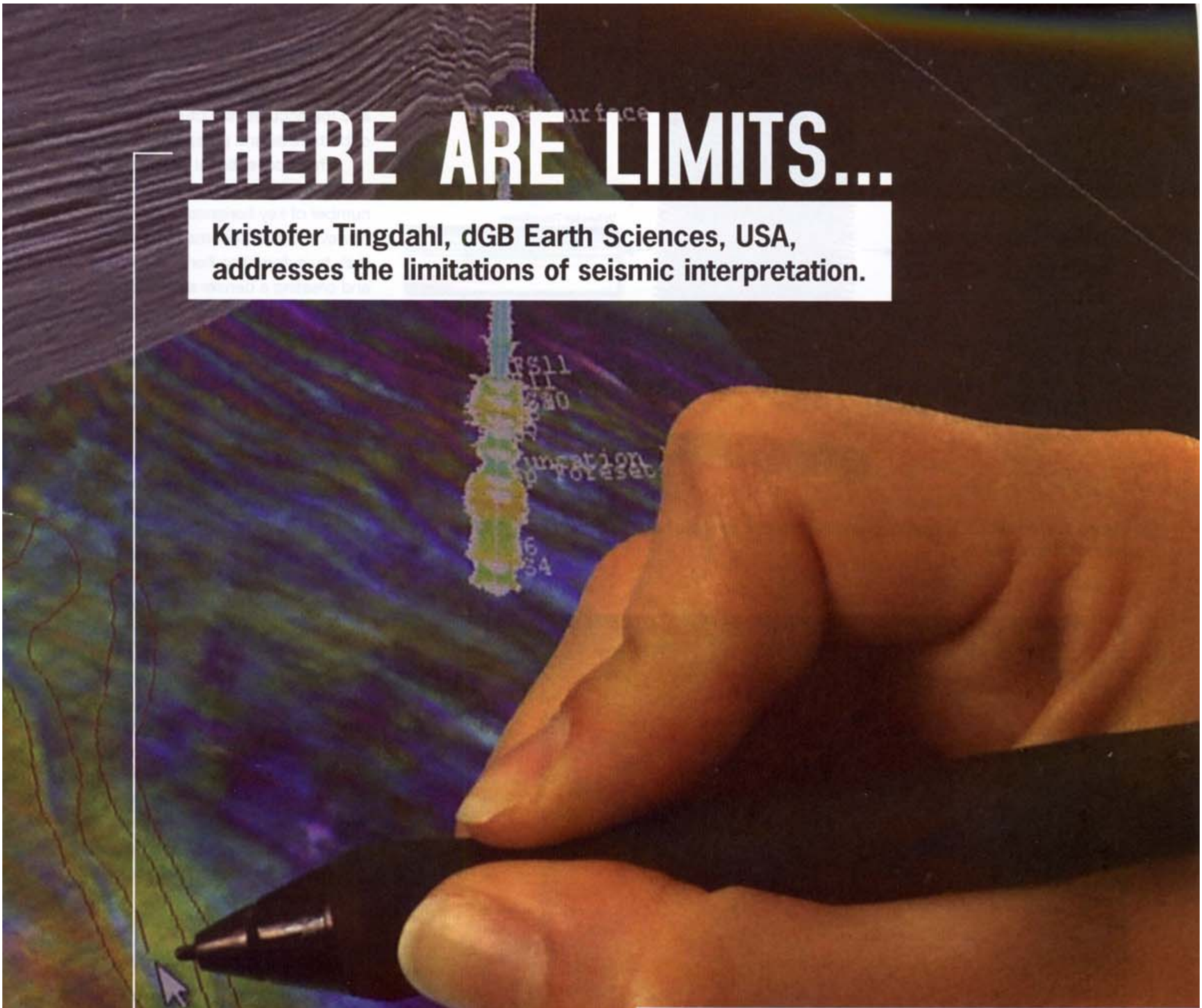
THERE ARE LIMITS...

Kristofer Tingdahl, dGB Earth Sciences, USA, addresses the limitations of seismic interpretation.



Few would argue against the premise that seismic interpretation tools and their ease of use have improved significantly over the last few years.

From advances in attribute analysis to fault mapping and horizon picking, seismic interpretation has made substantial advances in developing geologically consistent 3D representations of the subsurface. Interpreters today can also enjoy a highly visual graphics environment on which to rigorously interpret their geological data and maximise its value for future reservoir management decisions.

This being said, however, seismic interpretation today still comes with certain limitations, which are manifested in a number of ways. For example, many geological models, often containing gigabytes of data, still remain highly generalised. All too often, it is just kilobytes and megabytes of data, including just a few mapped horizons, from which important interpretations are derived. The result is that huge amounts of potentially valuable seismic information are being lost.

There is also often a lack of understanding of the full structure of the seismic data, a lack of integration across the workflow and a manual-focus to interpretation activities.

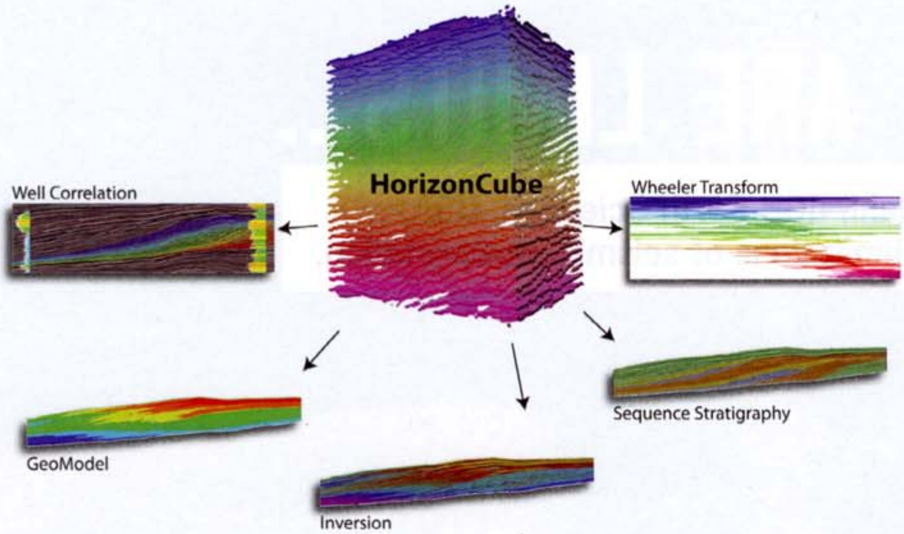


Figure 1. *The HorizonCube process and the impact it can have on all elements of the seismic interpretation workflow.*

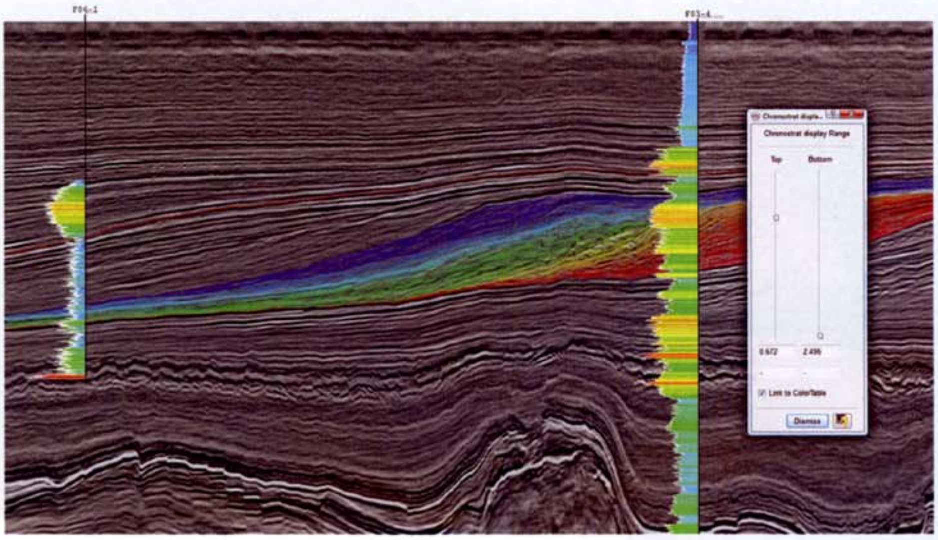


Figure 2. *The power of high density horizon tracking for chronostratigraphic correlation. All tracked events are assigned a relative geological age displayed with a corresponding colour.*

In this way, users are unable to gain a clear picture of the data's depositional history, and horizons and faults often have to be picked and edited manually.

Against this context, there is a clear need for today's seismic interpretation software to generate improved quantitative rock property estimations and clearer definitions of stratigraphic traps, create more accurate and robust geological models, and extract more value from the terabytes of high resolution seismic data.

This article will look at how these challenges are being met through a new automated horizon tracking tool and an improved graphics-focused environment.

The importance of horizons

Horizons – the term used to denote the surface in or of a rock or a particular layer of rock that might be represented by a reflection in seismic data – have always been central to seismic interpretation. Seismic horizon interpretation can result in automatic fault detection and definition and the accurate structural modelling of both fields and prospects.

While conventional interpretation workflows might only require a limited number of key horizons to be mapped, however, it has become clear to us that, by automating horizon tracking and creating a denser set of horizons, interpreters can extract more geology from their seismic data.

A dense set of auto-tracked horizons can help guide well correlations, generate an improved insight into the depositional environment, interpret systems tracts, and improve the chances of finding stratigraphic traps where oil might be found.

Furthermore, in comparison to standard workflows where the low frequency model is often considered to be the weakest link, having a dense set of horizons can result in a much more detailed model being built to be put forward for seismic inversion. By interpolating well data along the dense set of horizons, detailed geologic models can be generated that are fully consistent with seismic measurements.

This is the rationale and thinking behind the dip-steered auto-tracker dGB Earth Sciences has developed, known as the HorizonCube.

Building the HorizonCube

The HorizonCube is a new plugin which is part of the company's OpendTect seismic interpretation software, where a dense set of correlated 3D stratigraphic surfaces are developed into a set of continuous, chronologically consistent horizons through an advanced algorithm. All correlated 3D stratigraphic surfaces are assigned a relative geological age.

Figure 1 outlines the process as well as the impact the HorizonCube can have on all elements of the seismic interpretation workflow, from well correlation to inversion to sequence stratigraphy.

To create a HorizonCube, all the user must do is input dip and azimuth cubes, at least two mapped horizons, and (optionally) mapped fault planes. Horizons are then created either in a model-driven way (through stratal or proportional slicing, for example) or in a data-driven way via a dip-steered, 3D chronostratigraphy auto-tracker.

The auto-tracker algorithm tracks the dip/azimuth field to generate horizons that are typically separated by one sample at the starting position. The dip/azimuth field is smoothed, reduces the impact of random noise, and allows the user to control the detail that needs to be captured by the horizon tracker.

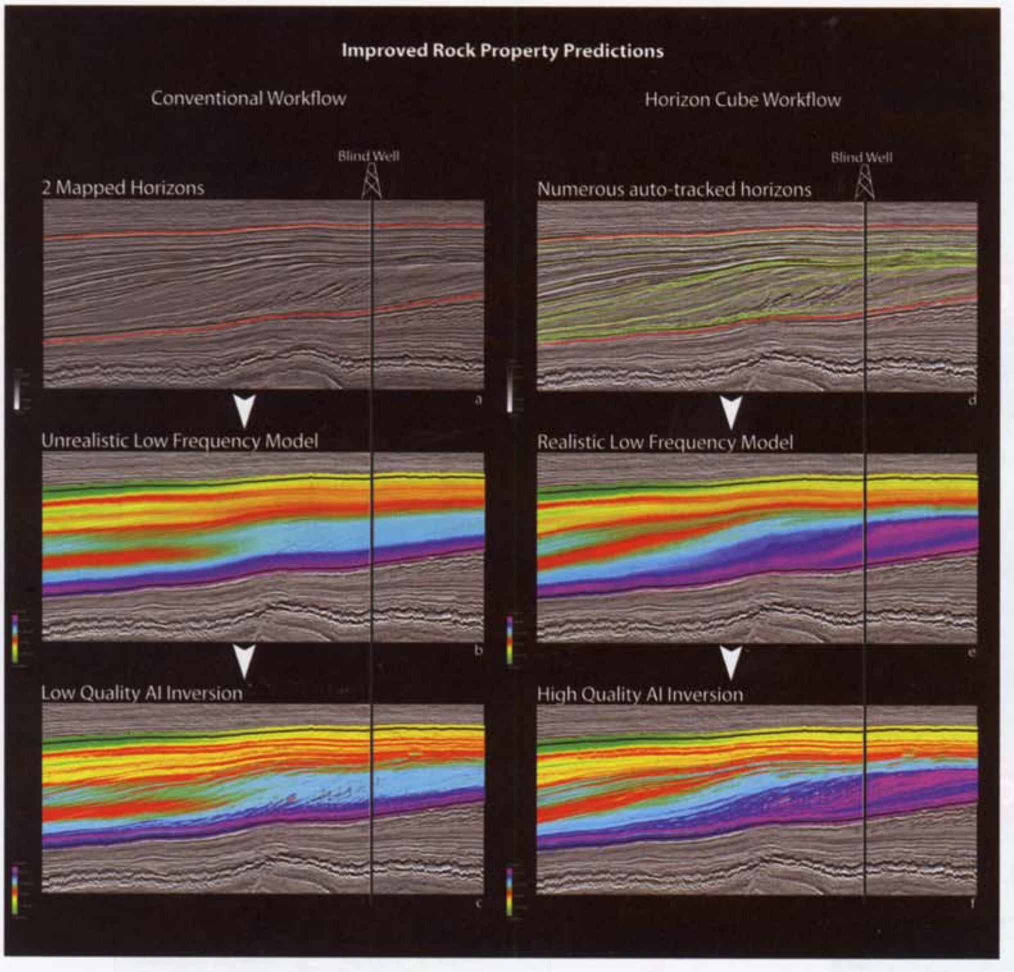


Figure 3. *The difference between the HorizonCube and the conventional workflow in regard to not only the quality of the model but also the quality of the Acoustic Impedance (AI) inversions.*

Another advantage is that smoothed dip fields are more continuous than amplitude fields, that are used by conventional auto-trackers that pick amplitudes and/or trace similarities and then stop when the constraints are no longer satisfied. The result is a series of patchy horizons rather than continuous, chronologically consistent horizons as is the case here with HorizonCube. Horizons with watertight intersections at the faults are also generated through the HorizonCube by automatically stopping against mapped fault planes.

Figure 2 demonstrates the power of high density horizon tracking for chronostratigraphic correlation. To facilitate correlation, a random line created from the 3D volume through the wells and a dense set of horizons is auto tracked. All tracked events are assigned a relative geological age displayed with a corresponding colour with an interactive slider used to add or remove these chronostratigraphic events.

The process highlights in detail how events are correlated between the wells and aids in the understanding of how rock properties vary laterally. For example, the sandy shelf-edge facies observed in the right well correlates with a shaly, toe-of-slope facies in the well on the left.

The benefits of HorizonCube

So what are the benefits of the new HorizonCube?

Firstly, the auto-tracked horizons allow a detailed and accurate low frequency model to be developed. Figure 3, for example, demonstrates the difference between the HorizonCube and the conventional workflow in regard to not only the quality of the model but also the quality of the Acoustic Impedance (AI) inversions.

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 honour the seismic while the detailed model does. The inverted results which are driven by the input models reflect these differences (c & f).

In this way, operators can get a lot more geology out of their 3D models and highly accurate low frequency models can be used to create geologically correct AI and Elastic Impedance (EI) cubes through the use of Deterministic and Stochastic Inversion plugins.

A clearer image of reservoir geometries can also be obtained. For example, Figure 4 shows the thickness maps of the depositional sequences with and without HorizonCube interpretation on a field, offshore Abu Dhabi.

In this case, one of the main challenges of the seismic interpretation was the poor quality of the 3D data, where, due to this poor quality, the automated tracking of chronostratigraphic unit boundaries was not possible using conventional tracking methods (amplitude and phase responses were too indistinct for the tracker to trace for any distance in a consistent manner).

Through HorizonCube, however, it was possible to create a dense set of auto-tracked horizons and seismic-based maps of depositional cycles and system tracts – in this case, reflecting sediment build-up on the reef surface.

Well correlation and seismic/well data integration

Two of the biggest challenges in seismic interpretation today are the ability to effectively use seismic data to aid well correlation and to support this through the integration of well-based sequence stratigraphy with seismic sequence stratigraphy.

To this end, the densely tracked horizon mapping and the interactive slider of HorizonCube allows interpreters to correlate and update well markers and horizons in order to improve well correlation. It allows the interpreter to reveal the spatial evolution of the sedimentary succession by visually moving forwards and backwards in geological time, highlighting in detail how events are correlated between the wells and aiding in the understanding of how rock properties vary laterally.

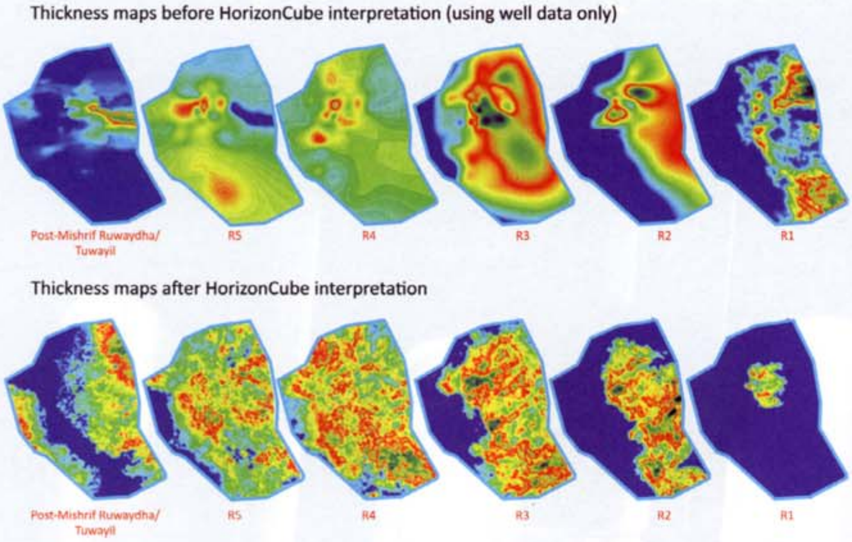


Figure 4. *The thickness maps of the depositional sequences with and without HorizonCube interpretation on a field, offshore Abu Dhabi.*

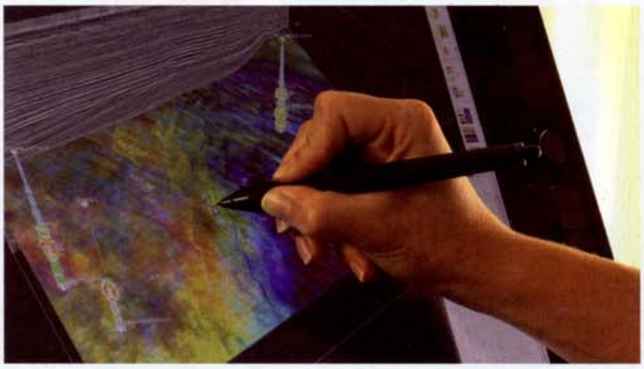


Figure 5. *Seismic interpreters can use HorizonCube to interact directly with the tablet in their editing and visualisation activities.*

Furthermore, in partnership with third-party specialists, dGB now offers the stratigraphic framework analysis of associated well log data, as an add-on to its Sequence Stratigraphic Interpretation System (SSIS).

Here, the stratigraphic analysis of well logs is conducted interactively with the seismic data analysis, adding to both the robustness and resolution of the resulting chronostratigraphic scheme.

In particular, dGB offers unconventional, data-driven attribute analysis of well logs with which it can either QC preferred well log markers for consistency with its SSIS results, or build a completely new log-based framework, based on sequence stratigraphic principles.

Like seismic data, well logs carry geological information in attributes that are unseen in conventional displays, and that are therefore unexploited for stratigraphic interpretation.

Based on linear predictions, the transforming of a facies-sensitive log (such as GR) reveals depositional patterns - correlatable from well to well - even across lateral facies variations. These define packages of strata, bounded by surfaces corresponding to the flooding surfaces and base level falls of sequence stratigraphy. The packages range in scale from the sequences and para-sequences of seismic stratigraphy down to the limits of the resolution of the logs. The analysis is carried out using the CycloLog software package from Enres International and is deployed by consultants with extensive experience in this method.

The combination of this innovative approach to the stratigraphic analysis of well data with dGB's SSIS technology offers clients a powerful means of building a stratigraphic and hence depositional framework.

The importance of an accessible, intuitive workflow

HorizonCube can only be fully effective, however, if interpreters move away from the manual-focused and limited graphics environments of the past and operate in an environment where workflow processes are more accessible and intuitive.

It's with this in mind that dGB has teamed up with the Japanese company Wacom, a world leading manufacturer of pen tablets and digital interface solutions, allowing seismic interpreters using HorizonCube to interact directly with the tablet in their editing and visualisation activities (see Figure 5).

This allows for the drawing of horizons, faults and objects within a highly user-friendly and graphics-focused environment, with the interactive pen display allowing the user to directly work with the pen on the screen and thereby making the process of analysing data much more efficient. This is due to the perfect hand-eye co-ordination of the pen display and the fact that the user works exactly at the point on the screen where he wants the cursor.

To this end, HorizonCube can be used for sequence stratigraphy interpretation where the horizons are used to mark sequence boundaries and faults can be directly drawn into the data set. The result is a highly innovative but practical tool.

Generating a different perspective

Seismic interpretation today is all about generating a different perspective on the geological and stratigraphic aspects of data volumes and squeezing maximum geological value out of this data.

With applications, such as HorizonCube, and partnerships with companies such as Wacom, where dGB is using its experience in the photography, graphics, and fashion design industries and applying it to seismic interpretation, the company is seeing how seismic interpretation has the power to innovate and the overcome limitations of the past.

Geoscientists will finally be able to enjoy the full benefits of knowing the complete structure of their reservoir data, leading to geologically sound rock-property predictions, effective well correlation and more geological information from seismic than ever before.