Gravity Gradiometry – Giving a 3-D Perspective to 2-D Seismic

FTG data can help 'connect the dots' between sparse 2-D datasets.

Contributed by ARKeX

The pursuit of information drives all exploration decision-making. Decisions as to whether to drill, drop, or obtain more data are all determined by the information the explorationist has of the subsurface. But what if there is not sufficient data to make these decisions?

This is a common problem faced by many companies operating in frontier areas of the world. In such cases, data is patchy with a few intermittent 2-D seismic lines dotted about or at worse nonexistent. While the answer is clearly to acquire new data, the logistics and costs of implementing comprehensive 3-D seismic surveys is often prohibitive.

Wide-azimuth (WAZ) surveys, for example, are often up to four times as expensive as narrow azimuth surveys – not helped by the fact that many of the world's frontier regions cover vast acreages and are not easily accessible.

It is against this backdrop that many operators are looking to new technologies to help generate more information on their subsurface geology. One exciting technology is full-tensor gravity gradiometry (FTG).

Obtained from either a ship or plane, gravity gradiometry data map the small density variations in underlying rocks by measuring the gradient of the earth's gravity field. The high-resolution measurements provide an increased signal-to-noise ratio and wider bandwidth than conventional gravity data.

Another reason why FTG is becoming increasingly popular is that it measures data outside of the plain of acquisition.

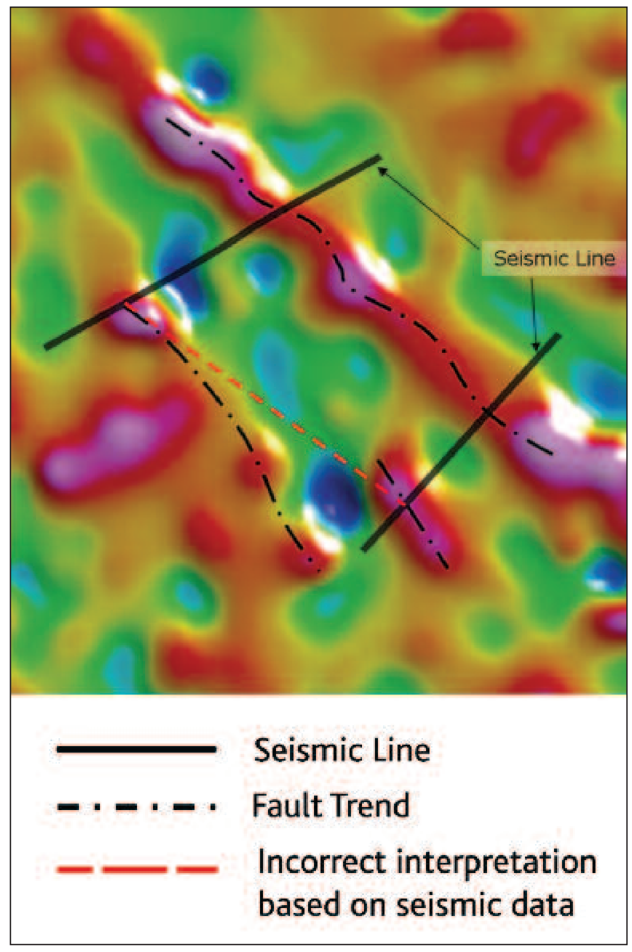
Rather than just measuring density contrasts that are directly beneath the survey line, FTG measures the influences on either side of the acquisition line. This can then be used to build a 3-D image of the geology and is especially useful in "joining the dots" between sparse 2-D seismic.

Whether mapping the correct location and direction of fault lines or the exact size and shape of salt diapirs, FTG has proven to be a cost-effective choice in obtaining an enhanced representation of the subsurface. Not only does it provide data over a wider area, but it can be used in the interpretation of the existing seismic to provide an additional and useful constraint.

When dealing with two 2-D seismic lines several miles apart (often the case with sparse 2-D seismic measurements), it is often difficult to appreciate how two independently interpreted faults may or may not be connected. Lacking any additional information, the interpreter often crudely connects the two fault planes without any strong evidence. FTG helps connect the faults correctly.

Once the data have been acquired and interpreted, the information the survey delivers can then be used to plan additional geophysical exploration.

It is the increased spatial awareness that FTG provides and the ability to provide an enhanced interpolation solution between sparse acquisition lines that enable FTG to play a key role in shaping, designing, and optimizing new surveys to improve seismic images.



In this example, the black line is the seismic line, the interrupted black line is the fault trend, and the interrupted red line is the incorrect interpretation based on seismic data. The addition of FTG data has enabled the fault trend to be clearly defined and has enabled the interpreter to confidently join the corresponding faults between the lines. (Image courtesy of ARKeX)

In 2010, ARKeX acquired an 890-sq-km (345-sq-mile) survey for Forent Energy in Nova Scotia. Forent used FTG as a cost-effective method of imaging the subsurface of its Nova Scotia prospect area, leading to the more efficient placement of its 2-D seismic lines and also creating minimal landowner impact.

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Horizon Mapping: Maximizing the Value of Seismic Data

More detailed horizon analysis creates a better view of complex geology.

Contributed by dGB

Seismic interpretation has improved dramatically over the last few years, with many of the results on display at SEG this week.

However, at a time when there is an increased focus on recovery rates and with fields becoming ever more geologically complex, operators are looking for that extra 1% or 2% to squeeze out of their seismic data – information that can often make the crucial difference to well planning and reservoir management strategies.

dGB Earth Sciences is helping to deliver this extra value through a clearer picture of the data's depositional history, improved quantitative rock property estimations, and more accurate and robust geological models. This is being achieved principally through horizons.

Horizons have always been an important element of seismic interpretation, but rarely have horizons been used to their full potential. Typically, a limited number of horizons tends to be mapped, leading to an oversimplified geological model.

This is what dGB's HorizonCube, a new plug-in that is part of dGB's OpendTect seismic interpretation software, is addressing. Through an automated horizon tracking tool that creates a denser set of horizons, interpreters can see their geology in radically different ways. They can use the horizons to guide well correlations, flatten data (e.g. through Wheeler transformations), obtain a better insight into the depositional environment, and increase their chances of finding stratigraphic traps.

Most importantly, HorizonCube results in a much more detailed model being put forward for reservoir engineering studies and for seismic inversion. By interpolating well data along the dense set of horizons, detailed geologic models are generated that are fully consistent with seismic measurements.

Such models can have a huge impact on the economics of reservoir management, whether it is for bid valuations, new field development and operational plans, production estimates, or divestments.

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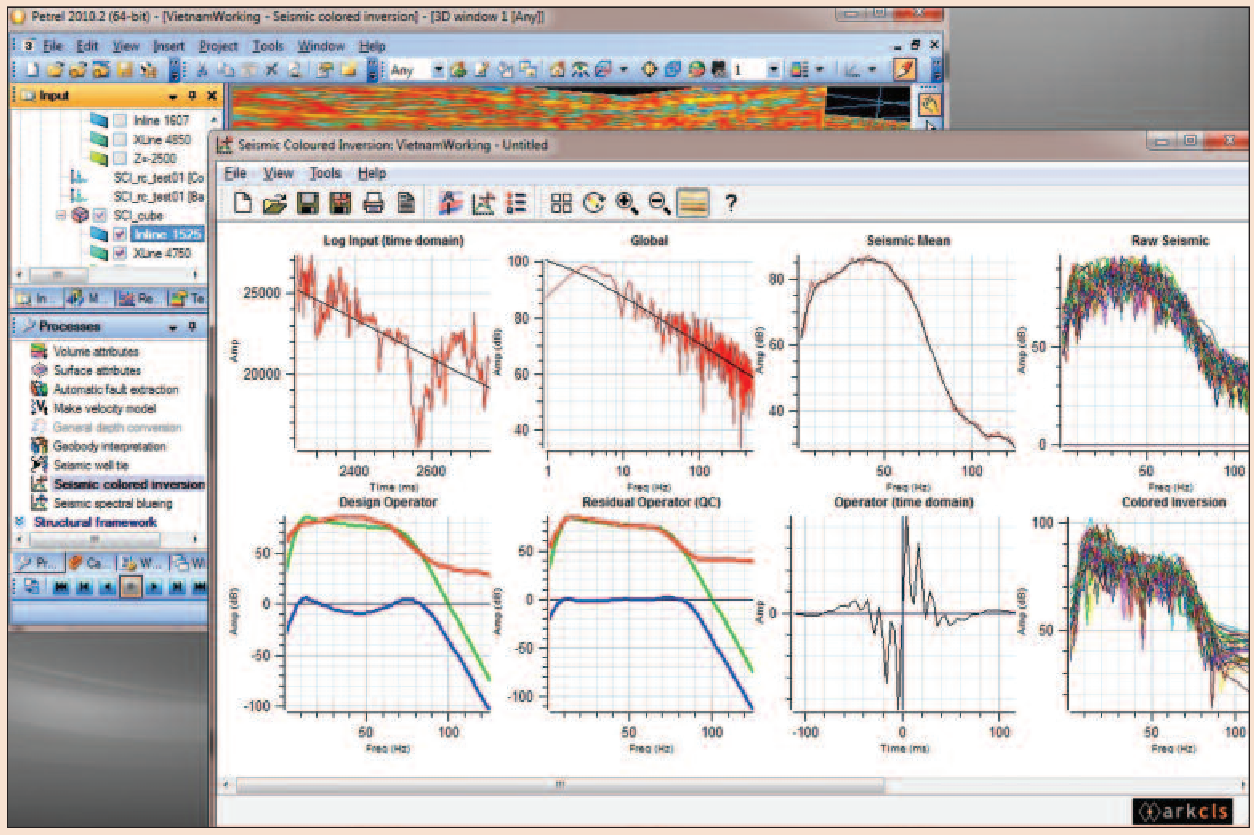
inversion results and enable the globally optimized spectral shaping of 2-D and 3-D seismic data.

As well as being able to connect seamlessly with third-party seismic and well data repositories such as SeisWorks, OpenWorks, and GeoFrame, the new direct data link plug-in also will enable users to carry out colored inversion and spectral blueing techniques within Petrel software, with both modules used in the Petrel workflow manager.

Making these advanced seismic inversion and spectral blueing tools available to the entire Petrel user community can only improve the integration of seismic interpretation and maximize the value of geological data with significant benefit to operators' exploration, appraisal, and development plans.

ARK CLS is developing a Petrel plug-in for its Seismic Net Pay software, an improved method to estimate net pay from seismic attributes. Seismic Net Pay is used to make estimates of either net pay or net rock volume, depending on the input data and calibration, and it already interfaces directly with Seisworks to read and write horizon data. A direct data-link with Petrel will increase this integration even further.



ARK CLS software is now available as a plug-in for Petrel. (Image courtesy of ARK CLS)

Seismic Feature Enhancement, a powerful utility for enhancing flat spots earlier in the interpretation life cycle used to reduce the risk of drilling dry holes, also is likely to be linked up with Petrel over the coming months.

Taking seismic inversion and spectral shaping to a wider interpretation community and creating a more seamless workflow can mean only one thing – more accurate inversion results, geologically sound rock property predictions, and a reduction in exploration risk.

The new plug-ins are downloadable at Schlumberger's Ocean store at *Ocean.slb.com*. For further information and a demonstration of the SCI and SSB software at SEG, visit ARK CLS at booth 3617. ■

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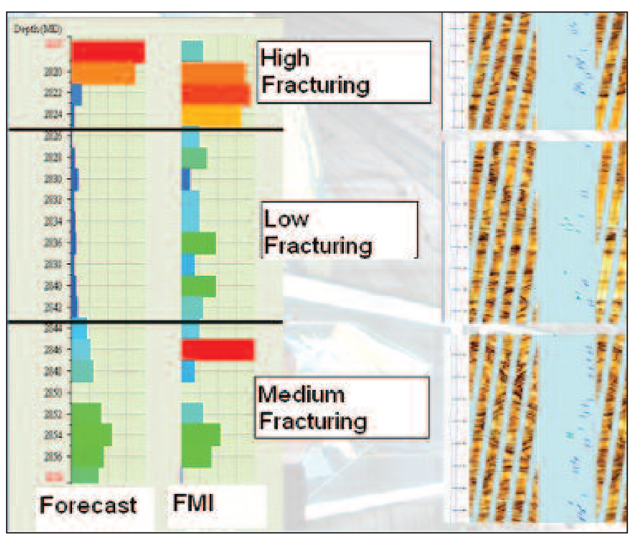
documented. And because the model can be continually updated as new data becomes available, it never becomes dated.

Field-tested and ahead of the curve

Russneft used SIGMA^3 CFM technology to better understand the complex natural fractures found in the Maloichskoe field in the West Siberian basin (SPE 102562) and challenged CFM to remove three existing wells from the model dataset that would later be used as "blind wells" to test the veracity of the model. When the CFM model was sampled along the well paths of these blind wells, the model predicted the fracture densities with striking accuracy.

Russneft used the model and recommendations from SIGMA^3 scientists to select the next well. That well, the first drilled in 20 years in Maloichskoe, encountered fractures as predicted by the CFM model. Comparison of the fracture interpretation from the formation log with the model forecast showed very good correspondence. In fact, the intervals with high, medium, and low fracture intensity are present approximately at the same depths in both. Most importantly, the production results proved good reservoir properties for the well, which has become one of the best producers in the field.



This image compares predicted fracture density from the CFM model to the actual formation logging data from the well after drilling in the Maloichskoe field. (Image courtesy of Sigma^3)

The results seen in Maloichskoe are not unusual for a CFM project. Similar results have been published for projects in the North Sea, the Middle East, China, and onshore US.

The proof is in the production

While there is no magic bullet for understanding fractures, SIGMA^3 has developed a customized, structured neural network to optimize the contribution of seismic attributes, geological data, and reservoir engineering data to the fracture model. SIGMA^3 has the expertise and technology to provide the highest quality inputs to the CFM process, ensuring the best possible model for the real locations and orientations of naturally occurring fractures in the subsurface.

Stop by the SIGMA^3 booth 914, and ask about the latest in CFM solutions. ■

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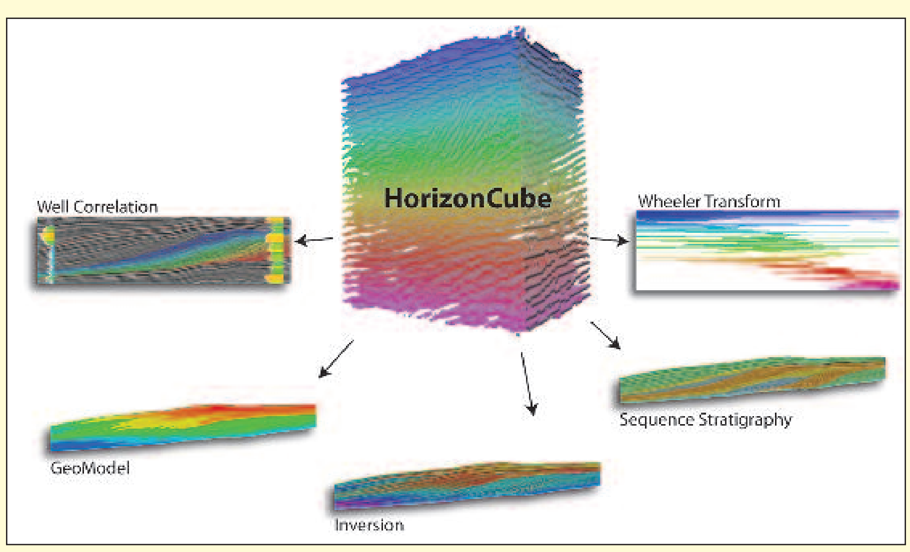
Building the HorizonCube is a simple process. The user inputs a steering cube containing local seismic dips, at least two mapped horizons, and (optionally) mapped fault planes. The software's advanced algorithms will then create a set of continuous, chronologically consistent horizons. Horizons are either created in a model-driven way (e.g., through stratal or proportional slicing) or in a data-driven way via a dip-steered, 3-D chronostratigraphy auto-tracker.

The dip-steered tracker is able to generate horizons that are typically separated by one sample at the starting position, with noise removed from the dip fields to enable the user to control the detail that needs to be captured by the horizon tracker. Horizons in the HorizonCube automatically stop against mapped fault planes with watertight intersections.

In this way, more geology is extracted from the 3-D seismic, and highly detailed and accurate low-frequency models are put forward for acoustic impedance and elastic impedance inversion.

HorizonCube is not the only new OpendTect plug-in being showcased by dGB at SEG this year. The company also is developing software that combines forward modeling, rock physics, and inversion into one package – a powerful means of lowering exploration risk and quantifying reserves.



One of the central elements of OpendTect 42 is the HorizonCube plug-in. (Image courtesy of dGB Earth Sciences)

With the SynthRock plug-in, the user can construct pseudo wells and generate prestack and post-stack synthetic responses. Simple wedge models can be generated to help understand the seismic response of the interval of interest, and more complex stochastic simulations open the way to advanced reservoir characterization workflows via cross-plots, PDFs, neural networks, or a unique inversion approach called the Hit Cube.

In the Hit Cube inversion process, stochastic pseudo-well synthetics are matched to measured seismic responses. Matching models are averaged to yield probability volumes of relevant rock and fluid properties. Hit Cube inversion is not restricted to 3-D seismic data. dGB has successfully predicted Hit Cube probability volumes of bypassed oil in 4-D studies.

Seismic interpretation today is all about squeezing maximum geological value out of seismic data. With applications such as HorizonCube and SynthRock, seismic interpretation is continuing to innovate and deliver more for the geoscientist. To find out more, visit dGB at booth 3818 in Hall B. ■