

Extracting more from seismic data to get better subsurface models

Paradigm has developed a range of solutions that help companies to extract more value from their seismic data. Keith Forward reports.

Paradigm hat eine Reihe von Lösungen entwickelt, die Unternehmen helfen können, wertvollere Informationen aus ihren seismischen Daten zu ziehen. Keith Forward berichtet.

Paradigm ha desarrollado una gama de soluciones que ayudarán a las empresas a obtener un valor mayor de sus datos sísmicos. Keith Forward informa.

Geologists confront a multitude of problems when trying to analyse seismic data to produce a model of the subsurface that can help identify where oil and gas is deposited, or assist reservoir engineers to optimise the production of a field.

The sheer volume of a seismic data set is itself a barrier to interpretation. The amount of data recorded and processed in wide azimuth offshore surveys, for example in the Gulf of Mexico, offshore Brazil or offshore West Africa, can exceed hundreds of terabytes.

This imposes a basic limit based on the computing power available and the speed of the algorithms used to process the data.

Also, different geologies may be more or less susceptible to being illuminated by seismic, and features in the rock, such as a salt dome, may reflect seismic energy and so obscure the details of underlying formations.

In recent years, companies have invested in rich azimuth seismic surveys which have been able to illuminate difficult to reach areas of a reservoir, but this has only increased the need for new seismic interpretation methods capable of extracting the full value from these investments.

Geologists have used a range of methods to simplify the problem, such as treating the subsurface as a series of two dimensional layers stacked on top of each other, or using only a proportion of the full recorded waveform, to make it viable with the processing power available.

Paradigm has been developing methods that do away with some of these simplifications, using a true 3D approach to constructing models which reflect more accurately the actual make-up of the subsurface.

This has been made possible as much by the increase in computing power as by the advent of efficient algorithms that reduce the calculations that are needed.

“Paradigm is committed to increasing the industry’s return on investment on their seismic programs by providing new methods and procedures of interacting with pre-stack data in all relevant domains consistent with the transition to rich and wide seismic acquisitions. These new methods and procedures are enabled by a proper decomposition of the full seismic wavefield

into in-situ full azimuth, directional data sets,” says Duane Dopkin, Senior Vice President of Technology at Paradigm.

With EarthStudy 360, the full recorded waveform from rich azimuth survey data can be used to illuminate difficult to access parts of the subsurface. The high angle reflections can provide more information on structures under features that reflect a high proportion of seismic energy.

Moving to a true 3D approach for CRAM (Common Reflection Angle Migration) leads to clearer, more detailed seismic images. It also makes it easier to analyse seismic amplitudes since you can see how amplitude changes at different angles, revealing more about the structure of the subsurface.

Using knowledge of how the geology was formed is also a huge advantage, and Paradigm’s SKUA approach allows interpreters to use all of the information available, regardless of its complexity, when building a model.

“Paradigm’s goal is to make it possible to interpret all the data in the richest possible way,” says Richard Jeffries, Paradigm’s regional vice president for Europe & Africa.

Full azimuth imaging

Paradigm has developed a new technology, codenamed ‘Wide Eye’ and marketed under the name EarthStudy 360, which can make use of the full recorded wavefield from a wide azimuth survey and reduce the need for time consuming manual manipulation of the data.

The amount of rich azimuth data available from onshore and marine OBC (Ocean Bottom Cable) acquisitions is greatly increasing as geoscientists are seeking better reservoir and hydrocarbon signatures and definition from

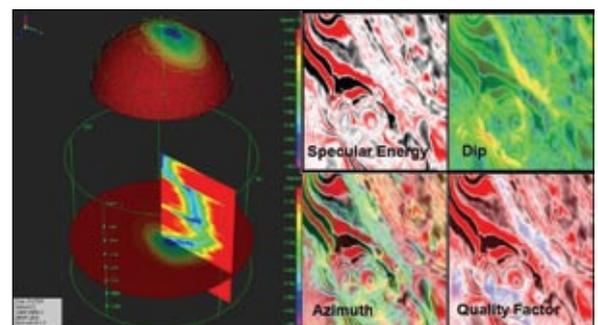
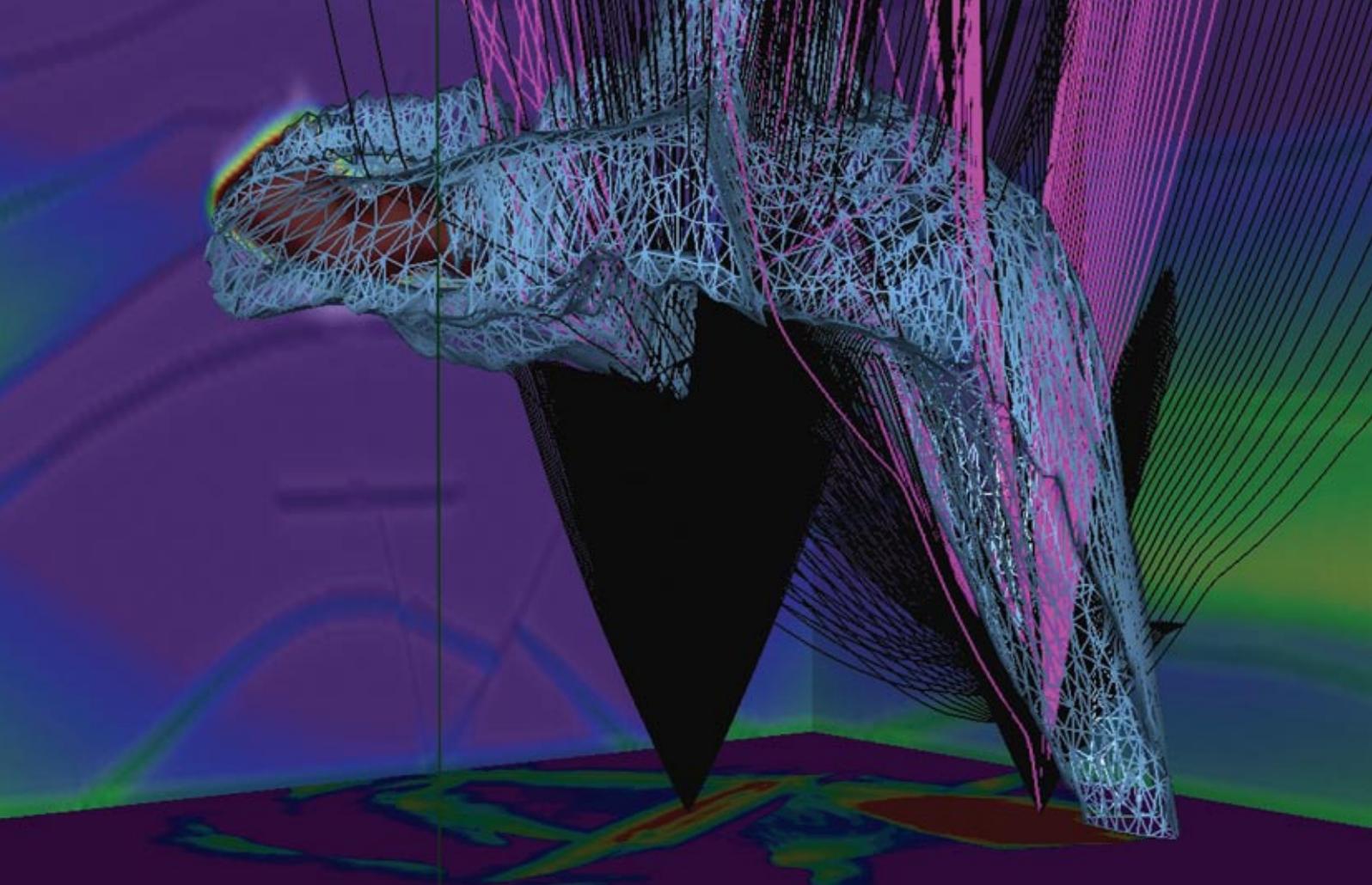


Fig. 1. EarthStudy 360 – Paradigm’s latest seismic imaging system’s directional seismic attributes.



seismic data.

However, Paradigm believes that advances in data gathering have not yet been translated into a full return on investment for the seismic program. While resultant seismic images incorporate some of the benefits from these rich acquisitions (e.g. noise attenuation, multiple suppression), application of current technology is not sufficient for realizing the full potential of these datasets.

“EarthStudy 360 gives a much richer analysis of the subsurface, the dip and strike, and the fabric of the substructure in the data. You can get finer granular detail of highly fractured reservoirs,” says Jeffries.

“The revolutionary nature of this new system is that it enables geophysicists to use the entire rich-azimuth data in the local angle domain, resulting in continuous full-azimuth angle-gathers, images and illumination coverage.”

“Currently, multi-azimuth and wide-azimuth datasets are processed and imaged independently by dividing the recorded data into a small and manageable number of offset-azimuth sectors. This type of process is quite rudimentary, especially for long offsets, as it does not properly make use of the entire recorded wavefield.”

It means that considerable human effort is needed as the individual sectors have to be treated independently and then brought together to make the final model. It also introduces a dependency on acquisition (source-receiver) orientations.

EarthStudy 360 generates continuous azimuth, angle-dependent images of the subsurface (full azimuth angle gathers), using the full recorded wavefield with a new, more efficient algorithm, extracting high resolution data and information related to subsurface angle-dependent reflectivity without human intervention.

Fig. 2. CRAM traces rays from the subsurface up to the surface to build the model.

EarthStudy 360 is being released in a controlled way to clients who Paradigm believes can benefit most from the software.

“We’ve got a greater demand than we can deliver. Right now, we are collaborating on some joint projects where we think clients can really benefit and working with them to ensure they get the most out of the software,” says Jeffries.

Illuminating the subsurface

A common problem with traditional seismic imaging is that the position and spacing of the source and receiving apparatus can affect the final model.

CRAM (Common Reflection Angle Migration) is essentially a method of tracing ray paths from every subsurface image point up to the surface in the local angle domain, rather than tracing them from the surface back down to the reflection point, as with conventional seismic imaging.

This means that the model is independent of parameters of the acquisition geometry, such as the offset - the distance between the source and the receiver. “We’re saying - why let the acquisition dictate the modelling - let’s let the subsurface dictate the modelling,” says Dopkin.

Common reflection angle migration is not new and has been used in a 2D version for some time. The breakthrough is to implement a 3D version - it has taken the advent of cheaper high performance computing as much as advances in ray tracing algorithms to bring it to market.

CRAM proves particularly useful when analysing waves which are reflected at rock boundaries with large angles and recorded at large offsets, or waves which may have quite complex pathing, for example those that are reflected beneath salt.

It also proves very helpful in seismic acquisitions containing a rich sampling of source to receiver azimuths and for which the resulting waves propagate through layers exhibiting a directional dependence of velocity on azimuth. Shales, for example, can exhibit azimuthal anisotropy resulting in mispositioning of geologic or drilling targets if not properly accounted for.

The rays can propagate through the same rock formation at different velocities depending on the direction ('azimuth') of propagation. If this dependency is not corrected by calculating the anisotropic velocity field, both mispositioning and misstacking of seismic reflection events can occur. The common reflection angle migration provides the platform to both measure and correct for anisotropy (Fig. 3).

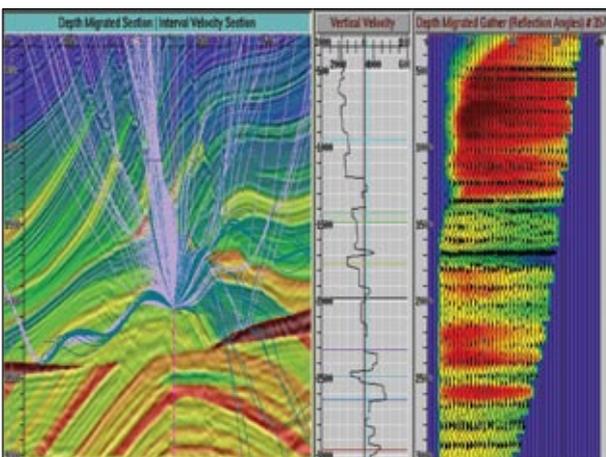
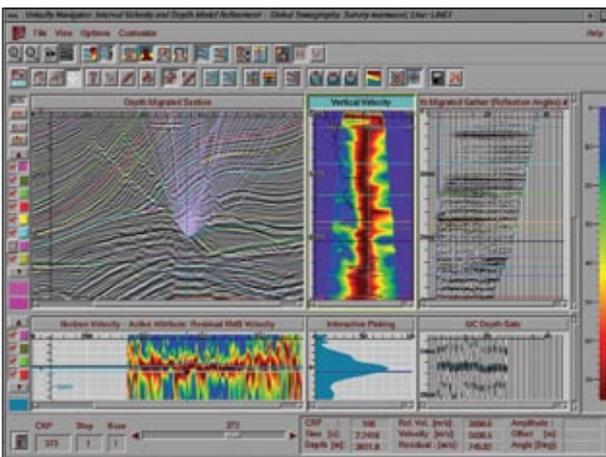


Fig. 3. Velocity analysis performed in the angle domain. Angle domain ray tracing (above) with angle domain gather output (below).

Since the calculations are done from every subsurface point, it is also possible to target imaging to a particular area of the subsurface, saving time and focussing on the information that is of most interest. The illumination can

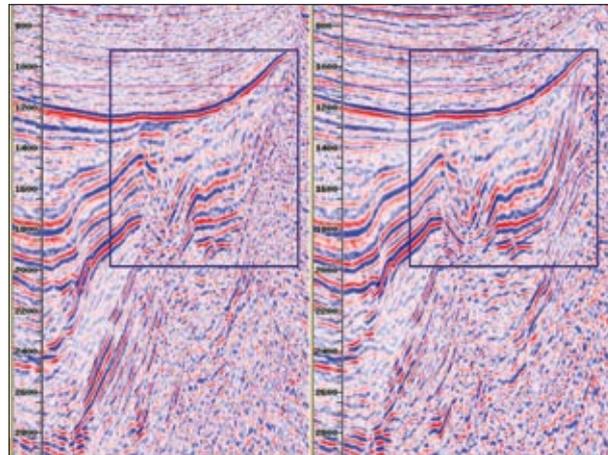


Fig. 4. Comparison of traditional Kirchhoff ray-based image (left) with Common Reflection Angle Image (right) showing a clearer delineation of features.

also be controlled by setting the range of azimuth and angle that are included in the calculation. This means the analysis can be tailored to specific needs and results in a more efficient workflow.

“If you can illuminate the subsurface from the bottom up, rather than the acquisition surface down – you have complete freedom in terms of controlling the illumination,” says Dopkin.

Essentially, CRAM gives a clearer, more detailed image of the subsurface particularly where traditional seismic processing methods do not work so well, for example imaging beneath salt structures (Fig. 4). CRAM is an add-on to Paradigm’s GeoDepth Velocity modeling and imaging solution.

Combining information

SKUA (Subsurface Knowledge Unified Approach) is a way of using knowledge about the geology of the subsurface to improve the building of structural models from seismic data.

It uses a true 3D approach that automatically constructs two models, one for geological modelling and one for flow modelling, rather than building up a single model from a series of 2D layers joined together by pillars aligned along fault lines, as is done at present.

The construction of pillars is a manual process that can be very time consuming, and structures with complex faulting may not be modelled accurately, as pillars may need to be removed or distorted to construct the 3D grid cells.

SKUA enables the user to obtain a complete 3D description of faulted volumes from the outset, where horizons and grid geometries are constructed simultaneously in the 3D space.

SKUA is based on the UVT-transform, which introduces three extra geological parameters that inform the model, T- the time of deposition of a layer, and U,V - the 2D coordinates at that time. It then maps from the depositional space, where all the 2D surfaces are flat planes as they were laid down at time T, to the



current time when those planes have been deformed and faulted to produce the complex structure that is being modelled today.

The UVT-transform honours all the information available and does not require any simplification or removal of the data. Structures with complex Y or reverse faults, thrust faults or very thin beds can all be included in the model.

It can also be performed much more quickly than conventional methods with little user interaction, which means the model can be constructed in many different ways to improve the results. It also makes it easier to correct problems with the model, such as missing or anomalous data, or change a fault type if you think it was reversed.

As more data becomes available about the field and the reservoir, the geoscientist can easily update the model in SKUA to obtain a more accurate grid for improved decision making.

Paradigm estimates that with this new system, it can reduce the amount of time to model a complex environment involving, for example, 51 faults, three thin beds and 12 horizons, from a typical 2 months down to days, or reduce the amount of time to model a thrust with 30 different faults from two weeks to hours.

By making two models, each can be optimised for its specific purpose; often a single model is created that is not optimal either for constructing geological grids or for flow simulations.

The geological grid is constructed by splitting cells at faults and offsetting the cells by the fault throw (Fig. 5).

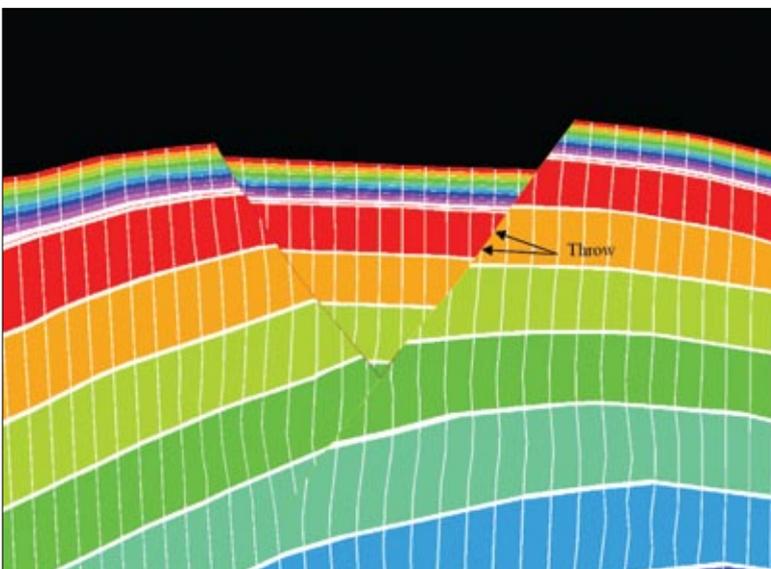


Fig. 5. SKUA - Cell geometry inside a geologic grid and fault throw. A correct geological grid ensures more accurate calculations for geostatistics.

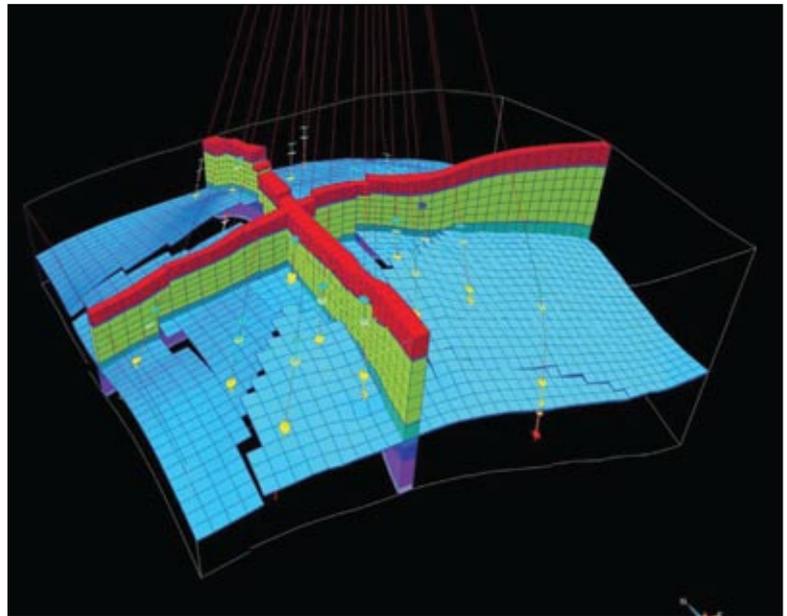


Fig. 6. Stair-step flow simulation grids generated by unified modelling approach with SKUA give a more accurate representation of how fluids will actually move through the reservoir.

Cells have constant dimensions and a regular shape. This is optimised for geostatistics, and ensures that the distance between two grid nodes is the same in the current space or in the depositional space anywhere in the volume. This means, for example, that well samples will be given the correct spatial correlation and hydrocarbon volumes will be calculated correctly.

Flow simulators require equally sized grid cells that are as orthogonal as possible, and this is achieved with stair-step representation of a fault (Fig. 6). These types of grids allow the integrity of the reservoir structure to be kept yet are optimal for numerical modelling of fluid flow.

The ability to update both models quickly, without lengthy manual intervention, means geoscientists can spend more time actually understanding the reservoir rather than manipulating the software, and this inevitably leads to better decision making and ultimately reduced costs.

All about risk

Paradigm has introduced a range of tools that address limitations with conventional seismic imaging and interpretation, revealing clearer, more detailed information about the structure of the subsurface using all the data available.

Essentially, all these tools allow oil companies to minimise risk through more accurate information, enabling them to pursue the optimal reservoir management and development program while using all the resources available in the most efficient way.

“Where we make our money is delivering less risk and better decision making to our clients, to maximize financial return. That way oil companies can pursue the least risky drilling program with the least number of wells and achieve better results for less cost,” concludes Jeffries. ●