A new INTERPRETATION

Jonathan Henderson, ffA, UK, examines geological expression software designed to deliver a step change in interpretation productivity.

The industry is entering a new era in hydrocarbon exploration and production. The shale revolution, the need to explore in more challenging environments, make marginal fields economic together with growing environmental concerns and increasing costs are changing the way the industry works. In this era, the level of geological knowledge and understanding required to implement economically successful exploration and development strategies has never been greater. This is the fundamental driver for the enormous investments that are being made in new techniques for acquiring and processing seismic data. The rationale being that having more, better quality data will lead to improved recovery from existing reservoirs and more oil and

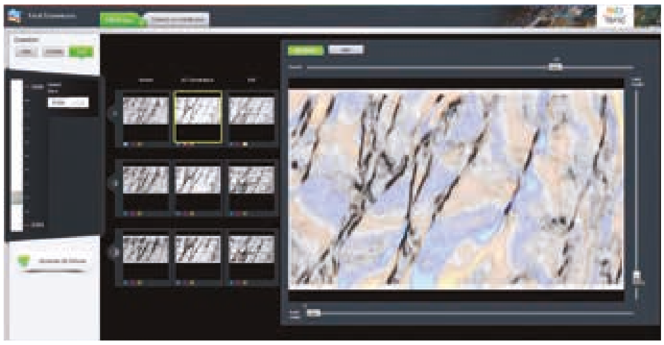

Figure 1. *The Fault Expression tool uses the principles of cognitive cybernetics to allow fast, intuitive interrogation of a complex parameter space making optimised fault imaging much easier.*

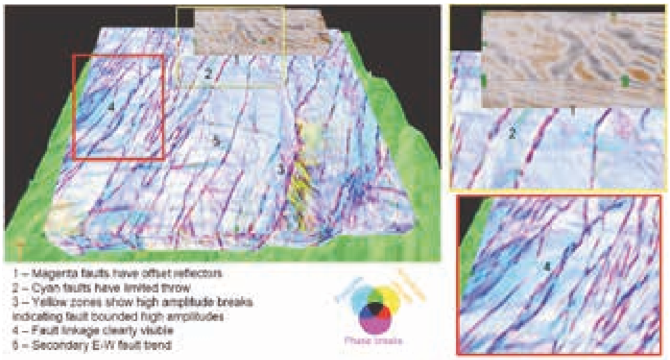

Figure 2. *CMY blending improves understanding of the imaged fault network by enabling intuitive visualisation of multiple fault attributes.*

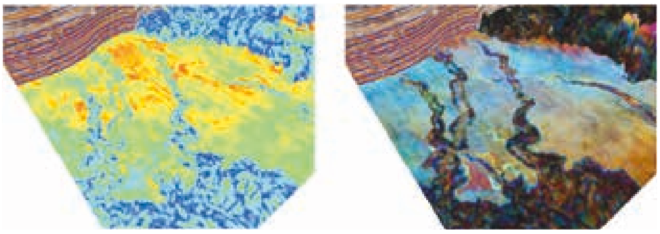

Figure 3. *Single attribute displays (right) contain much less information and are much more difficult to interpret than multi-attribute displays (left).*

gas being found. For this rationale to be valid better data needs to be translated into a better understanding of the imaged geology, i.e., it needs to be interpreted.

Undoubtedly, advances in acquisition and processing have improved the ability to image the subsurface but it has also increased many fold the amount of seismic data that needs to be interpreted with a number of interpreters that has hardly changed. On top of which, even with the improved imaging, seismic data has to be mined even more deeply if the imaged geology is to be understood at the levels of detail now required. Therefore, to realise the potential of improved seismic data new seismic interpretation technologies that enable the limited pool of experienced interpreters to utilise their knowledge and skills to maximum effect are needed. With the 'great crew change' that the industry is going through, the same interpretation technologies must also allow less experienced interpreters to become productive more quickly. The productivity increase that is needed will not be achieved by tweaking conventional interpretation systems; a wholly new approach is needed. This must be much more powerful and simpler to use. This step change in interpretation productivity is exactly what GeoTeric®, and the Geological Expression workflow that it enables, has been designed to deliver.

GeoTeric is seismic interpretation software that allows the geology that is imaged in the data to be visualised easily and effectively and supports efficient workflows for constructing and updating a 3D model directly from the seismic data. The purpose of GeoTeric is to directly translate geophysical data into geological information.

The Geological Expression approach that is at the heart of GeoTeric is founded on the user being able to interact easily with large quantities of data. This has required ease of use and efficiency to be foremost design considerations; as a consequence the software can be utilised to mine and, very importantly, communicate the information content of 3D seismic data sets incredibly quickly.

Geological Expression is fundamentally different from conventional interpretation techniques in that it is geologically rather than geophysically led. With Geological Expression image analysis and attributes are used to create 3D data sets that show the geology that is captured in 3D seismic data. The interpretation is then directed by data driven processes that are guided by the interpreter's geological knowledge to delineate the different geological elements that are visualised. This data driven, interpreter-guided way of working is fast, intuitive and gives the interpreter the control required to produce 3D representations of the imaged geological elements that match the data and what is geologically reasonable.

Efficiency and therefore productivity come from combining speed, reliability and quality. This is a non-trivial process made all the more challenging by the fact that geology is incredibly varied, how geology is expressed in seismic data is strongly affected by how the data was acquired and processed and seismic data only ever gives a partial and often ambiguous picture of the subsurface. GeoTeric recognises these issues and resolves them through the use of sophisticated, often computationally intensive, algorithms that the interpreter needs to parameterise. One of the reasons that GeoTeric is easy and efficient to use relates to the approach that is taken to parameter optimisation. Two of the areas in which changing parameters can have the most dramatic impact are data conditioning and fault imaging. To tackle these issues the Noise Expression and Fault Expression tools were developed. These utilise an example driven parameterisation technique based on the principles of cognitive cybernetics.

Noise Expression and Fault Expression work by presenting a set of results generated using different algorithms and with different parameters. The user can then interactively adjust the parameters associated with each of these options and compare the results with one another and with the original seismic data from which the results were generated. This creates a cognitive feedback loop, which helps the interpreter home in on optimal parameter settings very quickly. This cognitive feedback loop also promotes insight and understanding of the imaged geology and helps resolve the ambiguity issue by making it easier to understand why a given interpretation/processing result has been obtained.

Improving understanding

However, productivity is about more than just speed. Reducing the time it takes to create a geological model does not give a productivity gain if the model cannot be relied upon. Being confident that the correct interpretation has been made and that overall understanding of a system has been enhanced, only occurs when different

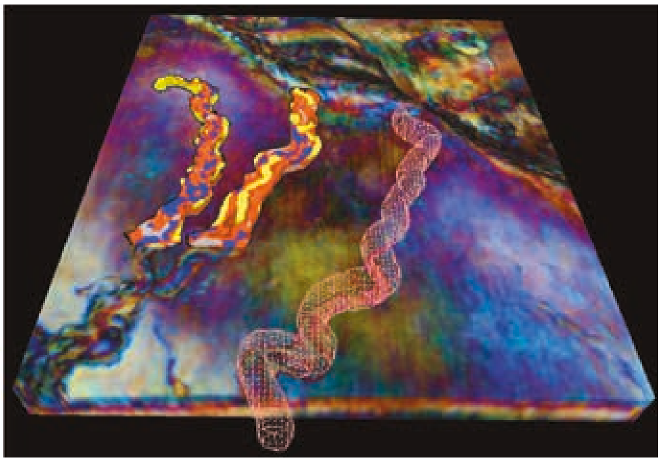

Figure 4. *RGB blending of multiple attributes combined with GeoTeric's data driven, interpreter guided techniques for object delineation and facies classification allow elements of the 3D model to be generated directly from the seismic data with great accuracy and efficiency.*

characteristics or attributes of the data can be compared 'in context'. The comparative aspect of data interpretation is often overlooked when taking a purely algorithmic approach to data analysis. This is not the case for Geological Expression, which has at its core the ability to compare attributes and generate multiple realisations.

An injection of colour

The keys to this are high resolution colour visualisation and lots of processing power. The computer games industry is to thank for the fact that it is now possible to access to both of these in standard desktop workstations and high-end laptops. Until recently, virtually all volume visualisation systems were limited to displaying at most 256 colours or shades of grey. This meant that data had to be compressed before it could be viewed volumetrically resulting in large information loss. It is now possible to work with volumetric colour displays showing more than 16 million colours. The use of such high resolution colour displays is critical in understanding the subsurface from seismic data as it greatly increases the ability to see, compare and analyse subtle but important features in data.

Understanding is most effectively generated by looking at the relationship between different pieces of information rather than considering separate pieces of information in isolation. Comparing pieces of information is additive in two senses, firstly it can give context to the information and, secondly, it actually increases the amount of information that is accessible. For example, if there are three attributes each containing N pieces of information, examining each of them separately gives 3N pieces of information at most. When looking at the three attributes in a way that shows the inter-relationship between the different values there is the potential to see up to N^3 (NxNxN) pieces of information. An extremely important point, and one which is perhaps counter-intuitive, is that despite in many ways producing a more complex image, an intuitive understanding of the imaged geology can be obtained more easily from a colour blended image than it can from viewing individual attributes.

Co-rendering of information from frequency decomposition using an RGB blending techniques is rapidly becoming a standard part of many interpretation workflows. Less well appreciated is how powerful colour blending can be for comparing and understanding the relationship between other types of information, for example looking at amplitude variation with offset or comparing multiple vintages of data in 4D workflows. The Fault Expression tool makes full use of colour blending, in this case using a CMY colour scheme to co-visualise different fault attributes. As the seismic expression of faults can vary along and between faults, a single attribute rarely gives a complete picture of the imaged faulting. Colour blending addresses this by allowing three different fault responses to be displayed simultaneously. Again the composite image conveys more information than can be accessed by side-by-side comparison of the different attributes as seeing how the different fault expressions relate to one another can help understand lithology changes along a fault and highlight the extent of fault damage zones.

Multi-volume visualisation is a very powerful tool for looking at the way geology is expressed in seismic data that is quick and easy to use. This is helpful in trying to get a complete picture of the imaged geology and for allowing different exploration and development scenarios to be examined in detail.

Communicating concepts

Initially, GeoTeric has focused on geobody delineation from colour blends and other multi-attribute data sets. Such data sets provide a very powerful way of understanding the 3D geometry of structures such as channels, fan systems, salt bodies, gas chimneys, karsts and injectites, whose geometry cannot be easily or accurately defined by horizons.

Geobody delineation is a very complex problem. Objects that can be obvious to the skilled interpreter can be extremely difficult to extract due to the variable, incomplete and often very subtle nature of their geological expression. They are seen as defined entities because the ability of the human visual process to filter out noise and to combine image information and prior knowledge to connect disparate parts of the image. To resolve the object extraction problem it needs to be understood that geobody delineation is as much an interpretive task as it is a data analysis task. Therefore, a methodology in which both the data and the interpreter's knowledge and experience are used simultaneously and interactively (i.e., a data driven – interpreter guided approach) is needed.

The patented Adaptive Geobodies technology used in GeoTeric is inspired by two approaches for image segmentation that have found widespread use in medical imaging, level sets and active contours. By merging these two approaches into a common mathematical framework a geobody can be defined on the basis of a complex 3D surface utilising a relatively sparse set of nodes and without prior knowledge of the boundary.

With the Adaptive Geobodies® technology, growth of a geobody is controlled by multiple forces. These forces are based on the local image gradient, the statistics of the data around the current mesh point and a surface elasticity constraint. Each node on the surface mesh moves as directed by the resultant of all these forces until an equilibrium state is achieved. The use of such a complex set of forces allows the use of the data in geobody delineation to be maximised. Despite the computational intensity of the process, the ability to define the geobody using a relatively sparse mesh allows the growing process to run in real time. Adaptive Geobodies is another example of how GeoTeric uses technically advanced and complex processes to produce tools that are both very powerful and simple to use.

The true power of the Adaptive Geobodies technique is the way it brings the data analysis and interpretation together. Interpreter guidance is enabled in three ways: interactive control over the data driven geobody delineation parameters, the ability to lock parts of a geobody whilst it continues to grow in other areas and direct interactive manipulation of the geobody surface. Changing parameters and the ability to lock sections of the geobody provide for interpreter guidance whilst keeping the process data driven. Interactive manipulation of the surface passes full control to the interpreter.

The combination of data driven and interpreter guided techniques means that the Adaptive Geobodies can be used to extract any stratigraphic geobody that is imaged within 3D seismic data. These geobodies provide a way of accurately incorporating detailed definitions of complex geology into a 3D model at full seismic resolution and helps to bring geology and geophysics together.

A unified approach

The Adaptive Geobodies method has been extended in the latest release of the software so that a similar approach can be used for delineating features from colour blends that are best represented by a single surface. This technique is called Adaptive Horizons and is being extended further so that the same framework can also be used for fault interpretation (Adaptive Faults).

GeoTeric also uses the data driven – interpreter guided approach to make seismic facies classification more intuitive and therefore more powerful. The Interactive Facies Classification tool (IFC+) utilises a similar mathematical framework for attribute classification as the Adaptive Geobodies and Adaptive Horizons use for object delineation. Again the emphasis is on providing sophisticated analysis techniques within an interactive, easy to use framework. IFC+ also brings well log data into the Geological Expression workflow and creates that critical link between 'abstract' seismic data and direct measurement of geological properties.

Having a common approach at the core of the tools required to define key aspects of the 3D model greatly aids productivity and minimises the time required for new users to become adept with the software.

Conclusion

GeoTeric and the Geological Expression approach to seismic interpretation bridge the gap between processing and conventional modelling. GeoTeric represents a step change in seismic interpretation providing access to some of the most powerful and sophisticated interpretation technologies available today within a software package designed to enhance the user experience and maximise productivity. GeoTeric increases the amount of data and the level of geological understanding that can be obtained from 3D seismic data. The interactive data driven, interpreter guided approach is fundamental to extracting value from the immense and ever increasing volume of seismic data that the industry is investing so heavily in acquiring.

Acquiring more or better seismic data only delivers net value when it leads to an improved understanding of the subsurface within a timeframe that allows that additional knowledge to be used effectively. This is what this system is designed to do. In essence, it directly translates geophysical data into geological information allowing a better understanding of the geology of the subsurface to be developed and communicated across the asset team.

Bibliography

1. Aversana, P. D, 'Cognition in Geosciences', EAGE Publications, ISBN 978-90-7384-41-5, (2013).
2. Henderson J., Purves S.J., Leppard C. and Spencer P., 'Automated delineation of geological elements from 3D seismic data through analysis of multi-channel, volumetric spectral decomposition data', First Break, 25, pp 8 - 93, (March, 2007).
3. Cremers D., Rousson M. and Deriche R., 'A Review of Statistical Approaches to Level Set Segmentation: Integrating Color, Texture, Motion and Shape' International Journal of Computer Vision, Volume 72, Number 2, 195-215, (February, 2007).
4. Lowell J., Hunter A., Steel D., Basu A., Ruder R., Fletcher E. and Kennedy l. 'Optic nerve head segmentation', IEEE Transactions on Medical Imaging 23(2) 1 – 9, (2004).
5. Liang J., McInerney T. and Terzopoulos D., 'United Snakes', *Medical Image Analysis*, 10 (2) 215 – 233, (2006).