

Making the Impossible, Possible!

A new paradigm in understanding the geology of the subsurface.



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As we discussed in a previous article (*GEO ExPro* Vol.9, No. 3), at ffa we call the data-driven/interpreter-guided approach for understanding and defining the 3D morphology of the geological elements imaged within the seismic data the 'Geological Expression' approach. This has several components in common with a conventional seismic interpretation workflow. The big difference is that at every stage this system allows the interpreter to interact seamlessly with information provided through an objective analysis of the geological expressions contained in the data.

The Geological Expression workflow has to reconcile a number of conflicting requirements, one of which is that it should give the interpreter free reign to explore the data and to examine different scenarios and investigate new concepts. By designing the Geological Expression approach around geologically directed workflows, the interpreter can target their approach efficiently without reducing the scope of their investigation.

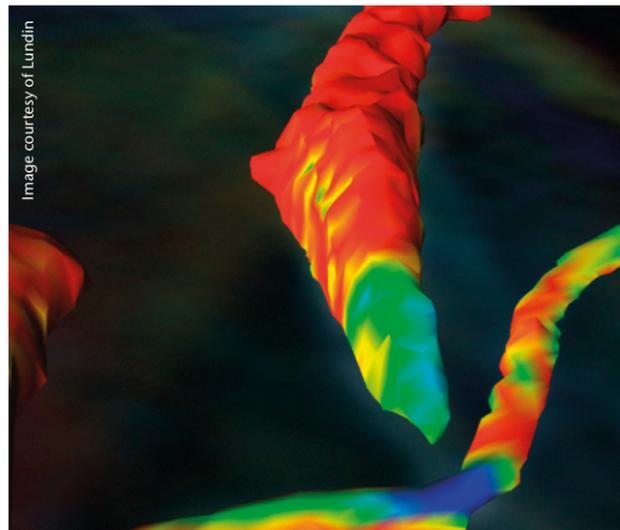
Color Blending

Color provides an intuitive means of examining the relationship between different aspects of the geology expressed in the data. Most of the time, we cannot gain the understanding we are striving for by looking at a single piece of information out of context. Equally if we are bombarded with a plethora of unrelated information, enlightenment is rarely achieved. How

many sources of information we can deal with depends on how the information is presented and the degree to which it is correlated. Spatial registration has a large impact on our ability to understand the information in multiple images. To illustrate this we can refer again to medical imaging where it has been demonstrated that the use of color blending and overlays is a far more effective way of defining pathological changes than viewing images side by side.

Color blending generally involves creating an image where the color at each point in the image is defined by the values in three, spatially registered input images using a Red-Blue-Green (RGB), Cyan-Magenta-Yellow (CMY) or Hue-Saturation-Value (HSV) color model. The results can be incredibly striking and extremely informative.

As shown in the examples on these pages, CMY blending can be used to combine three volumes of information which differentiate between sections of faults that are represented seismically by a sharp discontinuity, a flexure or an amplitude change. In addition to showing the position and inter-relationship between different fault systems and episodes of faulting, the color changes shown in the CMY blend give indications of potential lithological variations with brittle lithologies more likely to be associated with sharp discontinuities across the fault and ductile lithologies associated with flexures or subtle amplitude changes.



The geobody adapts to the a calculation of the 'goodness of fit' or the surface confidence values between each point on the surface of a geobody. If blue, a poor fit; if red a good fit.

Adaptive Geobodies

The understanding that can be developed through the use of these visualization techniques is enormously valuable, but what we see in these images needs to be extracted in a 'tangible' form so that it can be used in later stages of the workflow such as 3D geological and reservoir modeling. This is a non-trivial task. The human brain is an incredibly powerful image-processing engine and the process of 'seeing' is very complex. A common frustration arises when we can clearly 'see' an object in an image, but cannot extract it. To overcome this, we have to recognize that seismic data does not provide a complete and unambiguous representation of the subsurface and of the four components of seismic interpretation – information, analysis, knowledge and experience. We should only rely on the computer to provide the information and analysis parts.

ffa's Adaptive Geobodies® technology recognizes and makes geobody delineation a fully interactive data-driven/interpreter-guided process. What this means is that 3D geobodies representing geological elements imaged in the data can be defined based on a combination of data analysis and direct interpreter guidance. The process is interactive as the data-driven analysis 'grows' the geobody in real time but the interpreter can modify in 3D the position of regions of the geobody surface at any stage.

The data analysis, which underpins the

Adaptive Geobodies, has been designed to accommodate a significant degree of heterogeneity in the expression of the geological element being defined. This mimics the human visual process and maximizes the degree to which the data is driving the process and hence its efficiency. It also feeds back information on how well the geobody definition respects the data. This is important in a system which allows the output to be varied based on a subjective (user) input as it enables areas where the geometry, morphology and volume of the object are strongly supported by the data to be differentiated from those areas in which the geobody definition is based on an interpretive decision. The Adaptive Geobodies technique is an exciting development because it allows 3D geological elements to be defined from the data where previously this has been impossible. The Adaptive Geobodies allows complex geological elements to be incorporated into 3D geological or reservoir models based on a data-driven analysis rather than on a stochastic model-based estimation of what might be there.

Another example of how the Geological Expression approach can extract previously inaccessible information is in fault analysis. As mentioned earlier, looking at the different ways in which faults are expressed in seismic data can indicate lithological changes along a fault. Through utilizing an Adaptive Geobodies approach faults can be delineated as 3D entities as they are in nature rather than as 2D surfaces. Bringing these two approaches together opens the door to more effective use of 3D seismic data in fault seal analysis and understanding faults as hydrocarbon migration pathways or even reservoirs.

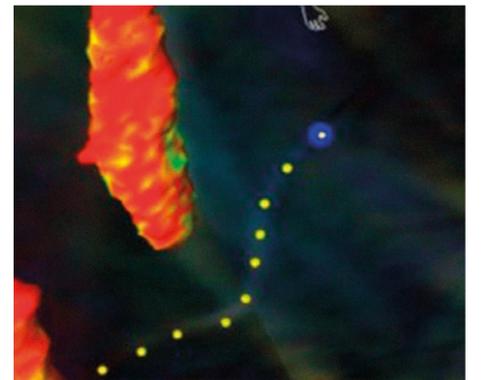
Bridging the Gap

A central aspect of improving workflow efficiency is making many of the processes in interpretation interactive. Seismic facies classification techniques have been an important but specialist area in seismic interpretation for a decade or more. In the Geological Expression workflow the interpreter is in direct control and can see the effect of their choices, removing the mystique associated with conventional methods, which are based on neural network approaches. As a consequence seismic facies analysis is made accessible beyond the specialist user population. It

also means that results are delivered in real time rather than at the end of long processing runs.

The primary focus at the moment is on post-stack Geological Expression workflows but it would be logical to extend these into the pre-stack domain. The use of pre-stack increases the data analysis burden by a factor of 100 or more. So, can we integrate pre-stack analysis without losing the interactivity which is central to the data-driven, interpreter-guided approach and which makes the Geological Expression workflow so efficient? It is increasingly looking like the answer to this question will be 'Yes'. Interactive pre-stack gather conditioning technologies are already commercially available, such as the Pre-Stack Pro system from Sharp Reflections in Norway. From where we are today it may be a large step in terms of technology development, but is a relatively modest intellectual step to a joint pre-stack / post-stack Geological Expression workflow.

The Geological Expression approach to seismic interpretation bridges the gap between processing and conventional interpretation, increasing enormously the level of geological understanding that can be obtained from 3D seismic data. By allowing the interpreter to manually edit the growth of the geobody and to interactively change parameters while the process of growth is active, this technique makes maximum use of both the available data and expert knowledge of the interpreter. The combination of local data



The first point in the Adaptive Geobodies workflow: multiple seed points are picked to adapt the region to be grown.

statistics and multi-attribute inputs means that the Adaptive Geobodies replicates some of the power of the human visual system whilst simultaneously providing objective analysis and understanding of the shape and geometry of neighboring features on a scale that cannot be achieved using surface-based horizon interpretation.

The Geological Expression workflow gives on-demand extraction of geological features, enabling the interpreter to consider and adapt what is being expressed within the geology – be this in automated fault delineation, facies classification, subtle karst features or complex fan geometries. The data-driven, user-guided approach means the speed of analysis will equal the speed of interpretation to reveal the optimum geography of the geology. Essentially it brings geology and geophysics together to directly translate geophysical data into geological understanding. ■

RGB display offshore Angola showing the incredible geological detail that can be achieved by utilizing high resolution color visualization to display information derived from 3D seismic data, showing three individual color channels and the RGB composite image.

