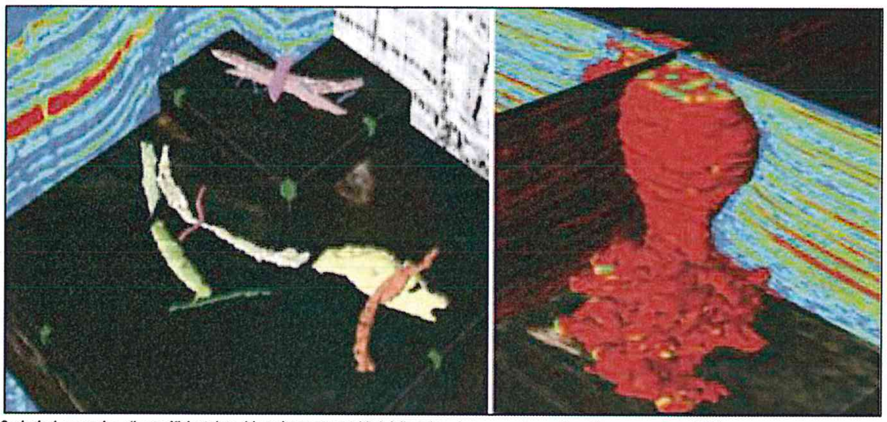
Combining Art and Science

New methodology converts geophysical data into geological images.

By Jonathan Henderson, ffA

Harnessing the power of human cognition and visual perception is a fundamental part of a data-driven, interpreter-guided workflow and is a central part of the geological expression approach to seismic interpretation. By converting seismic images into geological images, geological expression both improves interpretation productivity and sets new challenges.

The images created in a geological expression workflow can reveal the imaged geology with startling clarity, but to bring the understanding of the imaged hydrocarbon system that this provides into a geological model is not straightforward. This is in part because the images themselves are complex and are tailored towards generating geological intuitive insights. A key component of bringing information into a geological model is being able to define accurately the geometry and spatial relationship between the different geological elements. This entails extracting accurate 3-D representations of the imaged geological elements from the geological expression images; however, this cannot be done with conventional autotracking or current geobody delineation technology. Until recently, one of the few ways of extracting geological objects from these images has been manual digitization, and this is subject to large inter- and intra-interpreter variations as well as being very laborious and inefficient.



Geological expression allows efficient data-driven, interpreter-guided delineation of very complex geology. (Image courtesy of ffA)

Solving this problem is not straightforward. An automated way of extracting the objects seen in images is preferred; however, the human visual system is incredibly complex and sophisticated, and it can deal instinctively with factors such as varying contrast and character and interference due to overlying or adjacent structures that confound most image analysis software. The eye compensates for changes in image character by adaptively modifying the criteria it uses for recognizing different elements in an image and the scale at which it is doing the analysis. The "rules" by which the eye adapts depend on context, experience, and what the brain expects to see. Some of these factors are more tractable to being encoded within a software application than others.

To address this problem, ffA, in collaboration with Lundin Norge, has developed what it calls the Adaptive Geobodies technology. The Adaptive Geobodies technology is based on supplementing techniques that use an objective, data-driven approach that mimics some of the facility of the human visual system with interpreter guidance to address the situation where the "correct" object delineation can only be determined by applying external knowledge.

The data-driven aspect of the Adaptive Geobodies technology uses sophisticated statistical techniques to replicate the ability of the human eye to compensate for both the variations in contrast between the object of interest and its surroundings and the variations in character within and outside the object. This enables the Adaptive Geobodies to produce purely data-driven representations of the geological elements of interest in many situations. However, it is not uncommon to be presented with a scenario where there is a lot of ambiguity in what the data are saying about the imaged geology. In these situations, there often is only knowledge of what is geologically plausible or most likely on which to base the assessment of what the true extent of the object might be, and in these cases it is necessary to pass control back to the interpreter. The Adaptive Geobodies does this without reverting to manual digitization by providing a unique facility that makes it easy for the interpreter to morph the surface of the object boundary in 3-D. By intention this is introducing subjectivity and interpreter bias, but the impact of this on reproducibility is constrained by interrogating the data to make sure that the geobody surface position is locally optimized. Importantly, the Adaptive Geobodies technology also has been designed to provide confidence measures that indicate how well the surface matches the data. This makes it clear to the non-interpreter where the geology is defined by an objective data-driven process and where it is largely interpreter-defined. This confidence measure provides an objective way of understanding positional and volumetric uncertainties, information that is largely unavailable from conventional interpretation but can be very valuable in assessing the economic viability of marginal projects.

Geological expression is a new approach to seismic interpretation that maximizes interpretation productivity by combining a scientific approach in the form of advanced data-driven image analysis and the art of interpretation that enables geoscientists to more effectively deploy their knowledge and experience. Geological expression is about directly converting geophysical data into geological images to provide new insights into the subsurface. ■

Reservoir Characterization Changes the Picture

Six wells confirm predictions based on seismic inversion results.

Contributed by Fugro-Jason

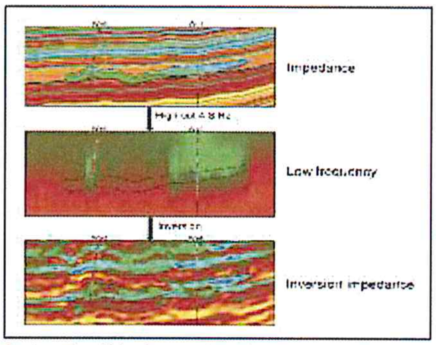
Success stories are compelling, especially when results relate directly to improved drilling success. A seismic inversion study by Fugro-Jason in a thin, complex channel sand reservoir in the Malay Basin provides a better interpretation of the seismic data and proves key in revising predictions and guiding early development drilling. The six wells drilled to date confirm greater accuracy in predicting the sand and fluid distribution for Newfield and Petronas, partners in the field. Fugro-Jason highlights the details of the study in its theater presentations at this year's SEG.

Seismic inversion should be considered an integral part of seismic interpretation, considering the success of the new wells. The end result provides the ability to make crucial predictions of the channel thickness and the fluid at the top of the channel to guide well placement and the horizontal wellbore to reduce drilling risk.

Inversion and interpretation prove to be of mutual benefit in the modeling process. Seismic inversion adds critical information and improves the understanding and interpretation of seismic data. With an improved interpretation, inversion results become more quantitative and reliable. Geological and rock physics modeling supply an essential framework in this successful Malay Basin study conducted by Fugro-Jason experts.

Field background

Similar to many productive areas in the world, the reservoir is a fluvial channel sand, deposited in an incised valley cutting into coastal siltstone and coals. The meandering stream creates stratigraphic traps for the hydrocarbons, with gross sand thickness of approximately 9 m (30 ft) with good porosity and sand quality. The varying height of the channel, thin oil leg, and smaller channels above and below complicate the seismic response. An underlying coal seam varying in thickness further confuses things. Fugro-Jason recommended a reservoir characterization study with inversion as part of the modeling process to help understand the complexities of the reservoir prior to drilling.



Supplementing with low frequency data yields greater reservoir detail. (Image courtesy of Fugro-Jason)

Rock physics modeling and seismic conditioning

Fugro- Jason's approach was to develop a rock physics model to predict accurate elastic logs based on a petrophysical interpretation of clay, porosity, and saturation. Forward modeling of the amplitude vs. offset response distinguished wet or oil/gas sand. Near- and far-angle seismic data showed response to coals and other features or a response to the channel. Modeling various fluid scenarios provides understanding of the seismic response. Conditioned seismic datasets achieve better velocity and anisotropic correction as well as reduction in random noise, multiples, and the acquisition footprint.

Inversion and interpretation

Seismic inversion converts seismic reflectivity to elastic rock properties. The seismic inversion in this study determines one model with impedances in the channel and in the coal, another model to interpolate well data only, and then a final combined inversion model. Porosity information from the wells and rock physics relationships are important in building the models. Because the very low-frequency component is

See RESERVOIR continued on page 20 >>