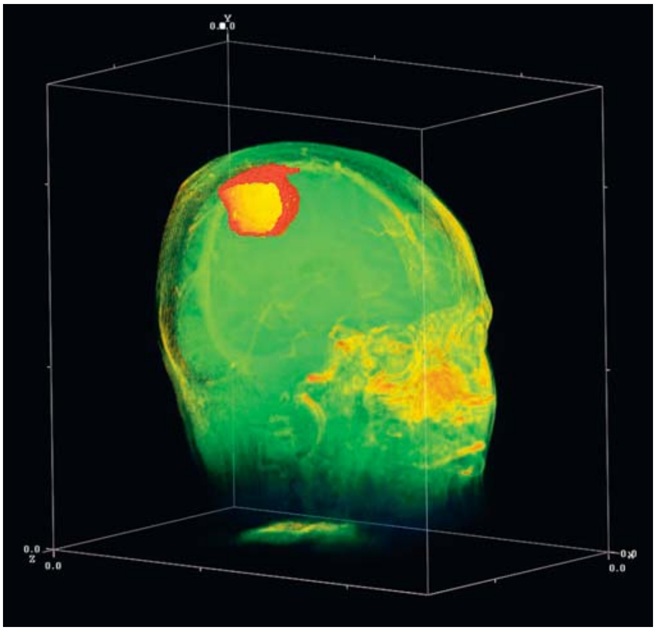
3D Seismic to Subsurface Information



3D visualisation of a brain tumour delineated using ffA's 3D IPA techniques

Even in mature basins such as the North Sea many operators believe there are still significant discoveries to be made. Investment in exploration – and exploration companies – is strengthening and competition for rigs is intense. Robust oil prices and bullish forecasts provide strong incentives to maximise oil and gas recovery from producing fields and reactivate abandoned fields. The opportunities are big, as are the challenges, and technology development is achieving new efficiencies at every stage in the E&P cycle.

BY JONATHAN HENDERSON

Understanding and managing subsurface risk is fundamental to the success of drilling, well planning and reservoir engineering decisions. A powerful 3D imaging technology with its roots in the life sciences is improving the quantity and quality of subsurface information and can have a substantial impact on the productivity and economics of exploration and development projects.

Huge Amounts of Data

For several years the industry has invested in 3D seismic surveys to provide higher resolution images of the subsurface than the traditional, and cheaper, 2D "line-by-line" approach. 3D seismic surveys contain huge amounts of data – a 100 km2 North Sea survey will take up several gigabytes of storage space and contains subtle and complex information which is often masked by noise. The task of the seismic interpreter is to extract meaningful and accurate subsurface information from the dataset, ultimately to assess the probability of drilling successful wells from play, trap and charge risks. This process is demanding, time consuming and squarely on the E&P critical path. For the majors interpretation productivity is a major factor in pursuing replacement reserves. For smaller independents with limited portfolios the difference between a dry hole and a productive well can be the survival of the business.

In the crucial subsurface domain the technological challenge is to transform large volumes of 3D data into information, efficiently and reliably. In the past ten years seismic processing techniques and 3D visualisation technology have enabled much improved data quality and imaging of subsurface features. However the sheer quantity and complexity of the data, and the inherent subjectivity of extracting information by eye, can result in key features being missed or mis-interpreted.

Recognising Patterns

Pattern recognition is a major component in the visual process. The human eye and brain do this job extremely well on 2D images. However interpreting 2D sections or surfaces of a volume of 3D data seriously inhibits perception when much of the subsurface information represented by the relationship between seismic data values is "under" the surface.

There are parallels in other domains, such as medical imaging and non-destructive testing, where increased reliance on 3D images such as MRI scans has driven large scale research into the visualisation of 3D data and computer processing and analysis of images. Essentially the aim is to advance diagnostic speed and accuracy by employing 3D image processing and analysis (IPA) software, rather than the observer, to carry out pattern recognition.

The potential value of 3D IPA to the oil and gas industry was recognised by Shell in the 1990s. After a global review of organisations developing and applying IPA software their geoscience research group entered into a major R&D collaboration with Foster Findlay Associates (ffA), then a leading innovator of 2D IPA technologies for medical imaging and other life sciences applications.

The result of the ffA/Shell collaboration was C_Images 3D, a library of powerful 3D IPA algorithms, and a toolkit for generating workflows to remove noise and extract geological information from seismic data sets of any size. Subsequently ffA worked with BP, Chevron, Statoil and Norsk Hydro to further develop and commercialise the technology and is now providing 3D IPA products and services for advanced volume interpretation to majors, NOCs and senior independents worldwide.

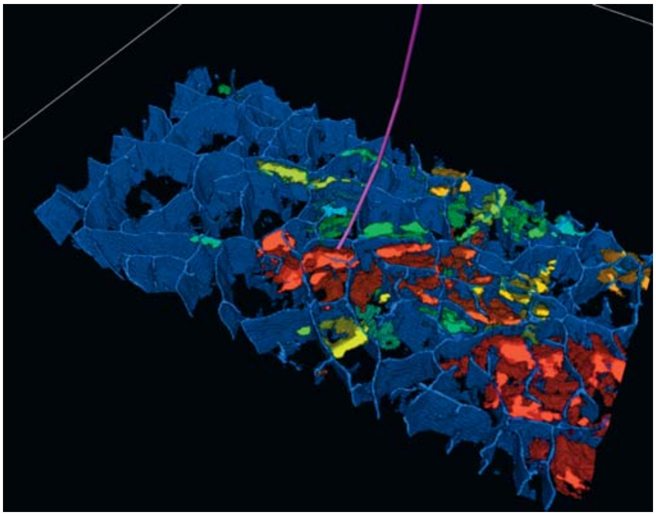
ffA has processed over 100 3D seismic data sets from all E&P regions and has a strong focus on the North Sea, often described by interpreters and geological modellers as "difficult" because of complex faulting and fracturing. In many cases potentially productive wells are not drilled at all because of poor delineation of the drilling target or concerns that geological structure may endanger the well path.

A key application for IPA technology is highlighting detailed variations in geological structure, which can be quite subtle, and their effect in understanding deposition of potential pay sand. Trying to do this by analysing a 3D seismic data volume as a set of 2D sections is extremely onerous and can introduce substantial uncertainties. A true 3D analysis of the data enables this information to be obtained accurately and reliably. This is one of the reasons that, for 3D images, computer aided pattern recognition and IPA techniques are able to detect features and highlight information more reliably than human observers.

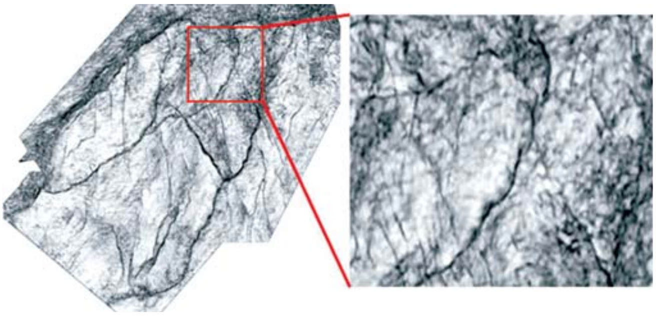
Interpreting Faults

Other benefits of using IPA can be illustrated by considering one of the most demanding tasks in the subsurface information workflow – fault interpretation. An accurate representation of the position and nature of fault is essential to a realistic appreciation of hydrocarbon trapping mechanisms, seal leakage risks and fluid migration pathways.

Fault interpretation is commonly carried out by manually digitising the position of fault planes on a set of vertical 2D sections from a seismic data set. In seismic data, the presence and position of a fault is not defined by an explicit set of consistent data values rather it is implied from the presence of characteristic patterns in the seismic data. Hence even fault planes that are clearly visible within the seismic data, must be digitised manually if they are to be extracted and used as 3D objects, for example in well planning or reservoir modelling systems. To generate a detailed fault model using manual digitisation techniques can take weeks or months.



Virtual well path to a fault-bounded geobody drilling target delineated by ffA



3D IPA structural reconnaissance clearly shows en echelon faulting that could be misinterpreted using conventional techniques

"ffA technology has been used on several Hydro NCS exploration projects and has consistently improved de-risking of prospects, selection of drilling candidates and delineation of well paths. In a recent NCS project, ffA results exposed previously unidentified reservoir compartmentalisation that improved confidence in volumetric estimates and was subsequently confirmed by a successful discovery well. In another project in the Oseberg area, ffA results exposed sand body geometries that have directly impacted on the choice of drilling target and associated well path design. ffA is a key partner in Hydro's Research and Development of advanced 3D interpretation tools".

Tom Dreyer, Chief Geologist – Infra-structure Led Exploration, Hydro

The process is slow and cumbersome and it is common for faults to be picked by sampling the data, for example on every 5th or 10th in-line and cross line. This means that only a small portion of the expensively acquired data set is used for producing information that can have a fundamental impact on drilling and field development decisions.

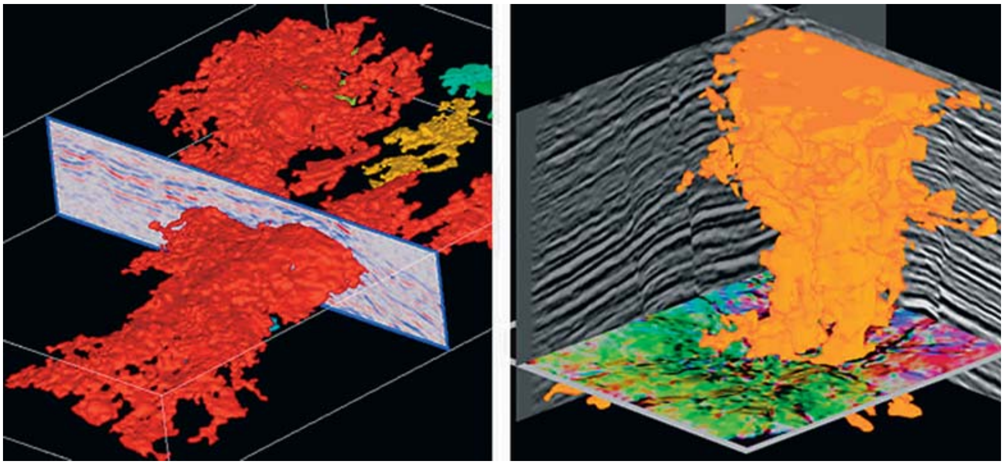
A further drawback with manual fault picking is that fault detection can depend on the viewpoint of the interpreter relative to the orientation of the seismic dataset. If the viewer's orientation is perpendicular to the fault planes then the faults can generally be seen clearly. If the orientation is parallel to the fault plane the faults are far more difficult to detect. Optimising orientation for major faults is usually straightforward. However, for small scale faults, which can be pivotal in evaluating development and production scenarios, optimising orientation is more difficult. If it is not done correctly important information can be missed. Advanced 3D IPA techniques achieve orders of magnitude gains in productivity by automating the process. Powerful algorithms are deployed to "interrogate" all the available data and highlight potential faults, independently of their scale and orientation, to produce rigorous and reliable results much faster than is possible with manual picking.

Other IPA techniques can be used to extract the fault network as a 3D "object". A further IPA step can be applied to embed the extracted fault network back into the original seismic data set so that the relationship between the faults and other information in the data can be assessed more easily. Faults are defined as 3D objects introduced into later stages of the 3D workflow to inform key processes such as prospect evaluation and well planning. IPA techniques achieve a detailed representation of faulting in a few days. Manual picking is unlikely to produce a comparable level of detail and accuracy.

Subsurface Understanding

Whenever there is a requirement to get an accurate and detailed 3D understanding of the subsurface from 3D seismic data IPA techniques can have a significant impact on both the quality of the information obtained and the speed with which it is accessed. Fault imaging is an important application; there are many others, including analysis of sand body and gas chimney geometries, mud diapir and salt body delineation and 4D studies of changes in oil/water contact in producing reservoirs.

The application of 3D IPA techniques in seismic interpretation is becoming a key part of the mainstream interpretation workflow for many majors, NOCs and senior independents and the benefits of 3D IPA have been validated by several E&P companies. ■



3D IPA extraction of sand body (UKCS) and gas chimney (Gulf of Mexico) geometries produced by ffA without interpretation (UKCS data courtesy of Marathon UK Limited)

The Author:

Jonathan Henderson is Managing Director of Foster Findlay Associates (ffA) and has extensive experience in the development and application of image processing and analysis techniques in both medical and seismic imaging. Foster Findlay Associates Limited ("ffA") is a world-leading originator of high quality, multi-platform, 3D Image Processing and Analysis (IPA) software for the oil and gas industry. ffA also provides 3D Image Processing and Advanced Volume Interpretation (AVI) consulting services. For more information visit www.ffa.co.uk