The ultimate goals of seismic reservoir characterisation are to identify reservoirs, delineate them, and determine the distribution of their relevant properties, such as lithology and porosity, which will provide an early determination of the reservoir's economic potential.

Challenges and solutions in seismic driven reservoir characterisation

A *TYPICAL RESERVOIR* characterisation project using seismic data and well data is subject to continuous processes of transformation, calibration and interpretation, and is often refined through iterations over each of them. Proper selection and application of these processes contribute to the accuracy of property determinations and to the success of the project.

Transformation

Seismic data contains information on reservoir properties. Seismic signatures change as waves propagate through rocks with varying rock and fluid properties carried by their respective media. The rock properties affect the observed acoustic and elastic behaviour of seismic data as witnessed by differences in the kinematic (e.g. travel time) and dynamic (e.g. AVO) responses. Through seismic inversion, attributes such as AVO reflectivities and impedances and their derivatives (e.g. Lambda-Mu-Rho), which are often indicative of the presence of hydrocarbons, can be generated. Although there are many types of qualitative transformations of seismic data that can contribute to a seismic characterisation project, seismic inversion is the fundamental transformation that can return quantitative descriptions. The following factors often challenge the E&P geophysicist in the transformation process:

Seismic inversion is the fundamental transformation that can return quantitative descriptions.

1.Quality of the input Data.

Many reservoir characterisation projects are performed using the Common Reflection Point (CRP) gathers after the prestack migration. Due to the presence of residual velocity, the events of the CRP gathers are not flat. This affects the kinematic accuracy of the AVO attributes, impedances, and additional derivative attributes. If not corrected, the qualitative and quantitative interpretations of the reservoir and its properties using these attributes carry large uncertainties. A number of technologies have been established to resolve the issue, including automatic and continuous semblance and AVO-based residual moveout correction and longer wavelength tomographic inversion solutions to update the velocity model etc. The most cost- effective solution is the automatic AVO based residual moveout technique which provides relatively consistent corrections with fast turnaround.

Other equally important dynamic corrections come from best amplitude conditioning practices and an understanding of the processes that adversely impact the amplitude versus offset behavior of seismic trace data. Calibration to well synthetics is recommended.

2.Impedance inversion

Impedance inversion transforms elastic boundary reflectivities to layer impedances. Traditional inversion methods demonstrate a number of difficulties such as non-uniqueness, noise-sensitivity, and stability (calibration) issues resulting from independent inversions of p- and s-impedances. Simultaneous inversions, on the other hand, overcome or minimise these difficulties by incorporating multi-offset or multi-angle seismic data into a single solution. A robust simultaneous inversion is typically implemented as a model-based procedure that incorporates a multi-channel and geologically-oriented operator to constrain the interaction with the background impedance models and to improve the resolution and lateral consistency of the final results. The process inverts for P and S impedance simultaneously using AVA theory (forward modeling using the Zoeppritz equation) as an iterative constraint.

Calibration and interpretation

Well log data provides a detailed sampling and understanding of lithology and

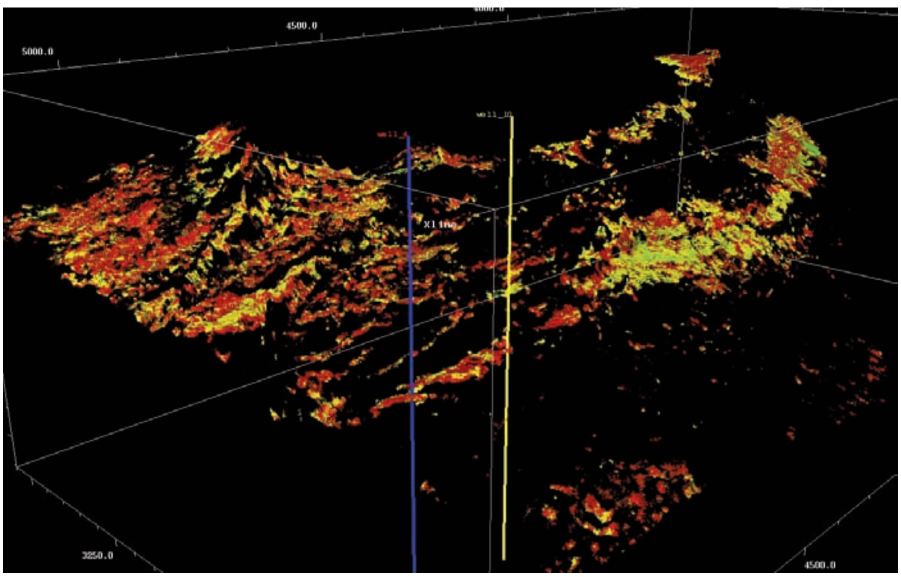

Figure 1a. AVO anomaly distribution in a North Sea survey visualized in a voxelbased visualization environment (1a). A gather displayed at the well location (1b) which encounters hydrocarbons. The gather retrieval option is performed by a point and click operation on the AVO anomaly volume. (Images courtesy of Paradigm)

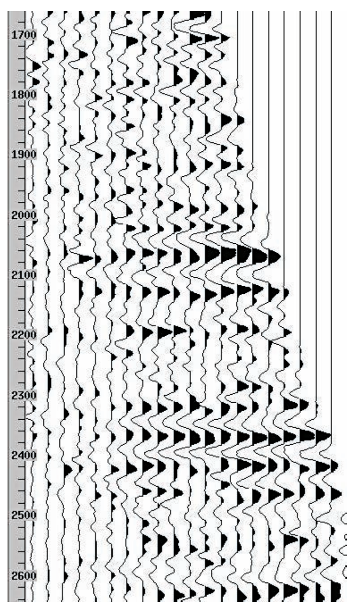

Fig 1b

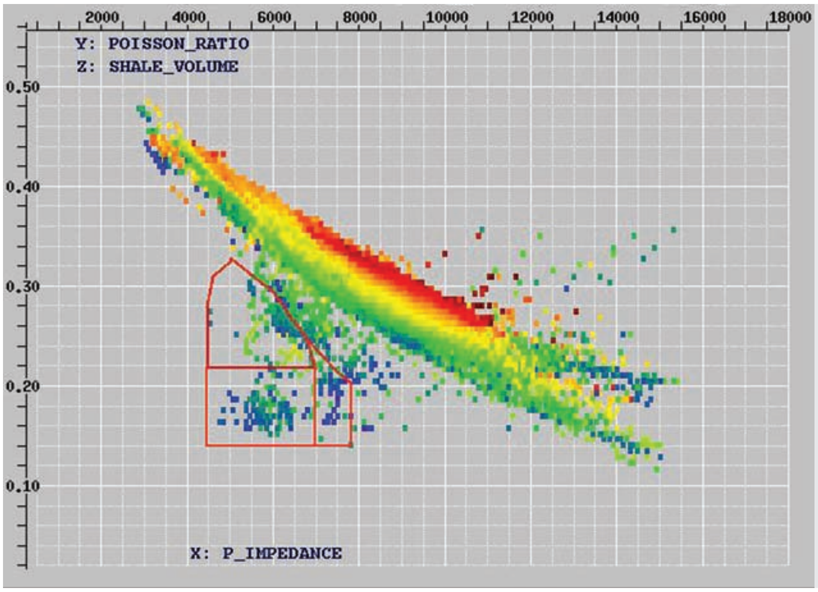

Fig 2.Crossplot of well data isolates the zone of sands using the attributes of P impedance and Poisson's Ratio. Once defined, such criteria can be applied to the seismic-generated P impedance and Poisson's ratio to predict rock property spatial distribution

rock property distribution along the wellbore as well as an understanding of the seismic response to lithology and fluid changes. Once calibrated, the 3D seismic data provides the necessary sampling to make spatial inferences about the reservoir. Proper application of interpretation techniques can bridge the gap between the seismic and the well data, extend our understanding of lithology and fluid from 1D to 3D, generate quality prospects, and reduce reservoir characterisation uncertainties.

How should the well log data be used in relation to seismic inversion? The well data can be used to evaluate the reservoirs and their properties, and further to determine the following:

- A set of logs that is sensitive to the reservoir lithology and/or fluid, such as P and S impedances, Poisson's Ratio, LMR attributes, etc, which can be derived from the seismic through transformation.
- AVO anomalies that provide lithology or hydrocarbon indicators through synthetic modeling.

These determinations can be made prior to performing the seismic inversion. The conclusions from the process can be used to plan the strategy on the seismic inversion (e.g. what attributes to directly invert and what to calculate). Once the seismic attributes are generated and calibrated to the well data, the interpretations of the attributes yield qualitative or quantitative descriptions of the reservoirs.

Seismic reservoir characterisation is an important discipline in exploration and field development

AVO attribute interpretation

Prospect identification using AVO attributes applies isolation and distribution mapping techniques to AVO anomalies. Interpreters that work with AVO attributes are often challenged with the following issues:

- Identifying AVO anomalies in different formations at different depths.
- Mapping the anomalies that are significant.
- Recognising any pitfalls that may cause false AVO anomalies.
- Working under tight deadlines.

Today's technology and software implementation allow the interpreter to confidently meet all of the above challenges through the following key steps:

- Incorporating structure interpretations into the AVO attribute interpretation. With the constraints applied, the AVO anomalies can be analysed at the target formations without distraction from the others.
- Using the automatic tools such as automatic horizon interpretation to reduce the cycle time.
- Incorporating advanced visualisation technology, such as voxel-based technology with advanced crossplot techniques to isolate, visualise, filter and map the 3D geobodies that represent the AVO anomalies.
- Including multi-domain data in the interpretation process, such as the well data and prestack seismic data to qualify the geobodies and identify any possible pitfalls.

Fig 1a shows AVO anomaly distributions in a North Sea survey visualised in voxel-based visualisation environment. The gather at an anomaly location (Fig 1b) is displayed by point and click operations.

Impedance attribute interpretation

Elastic attributes (P & S Impedances and Density) generated by the seismic inversion can be used to calculate other attributes such as Poisson's ratio, lambda-rho and mu-rho. Using well log data, we can develop an understanding of the attribute behavior with changes in lithology and/or fluid. The crossplot of well data in Fig 2a isolates the zone of sands using the attributes of P impedance and Poisson's Ratio. Once defined, such criteria can be applied to the seismic-generated P impedance and Poisson's ratio to predict rock property spatial distribution. Fig 2b shows the mapped geobodies that represent sands co-visualised with automatically extracted faults. Both the geobodies and faults are extracted automatically, with carefully calibrated constraints, saving the geoscientist considerable time isolating complex or hidden features. Additionally, we can begin to appreciate potential trapping mechanisms of hydrocarbon prospects.

Conclusions

Seismic reservoir characterisation is an important discipline in exploration and field development with applications from prospect identification to detailed reservoir delineation including reservoir geometry, reservoir lithology, sealing capability and reservoir quality. To improve the accuracy of reservoir property prediction and minimise the uncertainties, considerable attention needs to be placed in generating quality seismic data, in selecting the seismic inversion method, and in the integration of multiple domain data (well data, seismic attribute and prestack seismic) for the calibration and interpretation phases. Today's technologies provide powerful tools and environments that allow the geoscientist to effectively and efficiently make use of multi-dimensional data in the search for new reservoirs or in the optimum depletion of existing ones. ■

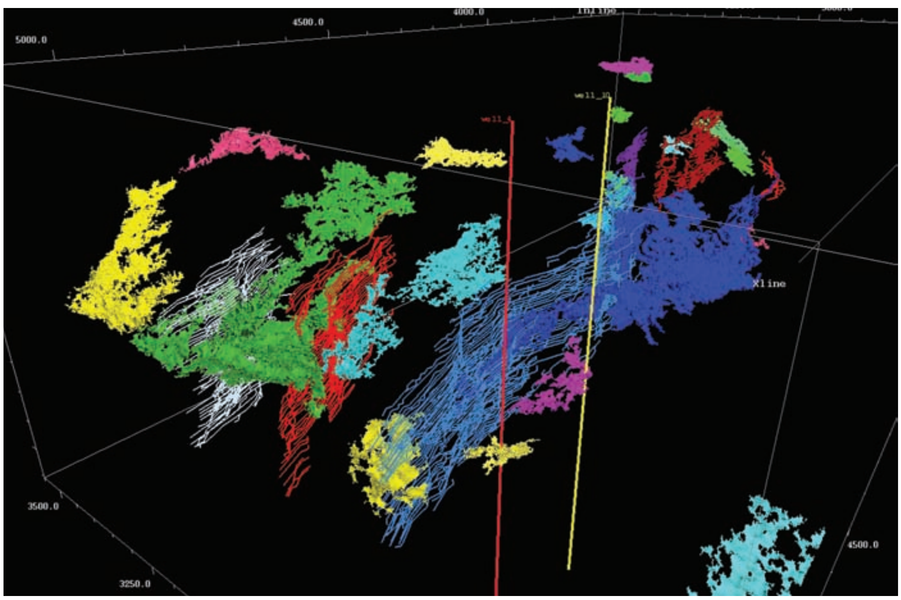

Fig 2b. The mapped geobodies (right) represent sands co-visualised with automatically extracted faults.