Joanne Wang and Duane Dopkin, Paradigm B.V, The Netherlands, explore visualisation in seismic driven pore pressure prediction.
Technical difficulties in drilling often occur when over pressured formations are encountered unexpectedly. Understanding the pressure distribution, especially the presence of abnormal pressure, is mandatory for designing and drilling successful wells and minimising drilling risk and cost. Predrill pressure prediction using seismic data can provide pressure distribution in 3D. Calibrated with pressure measurements, seismic predicted pressure volumes can be essential deliverables for drilling design.

Many factors can affect the accuracy of the pressure estimation and interpretation, among which are the integrity of the seismic velocity and the knowledge of lithology distribution. Quality assurance must be conducted at each stage of pressure prediction. Visualisation and covisualisation play important roles in a successful pore pressure prediction project as enablers for QC, analysis and interpretation.

Seismic velocity analysis for pressure prediction

A commonly used pore pressure prediction method is the empirical relationship between vertical effective stress and interval velocity developed by Eaton. In the Eaton method, interval velocity is a key input that determines the accuracy and the resolution of the output pressure volumes. A typical workflow for seismic velocity analysis for the purpose of pore pressure prediction is shown in Figure 1.

Prestack data visualisation

Lack of flatness in the events of migrated prestack seismic gathers is an indicator of residual velocity. Visualising prestack data in 2D and 3D settings can help a geophysicist determine the presence of velocity error, the locations and distribution of velocity error, and procedures and parameters for correcting these velocity errors. Figure 2 is an example of prestack data visualised in 2D settings. It is clear from Figure 2 that the gathers are not flat and velocity error exists.

Velocity before and after

Residual velocity analysis is often performed automatically using a set of optimised parameters. This approach picks the velocity at a dense grid to ensure required spatial and temporal velocity resolution. Following the automatic residual moveout, an updated velocity is created. A constrained approach is recommended to generate the interval velocity field using the result of high resolution residual velocity analysis. This approach makes use of a background velocity trend and additional constraints so that the dense residual velocity update returns a geologically plausible interval velocity. Nevertheless, automated picking approaches are subject to error and visualisation of the velocity volume can help identify potential problems. Figure 3 shows a velocity slice indicating noise contamination, which must be removed before it is used for pore pressure estimation.

Crossplot techniques can also be used to visualise and analyse the difference before and after velocity analysis. The left panel of Figure 4 is a migration velocity field determination developed with a horizon based technique. The right panel is the interval velocity field determination after high resolution residual velocity analysis. The
difference is noticeable. A crossplot of the two velocity fields is used as a vehicle to isolate the differences.

The colour cube displayed (Figure 5) is created using crossplot technique. Blue and green indicate small or no change before and after velocity update. Yellow and red indicate large change. By dimming out the blue colour through editing operations performed on the opacity curve, the large velocity differences (red and yellow) are highlighted (Figure 6). Note the larger changes are distributed along the fault. Using different colour coding techniques, positive and negative changes can be mapped as different colours.

Pressure visualisation and interpretation
Once the velocity is updated and calibrated to the well data, pressure can be estimated. A number of pressure volumes can be generated in the transformation process, including pore pressure volumes and fracture pressure volumes. The visualisation system provides an environment to visualise the pressure in the following ways:

- Pressure display and rendering.
- Pressure range distribution displays, for example, hard pressure spatial distribution.
- Pressure along wellbores.
- Pressure along arbitrary traverse.
- Pressure distribution between wells.

Figure 7 shows the 3D distribution of the pore pressure in mud weight units of approximately 13 ppg and Figure 8 shows pore pressure along an arbitrary traverse and a well traverse. These visualisations are useful for planning casing and drilling programmes.

The power of covisualisation should not be under estimated. Figure 9 shows a covisualisation of seismic, pore pressure, structure interpretation and well trajectories of a survey from the Macuspana basin in the south of Mexico. The cool colours, blue and green, represent normal to low pressure, while the warm colours, yellow, orange and red, represent high pressure. Through covisualisation of pressure, seismic, structure interpretation and wells, the following conclusions can be made:

- Pore pressure distribution in the survey area is highly compartmentalised.
- The pattern of pressure distribution is closely related to the structure settings, especially to the pattern of the faults.
- The two wells shown in the image are in different fault blocks, which have different pressure profiles.

The above observations agree with the understanding of the basin history and the pressure measurements at the well sites.

When interpreting seismic predicted pressure, one must keep lithology in mind because empirical based prediction methods are suitable for low permeability rocks such as shale, not for sand. Consequently, only the pressure predicted in shale is valid. Two steps are often taken to accurately interpret the pressure: 1) isolating the zone of sands, 2) re-estimating the pressure of sand using the Centroid Concept. Visualisation is an important technique in helping us identify issues in the process of interpretation.

Technologies in reservoir characterisation can be used to identify lithology and its 3D distribution, such as AVA, AI/EI inversion, facies classification and neural network lithology prediction, etc.

Conclusion
Pore pressure prediction is a cross disciplinary application, which often demands the teamwork of geophysicists, petrophysicists, geologists and engineers. Visualisation and covisualisation are important processes that should be performed at each stage of the pore pressure prediction process, providing necessary quality controls for seismic data, velocity data, structure interpretation, etc. as well as analysing pressure volumes concurrently with all of the available data.

References
1. EATON, B. A. 'The equation for geopressure prediction from well logs' Society of Petroleum Engineers of AIME, SPE-5544.