Drilling Success As A Result of Probabilistic Lithology and Fluid Prediction
A Case Study in the Carnarvon Basin, WA

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Introduction –

A comprehensive quantitative interpretation (QI) workflow, based on four existing dry holes has been used to successfully predict six consecutive exploration wells.

Five of the wells were discoveries consistent with the prediction based on QI support. One of the wells, drilled based on other geological criteria, was dry. This result was also consistent with the QI products.

The aim of quantitative interpretation is to predict lithology and fluid content away from the well bore. This process should make use of all available data, not well and seismic data in isolation. Geological insight contributes to the selection of meaningful seismic attributes and the derivation of valid inversion products.

Uncertainty must be taken into account at all stages to permit risk assessment and foster confidence in the predictions. The use of the Bayesian framework enables prior knowledge, such as a geological model, to be incorporated into a probabilistic prediction, which captures uncertainty and quantifies risk.

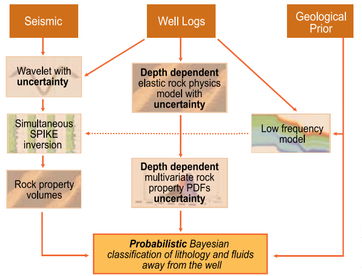

Figure 1. The comprehensive QI workflow used in this study.

Rock physics

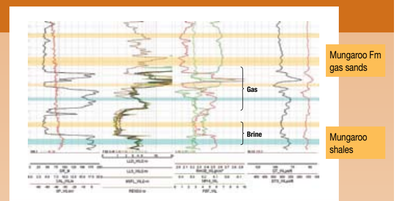

Figure 2. Example well from the study illustrating the end member picks. Sands are straw coloured and the shales are aqua blue.

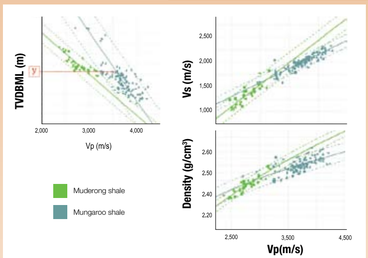

Figure 3. Shale trends for the two dominant shales. Each picked interval from the end member interpretation is upscaled and then plotted as a single point on these cross plots. y indicates the pivot point above which shales are softer than sands and below which shales are harder than sands.

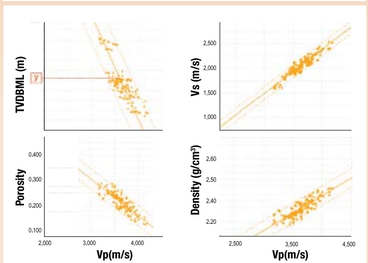

Figure 4. Sand trends for the area. As for the shales, each point represents an interpreted, upscaled end member interval.

Modelling

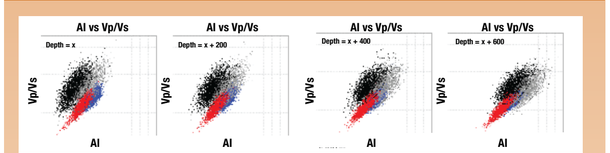

Figure 5. Stochastic forward modelling results. The four major fluid/lithology combinations are represented here. Ellipses represent the two standard deviation contours around the probability density functions. Notice that the 600m depth step has resulted in the entire four clusters being grossly translocated as well as the shale and brine clusters swapping relative positions.

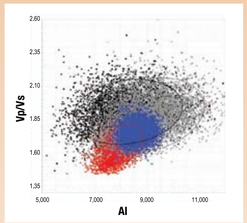

Figure 6. Stochastic forward modelling from the depths of X to X + 600 m combined. Consider the point at the position AI=8,500 and Vp/Vs=1.65. On this plot the probability of it being hydrocarbon, brine or shale is roughly equal. In Figure 5 the same point has an overwhelming probability of being hydrocarbon.

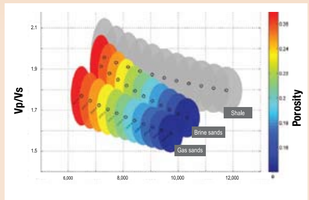

Figure 7. A plot of AI vs Vp/Vs for varying depths and porosities. Ellipses are illustrative of ~1 standard deviation of scatter. Ellipse rotation is not accounted for in this figure. Fluid discrimination is good at all depth levels, however does decrease with increasing depth. Fluid and lithology discrimination is maximised using both P and S attributes. Lithology discrimination increases with depth.

Seismic inversion

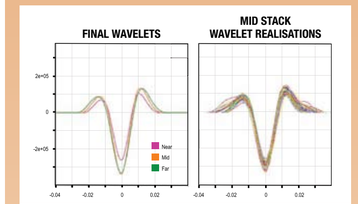

Figure 8. Final wavelets (multi-well extraction). The bunching of the wavelet realisations illicits confidence in the result.

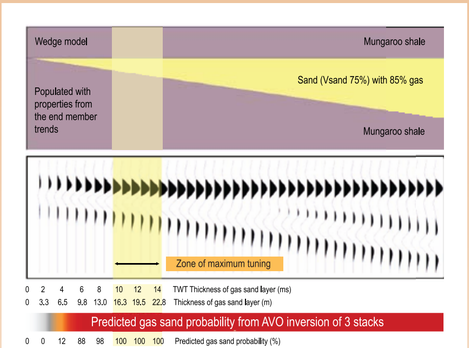

Figure 9. This figure shows the resolution limit of the QI flow. A wedge model, populated with the rock properties from the project, was used as a basis for the generation of near, mid and far seismic stacks. The simultaneous inversion was run on these stacks followed by the lithology and fluid classification procedure. It is clear that the procedure correctly predicts sands down to around 10 m thickness—well below the seismic tuning thickness.

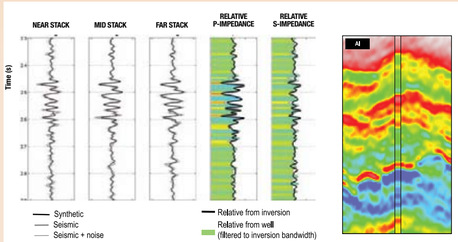

Figure 10. Relative impedance ties at one of the discovery wells.

Figure 11. Acoustic impedance tie at one of the wells.

Lithology and fluid analysis

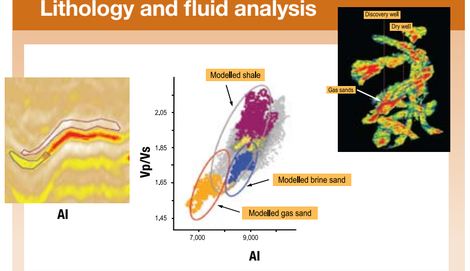

Figure 12. Comparison of rock properties from the seismic inversion with the PDFs (from the appropriate depth) produced from the rock physics model.

Summary –

Five significant gas discoveries have been made in an exploration permit following a comprehensive QI study. Two of these wells were close to dry holes. In addition, one of the discovery wells was down dip from an earlier dry hole. Simultaneous inversion products were compared with multivariate rock property PDFs to make probabilistic, volume-based fluid and lithology predictions using a Bayesian framework. A depth dependent rock physics model is essential. The sparse spike inversion was able to detune the seismic data to a large extent. Although this workflow involves considerably more work than the standard approach, it is scientifically justifiable and has delivered remarkable success.

Acknowledgements –

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Correlation of drilling results with hydrocarbon probability volumes

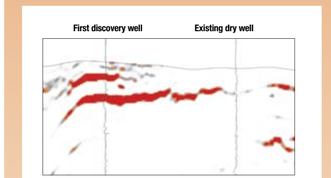

Figure 13. Gas probability data provided confidence to drill downdip of a 12 m brine sand resulting in the first discovery.

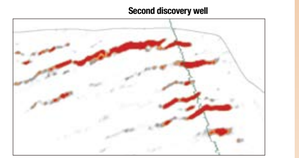

Figure 14. A cross section through the gas probability volume at the 2nd discovery well. Well drilled at 67° to hit the multiple anomolies.

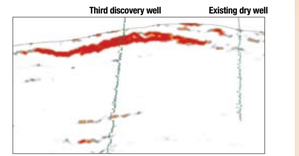

Figure 15. Third well, 3rd discovery. Arbline showing discovery well position along with previous dry hole.

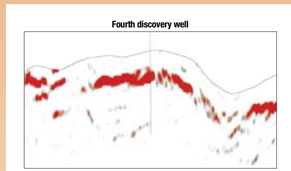

Figure 16. Fourth well, fourth discovery.

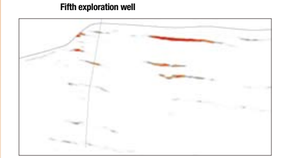

Figure 17. Fifth well was dry. The QI study predicted a dry hole. The well was drilled based on other criteria.

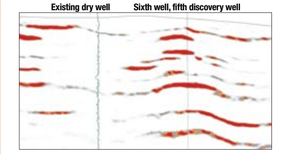

Figure 18. Sixth exploration well, fifth discovery, shown on arbline alongside previous dry hole.

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