Reservoir characterisation in the presence of thin beds and elastically ambiguous facies

Ask Frode Jakobsen, Henrik Juhl Hansen, Rob Ross*

Qeye

Motivation

- An infinite number of facies and fluid configurations can give rise to any given seismic response
- Traditional reservoir characterisation workflows struggle to resolve thin beds and elastically ambiguous facies
- Facies may be elastically very similar but petrophysically very different
- Traditional workflows fail to deliver robust, data driven measures of confidence in the characterization

Objectives

- Robust results in the presence of noise
- Rigorous and data driven confidence in facies classification
- Potential for sub-seismic resolution
- Better discrimination of elastically ambiguous facies

Test geological setting

- Interbedded 1D sand, shale, silt system
  - Thin beds – down to ~5m
  - Elastically ambiguous

Synthetic generation

For each facies characterise the observed distribution of thicknesses (fig 1) and the allowed transition to other facies (fig 2).

For each facies characterise the elastic response and construct a stochastic rock physics model that captures the facies variability (fig 3).

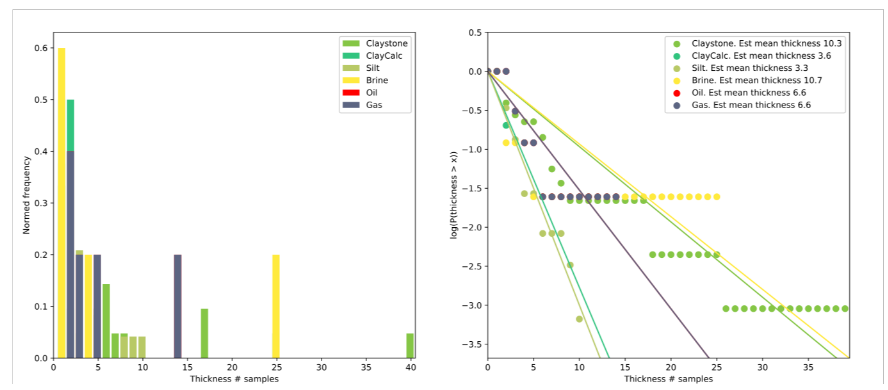

Figure 1: Thickness distributions by facies. In this case and in general, although not required by the method, the distributions are exponential. The prior supports beds thinner and thicker than those observed in the wells.

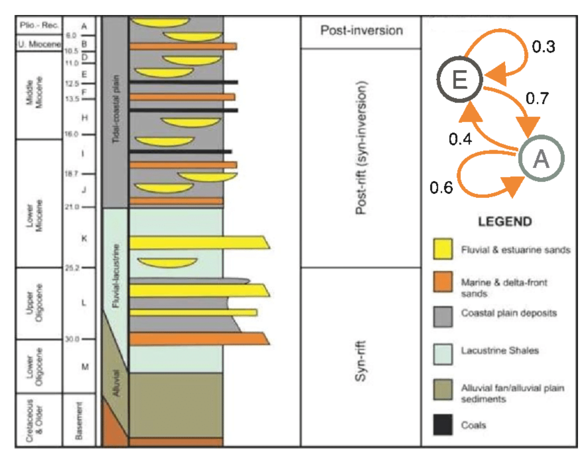

Figure 2: An example stratigraphic column. Many facies are defined based on unit ordering as well as mineralogy. In the top right is an example of a two state Markov chain. By using Markov chains stratigraphic and gravitational fluid ordering can be imposed.

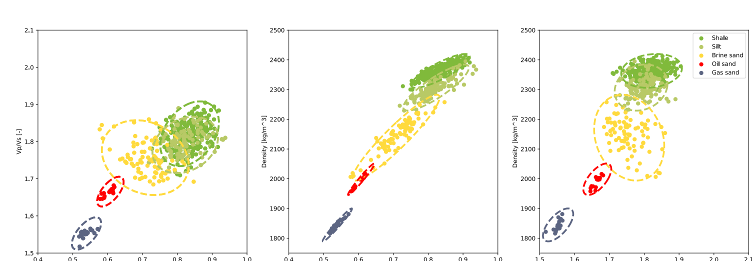

Figure 3: Elastic well data (points) compared to realisations from the stochastic rock physics model (elipses). The rock physics model reproduces the observed trends but permits (slightly) greater variation than is observed in the wells.

Qeye
beyond elastic

The Seapex Exploration Conference SEC2019 For the Industry : By the Industry
APRIL 2-5TH Fairmont Hotel SINGAPORE

The complex spatial statistics around each facies is found by sampling the prior to arrive at an approximate rock physics likelihood. Combining this with the standard seismic likelihood we can connect the facies domain with the seismic domain.

The synthetic input is generated by a realisation from the prior and constitutes the ground truth. The synthetic gather data is then produced by convolution with angle dependent wavelets. Finally, noise is added (fig 5 panels 1 & 2).

Inversion overview

- Bayesian framework: prior information is updated by data to produce the posterior.
- One step inversion approach that consistently tracks spatial correlation from seismic data to the facies domain
- Prior information
  - Stochastic rock physics model
  - Permitted facies transition rules and thickness

The prior information allows for a broad solution space constrained to only plausible solutions honouring fluid ordering and facies sequence.

Inversion results and conclusions

The inversion framework produces an approximation to the posterior in each sample position.

The results accurately predicts thin interbedded acoustically ambiguous facies.

The resolving power decreases with increasing noise, but the algorithm remains robust at high noise levels (fig 5 panels 4 - 7).

Talk to the author for real data examples.

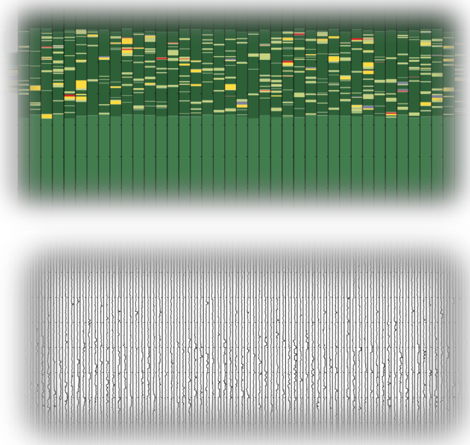

Figure 4: QC prior model: Realisations of the prior generating synthetic facies (top) and elastic logs (below).

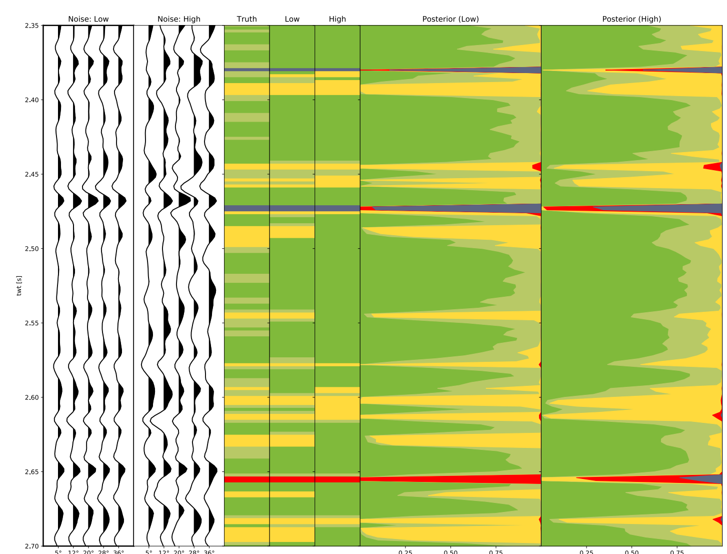

Figure 5: L->R; forward modelled seismic (low and high noise cases), input facies logs for seismic modelling, most likely facies from inversion (low and high noise cases) posterior facies (low and high noise cases).

Further reading

Bosch, M., Mukerji T. and Gonzalez, E.F. [2010]
Seismic inversion for reservoir properties combining statistical rock physics and geostatistics: A review.
Geophysics, 75, No. 5, 75A165-75A176.

Jullum, M. and Kolbjørnsen, O. [2016]
A Gaussian-based framework for local Bayesian inversion of geophysical data to rock properties.
Geophysics, 81, No. 3, 1-13.

Madsen, R. B., Zunino, A. and Hansen, T.M. [2017]
On inferring the noise in probabilistic seismic AVO inversion using hierarchical Bayes,
SEG Annual Meeting Proceedings, p. 601-605.

Acknowledgements

UNIVERSITY OF COPENHAGEN

Innovation Fund Denmark