

PS Combining Seismic Inversion and Geostatistics to Predict Reservoir Properties*

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Abstract

The main purpose of using inversion is to convert the seismic section in order to more accurately represent the properties of the Earth's subsurface. Often in exploration areas we have data of high uncertainty due to the lack of drilled wells; so we have to rely completely on seismic reflection data.

In seismic inverse modelling, the result of reflection seismology, the seismic trace, is reversed. Geophysical inversion involves mapping the physical structure and properties of the subsurface of the Earth using measurements made on the surface and possibly constrained by well log measurements.

The first step is de-convolving the trace, the result being the reflectivity series. This reflectivity series is then displayed side-by-side as a set of pseudo-acoustic logs, which we can then interpret as a cross-section of the subsurface in terms of its acoustic impedance distribution. Basically, inversion is the process of extracting, from the seismic data, the underlying geology which gave that particular seismic response.

Traditionally, inversion has been applied to post-stack seismic data, with the aim of extracting acoustic impedance volumes. However, we used inversion results to directly predict lithologic parameters, such as porosity and water saturation. We can estimate from seismic numerous properties, such as: the lithofacies, porosity, depth, age, diagenesis, pressure, fluid type (oil, gas or water), etc.

The main benefit, amongst many others, of seismic inversion is that it improves exploration and reservoir management success, producing more hydrocarbons with fewer, more highly productive wells. On the other hand, geostatistics provides a toolbox for the geologist to use in analysing data and transferring such analysis and interpretation to the task of reservoir forecasting. Another very important benefit of geostatistical methods is the availability to assess uncertainty associated with kriging and cokriging, using stochastic methods.

The main conclusion of this paper is that the interpretation of secondary data sets, such as Acoustic Impedance from Seismic data, can significantly reduce inter-well estimation uncertainty and that this method is suitable for reservoir characterization and similar studies in

petroleum engineering. Also, by combining seismic inversion with geostatistics leads to significant results. The Kringing model is smooth and we have observed that for the studied area Kringing with external drift (KED) is more accurate than cokringing when estimating the depth of the horizon when there is insufficient data.

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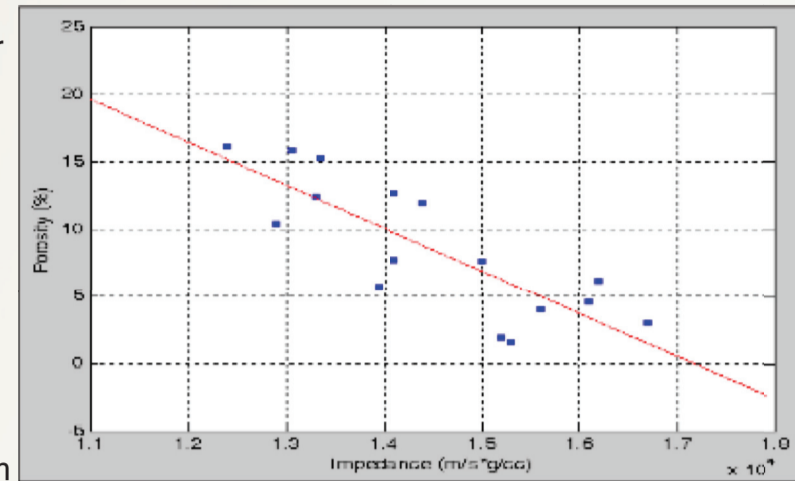


Fig.1. The regression line is the least-squares fit between porosity and impedance.

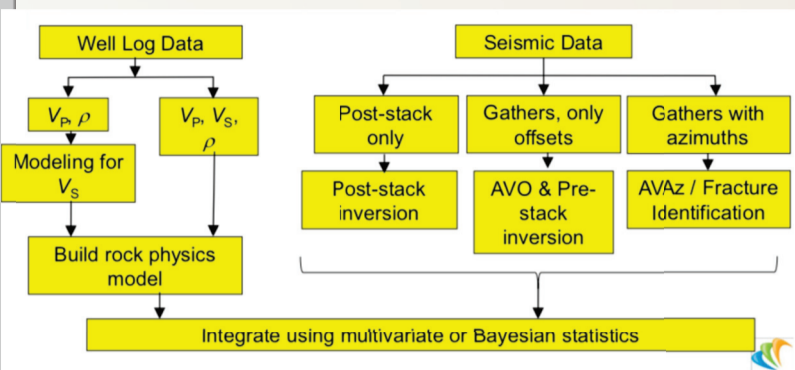


Fig.2. Suggested workflow (after Russell)

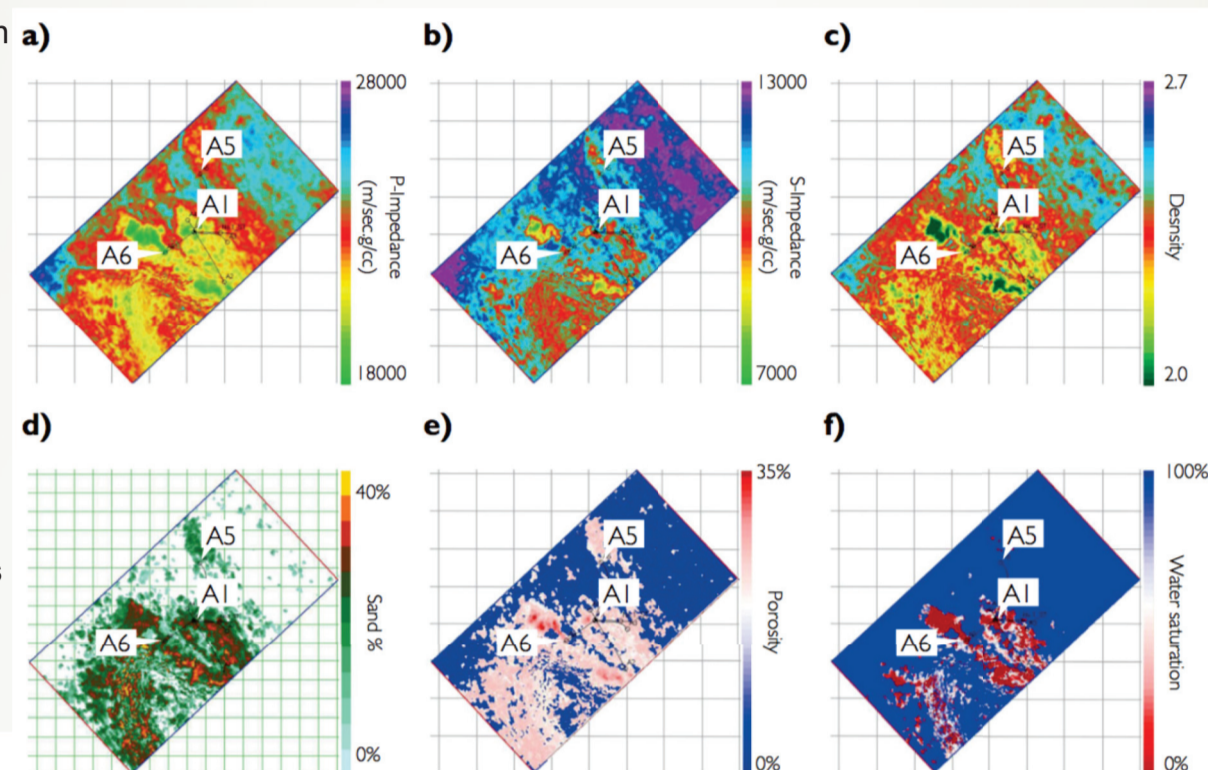


Fig.3. Simultaneous inversion products from Marlin Field, Gulf of Mexico; (a) P impedance, (b) S impedance, (c) density, (d) N/G based on inverted density, (e) porosity based on inverted P impedance, (f) saturation based on inverted density (after Russell et al., 2006).

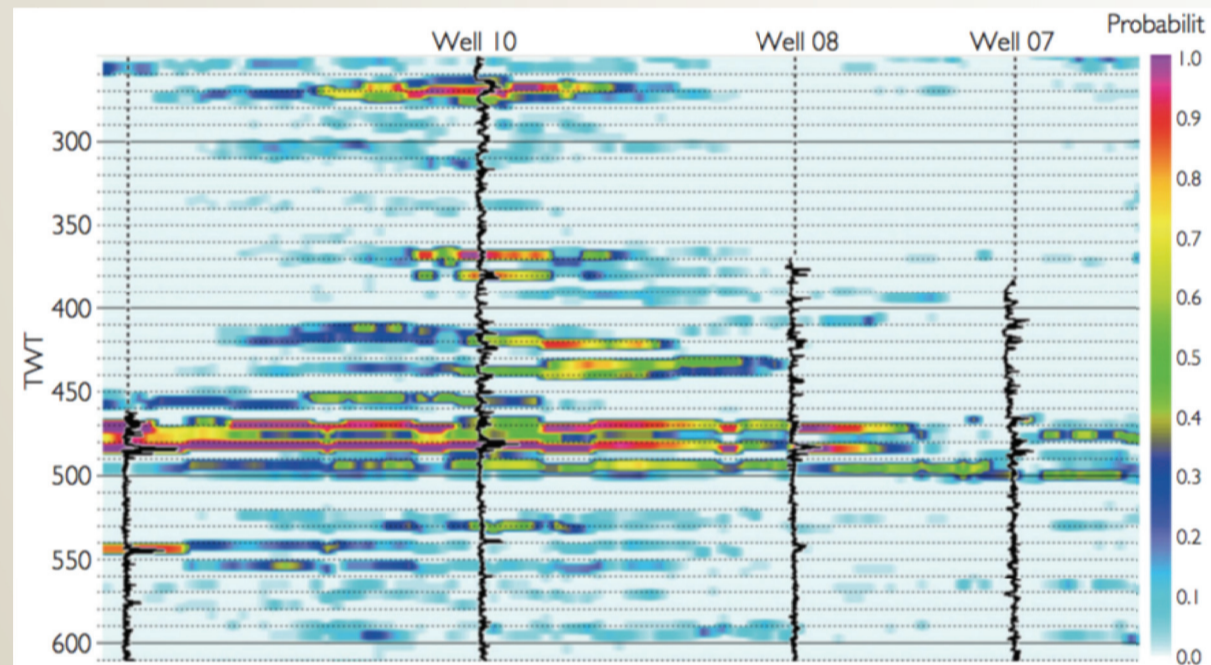


Fig.5. The probability of sand occurrence based on 50 stochastic results (after Francis, 2002).

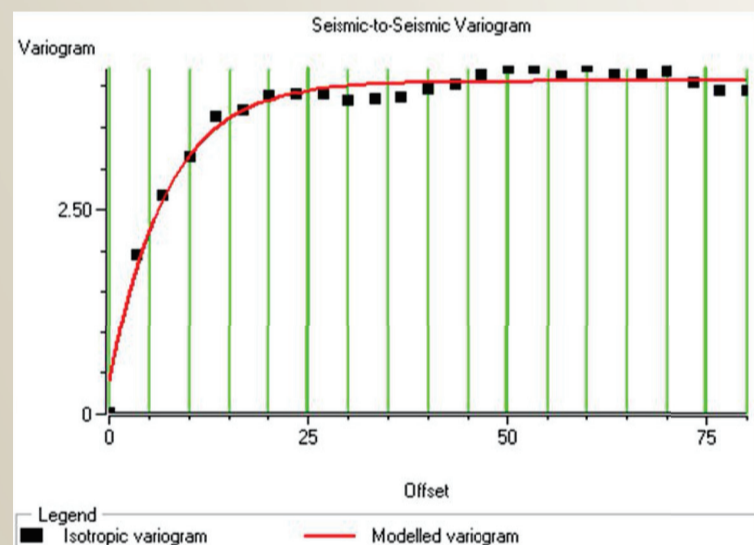


Fig.6. Seismic variogram used in the final cokriging process. Note that this is an exponential lift.

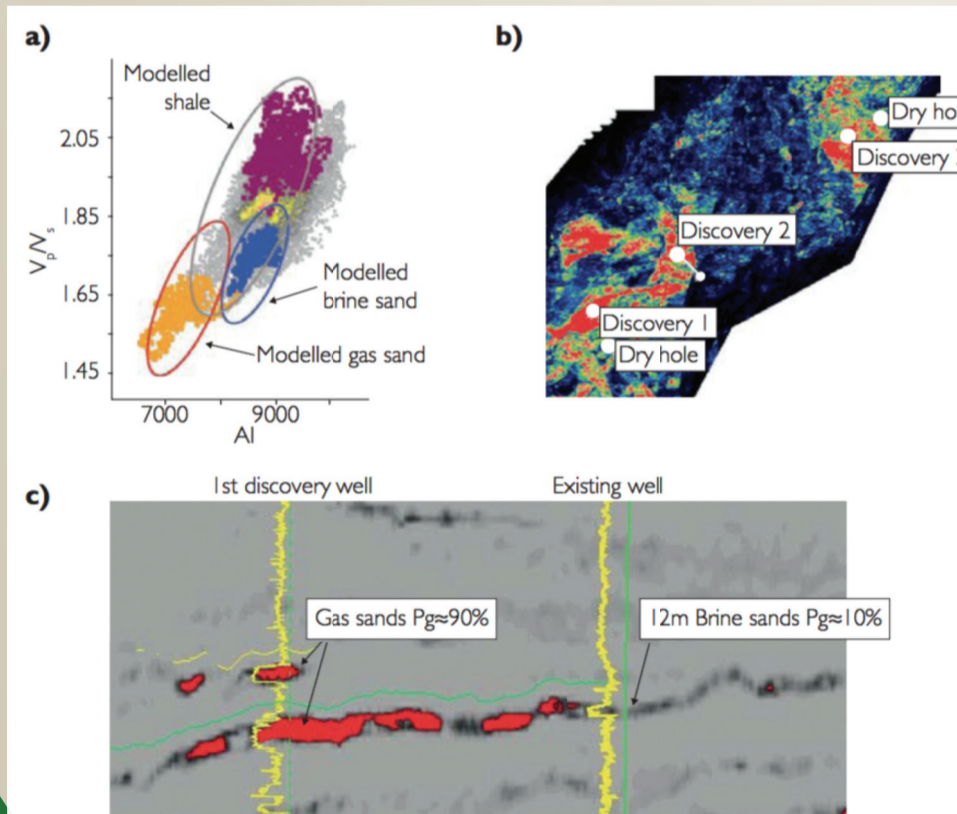


Fig.7. Results from a Bayesian classification approach applied to deterministic inversion results; (a) rock model, (b) map showing probability of gas sands occurring (high probability 1/4 red) and (c) seismic section showing the location of a discovery well down dip from a well with water sands and based on the probability prediction (after Lamont et al., 2008).

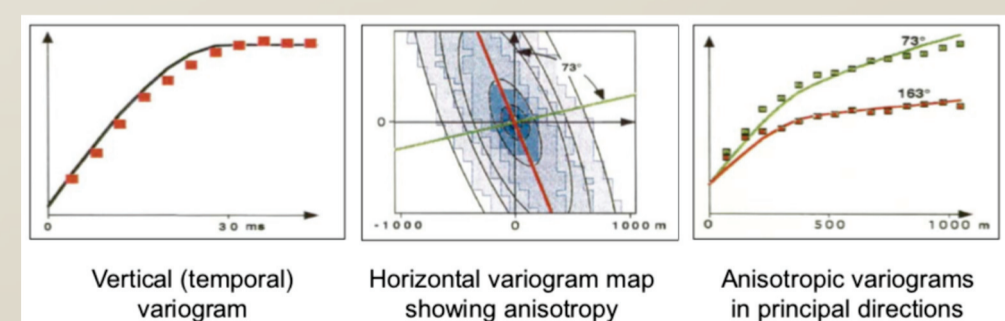


Fig.8. Variograms showing the vertical, or temporal change, and the horizontal change including anisotropy (after Haas and Dubrule, 1994).

Conclusions

The main purpose of using inversion is to convert the seismic section in order to more accurately represent the properties of the Earth's subsurface. Often in exploration areas we have data of high uncertainty due to the lack of drilled wells so we have to rely completely on seismic reflection data.

Stochastic inversion is a natural extension of deterministic inversion and it can provide additional information, such as:

- Lithology probability (Figure 5)
- Facies distribution
- Volumetrics
- Petrophysical parameters.

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