PSCombining 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-convelving 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 cokringing, 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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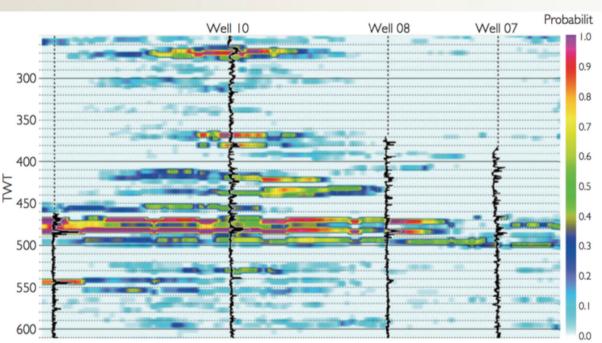
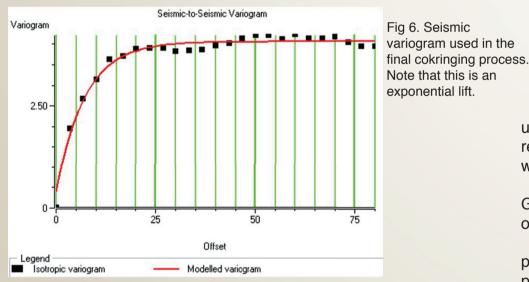


Fig.5. The probability of sand occurrence based on 50 stochastic results (after Francis, 2002).



2.05

Modelled shale

Discovery 3

Discovery 2

Modelled brine sand

Discovery 1

Dry hole

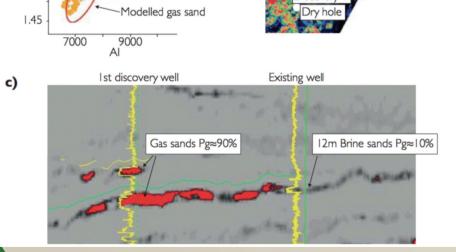
Discovery 1

Dry hole

Dry hole

Discovery 1

Dry hole



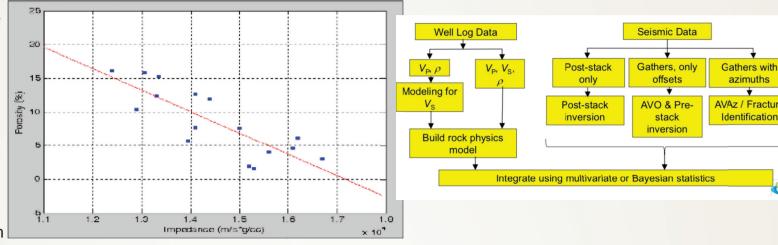


Fig.1. The regression line is the least-squares fit between porosity and impedance.

Fig 2. Suggested workflow (after Russell)

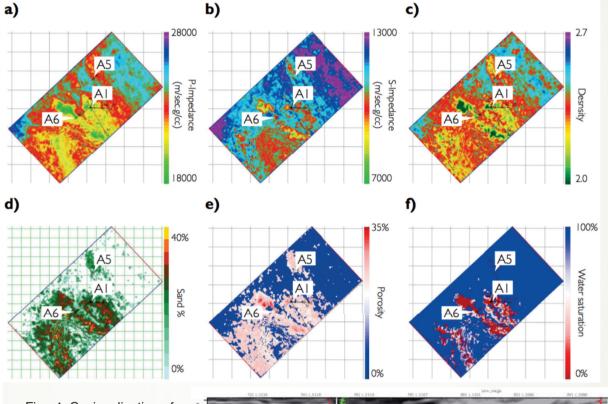
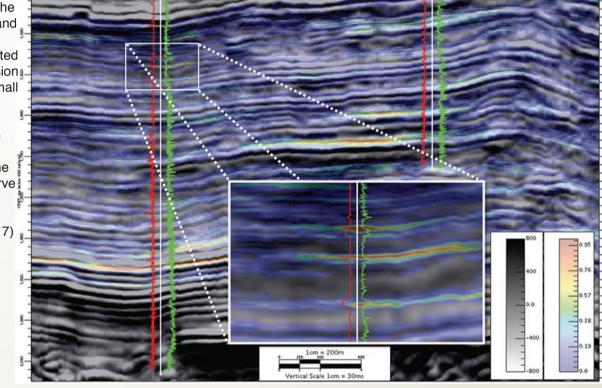


Fig.3. Simultaneous inversion products from Marlin Field, Gulf of Mexico; (a) P impedance, (b) S impedance, (c) density, (d) N:G based on inverted density, (e) porosity based on inverted P impedance, (f) saturation based on inverted density (after Russell et al., 2006).

Fig. 4. Covisualization of equivalent sections from the AVTHF volume (in grey) and the probability of pay (reservoir) volume computed using geostatistical inversion in color. The zoom of a small section seen in the foreground exhibits the correlation detail between the covisualized data and the two well log curves, the spontaneous potential curve in red and the resistivity curve in green (after Luis Vernengo and others, 2017)



Stochastic inversion (or geostatistical inversion) is the technique of simulating possible rock property models using the seismic. This has many technical advantages for use in reservoir modeling and uncertainty analysis: it removes tuning effects, it models the uncertainty and it can be computed at fine scale, but these advantages must be weighed against its higher cost and the large data quantities that must be managed.

Geostatistics differs from statistics in that it recognizes that only certain outcomes are geologically plausible. Geostatistical inversion integrates data from many sources and creates models that have greater resolution than the original seismic, match known geological patterns, and can be used for risk assessment and reduction.

Seismic, well logs and other input data are each represented as a probability density function (PDF), which provides a geostatistical description based on histograms and variograms. Together these define the chances of a particular value at a particular location, and the expected geological scale and composition throughout the modeled

Unlike conventional inversion and geomodeling algorithms, geostatistical inversion takes a one-step approach, solving for impedance and discrete property types or lithofacies at the same time. Taking this approach speeds the process and improves accuracy.

Histograms and variograms are generated for each stratigraphic layer and lithology, and preliminary simulations are run on small areas. The AVA geostatistical inversion is then run to generate the desired number of realizations, which match all the input data. The results are quality controlled by direct comparison of the inverted rock property volumes against the well logs. Further QC involves review by a multidisciplinary team of all input parameters and the results of the simulation.

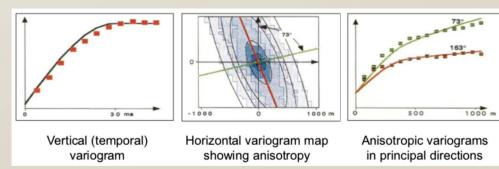


Fig. 7. Results from a Bayesian classification approach applied to deterministic inversion results; (a) rock model, (b) map showing probability of gas sands occurring (high probability 1/4 red) and (c) seismic section showing the location of a discovery well downdip from a well with water sands and based 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 Dubrulle, 1994).

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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:

- i) Lithology probability (Figure 5)
 - ii) Facies distribution
 - iii) Volumretrics
 - iv) Petrophysical parameters.