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New Technique for Rock Physics Prediction Based on the Seismic Interpretation

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SUMMARY

This work presents an innovative method to predict rock properties within the seismic volume. The propagation of well log data is guided by a relative geological time model, resulting from a global seismic interpretation. Whereas most of the classical techniques are based on the propagation of the data along a few selected horizons with a vertical interpolation, the method proposes a global propagation directly inside the RGT model to reduce uncertainties in the prediction of the rock property. Among all the existing geostatistical methods, we have used inverse distance, kriging and cokriging for the interpolation. Since a volume is composed by various geologies characterized by the variability of the seismic facies, the parameters of the propagation have to be adjusted for each defined stratigraphic interval. Applied on a North Sea case study in the K05 area, this technique has shown successful results, where spatial and vertical heterogeneities of complex faulted deposits could be enhanced in the reservoir level. The method appears to be particularly efficient in strongly faulted areas where the interpretation is difficult. It can be used to generate velocity or synthetic model or, to some extent, the a priori model for the seismic inversion process.

Introduction

The rocks properties analysis is a significant part of the seismic interpretation process. Different methods are widely used, mainly based on the interpolation of well log values along horizons. However predicting rock physics within a seismic volume is a more challenging process. A simple way is to perform a vertical interpolation between horizons but in such a case lots of assumptions have to be done by the geophysicist. Stochastic and deterministic inversions are more accurate techniques but they are time consuming and require a strong level of expertise. In this work, an innovative direct approach is presented to propagate log information using the stratigraphic patterns in the seismic space with different interpolation methods.

Methodology

The volume populated with the well logs values is obtained from a Relative Geological Time (RGT) model (Pauget *et al*., 2009). The RGT model (Figure 1b) comes from a global seismic (Figure 1a) interpretation process. During the first step, horizons are automatically tracked within the entire seismic volume to constrain a grid and a relative geological time is computed for each point. The seismic interpreter then checks the auto-picked horizons and refines them locally inside the grid until an optimum solution is obtained. The method has already been tested on various case studies (Gupta *et al*., 2008; Lemaire *et al*., 2010; Beller *et al*., 2012; Vidalie *et al*., 2012; Schmidt *et al*., 2013). Applied to rock physics, the propagation of log values is performed on each isotime of the RGT model (Figure 1c). Depending on the distribution of the wells and the propagation method, it allows to compute and predict rock properties with different levels of confidence.

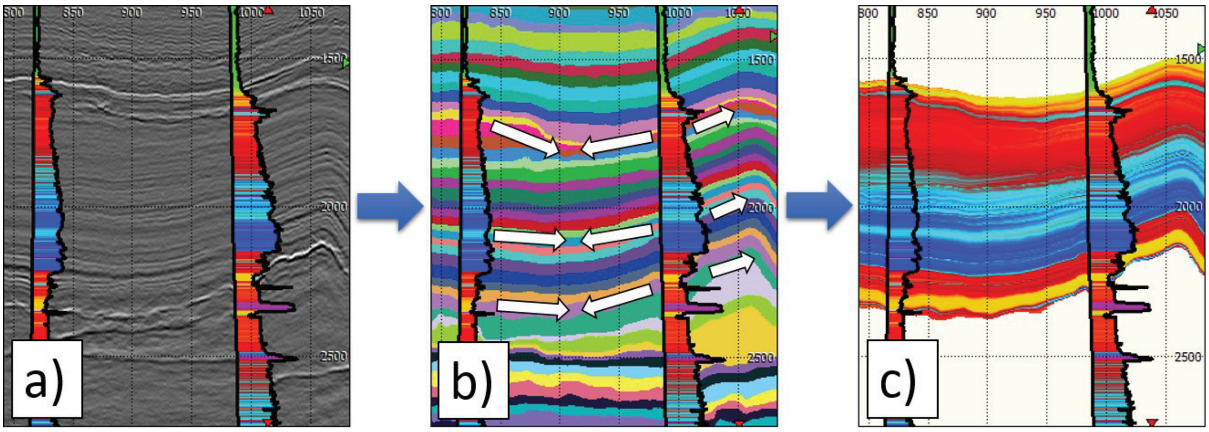

Figure 1 *Propagation of well logs data guided by the RGT model. a) Acoustic impedance logs displayed on the seismic amplitudes volume. b) The corresponding RGT model. c) Resulting acoustic impedance volume.*

According to the lithology, stratigraphic and structural features, different interpolation parameters have to be defined. In particular, geostatistical methods require a variography of the rock property, which can be totally different from a layer to another. For this reason we propose to define different parameters for several stratigraphic intervals controlled by the RGT model.

Propagation Methods

Among the various interpolation methods, three of them have been applied to test the effectiveness of this rock physics propagation: inverse distance, kriging and cokriging.

Inverse distance is the simplest interpolation method (Figure 2). It provides a basic interpolation using the power as single parameter to weight the influence of the logs as described in the following formula:

$$u(x) = \frac{\sum_{i=0}^{n} w_i(x) u_i}{\sum_{i=0}^{n} w_i(x)} \qquad w_i(x) = \frac{1}{d(x, x_i)^p}$$

Where *u(x)* is the property value of the current horizon at point x, u_i one of the n known data and $w_i(x)$ the inverse distance interpolation weight.

To better control the influence of logs in the model, the kriging is a more suitable method. It takes into account the amplitude of the logs values and their spatial distribution to obtain the variability of the property also called variogram. The obtaining of the optimum variogram is a two-step workflow: an empirical one is first computed from the logs values and is then fitted with a variogram model by adjusting a set of parameters. Following this model, a simple or ordinary kriging (Figure 2) system (Isaaks and Strivastava, 1989; Wackernagel, 1993) is established to get the interpolation weights. The property is finally performed using the below formulas:

$$u_{SK}(x) = m + \sum_{i=1}^{n} \lambda_i(x)(u_i - m) \qquad u_{OK}(x) = \sum_{i=1}^{n} \lambda_i(x)\, u_i$$

Where $u_{SK}(x)$ is the simple kringing interpolation at point x and $u_{OK}(x)$ is the ordinary kriging one. m is the average of the well log values along the corresponding horizon and $\lambda_i(x)$ the kriging weights computed from the variogram model.

Univariate interpolation methods are suitable only if the required property is available over a large number of points, otherwise the interpolation cannot be reliable. If a secondary property linearly linked to the main one is well-known, the cokriging technique (Figure 2) proposes a more accurate interpolation. In such a case the most efficient additional input for cokriging is a volume of property, like seismic amplitude or any attribute which permits to minimize uncertainties of the propagation. The impact of this second property can be adjusted using the correlation as single parameter, as described in the below formula:

$$\frac{u_{CK}(x) - m_u}{\sigma_u} = \sum_{i=1}^{n} \lambda_i(x) \frac{(u_i - m_u)}{\sigma_u} + \alpha \frac{(v_x - m_v)}{\sigma_v}$$

Where $u_{CK}(x)$ is the collocated cokriging interpolation (Xu *et al.*, 1992) at point x, v_x the auxiliary property at point x, m_u the well logs average of the main property, m_v the average of the auxiliary property, $\lambda_i(x)$ and α the cokriging weights respectively associated to the main and the auxiliary property.

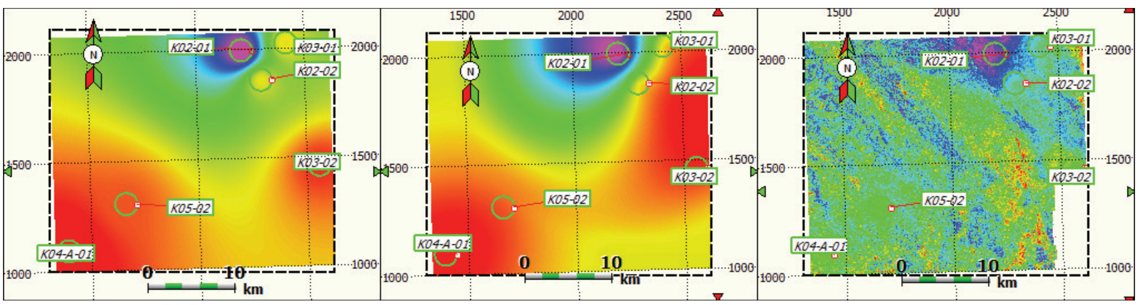

***Figure 2** Result of the propagation of 6 logs,* K03-01, K02-02, K02-01, K05-02, K04-A-01 and K03-02, *along a horizon for inverse distance interpolation (left), kriging interpolation (middle) and cokriging interpolation using seismic amplitudes (right).*

Application to a North Sea Oil Field

To assess the potential of the rock properties modeling method steered by RGT model, it has been applied on a complex area, located in the K05 block in the southern part of the North Sea (Daynac *et al*., 2014). From a geological stand point, the zone is characterized by five main stratigraphic levels from late Carboniferous to Tertiary. The reservoir zone below the salt presents strongly faulted Paleozoic deposits, which contain Early Permian reservoir rocks (Slochteren formation), hence its interpretation is a challenging step. In order to better characterize these subsalt deposits, a RGT model has first been computed based on an accurate seismic interpretation. To evaluate the acoustic impedance distribution, a cokriging method was applied using six acoustic impedance logs and the seismic amplitudes as auxiliary property (Figure 3).

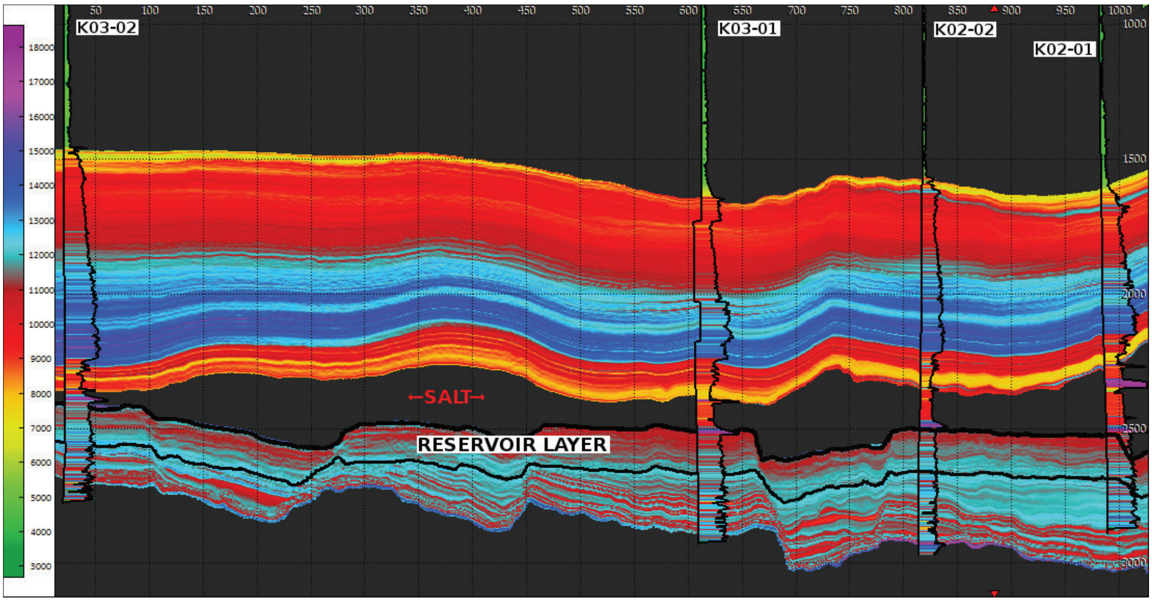

Figure 3 *Result of collocated cokriging propagation with the corresponding AI logs,* K03-01, K02-02, K02-01, K05-02, K04-A-01 and K03-02, *in the different lithostratigraphic units of the volume, the salt layer was intentionally ignored.*

A variographic analysis was performed on several intervals in order to define the optimum parameters for each stratigraphic level. In the faulted reservoir level, it enhances vertical and spatial heterogeneities, unseen by a simple well correlation on the top and base of the reservoir, at a seismic sample resolution. In spite of the complex fault system present in the area, the results performed by the cokriging interpolation appear to be consistent with the geology and bring more insights to better characterize the reservoir zone.

Conclusions

This work presents an innovative and adaptive method to populate rock properties within a seismic volume. This technique uses a relative geological time model in order to guide the interpolation of well log data within certain stratigraphic intervals. Kriging and cokriging techniques appear to be the most adapted solutions to supervise such a process. Although it requires more computation time, the cokriging with an auxiliary property, such as seismic amplitudes, improves drastically the lateral accuracy of the propagation. Applied to a North Sea dataset, this method has shown consistent results particularly in complex faulted deposits of the reservoir level, where seismic interpretation and reservoir characterization are difficult. These methods could also be applied to generate velocity or synthetic model or, to some extent, the a priori model for the seismic inversion process.

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