Calibration of a 3D PSTM Velocity Cube: Applied Workflow and Results Discussion.

Bourges Matthieu[1], Deraisme Jacques[1], Derksen Richard[2], Reutemann Markus[2]
(1) Geovariances, Avon, France
(2) RAG Rohöl-Aufsuchungs Aktiengesellschaft, Vienna, Austria

Introduction

A velocity calibration has been performed using a 3D PSTM velocity cube and 600 well time/depth curves. The purpose was twofold: to perform the quality control of the data and measure the added value of the seismic data integration to obtain a velocity model. This model was then used to convert 3D seismic to "depth" in order to better identify smaller structures not visible in the time domain. Therefore two velocity models have been obtained; one using only the wells information, the other integrating the seismic velocity. These two velocity models have then been checked and compared. The velocity models show rather large misties at wells. This is mainly explained by the filtering during the interpolation of a small scale variability component that has been interpreted as artefacts. Finally, several perspectives that may help to reduce the misties are discussed.

Multivariate geostatistical interpolation methods

In order to integrate the seismic information to the wells data during the estimation process, a geostatistical method as collocated cokriging can be used (Chilès and Delfiner, 1999).

As for any geostatistical interpolation, the collocated cokriging is based on a linear combination of data values:

$$\square_{\square}^{\square *} = \sum \square_{\square}^{\square} \square_{\square}^{\square} + \sum \square_{\square}^{\square} \square_{\square}^{\square} + \square_{\square}^{\square} \square_{\square}^{\square}$$

Where the main variable $\square^{\square}$ at the target point denoted "□" is estimated from a linear combination of the neighbouring data information concerning both variables and using respectively the weights $\square_{\square}$ and $\square_{\square}$. An extra value is added, corresponding to the value of the secondary seismic variable at the target location $\square_{\square}^{\square}$. To estimate the main variable, the kriging weights are computed from a cokriging system using the variogram information.

Applied workflow

Firstly a data quality control has been first performed both on the seismic and the wells data which were sampled at 20 msec. A variographic analysis has been performed on the seismic data to look for possible high frequency components that may need to be removed. In that case, the seismic velocity presents a continuous behavior without high frequency component.
On the wells data, the average velocity/time profiles and the correlation crossplots average velocity/PSTM velocity have been quality checked. The velocity/time profiles should show an increase of average velocity in time and the correlation between average velocity and seismic PSTM velocity must be high enough to ensure an integration of the seismic information. Consequently around 6% of the wells have been discarded during the data analysis due to an anomalous behaviour of the velocity in time (see Figure 1 left) or a low correlation (see Figure 1 right).

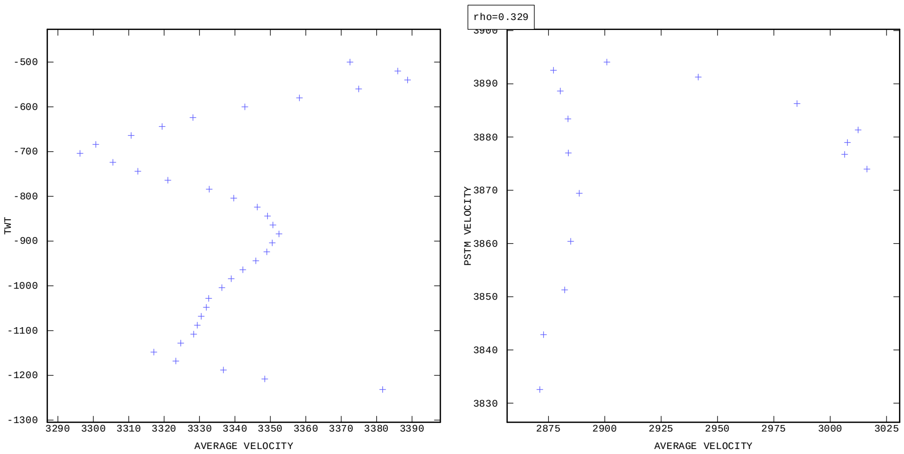

Figure 1: Cross plots on 2 different wells: profile of average velocity decreasing in time (left), low correlation between average velocity and PSTM velocity (right).

During the variographic analysis at wells, a small scale variability component has been detected on the variogram of average velocity (see Figure 2). It has been interpreted as artefacts.

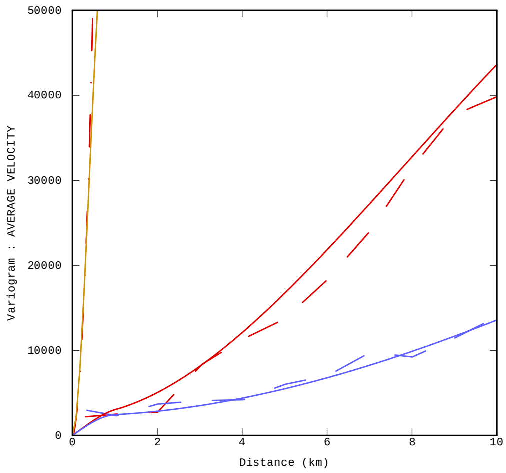

Figure 2: Experimental (dotted points) and modeled variograms of average velocity.

Two interpolations of velocity models have been carried out with the small scale variability component being filtered out. This filtering removes unrealistic features during the interpolation process (see Figure 3):

- Kriging of average velocity using only the wells.
- Collocated cokriging of average velocity integrating the seismic information.

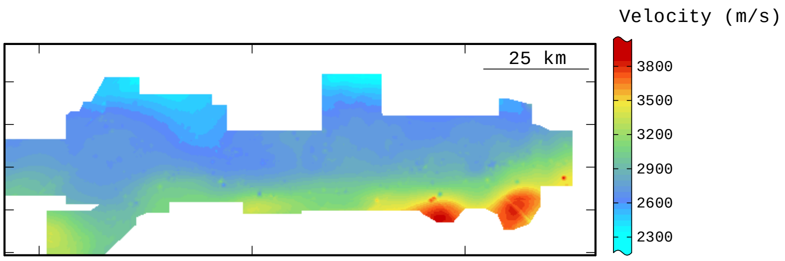

Figure 3: Time slice of the velocity model integrating the seismic PSTM velocity without geostatistical filtering. Unrealistic interpolated features are seen especially in the south east part.

An analysis has been carried out on the two velocity models. The velocity model integrating the seismic shows a better behaviour between the wells than the one using the wells due to the seismic constraint (see Figure 4). However, both models present rather large misties at well locations (see Figure 5).

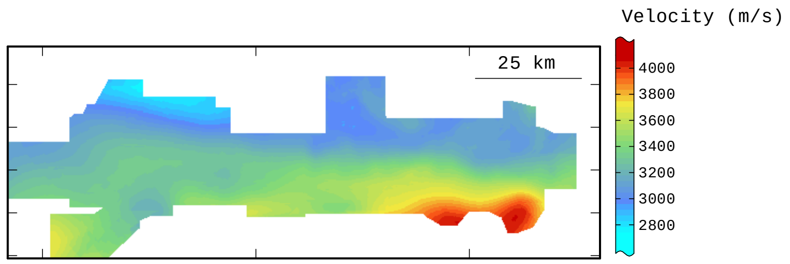

Figure 4: Time slice of the velocity model obtained by collocated cokriging integrating the seismic PSTM velocity.

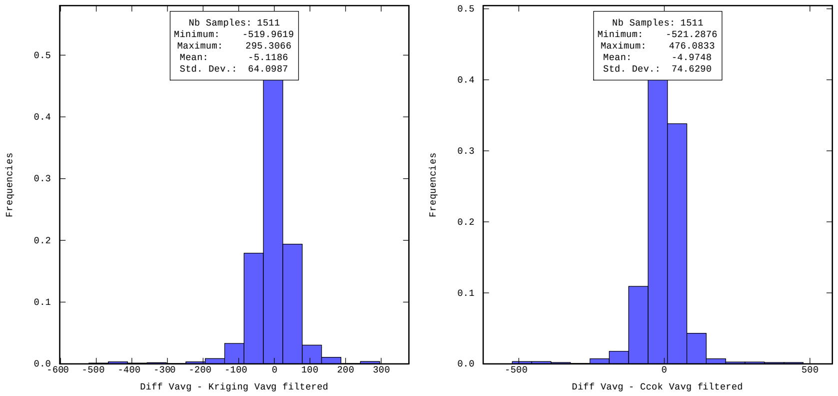

Figure 5: Histograms of misties at wells: Average velocity – Kriging of average velocity (left), Average velocity- Collocated cokriging of average velocity (right).

The misties at wells are mainly due to the filtering of the small scale variability component during the interpolation process. This small scale variability may have different origins: acquisition artefacts, data errors or integration of data from different layers. As several wells showed some anomalies, it seemed logical to assume that the well velocities were subject to some uncertainty. As a consequence, by filtering this small scale variability, we obtain a smooth 3D velocity model which honours the well data in average but has local misties with the actual velocity values. The small scale component accounted for around 3% of the total variability and may reach 100 m/s at an average velocity of 3000 m/s. This translated into potential depth “errors” that require further analysis. To tackle this issue, several perspectives are discussed hereafter.

1/Interpolation along the main horizons

Experimental variograms have been computed in real X, Y and Z space; therefore, the horizontal variogram may integrate samples belonging to different layers, due to their potential dipping. Mixing up samples from different layers, combined with sampling along the time axis can obviously increase the small scale variability. To illustrate that, a 2D N0^{o}-N90^{o} variogram of average velocity has been first computed horizontally at a particular time corresponding approximately to the average time of a reservoir horizon, then a similar 2D variogram has been calculated at the time interpreted for that reservoir horizon, following the dipping of the horizon. Along the horizon, the computed 2D variogram is rather continuous and only shows a limited small scale variability component. However, the variogram computed along the time slice, shows much more (see Figure 6). It seems to validate a more homogeneous behavior of the velocities along this horizon. Therefore one solution may be to interpolate velocities and perform the depth conversion independently along each key reservoir horizon.

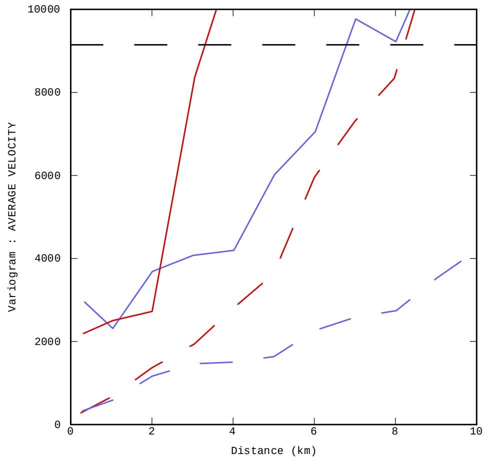

Figure 6: 2D experimental variograms of average velocity at wells (N0°: red, N90°: blue) for small distances. Computed horizontally at a time corresponding to the average horizon time (line) and along the horizon (dotted points).

2/Use of local parameters

In the reservoir, the structural heterogeneities depend of the location in the space (dipping horizons, anisotropies …). This has a direct influence to the reservoir attributes (velocities, depth and time variables). One option is to optimize locally the anisotropies in order to honour the structural information. This can be done through the use of local parameters (as azimuth, dip) for the variogram and the neighborhood during the interpolation process (Magneron and Jeannée, 2009). Such method can be applied on a whole 3D cube.

3/Flattening

An intermediate approach, to work with the full 3D cube, is to perform a preliminary flattening using a key horizon as reference and then to work within this stratigraphic space. This could be successful in the case of a simple layer-cake system, but probably more difficult in presence of salt domes or other structural complexities.

Conclusion:

The velocity calibration included cleaning the data from wells with anomalous behaviors. Artefacts which may have different origins have been detected on the data. Therefore a geostatistical filtering has been performed during the interpolations of the velocity models in order to avoid unrealistic features. The analysis of the obtained velocity models highlights a better consistency between the wells for the model integrating the seismic information. Both velocity models show rather large misties at wells, mainly explained by the artefacts' filtering. To help reducing these misties, several perspectives have been discussed.

Acknowledgement

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References

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Magneron C., N. Jeannée (2009), Noise reduction by M-factorial kriging, In *Proceedings of the IAMG 2009 Congress*, Stanford, August 2009.