Velocity Models Building (Geological and Tomographic Process Updates Emphasis)

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Abstract

Introduction

During seismic depth migration processes it is very common to observe a high discrepancy among used interval velocities and seismic response/ seismic facies, structural domains, etc.

Seismic migration technics or algorithms, especially depth migration have strongly improved in performance in the last years. It is more notable when using RTM (*Reverse Time-Migration*) technics. Beyond that, we are facing also high evolution in terms of anisotropy.

Despite the evolution of these two considered aspects together (migration and anisotropy), a good initial velocity model is mandatory in order to obtain a final velocity model for the best seismic image. The tomographic process complement all the previous considerations in order to obtain this better seismic image, regarding also depth position and seismic amplitude quality.

The standard way to build a velocity model for depth migration is based on an initial velocity field, using well information and previous RMS or PSDM velocities to perform tomographic inversion in order to get best alignment over CRP (*Common Reflection Points*) groups.

Besides, more advanced seismic technics as FWI (*Full WaveForm Inversion*), intending at least to update velocity model, also require a good initial interval velocity model, or a geologic velocity model.

All the described considerations show the importance of combining a good and geological initial velocity model with the best available migration technics, as well as anisotropic concepts and tomography updates to build a realistic seismic image, especially for structural complex areas.

As per Vigh & Starr, 2008 the RTM application success is susceptible to the resolution observed in the velocity model during the migration process. These authors indicate the FWI methodology has the potential to generate this high-resolution velocity model for the RTM migration. However, Vigh *et al.*, 2009 indicated the main challenge to use the FWI technics is to produce (or reproduce) a good velocity model to be used to forecast seismic data with geological confidence regarding the subsurface geology where it has been acquired.

In this paper we presented an interval velocity model built using geological model tools, all the available information such as previous seismic migration, previous velocity analysis and migration velocity, interpreted horizons and faults, log information, etc.

We also illustrated how to accomplish seismic facies and velocity honoring the existing geologic behavior. From this new model, we suggest a new tomographic process to generate another migration with less computational effort to align CRP´s gathers.

Method

The methodology here proposed is divided in two parts: the first one explains how the geological velocity model was built and the second one presents how this new geological velocity model could be incorporated in seismic processing during the velocity update: using tomography and evaluating the gathers alignment.

The first part could be considered as an adaptation of the methodology developed by Maul *et al.*, 2016 (2005), trying to represent more geological aspects in velocity models. The initial assumption assumes the interval velocity should reflect the structures portrayed by the interpreted horizons and faults in the study area.

Pombo *et al.*, 2015 already presented enhancements in terms of velocity modeling when considering part of this methodology for illumination studies in a complex area. This is similar to the analysis performed by Maul *et al.*, 2015 e Jardim *et al.*, 2015.

Therefore, to build the geological velocity model was necessary to take the following inputs: seismic image, migration velocity and velocity analysis from the previous processing, interpreted horizons and faults, and well log information.

The second part of this approach starts using the previous result (the geological velocity model) as an input to establish through tomographic updating, the best velocity values, now following the existing geology to align reflection and the analysis of CRP gathers as a quality control tool.

This gathers analysis approach could be considered the same performed by Gobatto *et al.*, 2016, which evaluate the effect of including stratifications inside salt section on gathers alignments, in other words, considering the geological aspects.

Examples and Applications

As described below, the first step of the proposed methodology consists in building a 3D geological model to fill it with interval velocity as described in Maul *et al.*, 2016). This model must reflect all the structural and stratigraphic complexity in the studied area, using interpreted horizons and faults (figure 1).

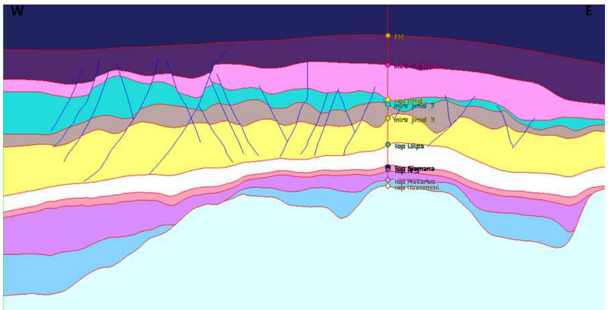

***Figure 1**: Structural geologic complexity to be imposed to velocity model, emphasizing the necessity of the geologic behavior.*

In this case, we proposed a geologic grid instead a regular one (figure 2) to simulate the interval velocity information from seismic and wells. The advantage of using such frame is that the geostatistical method will work following the internal layering that reflects the stratigraphy and honoring the fault throws as well.

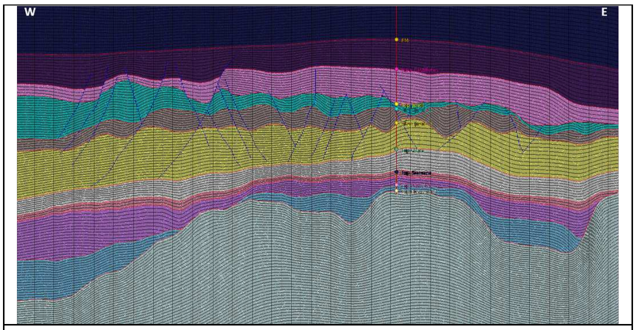

***Figure 2:** Simulation grid (structural/stratigraphic) to be used for interval velocity filling in order to honor the geology obtained from intepretation in previous seismic migrations.*

Having as an assumption this velocity model should represent the existing complex geology in the studied area, it is important to compare the previous data (seismic velocities and amplitude response) with the generated one (using the proposed methodology).

Through the figure 3, it is possible to compare these "old" and "new" models in terms of coupling of the structural and interval velocity models. In figure 3a, the tomography effect of trying to represent the existing geology using mathematics (in figure 3a there is no geology influence as in figure 3b).

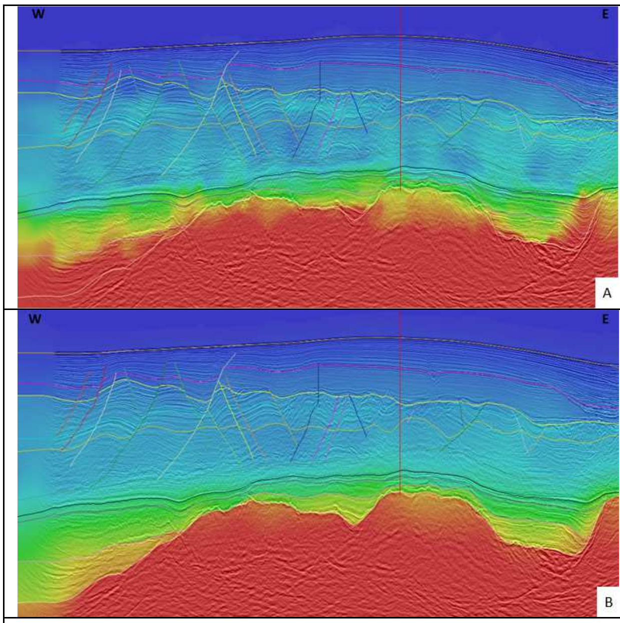

***Figure 3**: Seimic amplitude overlayed by interval velocity: (A) original velocy from the previous processing and (B) modeled velocity following the geology. Note the best coupling between interval velocity and seismic facies in model "B" not presented in model "A".*

As described before, the second step of this methodology suggests the usage of this modeled interval velocity following geology criteria as input for tomographic process, using gather panels to show good alignments without many iteration efforts as observed by Gobatto *et al.*, 2016.

As expected, the tomographic update is always needed in order to get the gathers alignment for both models. It seems evident when comparing the gathers panels using both models (original and modeled), the necessity to increase or decrease the velocity in order to get better flattening of the reflectors. Figure 4 presents the obtained results from migration using the two available models with the corresponding gather panels allowing all the possible comparisons.

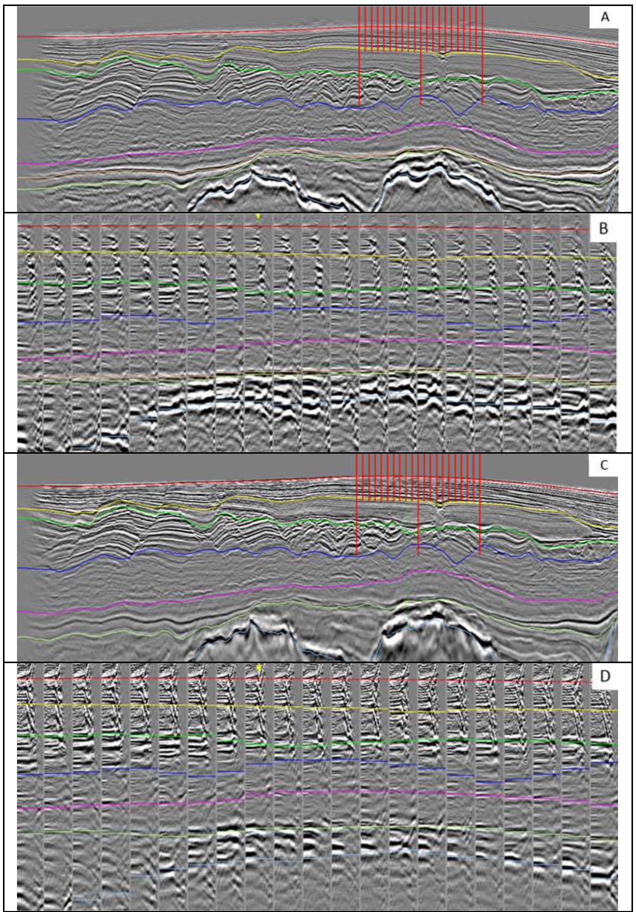

Figure 4: *(A) Seismic image using the original interval velocity model and the tomograpy effort to obtaint it; (B) Details of gathers panels obatined during the tomographic process using the original velocity; C) Seimic image using the modeled interval velocity and the tomograpy effort to obtaint it; (D) Details of gathers panels obtained during the tomographic process using the modeled interval velocity.*

The obtained velocity models used for the migration process after the tomography updates, applied over the original interval velocity and over the geological interval velocity model are presented in figure 5.

The initial purpose of the methodology was a better match between structure and velocity once the velocity is following the interpreted geology (horizons and faults). However, in both updated velocity models, the observed anomalies would be related to fault proximity, seismic facies variation, etc.

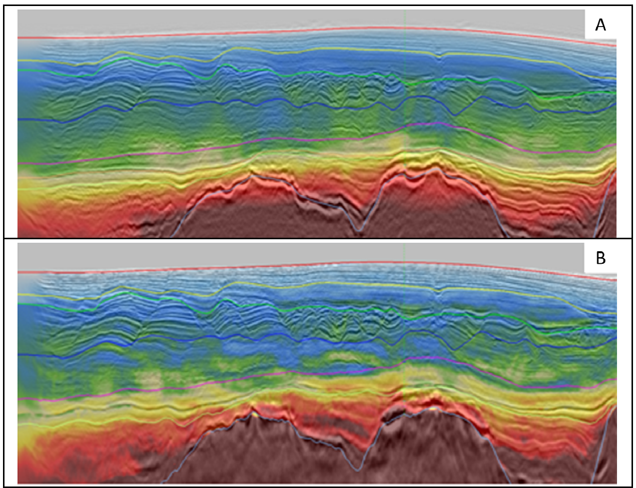

Figure 5: *(A) Tomographic update over the original interval velocity; (B) Tomographic update over the modeled geologic velocity. Variations in velocity are following the structure*

Conclusions

Building velocity models honoring as much as possible the existing geology in complex areas can be considered as a key point for seismic processing and reprocessing.

When using technics such RTM and FWI seems to be mandatory to have a more geological velocity model in the beginning of the process as well as considering the increase in terms of resolution, and the presented work shows this two aspects: geology confidence and resolution.

The update performed over the model generated using the proposed methodology would correct the velocity following the interpreted geology and not only honoring the mathematical aspects.

In addition, due to the more reliable geological model in terms of velocity, the anisotropy analysis and application would be more confident when applied in models like the presented here.

The methodology to build geological velocity models have been used for several purposes such as: illumination studies, seismic inversion, seismic amplitude quality, depth positioning, geomechanical analysis and recently as input for reprocessing (Gobatto *et al.*, 2016). Therefore, is reasonable to believe the methodology is just beginning and we have a lot of evolution to work in the next years.

Regarding the referred test-project, the updated tomographic results are considered as tremendous over any model used (original interval velocity and modeled geological velocity). However, the computational effort needed when performing the tomographic update was lower when using the geological velocity model. Another model (a third one) was built using the classical layercake methodology and it was also necessary to perform the tomography in the same level.

We believe the velocity variation in the studied area would be influenced by fluid presence once main updates in terms of velocity was needed to decrease it.

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