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3D Regional Velocity Modeling - North Sea

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Summary

Regional velocity models are used mainly for time-to-depth conversion. At regional scales, where few horizons are available, the accuracy and consistency of the velocity models relies on the integration of seismic velocities which bring additional information in terms of lateral and vertical heterogeneities. Such heterogeneities can only be preserved with a fully 3D geostatistical approach. Besides, the use of a structurally driven merge and calibration process leads to consistent 3D regional velocity models. Finally, the combination of advanced geostatistical techniques coupled with geophysical and geological expertise allows to obtain realistic and accurate depth conversion products.

Introduction

Regional velocity models are used for a wide range of applications from regional interpretation and depth conversion workflows to new prospects and play generation. At local scales they can be used as velocity guides for seismic processing and as an input for seismic inversion or time-to-depth conversion.

At regional scales, the accuracy and consistency of the velocity models relies on the integration of seismic velocities. Indeed, the seismic velocities are a continuous measurement of the subsurface and they bring additional information in terms of lateral and vertical heterogeneities. Such heterogeneities can only be preserved with a fully 3D geostatistical approach. The integration of different seismic velocity datasets (different acquisition and processing dates, different structural content, etc.) is one of the biggest challenges since it is paramount in the preservation of the resolution of the seismic velocities.

3D Regional Velocity Modeling

An original fully 3D approach based on advanced geostatistical tools is presented. It is based on 3 sequential steps:

- geostatistical QC of the seismic velocity datasets
- 3D merge of the qualified seismic velocity datasets
- 3D calibration to the wells

The use of local geostatistical models (Magneron and Petit 2007) at each step allows to take into account variations in anisotropies and sizes of structures, common at regional scales. During the first step, acquisition and processing artefacts are filtered out with M-GS filtering technique (no post-smoothing procedure is applied, resolution is preserved). In the second step, seismic velocity datasets are merged together with a 3D factorial kriging technique and in the third step, the merge velocity volume is calibrated to the wells with a 3D kriging with external drift technique (KED).

Input data consists of:

- 3D and 2D velocity datasets (PSTM, PSDM)
- well time-depth functions (checkshots, sonics), well tops
- regional horizons

Interpretations are filtered and used during the modeling process as a regional structural guide. A consistent 3D velocity model is built. If interpretations are updated with time, the velocity model remains valid and usable.

Case studies (North Sea)

The 3D velocity modeling approach presented here has been applied on various projects over the world (Australia, Norway, UK, Netherlands, etc.). The presentation will focus on two case studies in the North Sea.

A regional velocity model has been built and updated over the entire Norwegian North Sea. The input data consists of the open data available in the DISKOS database (see Figure 1). More than two hundred seismic velocity datasets and nearly one thousand wells have been used for this project. A methodological overview and the final results are presented. For this kind of regional velocity models where density of input data is highly variable, the uncertainty estimation is essential. The use of geostatistical simulations allows the quantification of the uncertainty for each node of the velocity model volume.

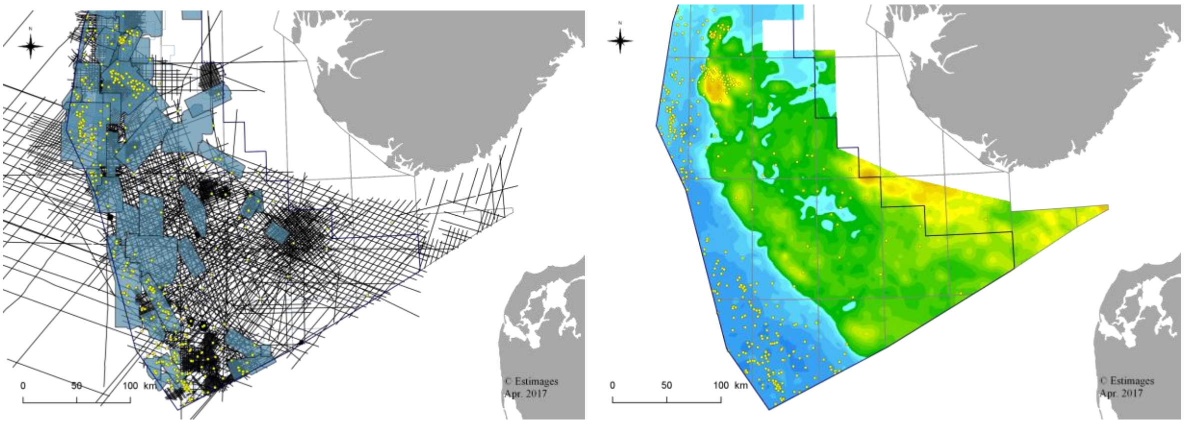

Figure 1 *Regional Velocity Model – Southern Norwegian North Sea (basemap and time-slice at 2sTWT)*

Through a partnership with TNO in the Netherlands, we have associated our expertise with the geological knowledge and the extended database of our partner to create the most value out of the available data. VELMOD-4 is a new generation of regional velocity models in the Netherlands. Historically, the regional velocity model VELMOD has been developed for depth conversion purposes, using velocity data recorded in boreholes (sonic logs, well-shoots…) for the whole Netherlands area. The 'layer cake' approach has been applied for all lithostratigraphic units, with the exception of the Zechstein Group (Van Dalfsen et al. 2006). Each new version of VELMOD (from VELMOD-1 to VELMOD-3) includes various changes, such as an increase in data density, a switch from analogue to digital data and more detail in some lithostratigraphic units. VELMOD-4 is the first 3D regional velocity model covering both onshore and offshore Netherlands integrating seismic velocity data.

Conclusion

The use of a fully 3D velocity modeling approach integrating seismic velocity data and allowing a structurally driven calibration process is a powerful alternative to the conventional 'layer cake' approach for example. It enables the construction of 3D consistent velocity models. Through the different regional velocity projects achieved or launched over the world in the last few years, it has been proven that advanced geostatistical techniques coupled with geophysical and geological expertise lead to the production of realistic and accurate regional velocity models.

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