North West Shelf 3D Velocity Modeling

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SUMMARY

The NWS is a major Oil&Gas area in Australia where regional velocity models exist for all the basins located in the province. Using an innovative 3D approach, a model covering the entire NWS has been built and is presented in this paper. The major challenge of the project was to honour as much as possible the resolution of the geological features and to ensure a global consistency of the model in a non-stationary environment at such a wide scale. Another one has been to work with more than 200 surveys and nearly 900 wells as input. The Estimage's 3D approach associated with advanced geostatistical techniques allowed us to build a geologically consistent model with a depth uncertainty far from the wells below +/-100m (at more than 100km from the wells).

Key words: Velocity Model, NWS, Geostatistics

INTRODUCTION

The North West Shelf (NWS), located in north Western Australia, is a world class gas province with minor oily sweet spots and thus is a high interest area for the E&P industry. Regional velocity models are more and more used for exploring the NWS province, however, most of those models are built at a basin wide scale. A model at an ultra-regional scale which covers the entire shelf should honour not only the local geological structures but also the regional ones. It is a significant challenge.

After building with success regional velocity models for most of the NWS basins by using an innovative 3D approach (3D regional velocity modeling, Magneron, 2014), it has been decided to use the same approach to build an ultra-regional velocity model over the entire NWS province. Building such an extended model (800 000km² - 12sTWT depth) with an acceptable quality level is only possible by integrating seismic velocity data on top of well data and regional interpretation surfaces (horizons). The proposed approach is adapted to do it in a proper way at an ultra-regional scale involving hundreds of seismic velocity data sets and wells. It is composed of three sequential steps:

- qualification of the seismic velocity data sets
- 3D merge of the qualified seismic velocity data sets
- 3D calibration to the wells

The use of advanced geostatistical tools is required at each step in order to get a final velocity model with the best resolution and spatial coherency as possible. In particular local geostatistical models (M-GS technology, Magneron, 2008) are very useful at this ultra-regional scale over which the structural content varies a lot, and present strong variations of anisotropies and sizes of structures.

METHOD AND RESULTS

TRUE 3D VELOCITY MODELING FOR TIME TO DEPTH CONVERSION

Seismic velocities are most of the time integrated by the industry into time-to-depth conversion workflows. They contribute to improve the quality of the velocity model as they bring some additional information about 3D velocity heterogeneities. Layer cake based approaches are not suited for a proper integration of the seismic velocities. Especially at a basin scale where few horizons are generally available. As these approaches work in 2D, layer by layer, heterogeneities coming from the seismic velocity volumes can be easily lost during the modeling process. Only true 3D velocity modeling approaches can fully valorize the seismic velocity information and thus deliver better velocity models for time-to-depth conversion.

ESTIMAGES has developed and uses an innovative 3D velocity modeling solution which has been applied with success in various operational contexts. At prospect scales as well at regional scales, offshore and onshore. Used at a regional scale (basin wide models) in an offshore context the solution leads to velocity models with an uncertainty starting from ~10m close to the wells and going up to ~100m very far from the wells (more than 100km). That uncertainty range has been observed on 5 basins in Australia and 3 basins in Norway. It is even lower in the Browse basin: ~70m very far from the wells.

The 3D velocity modeling solution makes use of the following data if they are available:

- checkshots
- sonics
- top markers
- seismic horizons
- seismic velocity volumes and/or 2D velocity lines

For building a regional model, the global workflow is:

- qualification and conditioning of the seismic velocities in order to remove acquisition and processing artefacts
- 3D merge of the conditioned seismic velocity data sets
- 3D calibration of the merge seismic velocities to the wells

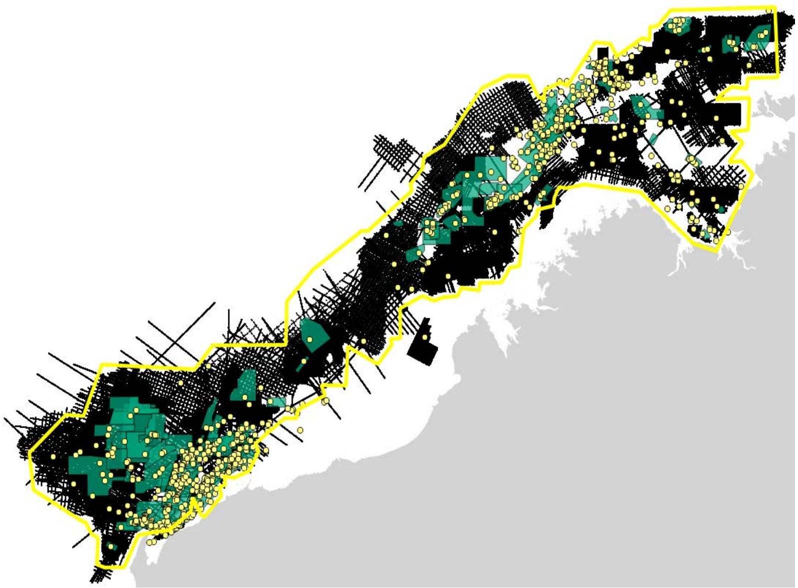
Advanced geostatistical techniques, in the form of M-GS techniques (M-GS technology, Magneron, 2008), are applied all along the processing sequence:

- factorial kriging is used for filtering out artefacts such as random noise, acquisition footprint and processing artefacts from the seismic velocities. Non stationary artefacts being handled by some non-stationary filtering parameters
- 3D merge is realized by factorial kriging technique with varying parameters. Note that no post-processing smoothing operation is required
- 3D kriging with external drift is used for calibrating the seismic velocities to the wells velocities

To get geologically consistent results, the two last steps are driven by the horizons. Finally the 3D velocity modeling sequence leads to a velocity model which is calibrated to the wells, consistent with the interpretation, and fed with some 3D heterogeneities coming from the seismic velocities.

NWS VELOCITY MODEL

The NWS province is a marginal rift with a break-up history which produced a complex spatial and temporal distribution of rift and post rift deposits, and which strongly control the efficiency and liquid hydrocarbon potential of the margin's petroleum systems (The North West Shelf of Australia - A Woodside Perspective, Longley, 2003). This area is also characterised by a dominance of gas which is due to the quality, and often the high maturity, of the source rocks within all identified hydrocarbon system. The NWS comprises 5 basins: Carnarvon, Roebuck, Offshore Canning, Browse and Bonaparte.



NWS data base map

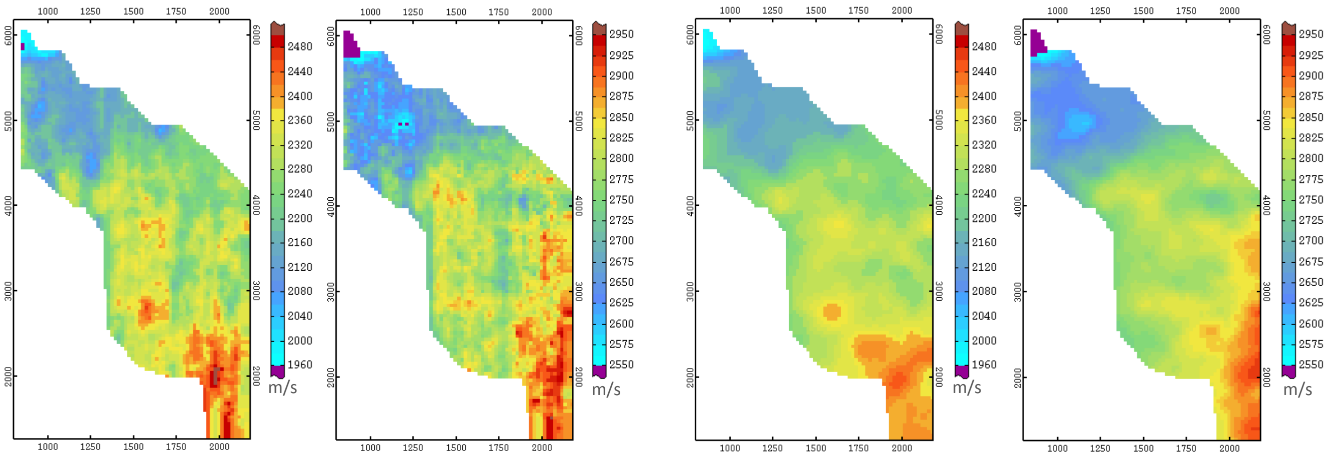
Figure 1

A first version of the NWS velocity model has been achieved in 2015. It has been obtained by using the 3D modeling approach described above. It covers the whole shelf exception made of the Canning offshore basin. Data available were:

- 108 3D seismic velocity data sets
- 130 2D velocity data sets
- 889 wells with time-depth functions
- 5 regional interpretation surfaces

The data coverage is quite good (Figure 1) but not homogeneous. Some areas are well covered by 3D seismic and wells while other are just covered by 2D seismic and few wells. The model covers a surface of 800 000km² (yellow polygon) and goes down to 12sTWT. The sampling is 2km x 2km x 80msTWT.

The first step of the modeling process was the qualification and the conditioning of the 238 seismic velocity data sets. Artefacts have been tracked and removed as it is illustrated for example for the Tiger 3D in the Bonaparte basin (Figure **2**).

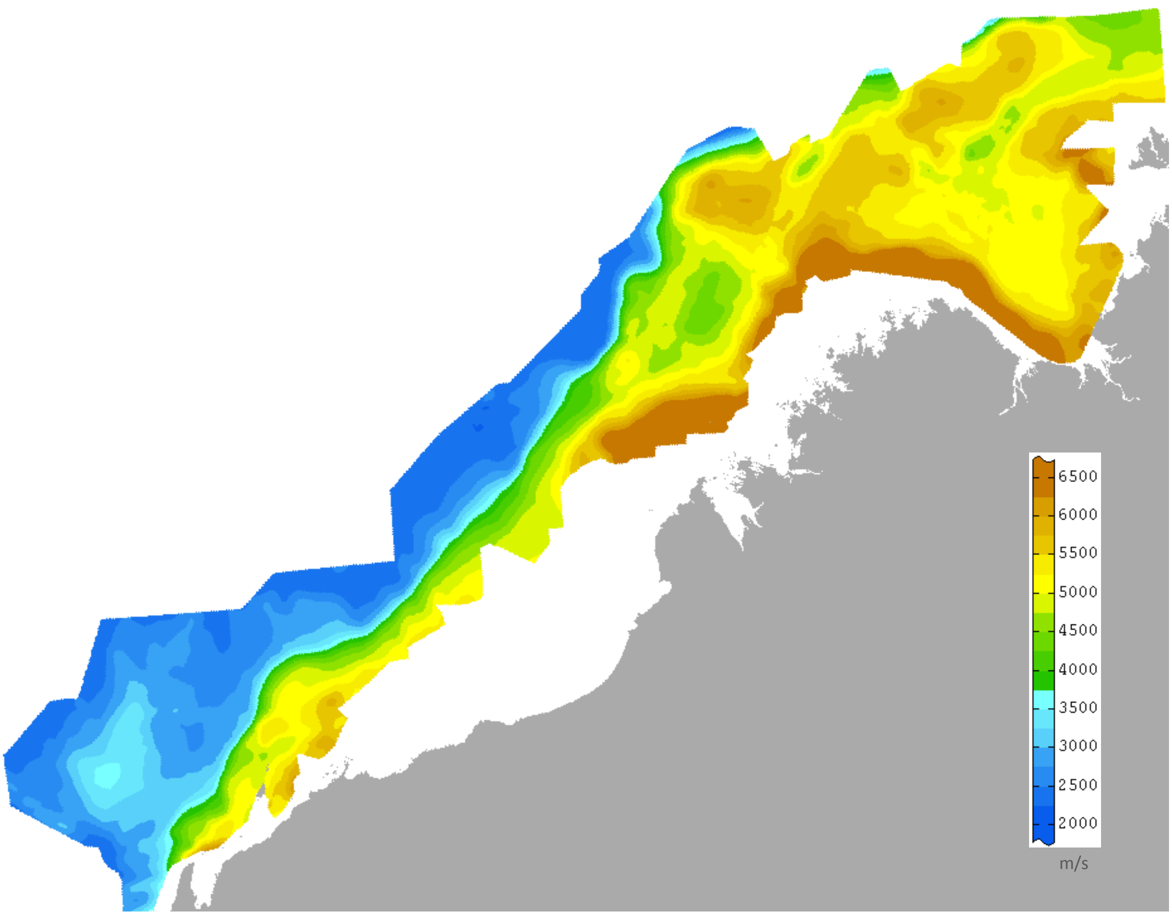


Raw velocities
Time-slices 800 and 1300msTWT

Filtered velocities
Time-slices 800 and 1300msTWT

Figure 2

The second step was the merge of the qualified seismic velocity data sets. Prior to the merge process itself, priority rules are usually defined in overlapping areas, for 3D data sets mainly. Considering the high number of data sets and hence overlapping areas to consider, it has been decided to define only one priority rule: 3D data sets prior 2D data sets. The velocity data sets have been merged by 3D non-stationary factorial kriging technique. That technique ensures a good spatial consistency of the merge velocity cube while preserving as much as possible lateral and vertical resolution. Attention was paid to take into account the regional basin structure by adapting the kriging operator spatially (M-GS approach). The depth version of the merge is displayed on Figure 3.

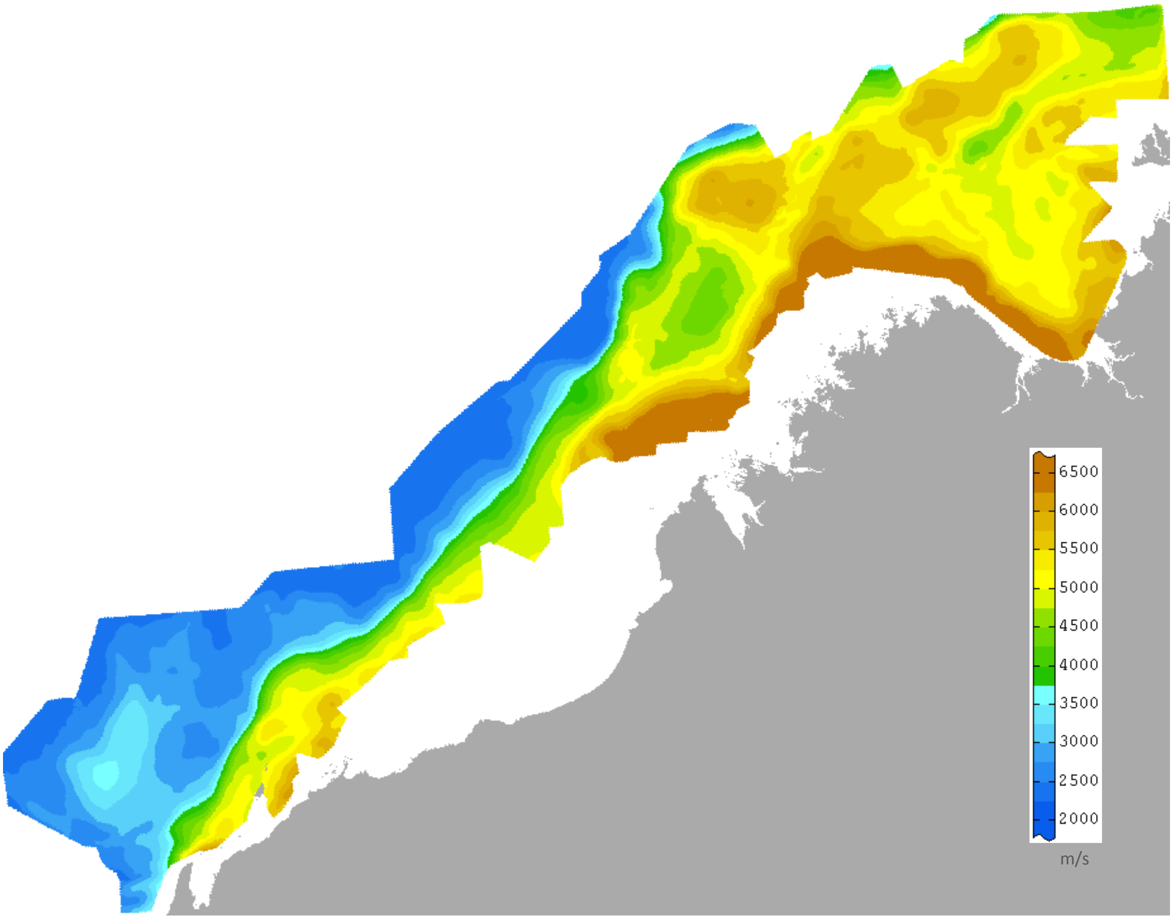


Merge – Depth at time-slice 3120msTWT

Figure 3

Please note that there are always some inconstancies between seismic velocity data sets in the deep area (below sea bed + 4sTWT) leading to unreliable results. As such, on top of above process, the deep area is also strengthened using interpolation of 2D regional lines. It has been the case for the NWS project.

The merge velocity cube is estimated from the seismic velocity data sets. The last step of the velocity modeling process is to calibrate it to the wells in order to get the final velocity model. For a regional calibration, a 3D local variographic analysis (M-GS approach) of the differences between the seismic and the well velocities is usually carried out. Considering the scale of this project, the variographic analysis had to be carried out at both regional (basin) and ultra-regional (NWS) scale. As geological structures vary from one basin to another the model had to be calibrated in a non-stationary environment. Where the basin variographic analysis led to the characterization of local variations of anisotropies and sizes of structures, the global variographic analysis enabled the determination of global structural parameters and a related estimation of the depth uncertainty far from the wells of ~100m. The merge velocity cube has been calibrated to the wells by using a 3D kriging with external drift technique leading to the NWS velocity model. The process being guided by the regional horizons. Results are illustrated on Figure 4.

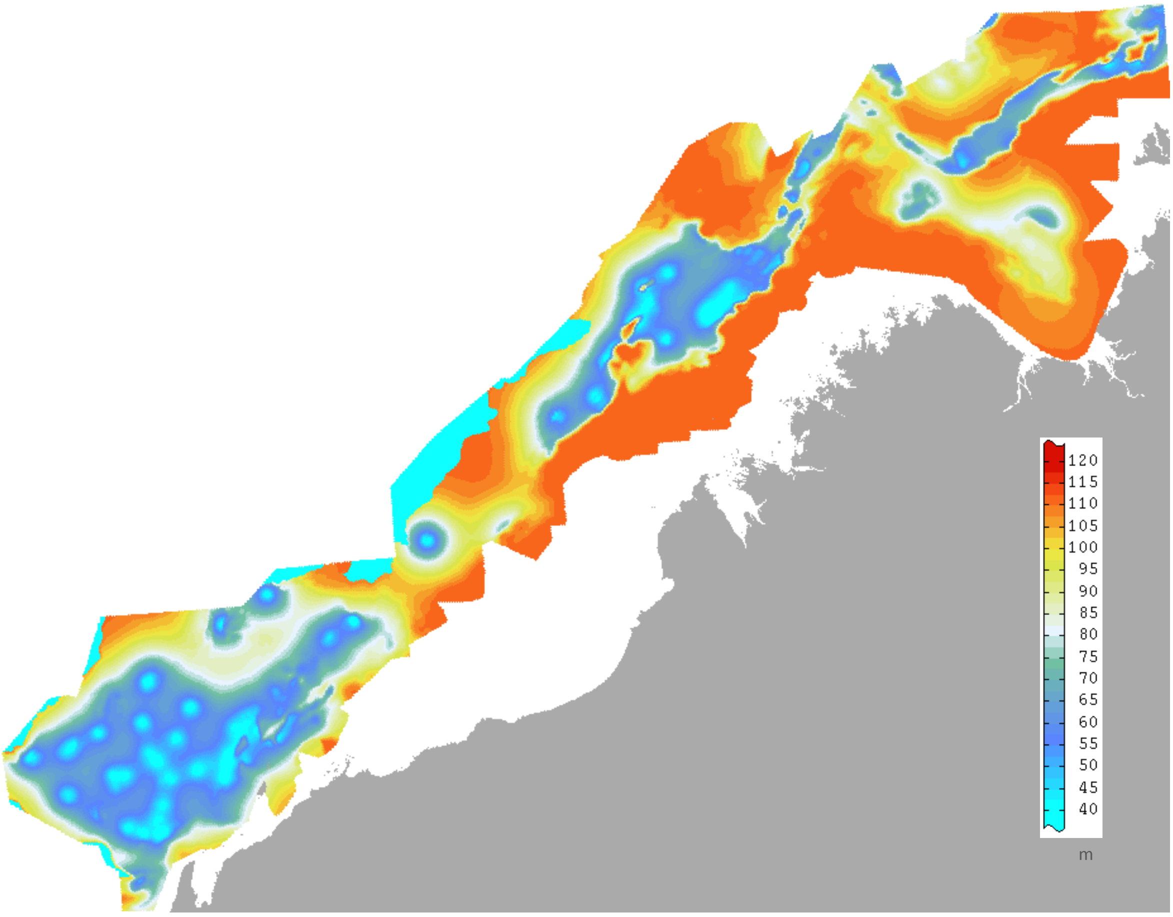


Calibration – Depth at time-slice 3120msTWT

Figure 4

Previous Estimages regional velocity models having been acknowledged by recognised Oil&Gas companies, a comparison with existing Estimages regional models has also been carried out to validate both the uncalibrated and calibrated velocity cubes. The comparison gave an average difference less than 50m except in the basins borders where the ultra-regional approach has improved the homogeneity from one basin to another.

An associated uncertainty cube, in the form of a depth error cube (2 x standard deviation), has been also generated by geostatistical simulations. It is illustrated on Figure 5.



Depth uncertainty at time-slice 3120msTWT

Figure 5

CONCLUSIONS

3D velocity modeling by using seismic velocity data and guided by the geological structure has been a proven technique at regional scale (basin wide) in the past and has now been tested at an ultra-regional scale over the entire NWS province. This larger scale has triggered new technical challenges with a major increase in the input data, and a wider non-stationary environment to take into account for the calibration. The fully 3D approach associated with the M-GS technology enabled to build a 3D consistent velocity models over an area of 800 000km². This new type of wide scaled velocity models gives a better picture at the basin boarders and ensures a better homogeneity of the model by taking into account large regional geological structuration.

ACKNOWLEDGMENTS

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