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Reflection-refraction Tomography and Complex Salt Structure - A Case Study from Offshore North Gabon

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Summary

elocity model building in basins with complex salt structure typically relies on a heavily interpretation-driven process. An industry-standard workflow would involve several rounds of top salt and base salt horizon interpretation, combined with several migrations to test the scenarios using different flood velocities. For very large surveys in areas with extensive salt bodies, the time and expense required for such an involved workflow can be prohibitive, particularly in the early stages of exploration. We show that an alternative approach relying on the careful application of refraction and reflection high resolution tomography can be used to resolve sufficient details in the velocity model to characterise the salt structure, allowing a more accurate interpretation with a reduced number of interpretation phases. This is illustrated using examples from offshore North Gabon, where the use of a data-driven approach to derive the starting point for an initial one-pass manual interpretation of the salt bodies was key to enabling the rapid turnaround of the model building. A traditional approach with multiple interpretation passes would have been impractical in the available time-frame, given the large area (approximately 5500 sq km) and multiple complex salt bodies.

Introduction

Velocity model building in basins with complex salt structure typically relies on a heavily interpretation driven process. An industry standard workflow would involve several rounds of top salt and base salt horizon interpretation, combined with several migrations to test the scenarios using different flood velocities. For very large surveys in areas with extensive salt bodies, the time and expense required for such an involved workflow can be prohibitive, particularly in the early stages of exploration. To improve efficiency, we combined high resolution refraction and reflection tomography, to resolve sufficient details in the velocity model to characterise the salt structure, and to allow a more confident interpretation with a reduced number of interpretation phases.

Salt velocity model building workflow

We describe the depth imaging exercises used for 5500 sq km of long offset 3D Multi-Client seismic, processed through a modern broadband sequence. This survey was acquired offshore North Gabon by Spectrum Geo Ltd. in 2017 over water depths of 15-1000m. The principal focus for the imaging was the sub-salt targets and the related hydrocarbon prospectivity. The large number of salt bodies, combined with a strict timeline, made an iterative salt-scenario driven workflow impractical.

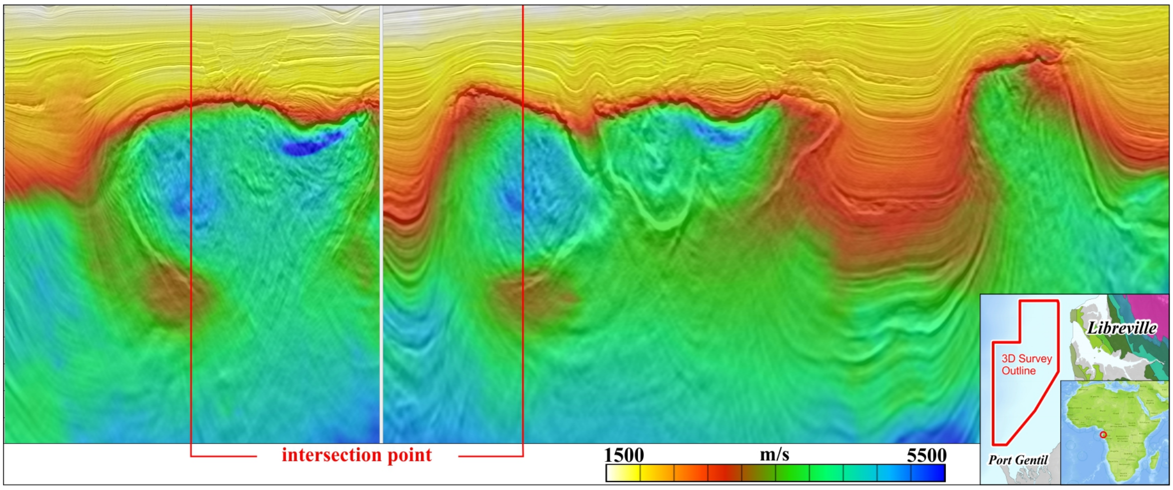

Figure 1 *Vertical interval velocity model after three iterations of tomography, overlaid on Kirchhoff preSDM stack. The robust tomographic algorithm detected the velocity inversion underneath the salt overhangs, whilst inserting plausible velocities within the salt bodies.*

We followed an alternative data driven workflow, relying directly on travel-time, ray-based tomography, using a combination of non-parametric residual move-out (RMO) and refraction based picks. High density picks, combined with structurally conformable smoothness constraints, correctly identified velocity inversions underneath the salt overhangs (Figure 1).

The updated velocity models and associated image gathers and stacks were compared to the available well data and regional velocity knowledge (Esestime et al, 2018) to validate the solution. After three tomographic updates, the interpreter was able to pick confidently both top and base of the allochthonous salt overhangs, then inserted in the velocity model as geobodies (Figures 2A and 2B). The key to the success of this simplified approach relied on a structure-aware regularisation scheme in the high-resolution tomography, preventing excessive smoothing across interfaces (including those with dip). It restricted the space of available models by adopting an algorithm from the image reconstruction and FWI communities - total variation regularisation. It promoted structural continuity in the absence of other information, while permitting abrupt changes when required, encouraging the tomography to generate contiguous regions of uniform model parameter updates, following the structure in the image, and with well-defined boundaries.

Structurally-oriented regularisation is applied in the construction of the total-variation constraint itself. It relies on the construction of a diffusion tensor field (Weickert, 1998). This spatially-varying field describes the orientation and strength of the smoothing at each point in the model. This enabled sharp lateral discontinuities to be positioned correctly, within the necessarily smoother taper zones used when applying the geobody-based editing to the model (Figure 2B).

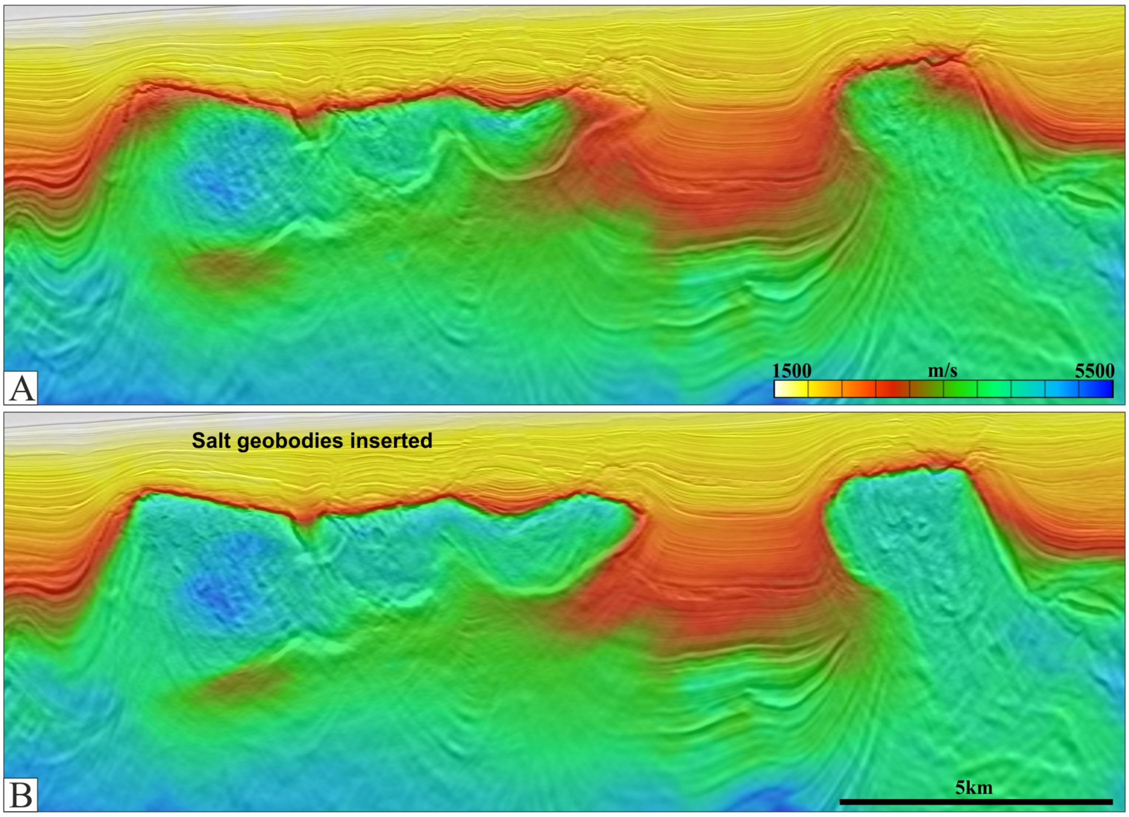

Figure 2 *A) Velocity model after three tomographic updates overlaid on TTI Kirchhoff pre-stack depth migration (preSDM) stack; B) The same seismic example after application of a minimum velocity within salt geobodies and subsequent tomographic update.*

Conclusions

The use of a data-driven approach to derive the starting point for an initial one-pass manual interpretation of the salt bodies was key to enabling the rapid turnaround of the model-building over this extremely large area with multiple complex salt bodies. A traditional approach with multiple interpretation passes and vertical velocity flooding would have been impractical within the available time frame. In the early stages of imaging for large exploration datasets in complex areas, the potential of modern high-resolution ray-based tomographic techniques to provide a suitable model in a short time should not be underestimated.

Acknowledgements

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References

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