The benefits of pre-stack wave equation depth migration for imaging in North west Europe

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Introduction

Pre-stack 3D wave equation depth migration has advantages over conventional Kirchhoff migration in being able to address multi-pathing issues. It is thus, fast becoming regular practice for the sub-salt imaging problems in the Gulf of Mexico. Other areas such as the complex deepwater Offshore Angola are also seeing the benefits. Soubaras (2002) implemented a no compromise explicit shot-record scheme which produces accurate artifact free angle gathers. We review the advantages and drawbacks of the different schemes available. Results from the use of this technique in the Gulf of Mexico show significant improvement for sub-salt areas. The benefits for imaging in the North Sea and adjacent areas are demonstrated with examples from mid-North Sea and North Germany.

Advantages of Wave Equation approach

Soubaras (2003) described the use of a shot-record migration based on the extrapolation design in Soubaras (1996). It is a L-∞ optimization of coefficients which weight recursive applications of a Laplacian operator to the data in the 3D case. This design guarantees that the extrapolation is correct in a (f-k_x-k_y) domain corresponding to propagations up to a given dip, and in a (k_x-k_y) domain corresponding to a given percentage of the spatial Nyquist bandwidth, irrespective of the velocity model. Typical values are 70 degrees and 70% Nyquist. Furthermore, it is possible to extract local angle information from the wavefield by computing a local harmonic decomposition of the incident and scattered fields, which in turn allows efficient computation of artefact-free angle gathers. These angle gathers allow both a quality analysis of the velocity-depth model and use for model update as well as post processing.

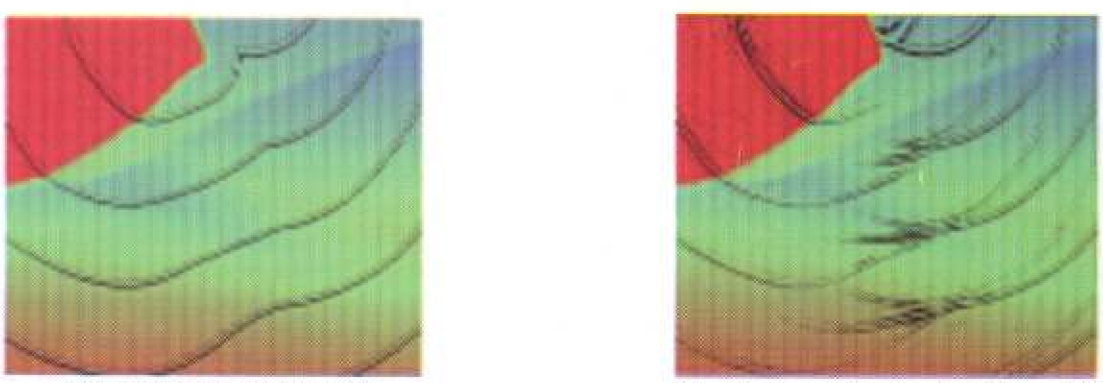
Multi-pathing sub-salt

The large velocity contrast between salt and sediment, coupled with the typically rugose contact, produces a complex wavefield. The assumptions made in normal Kirchhoff migration allow for a single wavefront type to be selected and thus, in areas of complexity, only part of the wavefield is imaged. The images (figure 1) illustrate this on modelled data at the edge of a high-velocity salt body surrounded by sediments with a typical Gulf of Mexico velocity gradient. The Kirchhoff approach, using only the most energetic arrivals, shows the progress of the wavefront as a continuous line. Wave equation depth migration uses a downward continuation approach to fully migrate the wavefield and resolve all multi-arrivals. The second image illustrates this well – demonstrating three different arrivals under the edge of the salt. The comparison images (figure 2) reveal the typical improvement seen in the final migrated data and emphasise the benefits for using WE PreSDM in the Gulf of Mexico.

Data Examples

The benefits outlined above can clearly be seen on this example (Figure 3) from the Green Canyon in the Gulf of Mexico. Salt, shallow in the section, produces complex raypaths which are correctly handled by the wave-equation migration to provide clearer images of the structures and faulting beneath the salt.

An onshore dataset from Northern Germany exhibits structural features typical of the southern North Sea. This study was targeting a play under the flanks of a significant salt structure with overhangs which produced tremendous



Kirchhoff- most energetic arrivals

Wave Equation - Migrating the full wavefield

Figure 1.

Kirchhoff- migration

Wave Equation Depth Migration

Figure 2

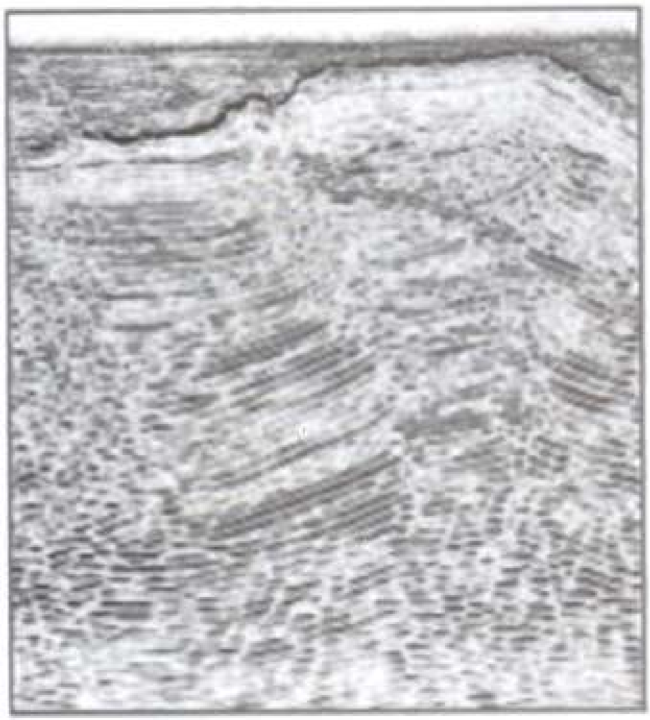


Figure 3: Example Green Canyon line with WE PreSDM demonstrates high quality sub-salt imaging

vertical and lateral velocity variations. The velocity-depth model was built using automated dense and continuous RMO picking, geostatistical processing and tomographic inversion for velocity layer update. Forward gravity modelling data was also available. However it was not possible to image across the sub-salt area with Kirchhoff methods due to multi-pathing (Figure 4). Using the Wave Equation pre-stack depth migration described above, the image quality was significantly improved and the base salt reflectors are now interpretable across the survey. Furthermore the output of angle gathers (Figure 5) has enabled analysis of the validity of the velocity model and post-processing to refine the image.

Mid-North Sea data, however, exhibits less significant structure and thus requires a less complex velocity-depth model. Normally one would expect the conventional Kirchhoff image to be sufficient. However the comparisons illustrate that there are resolution improvements to be gained from using the Wave Equation PreSDM. Both clarity and resolution of faults and events are improved and illustrated with comparison depth slices and sections (Figure 6).

Conclusion

We have presented a no compromise, explicit shot record, wave equation depth migration scheme which has a cost effective implementation and offers the advantage of angle gather output for velocity model analysis and post-processing. Application of this scheme to complex structures and sub-salt environments demonstrates clear benefits where multi-pathing can be expected The salt structures typically encountered in the southern North Sea/North West Europe have similar characteristics and show improved imaging with the wave equation migration. Interestingly in less complex areas where multi-pathing is not expected and one would expect Kirchhoff to produce a suitable image, we still see improved quality and resolution from the wave equation. Thus, Wave Equation depth migration is applicable to the region and offers the potential to image previously unseen areas.

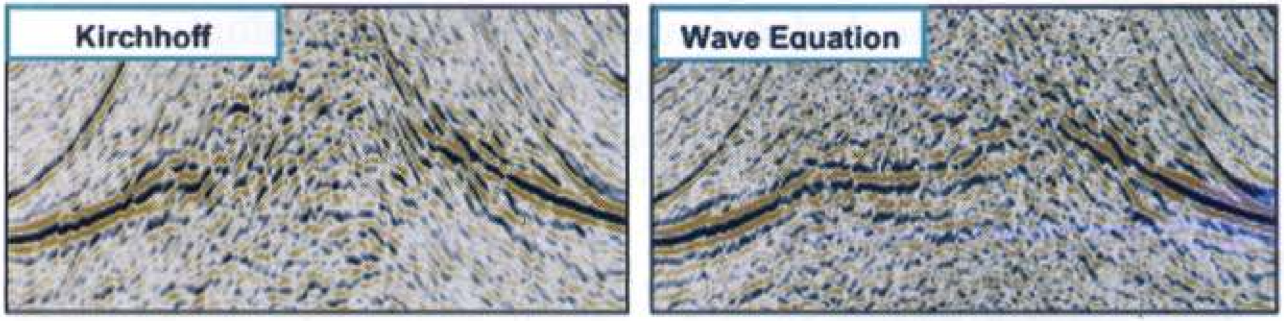


Figure 4: Onshore North German dataset exhibits improved base-salt imaging with wave-equation migration

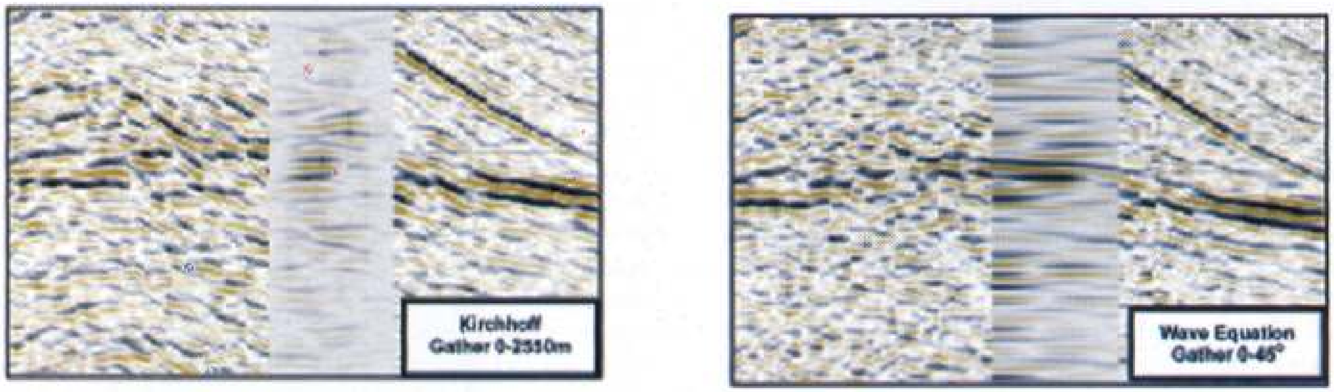


Figure 5: Comparison of final image and gathers on base-salt reflectorsComparison of final image and gathers on base-salt reflectors

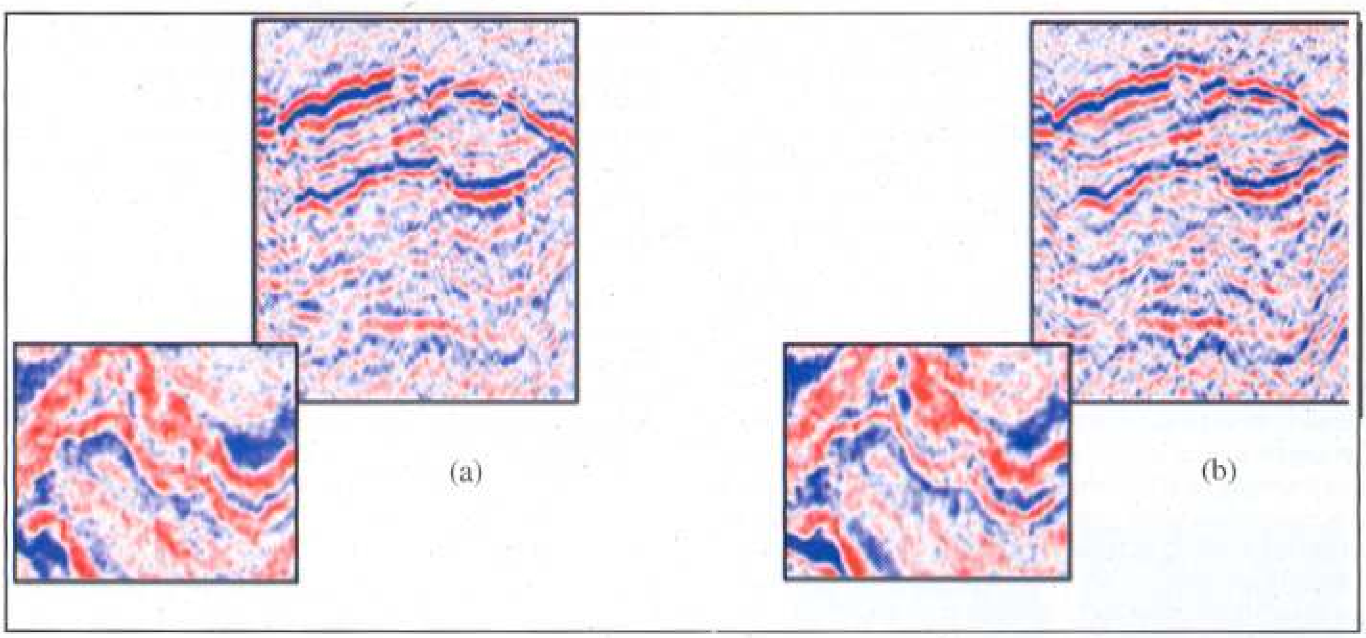


Figure 6: (a) Krichoff migration of North Sea dataset displaying section and depth slice. (b) Wave equation migration comparison showing improved resolution of events and faults

Acknowledgements

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References

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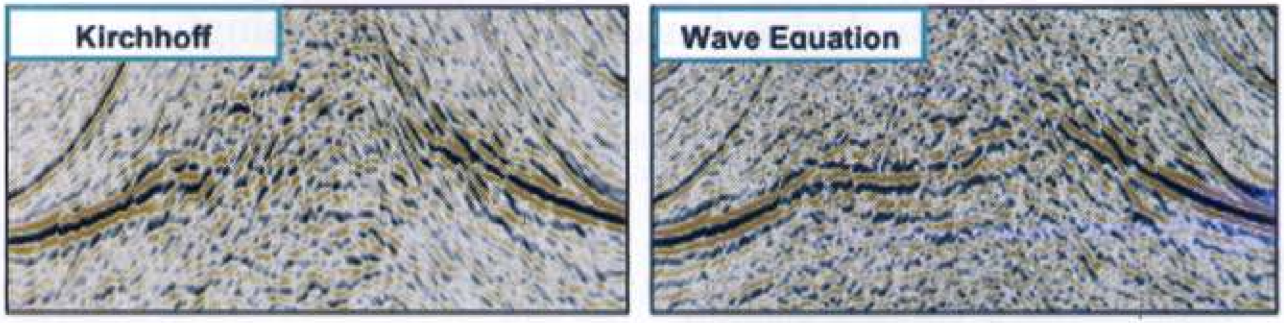

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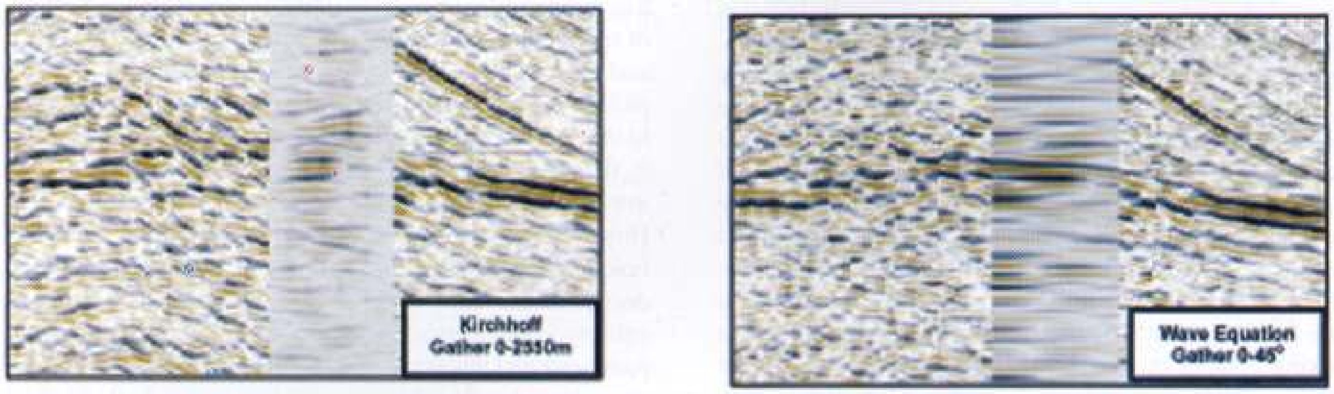

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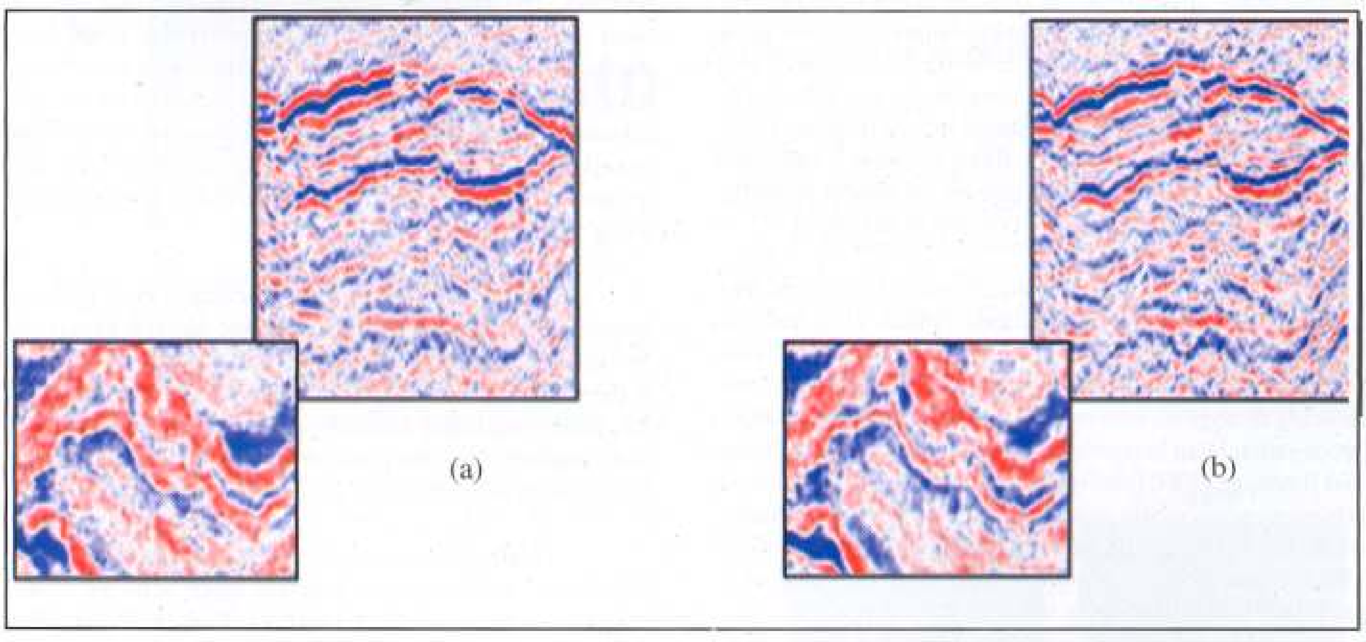

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