Challenges in Deep Offshore Imaging: West Africa

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Summary

The deep offshore of the Gulf of Guinea is a challenge to seismic processing and imaging techniques, due to the complexity of the salt body structures and the omnipresence of mode conversions that mask the primary signal. Even though true (Kirchhoff) prestack time migration can recover the top of salt and wide, sedimentary basins (not salt covered), it fails elsewhere. We show that wave equation 3D PreSDM is necessary to properly image target sedimentary reflectors in between and below salt domes, compared to Kirchhoff 3D PreSDM. However, this is true only for synthetic data using an exact model; in practice, the difficulty of deriving a proper model of sediment velocities drastically reduces the difference between the two algorithms. We show further that one of the difficulties of building this model, i.e. masking of sediment pinchouts against salt flanks by strong mode conversions, can be overcome using appropriate filtering techniques.

Introduction

Figure 1 illustrates the difficulties associated with this deep offshore environment: a dipping sea floor, complex coalescing salt structures overhanging prospective mini basins, proximity of the top of salt to the sea bottom. Strong surface related / interbed multiples and mode conversions at the top of salt are difficult to identify and eliminate, which makes stacking velocity or tomography inversion for sediment velocities difficult. The geometry of the salt bodies makes time processing assumptions *a priori* invalid.

Methodology

To devise the best methodology for producing high quality images in this area, we created a set of synthetic data using elastic finite difference forward modelling (Levander, 1988) with a model of appropriate complexity (figure 2): two salt bodies overlying narrow basins with turbiditic complexes. The data was first processed through true (Kirchhoff) prestack time migration, with velocities derived from the exact model and then updated from the CIG's. The resulting image demonstrated that, if the eastern sedimentary basin and the geometry of the salt bodies were well imaged, sub salt reflectors were either absent or lacked continuity.

Depth Migration

We then prestack depth migrated the data, first using the exact model. Multiple and mode conversion elimination were not applied. The result of Kirchhoff imaging with the best parameters (maximum aperture, highest ray density) shows that an acceptable image can be obtained of the deeper sedimentary bodies (figure 3 top). Wave equation migration, however (Dai et al, 2002), clearly improves the definition of the western turbidites below the salt flank, and generally produces a less noisy image (figure 3 bottom).

However, if we substitute to the exact model a model derived from tomography plus CIG analysis, as in a standard imaging flow of real data, the benefit of wave equation imaging is drastically reduced (figure 4). This implies that, in an operational context, the choice of wave equation migration will depend upon the possibility of obtaining an accurate velocity model.

Building the model

A major problem of building such a model, even with hybrid tomography methods, is the estimation of sediment velocities below salt flanks and between salt domes (the shape of the salt and its velocity are not too difficult to derive). Indeed, we observe that in both images (cf. figure 3), even with the exact velocity model, the termination of the undulating reflector around 4km against the left salt flank is not imaged at all. In a real context, it would probably be interpreted wrongly as a straight continuation up to the salt flank. This effect can be observed on real data imaged on a test zone in the same area (figure 5).

We can attribute this masking effect to the presence of high amplitude mode conversions that occur at the top of salt and create series of steeply dipping events sub parallel to salt flanks. Since those mode conversions are difficult to eliminate during preprocessing (they coincide with primary events and have similar, low velocity moveouts), we devised a technique to filter them during the migration which can help constrain the sediment velocities below the salt as well as the interpretation.

Conclusions

The deep offshore of the Gulf of Guinea is a challenge to seismic processing and imaging techniques, due to the complexity of the salt body structures and the omnipresence of mode conversions that mask the primary signal. We have shown that in this context, wave equation 3D PreSDM is necessary to properly image target sedimentary reflectors in between and below salt domes, compared to Kirchhoff 3D PreSDM. However, to benefit from this technique requires building a very accurate depth model using hybrid tomography methods. We have shown that one of the problems in building such a model, i.e. masking of sediment pinchouts against salt flanks by strong mode conversions, can be overcome using appropriate filtering techniques. These observations from forward modelling are confirmed by images obtained from field data on a test zone.

References

Dai, N., Willacy, C.N., Pascual, R.V., Gochioco, L.M., Sun, Y., & Mecham, B.B., 2002, 3D wave equation migration improves prospectivity by enhancing subsalt imaging, TLE, v 21, No.12. pp.1224-1226.

Levander, A, R 1988, Fourth-order finite-difference P-SV seismograms' Geophysics,V. 53, No. 11 pp. 1425-1436.

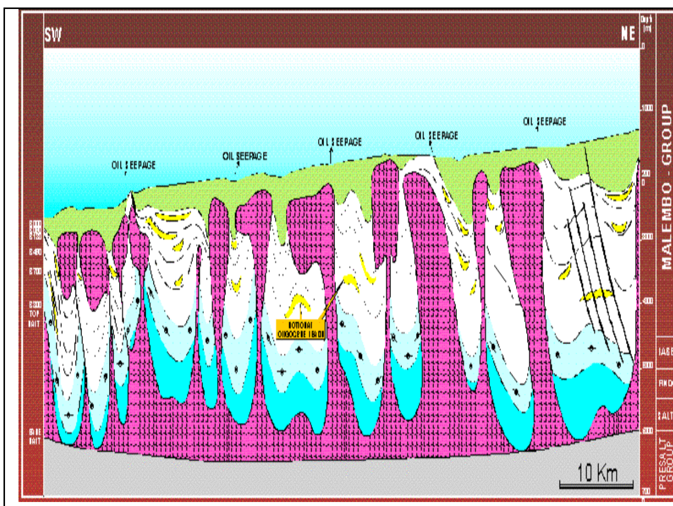

Figure 1. Schematic cross-section, deep offshore Gulf of Guinea.

Figure 2. Model used for synthetic data tests

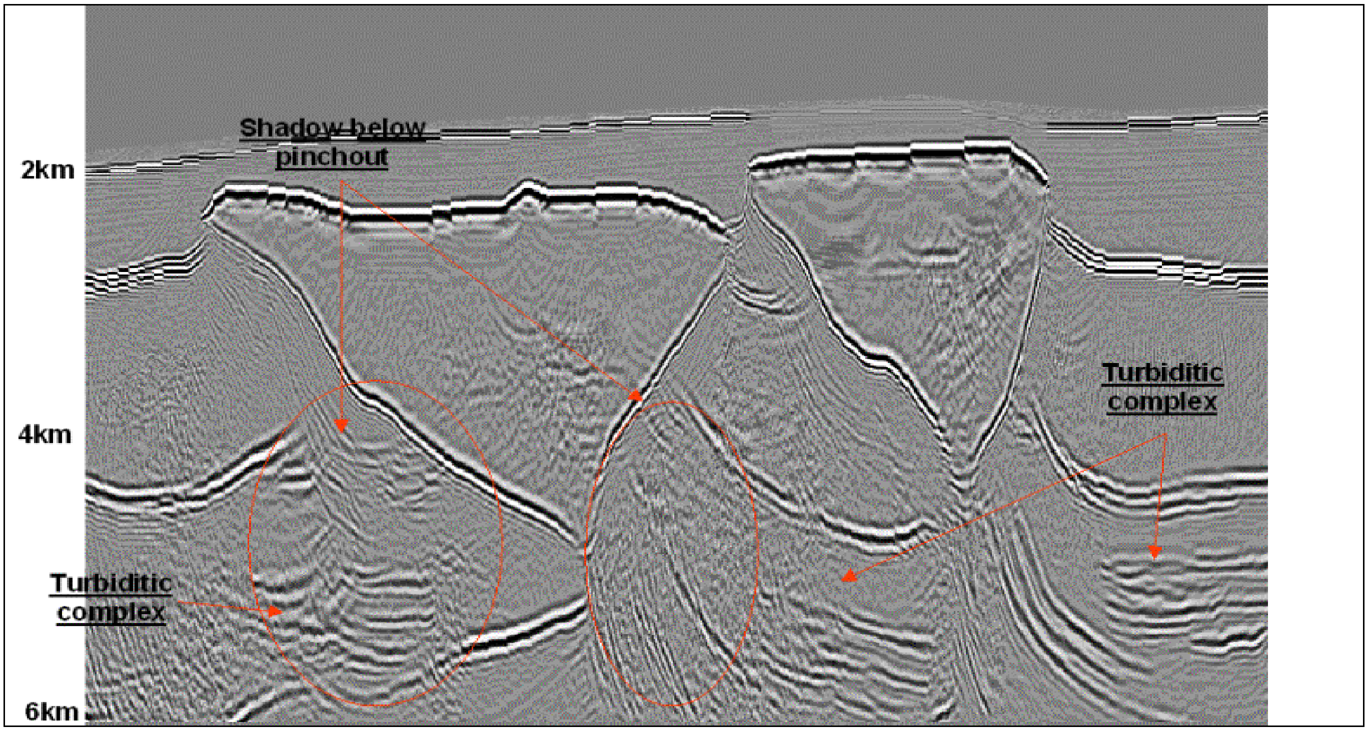

Figure 3a. Kirchhoff PreSDM with exact model..

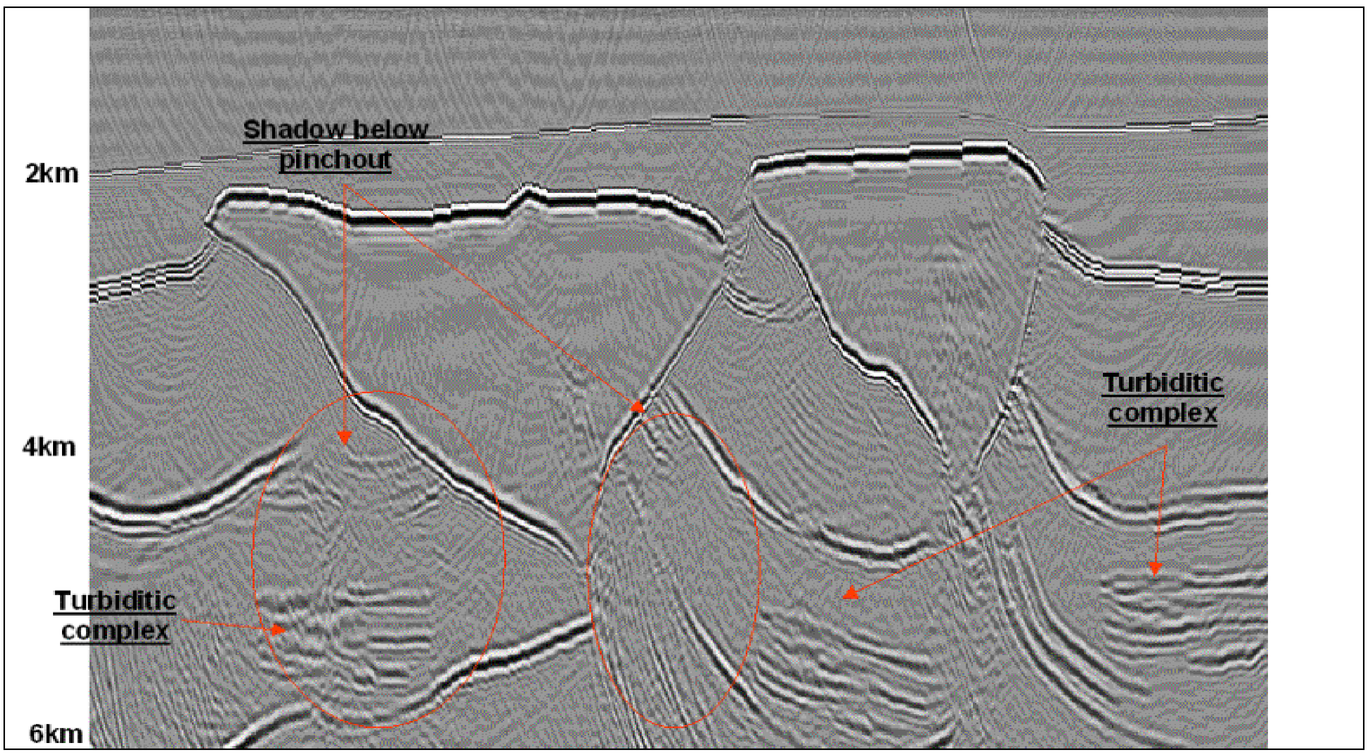

Figure 3b. wave equation shot record PreSDM with exact model.,.

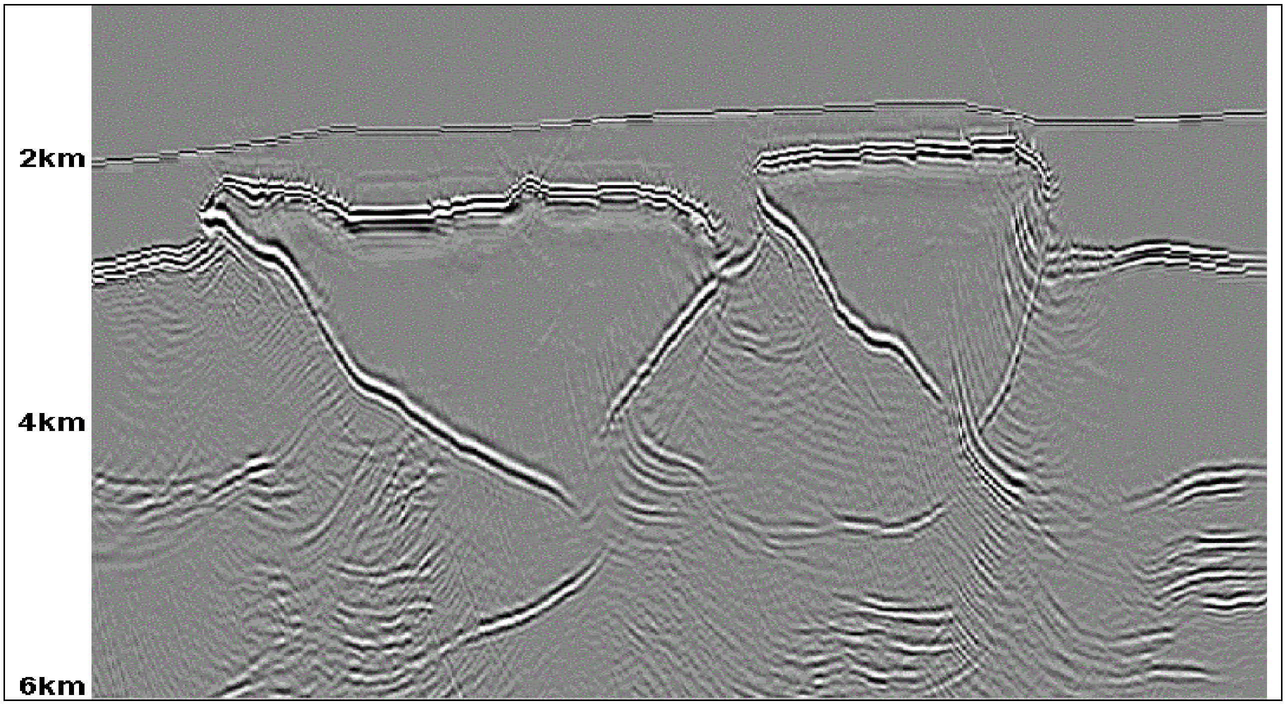

Figure 4. Wave equation shot record PreSDM of the synthetic data with model derived from the data (tomography plus CIG analysis). The image of the turbidites is strongly distorted.

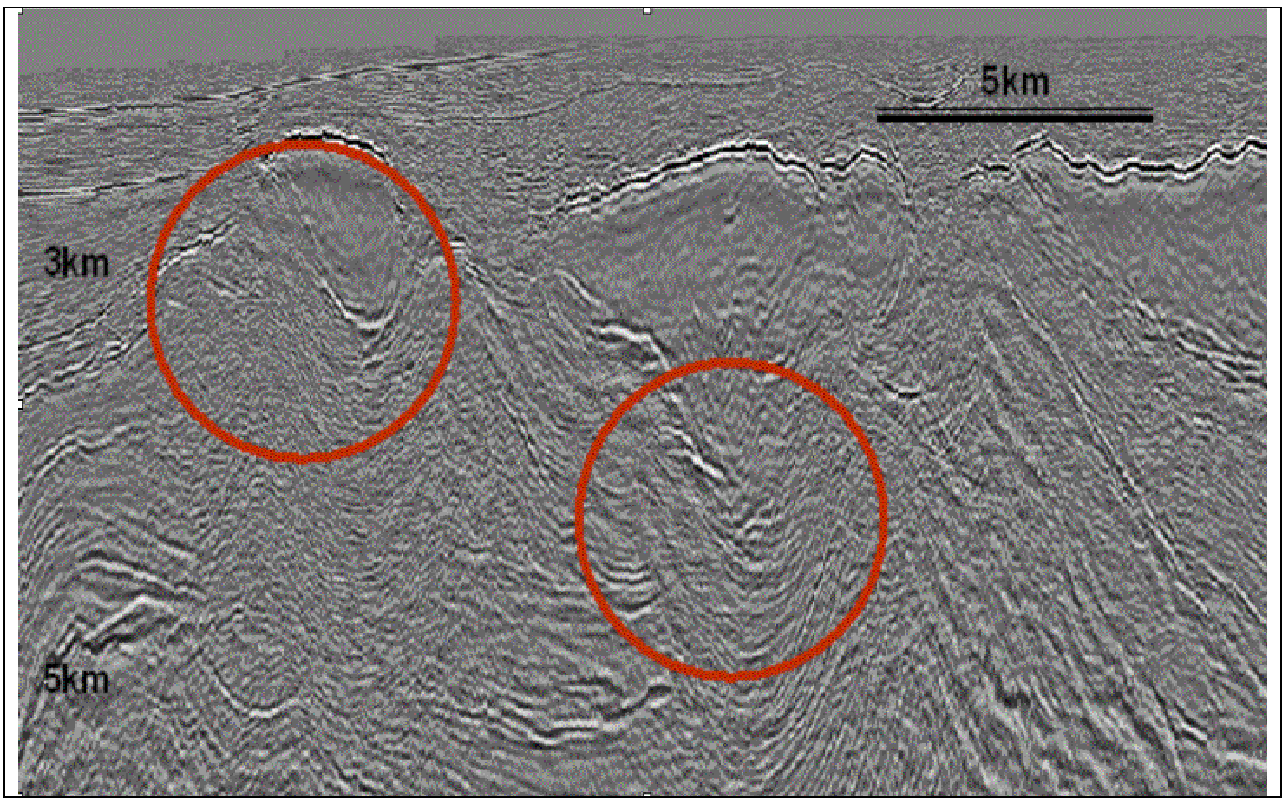

Figure 5. Kirchhoff PreSDM of real data from a test area in West Africa