



Complex Imaging Challenges: Offshore South East India.

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Summary

Imaging in deep water environments poses a specific set of challenges, both in the data pre-conditioning and the imaging. These challenges include scattered complex 3D multiples, aliased noise; and low velocity shallow anomalies associated with channel fills and gas hydrates. In this paper, we describe our approach to tackling these problems, concentrating our attention on multiple suppression, scattered noise attenuation, iterative velocity model building and depth imaging.

Deep Water Issues

Off the east coast of India, the transition from the shallower coastal waters to the deep shelf often encounters significant topographical variation in the sea bed, which gives rise to numerous effects which must be dealt with by the processing geophysicist. In addition to deep channels and steep slopes, we also encounter buried channels with low velocity fills and gas hydrates. Diffracted and “out-of-plane” multiples are the norm in these environments (Stewart, 2004), and must be dealt with in order to subsequently derive a reliable velocity model in order to deliver an acceptable structural image (Stewart et al, 2006).

To address multiples, differential velocity based methods such as Parabolic Radon have often been used in deep water. To some extent, the problem of aliasing of the multiples on far offsets can be addressed either by interpolation and/or use of a de-aliased (“beam”) Radon transform. However, Radon-based techniques fail for complex multiples, as the apex of the events in the CMP domain does not fall on zero offset for ray paths not in the plane of the shot-receiver axis. In these cases, an alternative method must be employed.

In recent years, the SRME technique has become popular in deep water. Near offset multiples in particular are better attenuated than with Parabolic Radon technique. Cascading 2D SRME and Radon has become an industry standard approach. However, the complexity of the multiple generator and “out-of-plane” effects can severely limit even this combination.

With the advent of 3D SRME, a theoretically more correct approach has become available, and here we demonstrate its effectiveness as compared to the ‘conventional’ approach.

In figure 1, we show data sorted to CMP gathers after application of the SRME technique (which is applied to shot gathers). We compare results from 2D SRME with those from 3D SRME. Complex ray-paths for the first sea-bed multiple and associated sedimentary layers, give-rise to a shifted-apex aspect to the moveout behaviour as seen in the CMP domain. Following either 2D or 3D SRME, additional de-noise techniques can be applied to deal with the aliased noise and other classes of noise.

In figure 2, we show the results after 3D preSDM. The migration following application of 2D SRME (2a) shows a swath of noise sitting over an area of interest (a major unconformity). This remnant multiple energy has been spread around during migration and is difficult to remove at this stage. Conversely, following 3D SRME (2b), the migration is mainly free of this multiple contamination. (Note that the 3D SRME migration also had trace regularization, but this is of secondary importance).



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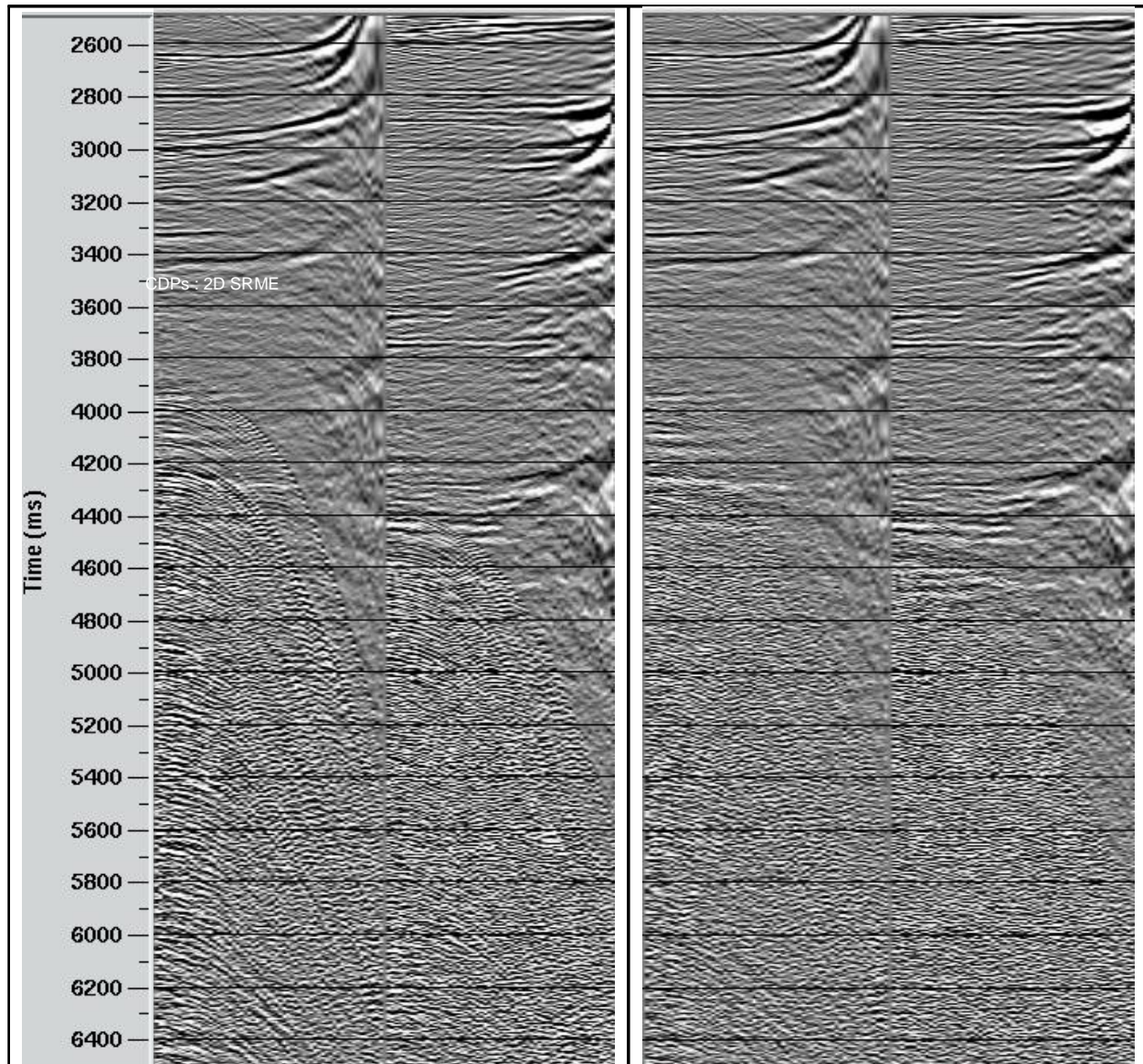


Figure 1: example deep water CMP gathers with 2nd order NMO. Left:- after application of 2D SRME. Right – after application of 3D SRME



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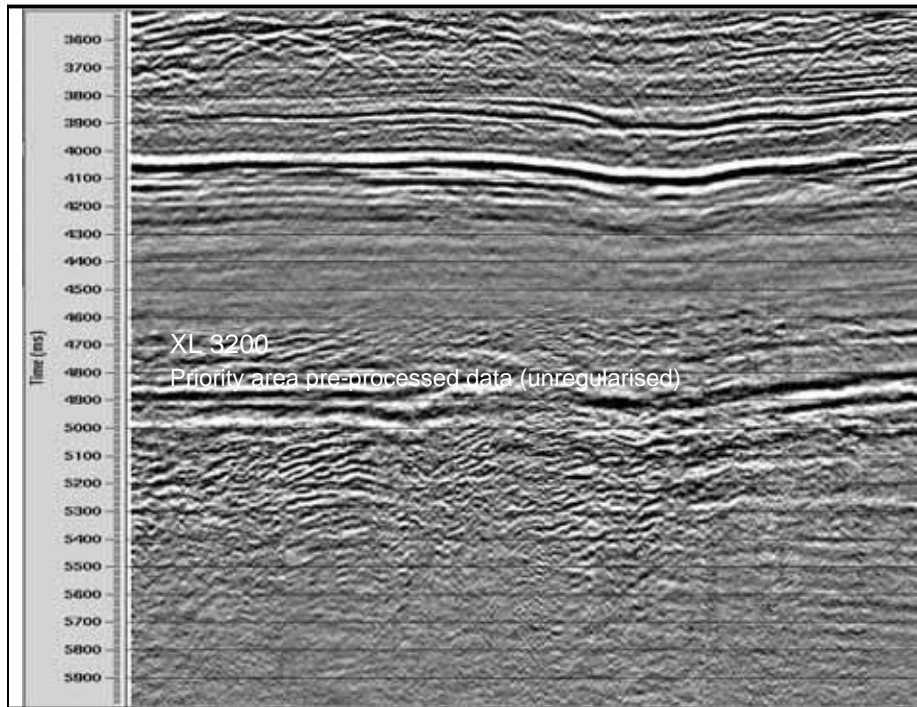


Figure 2a. 3D preSDM following application of 2D SRME

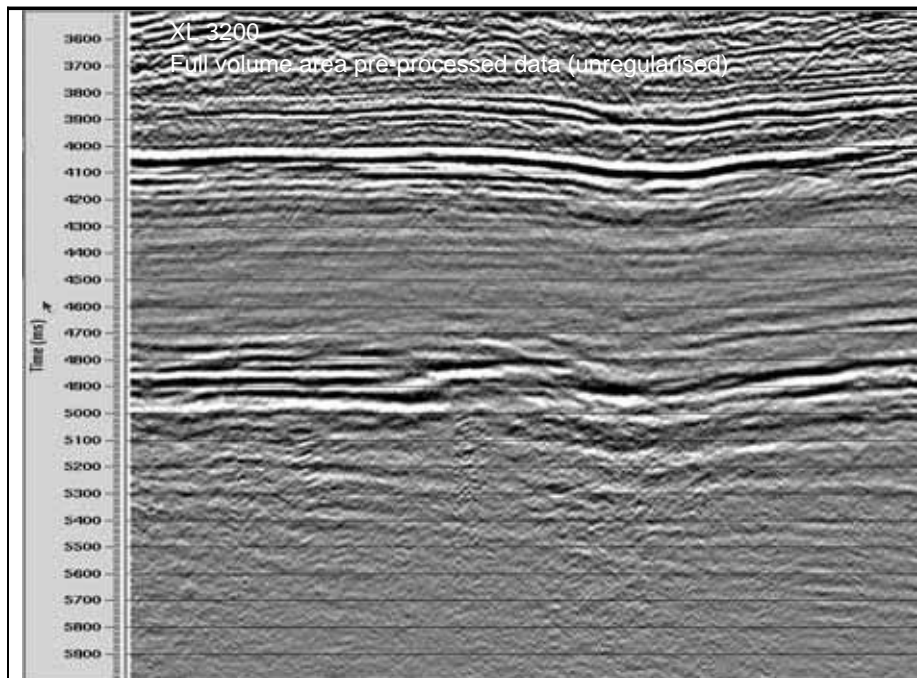


Figure 2b. 3D preSDM following application of 3D SRME (and trace regularization)



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Velocity Model Building & Pre-Stack Depth Migration

In an environment with punctual discontinuous velocity anomalies, such as those associated with narrow channel fills or gas hydrate accumulations, a purely layer based velocity model will be inadequate (Jones, 2003). Furthermore, a purely gridded approach may also encounter problems (Jones, et al, 2007).

In this project, we used a hybrid-gridded approach, where we combined conventional gridded tomography, high resolution gridded tomography, auto-picked layers, and detailed manually interpreted layers. The initial depth interval velocity was derived from the time-stacking velocity (smoothed and converted to depth interval velocity), and the water bottom was picked from a water- velocity depth migration and inserted in the initial model as an explicit layer.

Following this, several iterations of gridded tomographic model update were performed. This involves running an autopicker (in this instance based on plane-wave destructors - Claerbout, 1992; Hardy, 2003) on densely sampled CRP depth gathers, and inputting the autopicked

velocity errors and dip information to the gridded tomographic 3D solver.

For gas hydrate accumulations, we relied primarily on high resolution gridded tomography, and were able to resolve small-scale velocity features with $V_i \sim 1250\text{m/s}$, compared with the background sediment velocities of $\sim 1600\text{m/s}$. For detailed narrow channels, we relied on manual interpretation of the top and base of the channel features, and a scan over potential channel-fill velocities.

Figure 3 shows the first kilometre of data near the sea bed, where we see deeply incised sea-bed canyons, but also some small localised channels just below the sea bed. These channels result in a severe pull-down distortion of the underlying sediments due to their low-velocity fill. If we were to use a smooth velocity model, we would be unable to resolve these small-scale features (typically 200m in width) hence detailed manual picking is required. The 3D preSDM image shown in figure 3 was created using a smooth background velocity field (hence the pull-down is visible). The detailed channel-fill velocity model is superimposed. A migration velocity scan was used to determine the best channel-fill velocity: in this case 1200m/s was used.

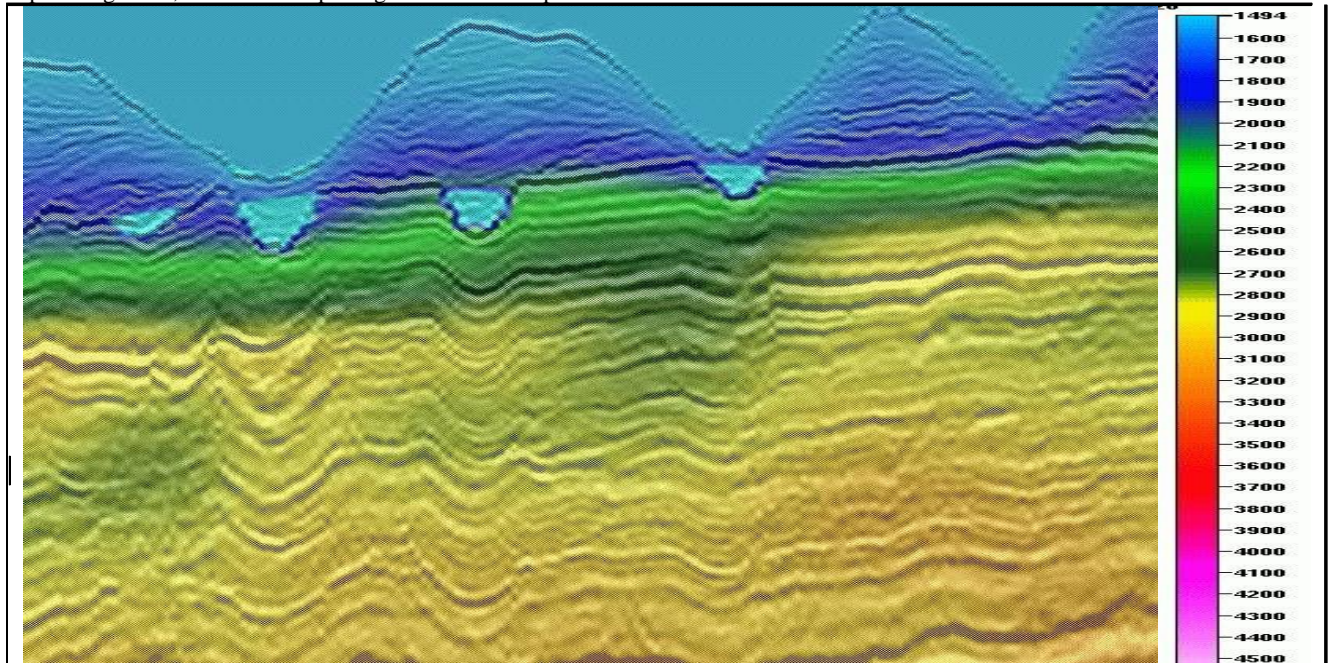


Figure 3: PreSDM using smooth model, with channel fill velocity model superimposed



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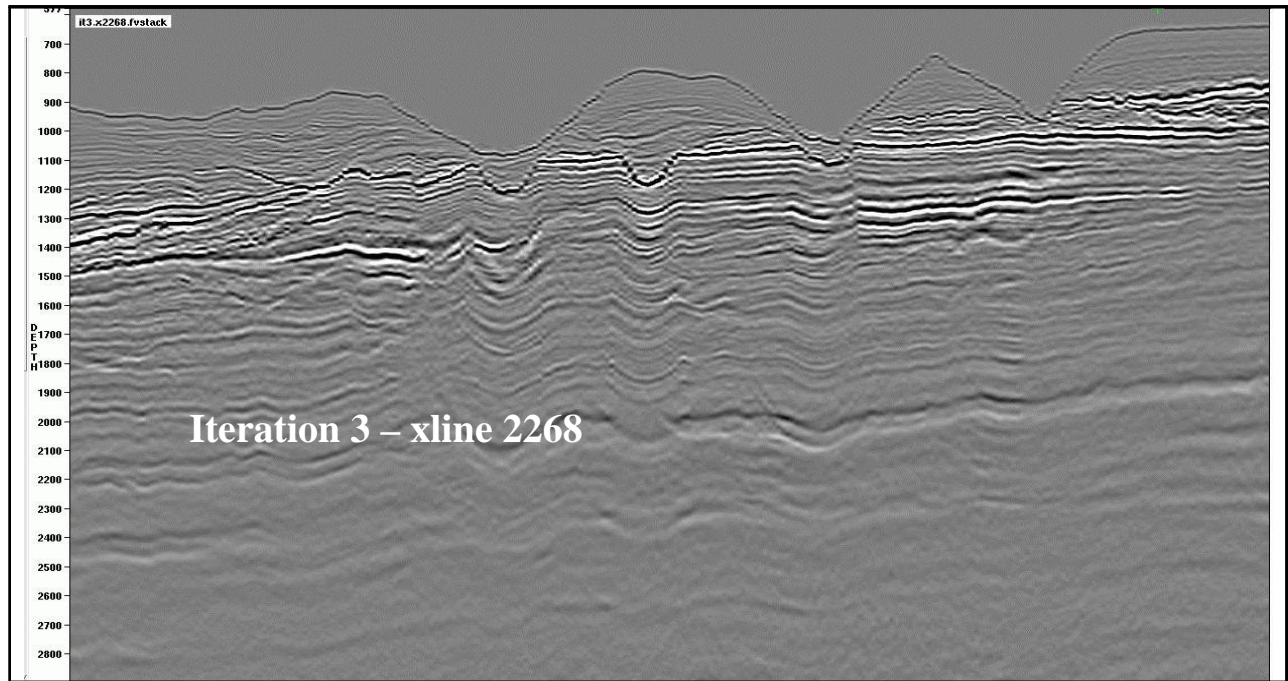


Figure 4a 3D preSDM with smooth background model:

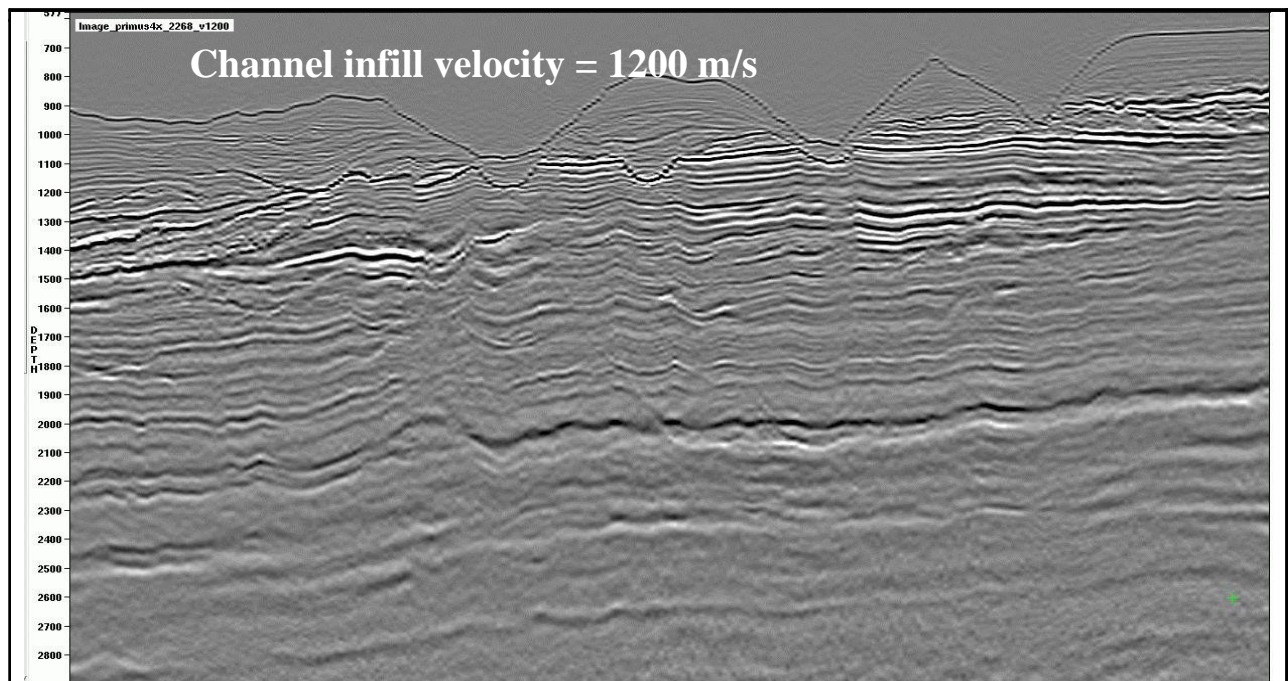


Figure 4b 3D preSDM with detailed low-velocity channel-fill model:



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Figures 4a & 4b compare the 3D preSDM result after migrating with a smooth background velocity field (no punctual channels included) versus the result incorporating the low-velocity fill channels. The improvement in the deeper section is significant. We have not perfectly resolved the shallow channel problems, but incorporating them in this way enables better resolution in the deeper section. Ignoring them is not a viable option.

Imaging

For the data under consideration here, we do not face any classical multi-pathing problems, hence for the final migration, an amplitude preserving Kirchhoff or Beam implementation is best suited for the problem. Here we have used Kirchhoff, and have input the resulting CRP gathers to an attribute estimation study.

Conclusion

For imaging in complex environments, it is necessary to employ a wide range of tools for suppression of the various classes of noise and multiple. This must be accomplished in the pre-stack domain so that automated dense picking can be performed on migrated gathers to permit reliable model update.

Utilization of such an approach for data offshore eastern India has resulted in an improvement in image quality compared to a recent pre-stack time migration, avoiding the structural distortion introduced by localized velocity variation in the near surface sediments, delivering gathers suitable for attribute work.

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