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Objective based depth imaging and its application to data from East coast of India

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Summary

Prestack depth migration is a popular tool to achieve reliable subsurface images. Several migration algorithms are available for the purpose. Every algorithm has its own advantages and disadvantages associated with it. The selection of the depth migration methods for a particular dataset should be guided by the interpretational needs, resolution requirements, complexity of the subsurface geology etc. Sometimes one depth migration may not be sufficient to meet the imaging needs for the entire section (from water bottom to basement) especially for complex geological settings. Here, two different depth migration algorithms viz., Kirchhoff and Fast Beam have been applied on two deep water 3D datasets from east-coast of India, to show the different imaging capability of these PSDM methods in different portions of the sections. The velocity model of the Fast Beam shows a smoother trend as compared to Kirchhoff. The shallow imaging, for both the datasets, above the basement is better in Kirchhoff section, whereas, the basements are better imaged on Fast Beam stacks. So the basement is well interpretable on Beam stacks, whereas, the other shallow objectives are on Kirchhoff sections.

Introduction

Due to recent advances in computer technology, 3-D prestack depth imaging is used increasingly in petroleum exploration as a high resolution-imaging tool, especially in areas of complex geological settings and lateral variation in velocity. Several PSDM algorithms viz. – Kirchhoff, Fast Beam, Gaussian Beam, Wave equation, etc. are available to handle the geological complexity and to meet different processing objectives. The output resolution, the runtime and the ability to handle the complexity varies from one algorithm to another. So the selection of the migration routine should be driven by the processing objectives, resolution required and the structural complexity present in the area.

Here, in this paper, two different depth migration algorithms viz. – Kirchhoff and Fast Beam have been applied to two datasets to meet different processing objectives at different depths.

Kirchhoff Migration versus Fast Beam migration

Several researchers have discussed about Kirchhoff (Schneider, 1978; Wang and Pann, 1996; Hua and McMechan, 2001, 2003; Yilmez, 2001) and Beam migration (Hill, 1990, 2001; Hill et. al., 1991; Sun et. al., 2000; Grey, 2005; Gao et. al., 2006; Tieman and Elsley, 2007) at length in their various research papers and

outlined the theory of both the methods with synthetic and real field examples.

Despite its limitations, Kirchhoff migration using ray theoretical traveltimes has many advantages and is currently the tool of choice for 3-D prestack depth imaging.

In Kirchhoff migration, the diffraction hyperbola is collapsed by summing the amplitudes along the hyperbola, then placing it at its apex. The aperture width used for the amplitude summation is an important parameter that affects the performance of the Kirchhoff migration.

Unlike conventional Kirchhoff migration in which the input seismic traces in time are migrated one trace at a time into the 3-D image volume for the earth's subsurface, the beam migration processes a group of input traces (a supergather) together.

The main advantages of Fast Beam over Kirchhoff are its ability to image steep dip events, multi-arrival imaging, less compute intensive and hence faster velocity model building. The computational speedup of fast beam migration over conventional Kirchhoff migration is roughly proportional to the average number of traces per supergather, resulting a theoretical speedup up to two orders of magnitudes.

Case study

The two data examples, shown here, are from deep water blocks located in the eastern coast off mainland India. The major processing objectives for both these surveys are two fold –

- To image the basement.
- To image the anticlinal structure above the basement.

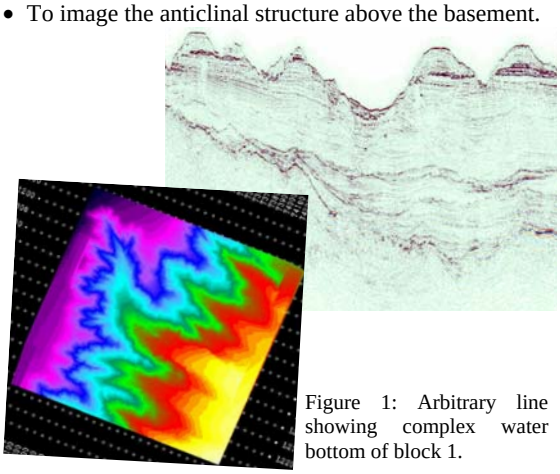


Figure 1: Arbitrary line showing complex water bottom of block 1.

The depth imaging in the block 1 has been taken up to address the poor imaging issues in the time sections, as evident from Figure 1, arising due to complex water bottom. In case of block 2 the PSDM has been carried out to have the confidence about the deeper structure in presence of shale-bulge and velocity inversion in this area, though its flat water bottom does not ask for any depth imaging.

The acquired data are preprocessed before depth migration to remove noise and multiples using standard processing steps viz. – editing of bad traces, low cut filter, resampling to 4ms with antialiasing filter, swell noise attenuation, linear noise attenuation, 2D surface related multiple attenuation, RADON de-multiple, frequency based diffracted multiple attenuation, etc. and then binned to a grid size of 12.5m × 25m with missing trace interpolation. These datasets are then depth-migrated using standard Kirchhoff and Fast Beam algorithms.

The PSTM velocity field (RMS velocity versus Time) after conversion to interval velocity versus depth and then smoothened to use as initial velocity model for both the depth migration schemes.

The typical grid size is using for both the migration algorithms are 25m × 25m × 5m in Inline and crossline directions. A grid size of 500m × 500m × 500m is used for the tomographic updation and a migration aperture of 4km has been used in Kirchhoff migration. In the Fast Beam, a superbin size of 400m × 400m × 100ms has been used.

The velocity models and corresponding stack sections from both the depth migration routines for the block 1 are shown in Figures 2 and 4 respectively. A comparison among the well velocity with the two velocity models has been made for block 1 and is depicted in Figure 3.

The frequency spectrums of both the stack sections of block 1 & 2 are computed and are displayed in Figure 5 and 6 respectively. An Inline stack section generated with these migration routines for block 2 are shown in Figure 7.

Results and Conclusions

A significant change in structural shape and improved continuity of the horizons in the depth migration over time migration have been shown in the Figures 4 & 7 for the blocks 1 and 2 respectively. Though the frequency content in the depth section is bit lower than time section, imaging is much better after PSDM.

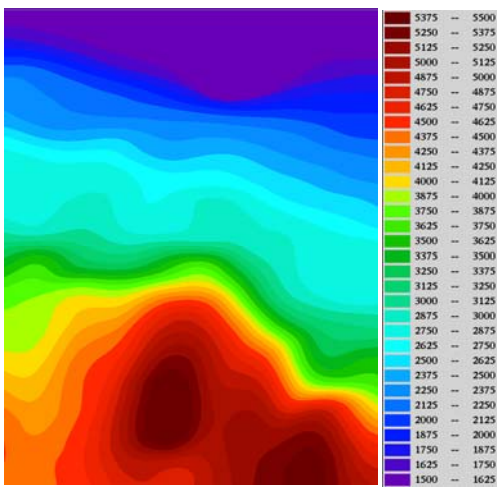
While comparing the depth stack sections (refer Figures 4b, 4c & 7b, 7c) generated with both the depth algorithms, basement is better imaged in Fast Beam output (refer Figures 4c, 6c) thus meeting our first objective. The anticlinal structure above the basement, which was our second objective, are better imaged in Kirchhoff output (refer Figures 4b, 6b). Kirchhoff has better frequency content than Fast Beam output as depicted in Figures 5 and 6, which helps in better resolution and better fault definition. Steeply dipping events (encircled in Figure 4) are found to better imaged in Fast Beam than the conventional Kirchhoff which can be attributed to the capability of the fast beam to accommodate multi-arrivals.

The two velocity models depicted in the Figure 2, clearly brought out the changes between two in terms of smoothness, resolution etc. The Fast Beam model is very smooth compared to that of Kirchhoff. The trend of Kirchhoff model is showing good match with the well velocity, whereas, the Fast Beam velocity model appears as an average background trend (refer Figure 3). Three zones (refer Figure 3) can be identified as follows based on the velocity trend –

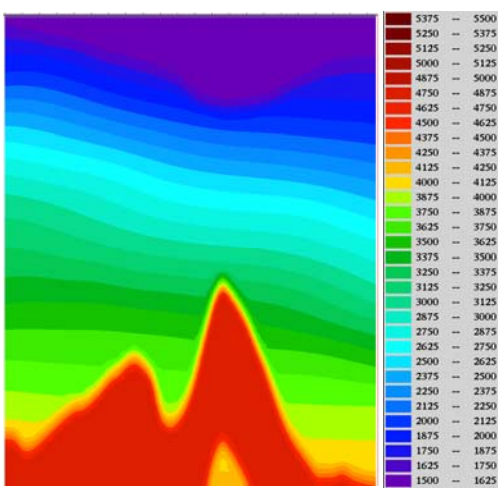
Zone-1: In this zone the Kirchhoff velocity and Beam velocity are following the same trend, the same can be observed in the velocity models.

Zone-2: In this zone Kirchhoff is slightly slower than Beam and is following the trend of well velocity.

Zone-3: In this zone Beam velocity is slower than that of Kirchhoff and well.



(a)



(b)

Figure 2: (a) Kirchhoff Velocity model, (b) Fast beam velocity model in interval vs depth format for block 1.

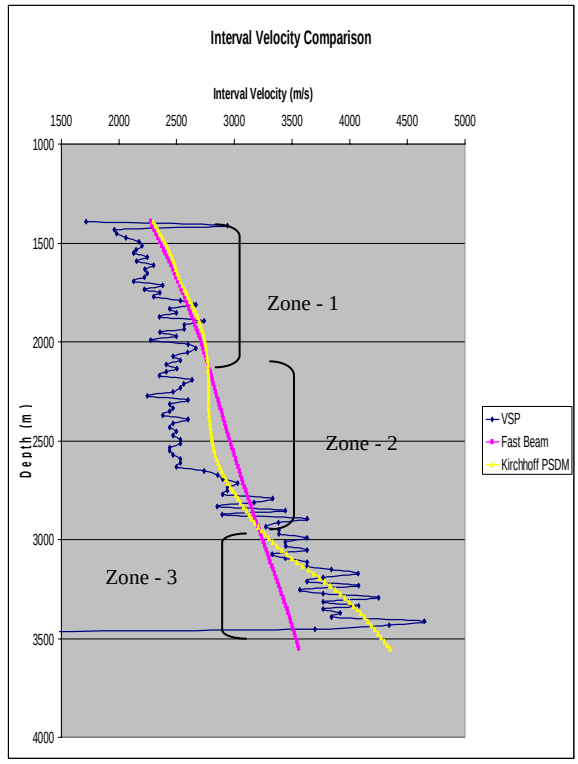


Figure 3: VSP, Fast Beam and Kirchhoff velocity model comparison for block 1.

Even though the Kirchhoff and Beam velocities are similar in zone-1, there is a significant difference in both the stack sections. Kirchhoff stack shows better resolution than Beam.

In zone-3, though Beam velocity is slower than well velocity, which is not the ideal case, the imaging is much better in the deeper section in Beam stack than in Kirchhoff stack.

From the above discussions it is clear that, with the same input data and initial velocity model different migration algorithms are arriving at different final models and different migrated sections. Any one of these two depth imaging techniques is not sufficient to image the entire section. A combination of Kirchhoff and Fast Beam may be used as a tool to meet the specific target oriented interpretational requirements.

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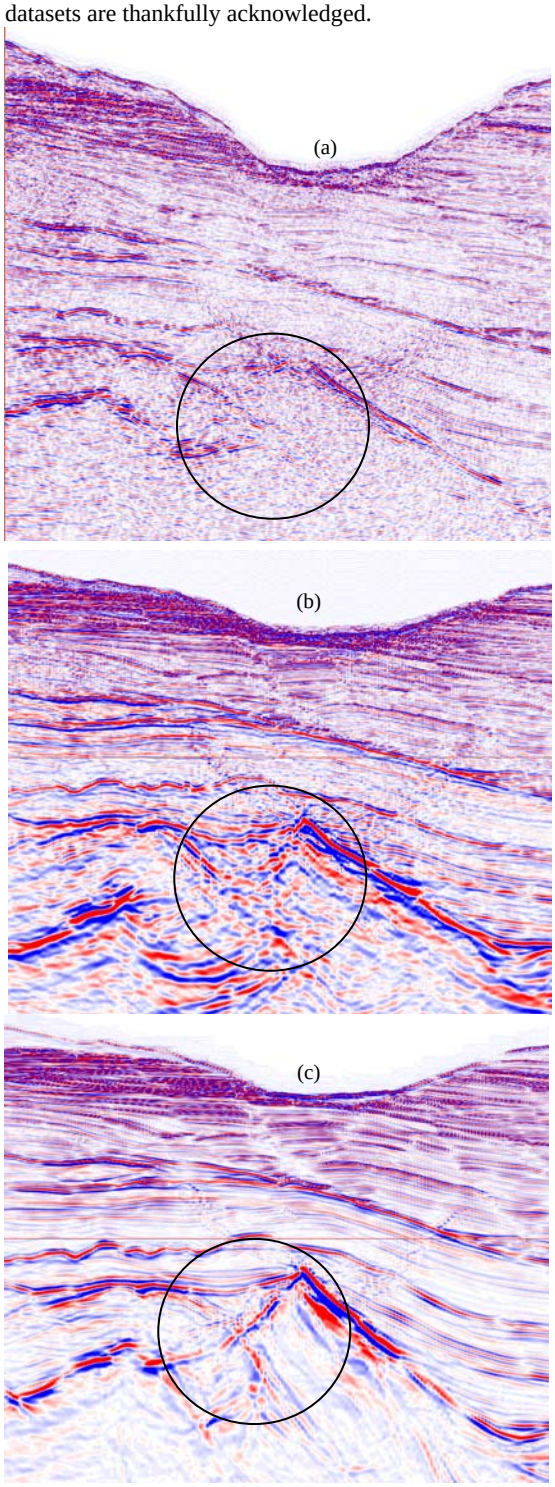

Figure 4: (a) Kirchhoff PSTM stack section, (b) Kirchhoff PSDM stack section, (c) Fast beam depth stack section in depth of deep water block 1.

Authors would like to state that the views reflected in this paper are of their own, and do not necessarily reflect the views of the organization they belong to.

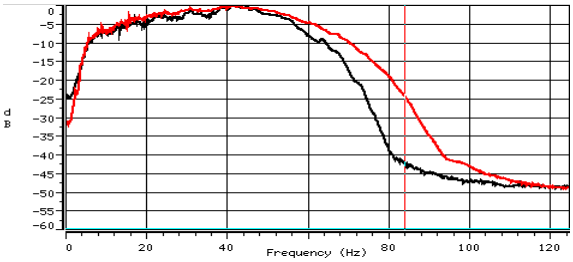

Figure 5: Comparison of frequency spectrum of block 1 depth sections. Red indicates Kirchhoff and black indicates Fast Beam.

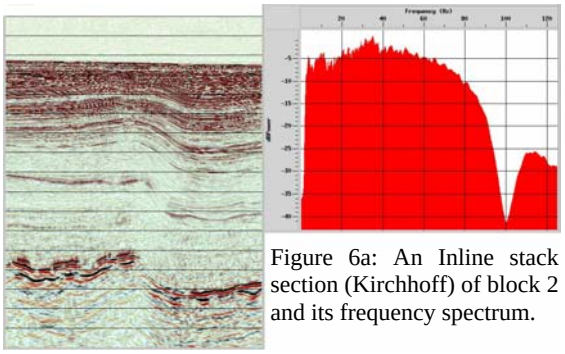

Figure 6a: An Inline stack section (Kirchhoff) of block 2 and its frequency spectrum.

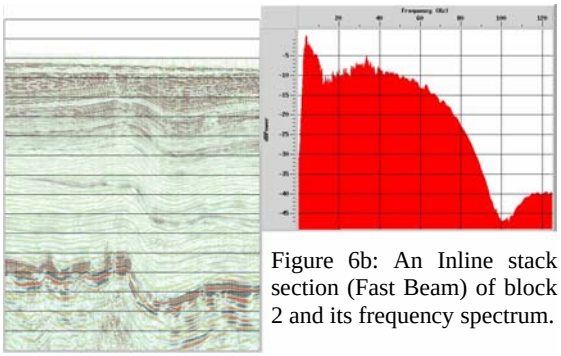

Figure 6b: An Inline stack section (Fast Beam) of block 2 and its frequency spectrum.

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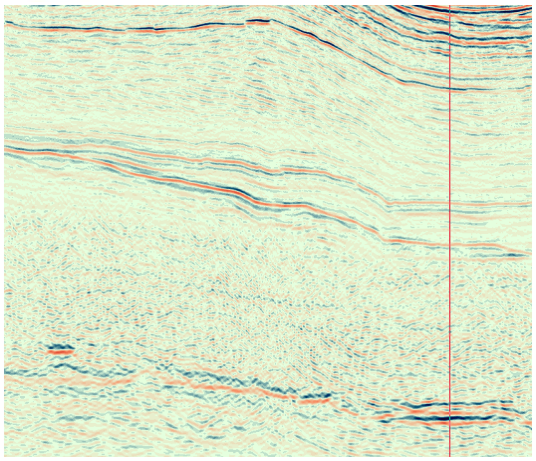
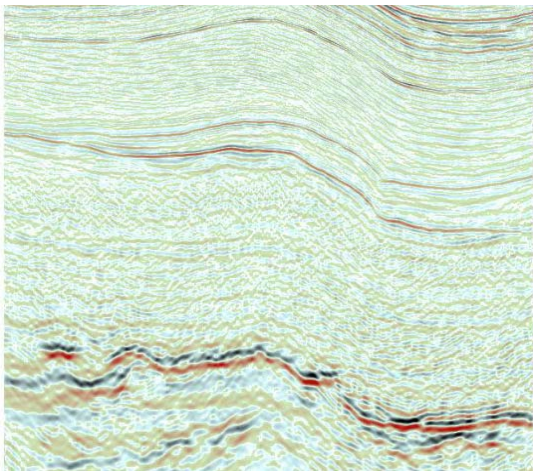


(a)



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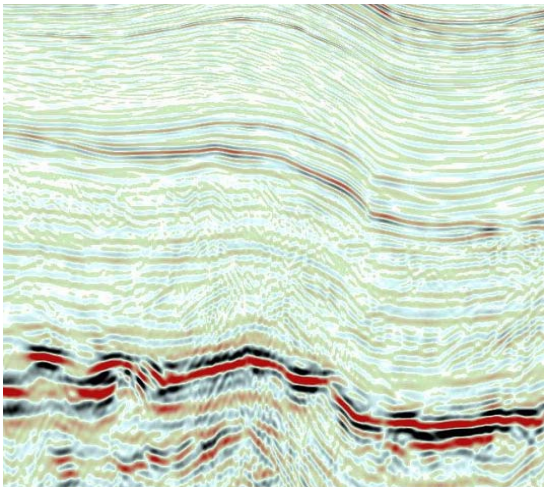

(c)

Figure 7: (a) Kirchhoff PSTM stack section, (b) Kirchhoff PSDM stack section, (c) Fast beam stack section in depth of deep water block 2.

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