Anisotropic model building with structurally constrained tomography inversion: A case study from the Angola Basin

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Summary

The Angola basin is characterized by steeply dipping sediments with rapid changes in dip direction particularly in mini-basins between salt bodies. This creates difficulties in anisotropic model building using grid-based tomography. Hence, we incorporated geologic dip information available from Kirchhoff Pre-stack Depth Migration (PSDM) stacks into the tomographic inversion to obtain better model updates which follow the geologic structure. This improves focusing, amplitude and continuity of reflectors after migration, and minimizes the use of additional smoothing after inversion.

Introduction

The area we are presenting lies in deep water offshore Angola located to the west of Africa, and the present work is a part of the model building for Anisotropic Tilted Transverse Isotropic (TTI) Kirchhoff and Reverse-time migrations.

The rapid changes of the velocity within and across mini-basins create a challenge in anisotropic model building. In areas of complex geology, various constraints have been used in the tomography inversion in order to obtain a more reliable model to improve the subsurface image (Versteeg and Symes, 1993; Gary et.al., 2011).

In this paper, we describe the methodology of incorporating structure into the tomography inversion for overcoming depth imaging challenges related to relatively narrow and deep mini-basins. The regular grid based tomography inversion without structure constraints distributes the velocity updates in an irregular manner along the rays. This results in event defocusing, amplitude dimming and less event continuity.

Building an anisotropic model in mini-basins with steeply dipping sediments requires very dense lateral and vertical residual curvature picking along with, dip estimates to be input to tomography. Kirchhoff migration using the updated model from this technique resulted in improved imaging due to better focusing of reflectors. In addition, the structurally constrained tomography helps convergence of the inversion and reduces the smoothing amount required after inversion.

Method

Figure 1 summarizes the general workflow used to obtain the model update. A high resolution tomography update was used to determine the model in the relatively flat shallowest part, and a depth migrated stack is obtained from TTI Kirchhoff migration using the updated velocity model.

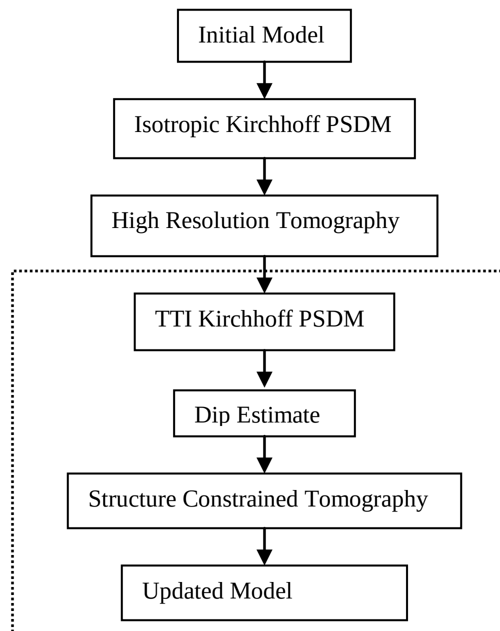

Figure 1: Workflow used for velocity model building with structurally constrained tomography. The dashed box shows processes iterated to obtain the best model.

After the migration, reflector dips in the cross-line and inline directions are estimated from the depth migrated stack and super-gathers are created by stacking gathers in a denser 100 m x 100 m window. Then residual move-out curvatures are picked on the super-gathers and ray tracing is conducted to the base of sediment basins.

In the next step, a structurally constrained tomography inversion is conducted using the ray tracing result and the reflector dips that were obtained from the depth migrated stacks. The result from the inversion is a structurally guided velocity update giving a more accurate velocity model for Pre-stack Depth Migration (PSDM).

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During the iterative anisotropic model building, optimum parameters were used in each stage to obtain high spatial and temporal resolution. Flatness of the PSDM gathers and amplitudes were also monitored in order to obtain reliable dip estimates which depend upon good focusing and continuity of the reflectors. These in turn resulted in a better tomography model update.

Data Examples

Figure 2 is a depth migrated stack overlying the tomography update with and without structural constraints. The figures show that the structurally constrained tomography inversion values follow the geologic structure and are more continuous. The main improvement in continuity occurs at the steeper margin of the basins.

The above observation is also illustrated by Figure 3 showing depth slices from the 3D stack volume and tomography updates with and without structurally constrained tomography. The structurally constrained updates better follow the basin outline. These indicate that anisotropic model building in narrow, deep mini-basins with steeply dipping sediments requires incorporating structural information during the tomography inversion.

In addition, the Angola basin consists of a thin high velocity Albian carbonate layer above Aptian salt (Cope, 2001), and the deeper high velocity updates in the area correlate with the carbonate layer.

Figure 4 shows the PSDM gathers which were migrated with the velocity model updated with regular grid tomography compared to the ones with structurally constrained tomography. The gathers migrated using the structurally constrained model update show improved flatness in the deeper part. This resulted in improved continuity of events, better focusing and therefore better structural features on the PSDM stack.

Depth migrated stacks without and with structure being incorporated into the velocity model are shown in Figures 5 and 6. The depth migrated stack with the structurally constrained velocity model has sharper more continuous events at the basin margins and close to the structurally high areas.

Conclusions

Narrow deep basins with steeply dipping sediments present a challenge in anisotropic model building and imaging. The result of our work shows that the main difference between the velocity updates in the tomography inversions with and without structural constraints occur close to basin margins. We also demonstrated that Kirchhoff migration using a velocity model updated with structure incorporated into the inversion, results in improved imaging of the basin margins and areas of high velocity contrast, due to more correct positioning of the reflectors. This also improves interpretability of prospect objective zones.

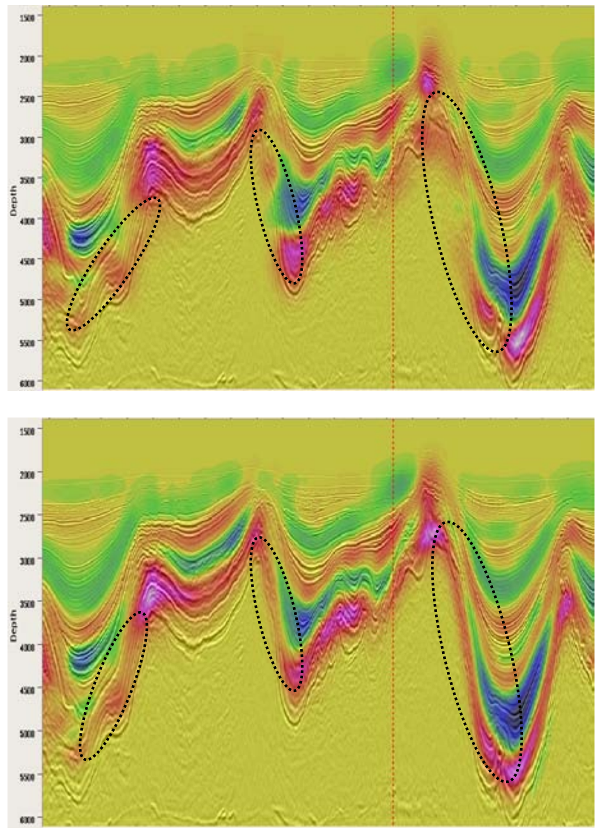

Figure 2: Migrated stack with tomography update overlay without (top) and with structural constrain. The main improvement occurs at basins flank.

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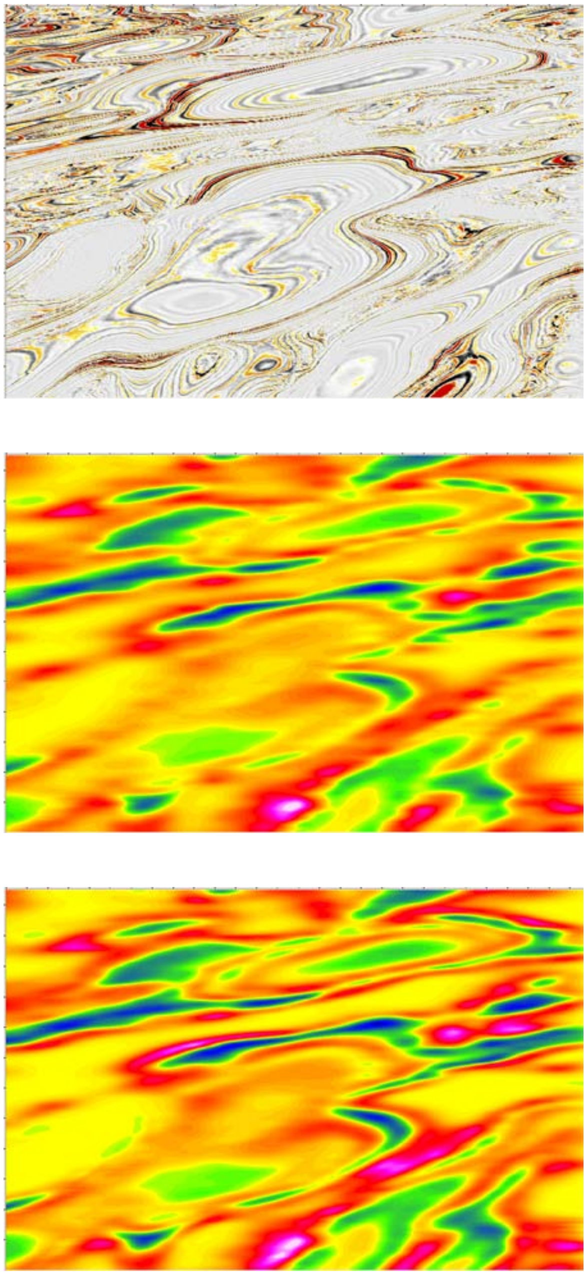

Figure 3: Depth slices from 3D seismic volume showing mini-basins(top), grid-based (middle) and structurally constrained (bottom) tomography updates. Structurally constrained updates follow the mini-basins outline.

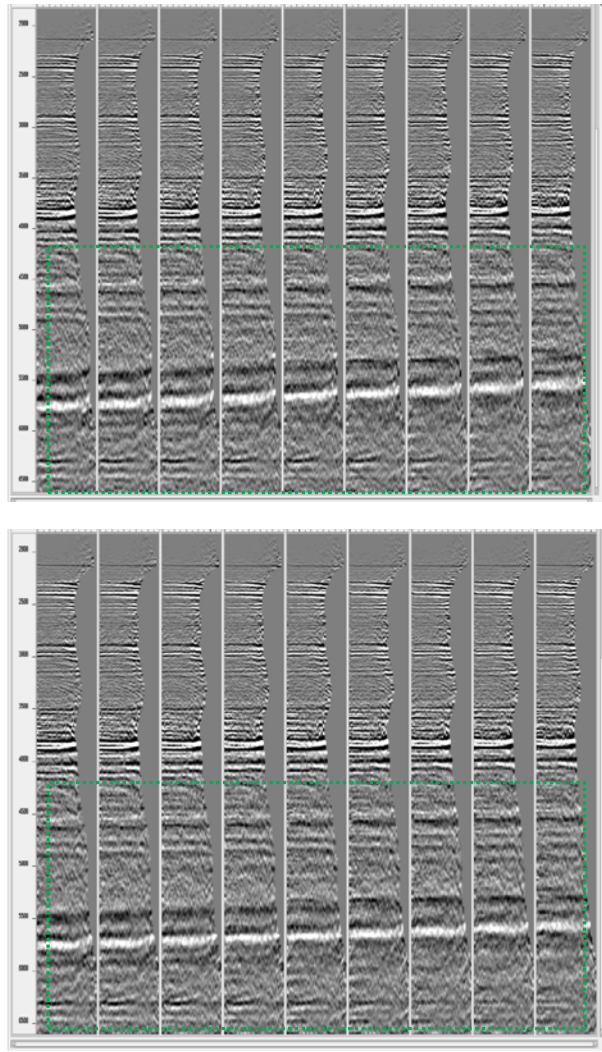

Figure 4: Gathers migrated using the model updated with grid-based tomography (top) and the ones with structurally constrained tomography. The bottom gathers show improved flatness below 4000 m depth.

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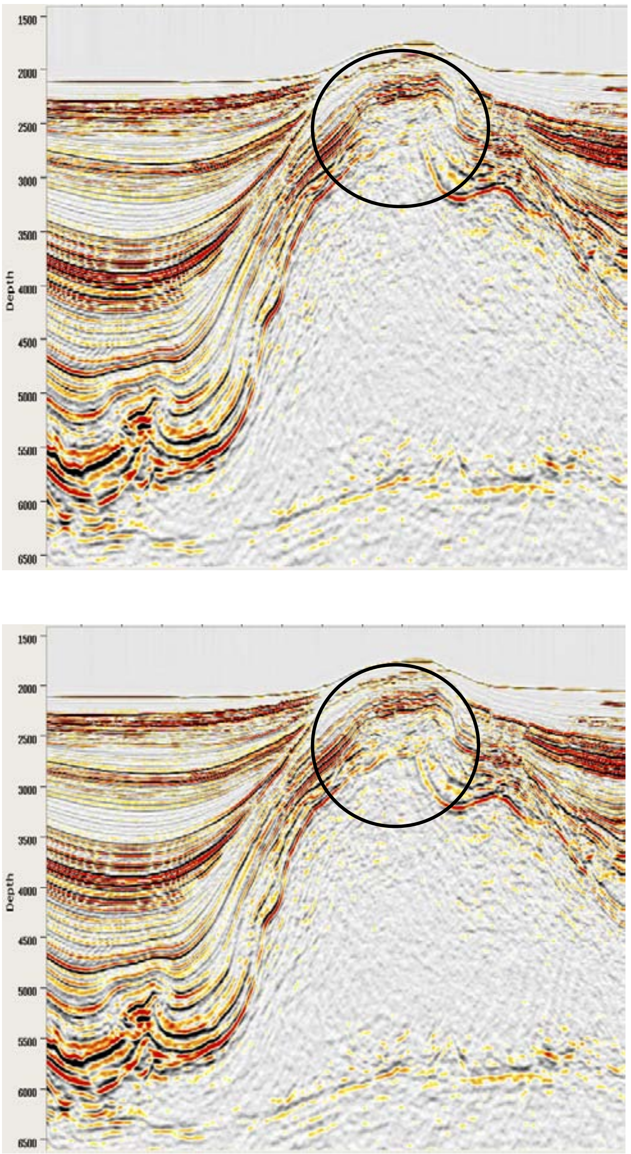

Figure 5: A PSDM stack migrated with a model updated without (top) and with structurally constrained tomography. The oval highlights the improved continuity.

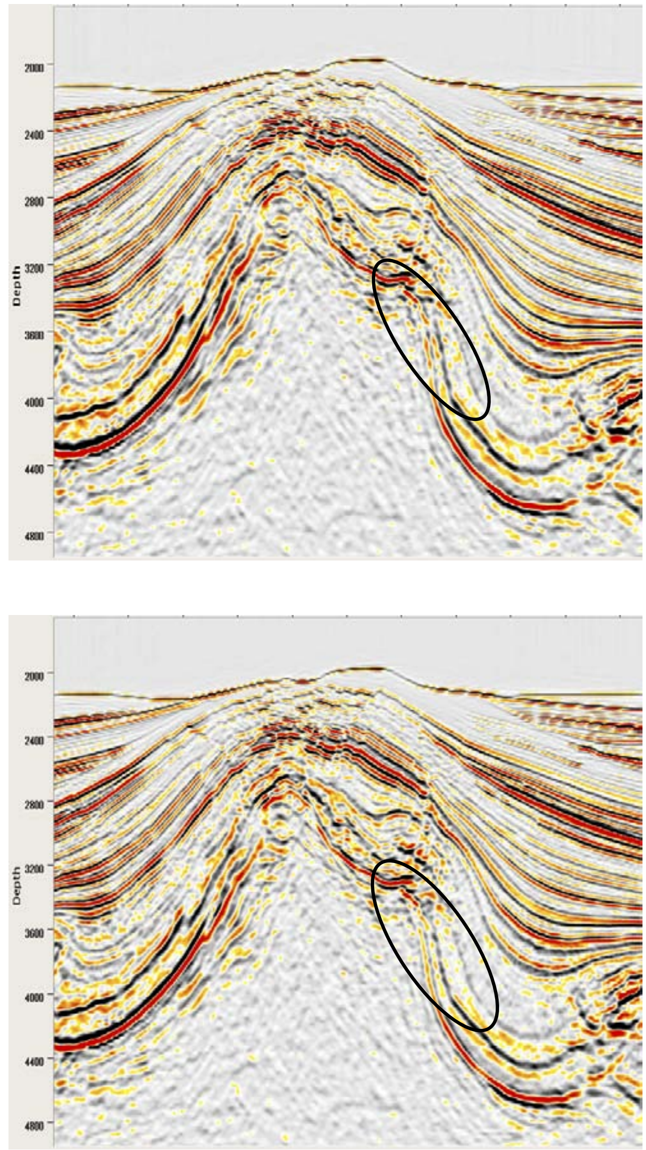

Figure 6: A PSDM stack migrated with a model updated without (top) and with structurally constrained tomography. The oval highlights the improved image.

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EDITED REFERENCES

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