Introduction

We present a case study that uses different methods of addressing a sharp velocity contrast across a major fault boundary in the southwestern Barents Sea. The area under investigation is known as the Hoop Fault Complex. The Hoop Fault Complex divides the Loppa High and the Bjarmeland Platform and lies between 72°50'N, 21°50'E and 74°N, 26°E. It is one of several NE-SW trending lineaments in the Southwestern Barents Sea (Gabrielsen et al., 1990). This depth migration project covered approximately 800 km^2 of a larger 3D survey acquired in 2009.

Figure 1 shows a schematic of the geology found in the area. The first sedimentary section is the Quaternary, characterized by a rather slow velocity trend (1550 m/s). This is followed by a rapid increase in the velocity trend (3500 m/s). This second layer is characterized by the major faults in the area which have a huge impact on the velocity profiles.

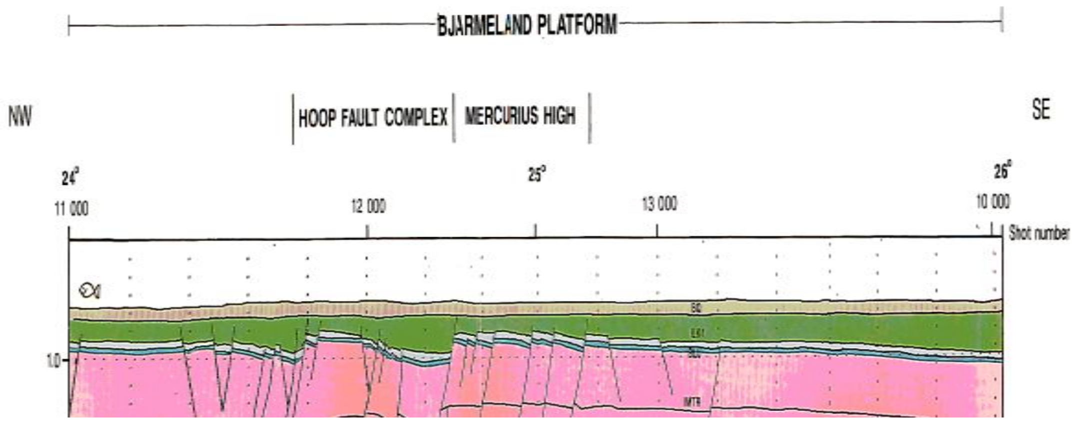


Figure 1 *Schematic of the Hoop Fault Complex (from Gabrielsen et al., 1990)*

If the velocity profile is not modeled correctly across the fault boundary, distortions in the depth of the structure could be introduced. Figure 2 shows a depth slice through the seismic at 1.5 km in depth. Note the major fault that runs through the survey (right third of the display), as well as a series of smaller faults throughout the survey.

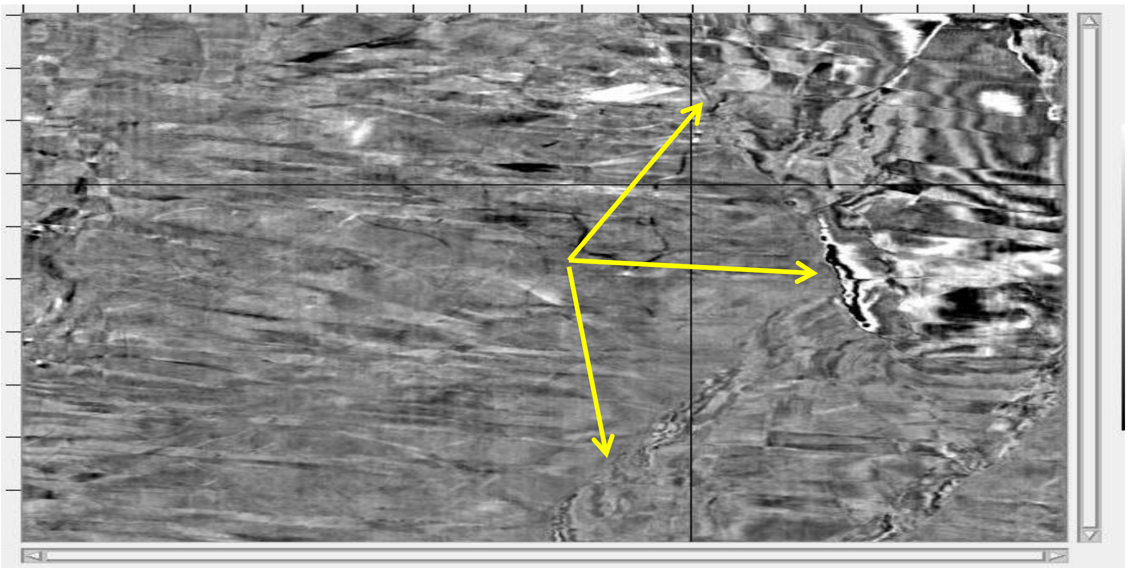


Figure 2 *Seismic depth slice showing major fault system*

Gridded tomography was used to derive the initial updates to the smoothed, starting velocity model. The gridded tomography solution did not completely address the problem of the fault induced velocity contrasts. To improve upon the model, tomography was run which constrained the updates on either side of the interpreted fault structures. Fault constrained approaches have been used in other geological regimes with success (Birdus et al., 2007). Fault constrained tomography yielded a model which was an improvement in the gridded tomography, but we felt more improvements could be attained. To further refine the velocity field horizon constrained tomography updates were used. In this method, errors in depth picked from angle limited stacked seismic images are back-propagated to derive velocity updates.

Method

Conventional Tomography

The initial migration model was built from the existing time migration velocities. They were first converted to depth interval and then smoothed. The addition of an interpreted slow velocity layer was needed to correctly remove the curvature of offset gathers introduced by the slow velocity of the very shallow layer. This layer was too thin for tomography to model. An interpreted horizon (base of the Quaternary) was used to define the slow velocity interval. A constant velocity of 1550 m/s filled the space between the water bottom and the base of the Quaternary.

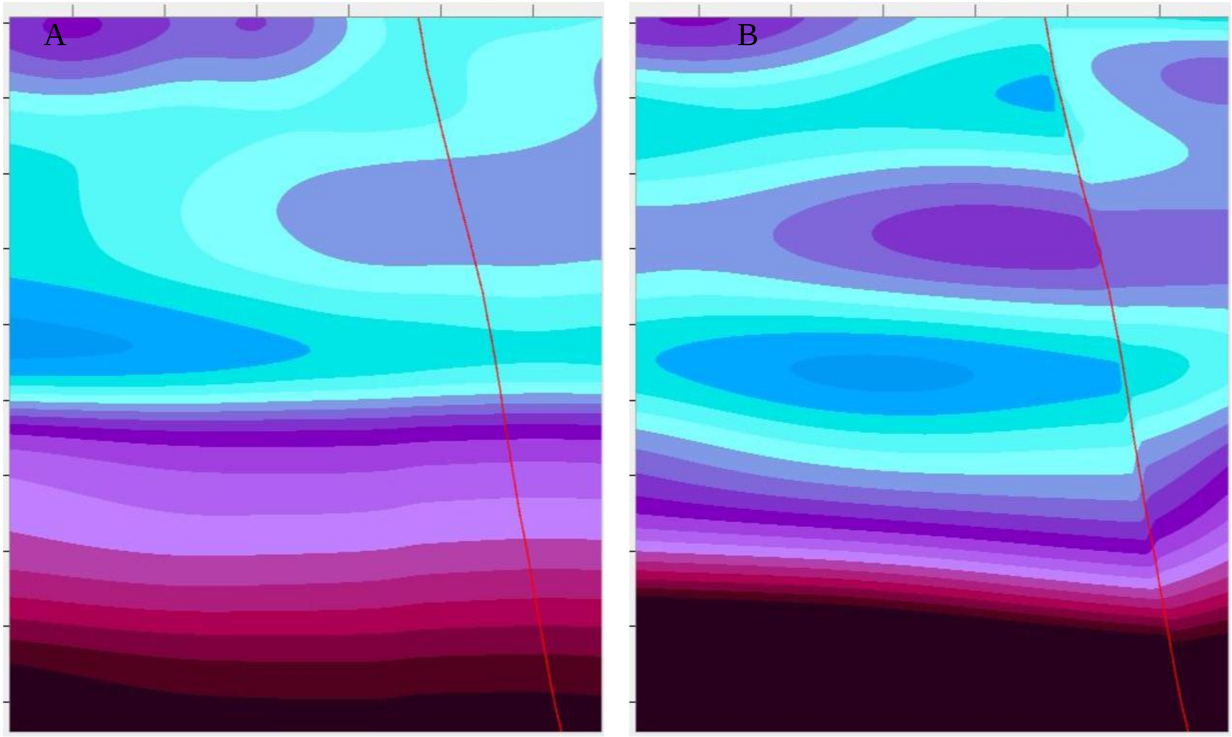
The PSDM gathers were scanned for residual curvature. To remove noise on the gathers an f-k filter as well as an angle mute were applied to the gathers before starting the tomographic sequence. Semblance panels of residual curvature were obtained on a grid of gathers spaced 100 m x 100 m apart. As the data was so shallow only the first 2700 m of data was used in this analysis. 3D constrained automatic picking of the semblance panels was done. The resulting residual curvature values, along with the inline and crossline dip information were used to derive the tomographic update. The derived delta velocity values were added back to the starting velocity model to generate the updated velocity field. Two iterations of standard gridded tomography were done, each improved somewhat on the previous results.

Fault Constrained Tomography

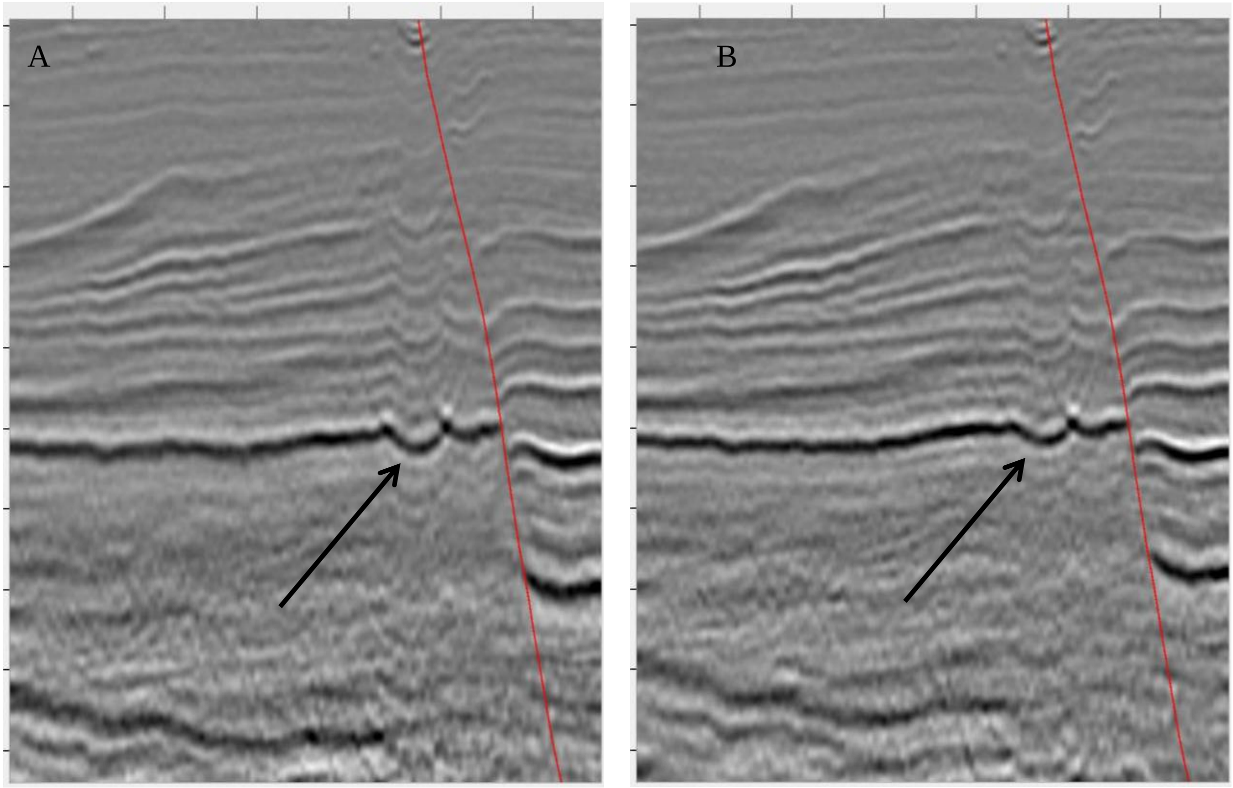
While there were improvements with each iteration of tomography, it was felt that a method which more explicitly honored the fault plane would be required for further improvement. To this end, a fault constrained tomography was done. Residual curvatures were made as before but the velocity model was divided into two half spaces separated by an interpreted fault. Updates for each half space would be done separately and updates would be constrained to either side of the fault. Figures 3A and 3B show the velocity model before and after fault constrained tomography. Figures 4A and 4B show the image improvements before and after the fault-constrained tomography. We had reduced the sags below the fault plane, however, further improvements are still needed.

Horizon Constrained Tomography

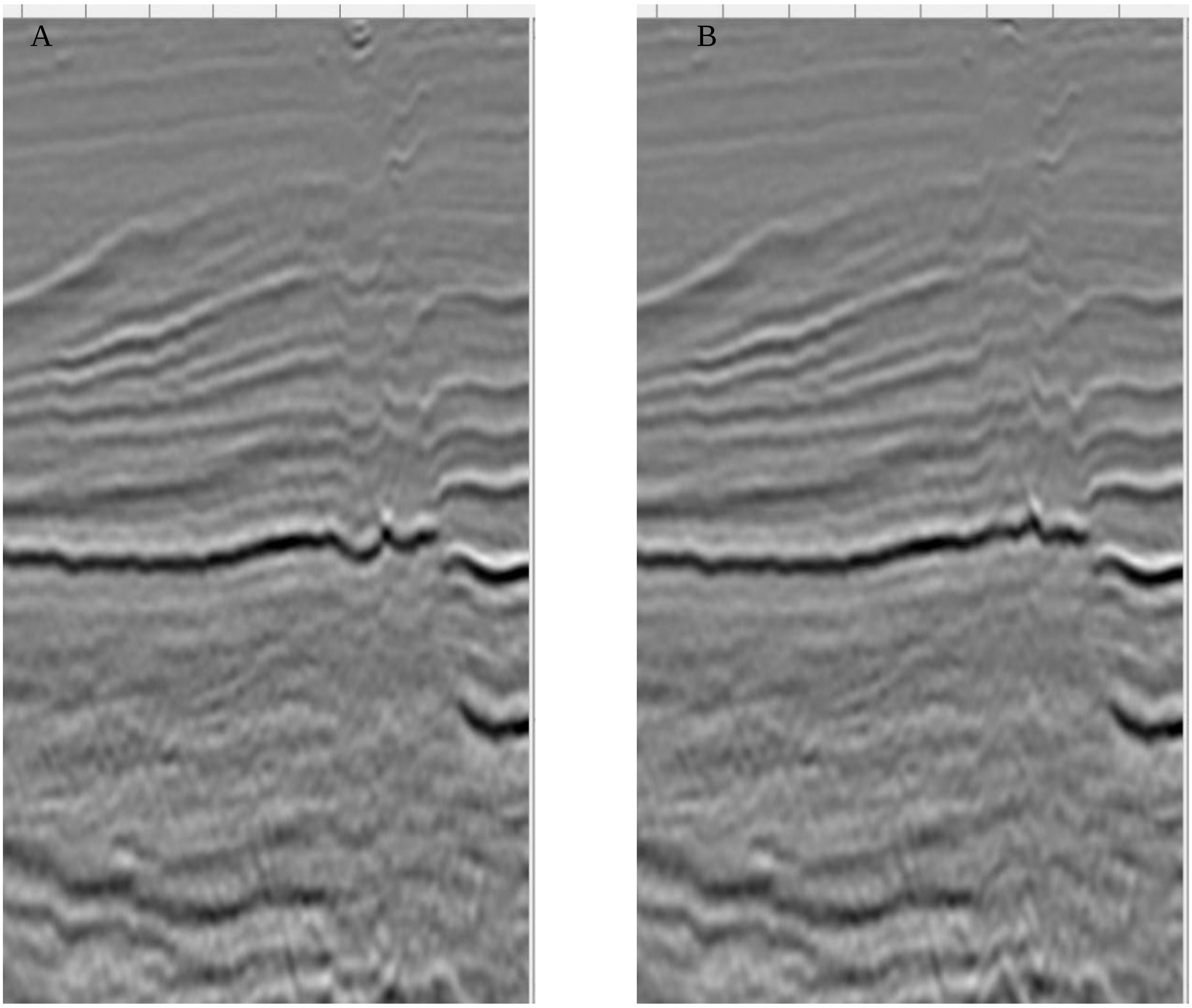
The results of fault-constrained tomography showed some improvement, but the low velocity sag induced by the velocity contrast across the fault remained. In order to better address this problem, a horizon constrained tomography was implemented. Residual depth delays were picked explicitly from the stacked seismic data after analysis on different angle ranges. The depth delays were used to generate a tomographic update that would be constrained by both the horizon and the fault plane. Figures 5A shows the result of fault constrained tomography. Figure 5B shows the results after incorporating horizon constrained tomography . The fault sag has clearly been improved. Structures are more geologically sensible.



***Figures 3A and 3B:** Velocity profiles before and after fault constrained tomography*



Figures 4A and 4B*: Seismic sections before and after fault constrained tomography*



Figures 5A and 5B: *After fault constrained tomography and after horizon constrained tomography*

Conclusions

The Hoop Fault complex in the Barent Sea presented an imaging challenge to accurately model the sharp velocity contrast across the major fault. The depth sag introduced by this contrast was addressed by an interpretation based approach which uses faults and seismic horizons as constraints to tomography. The integration of geological interpretation and seismic tomography has improved the interpretability and the quality of seismic images in the area.

Acknowledgements

We would like to thank TGS for permission to present this work.

References

Gabrielsen, R., Faerseth, R., Jensen, L., Kalheim, J., Rus, F., 1990, Structural elements of the Norwegian continental shelf, Part I: the Barents Sea Region, NPD-Bulletin No 6

Birdus, S., 2007, Removing fault shadow distortions by fault constrained tomography. 77th Annual International Meeting. SEG, Expanded Abstracts, 3039-2042