Imaging the Hoop Fault Complex via horizon and fault constrained tomography

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Summary

The Hoop Fault complex in the Southwestern Barents Sea presents an imaging challenge to accurately model the sharp velocity contrast across a major fault boundary. Improperly accounting for this velocity discontinuity would lead a poorly focused image and false structures. We present an approach that leverages interpreted fault planes as well as marker horizons to drive and constrain tomographic velocity updates.

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 an extremely slow velocity trend (1,550 m/s). This is followed by a rapid increase in the velocity trend (3,500 m/s). This second layer is characterized by the major faults in the area which have a huge impact on the velocity profiles.

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.

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 driven 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

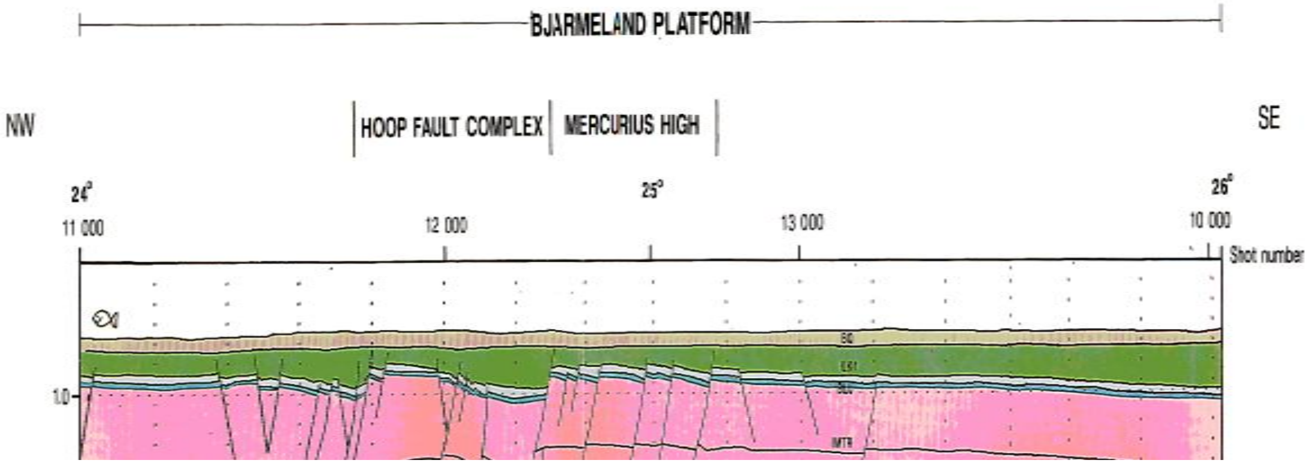

Figure1: Schematic of the Hoop Fault Complex (from Gabrielsen et al., 1990)

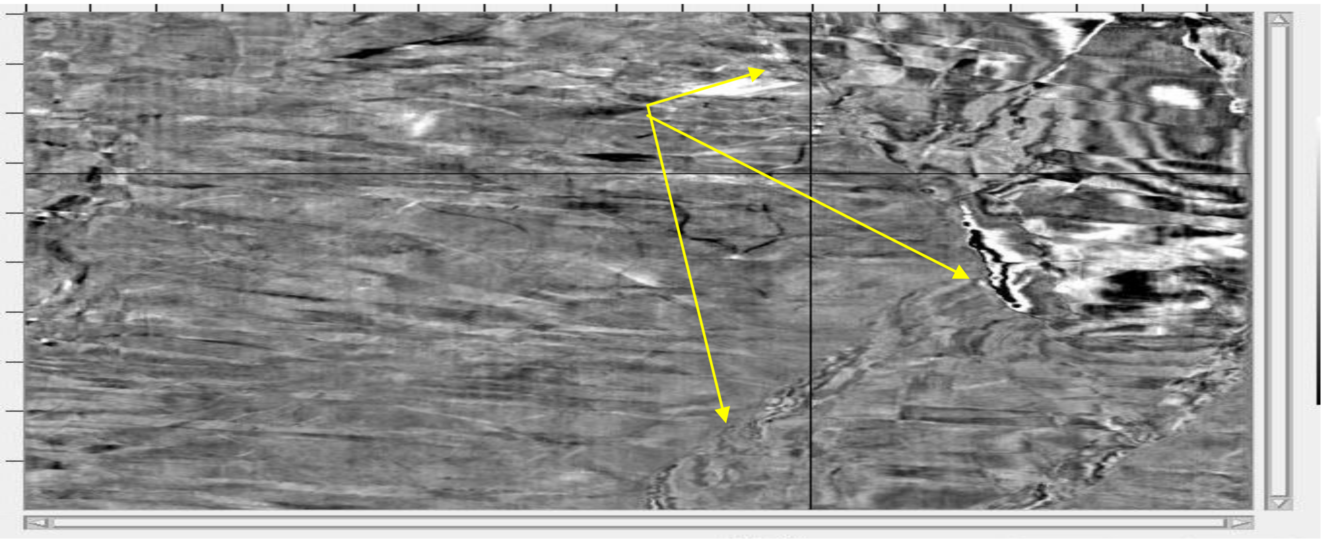

Figure 2: Seismic depth slice at 1.5 km showing major fault system

thin for tomography to model. An interpreted horizon (base of the Quaternary) was used to define the slow velocity interval. A constant velocity of 1,550 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 was applied. Additionally an angle mute was applied to the gathers before scanning for semblance.

Semblance panels of residual curvature were obtained on a grid of gathers spaced 100 m by 100 m apart. As the data was so shallow only the first 2,700 m of data were used in this analysis. Three-D 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 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 velocity models before and after fault constrained tomography. Figures 4A and 4B show the image improvements before and after the fault-constrained tomography. We 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. Figure 5A shows the result of fault constrained tomography. Figure 5B shows the result after incorporating horizon constrained tomography. The fault sag has clearly been improved. Structures are more geologically sensible.

Hoop Fault Complex – Constrained Tomography

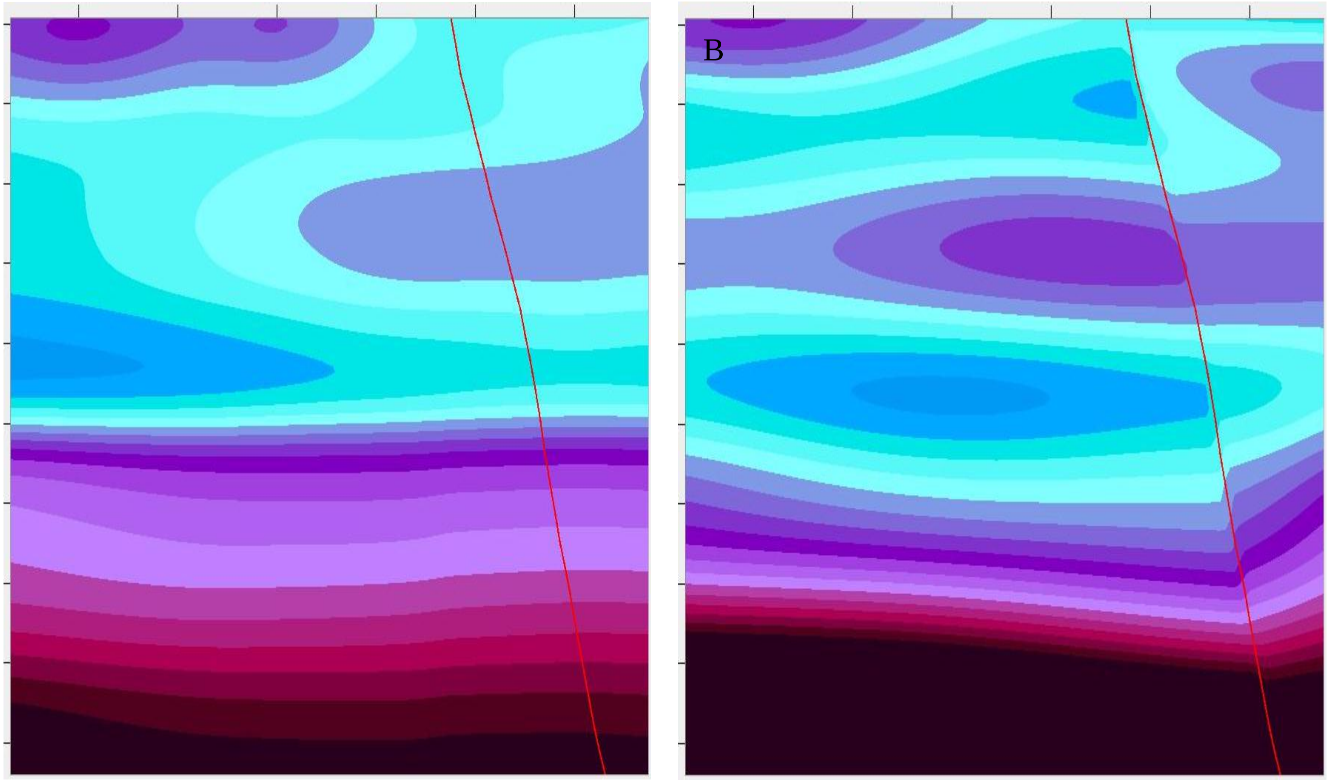

Figure 3: Velocity profiles before (A) and after (B) fault constrained tomography

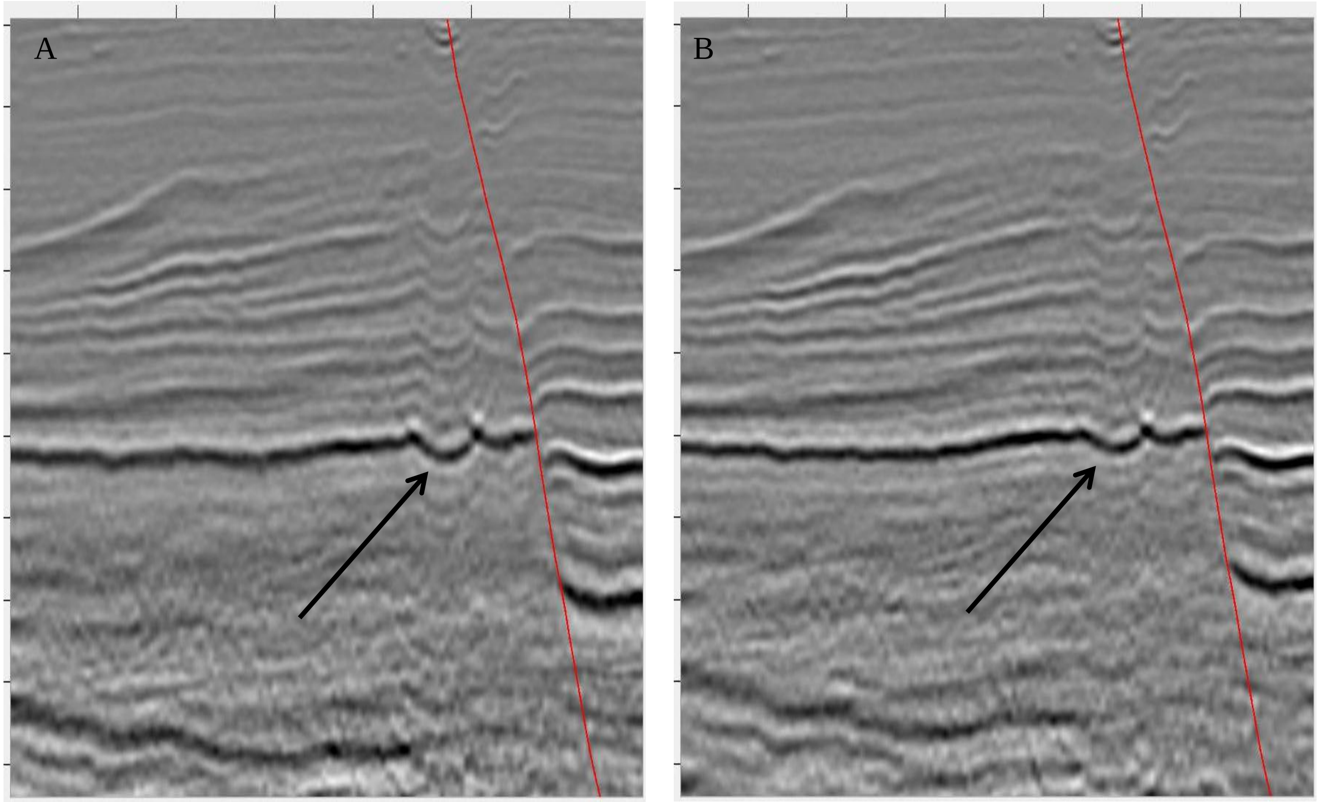

Figure 4: Seismic sections before (A) and after (B) fault constrained tomography

Conclusions

The Hoop Fault complex in the Barents Sea presented several imaging challenges. A thin slow velocity layer, followed by a major fault with a sever velocity discontinuity introduced false dips in the structure. This contrast was addressed by an interpretation based approach which used 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

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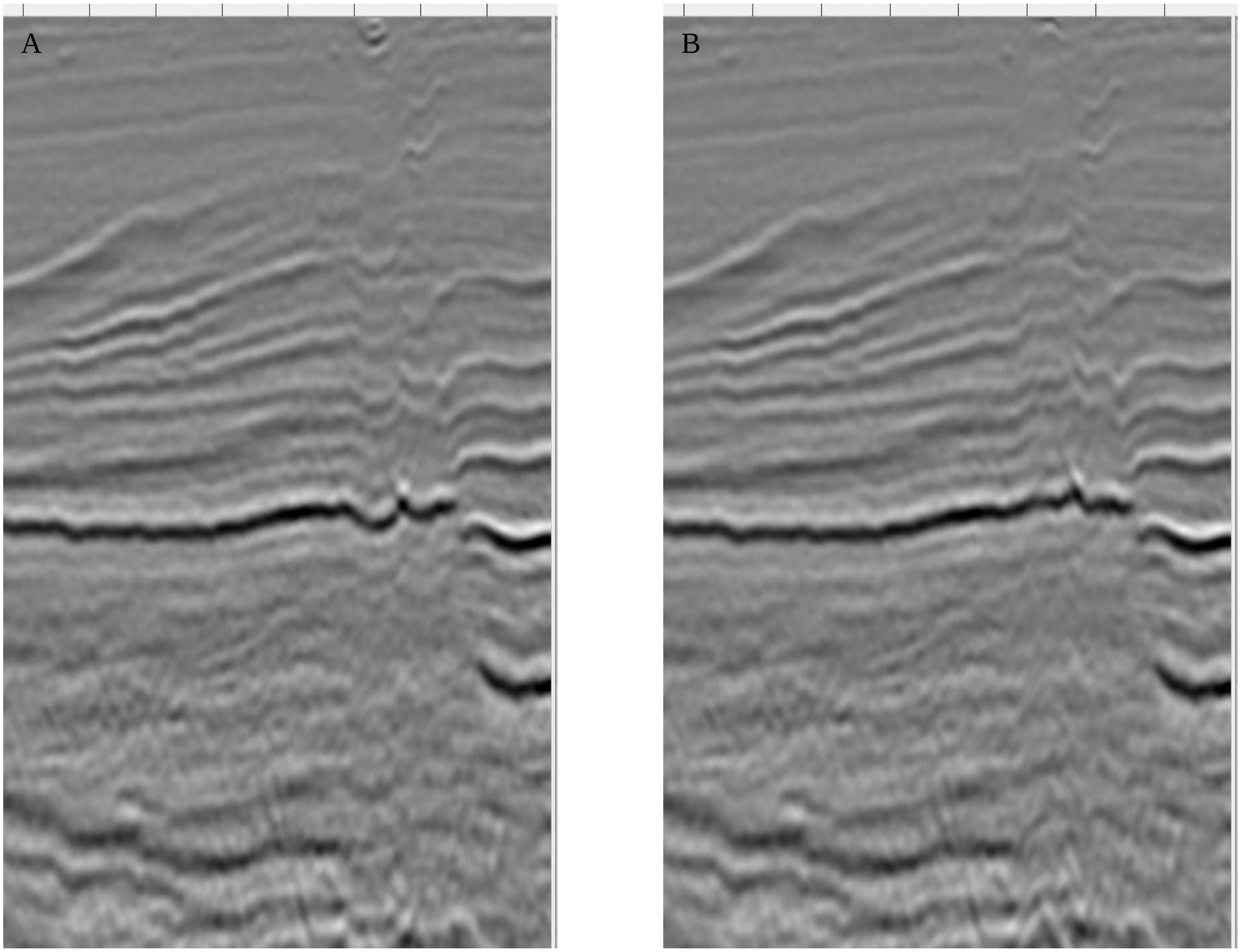

Figure 5: Seismic sections before (A) and after (B) horizon constrained tomography

EDITED REFERENCES

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