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A FWI Velocity Model Building Workflow across the Senja Ridge in the Norwegian Barents Sea

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Summary

The Senja Ridge is a structurally complex high located in the western margin of the Norwegian Barents Sea. A two stage velocity model building approach is implemented, utilising diving wave FWI and high resolution image guided tomography. Shallow gas clouds and shallow channels are resolved with the FWI updates, deeper structures including basement horsts within the Senja Ridge and the flanks of salt diapirs are solved with the tomographic updates.

Introduction

Acquired in 2017, the Carlsen 3D survey images the structurally complex Senja Ridge and surrounding salt provinces of the Tromsø and Sørvenstsnaget basins in the western margin of the Norwegian Barents Sea.

PSTM processing of the dataset has imaged previously unresolved complex structures within the Senja Ridge, shallow gas anomalies and channel features are observed across the survey with the 3D migration also better positioning the salt energy. These identified geological features immediately point to a PSDM processing solution being required, with velocity model building identified as the key stage in correctly imaging the structures.

We discuss the key velocity-model building steps.

Method

The survey is in relatively shallow water, resulting in limited offset coverage of the shallow events prior to the energy turning critical. The shallow gas clouds and channel features that are identified across the survey will also introduce potential distortions into the velocity field unless correctly handled at the initial stage. Tomography techniques will struggle to resolve the shallow anomalies, so a two-stage approach, utilising diving wave FWI and image guided tomography is implemented.

An initial pass of tomography is run using the smoothed PSTM velocity model, this is calibrated to the wells within the survey area. Diving wave FWI, using the calibrated velocity model as an input function, is used to build a detailed shallow velocity model down to a depth of approximately 1 km, based upon ray coverage analysis, where the salt bodies or the Senja Ridge structure is shallower that 1km, the FWI update is masked to exclude these high velocity areas.

The first step of the FWI processes is to invert for epsilon, this is converted to a delta using a ratio derived from the three wells that cover the survey area. Velocity updates are run using this anisotropy field, the inversion is run up to a maximum frequency of 12 Hz. Image-guided smoothing (Mao et al., 2016) and κx-κy footprint removal are incorporated into the workflow to separate the acquisition footprint from the geologically driven variations in the velocity model. The results of the initial FWI update are presented in Figure 1.

High-resolution image-guided tomography is used in a top-down, layer-stripping approach. Delta and epsilon anisotropy parameters are estimated at the three well locations; base-Pliocene and base-Cenozoic horizons are used to constrain the subsequent extrapolation across the survey area. All subsequent migrations for tomographic model building are run as TTI.

Tomographic updates are initially constrained to the postsalt sediments in the shallow, the Senja Ridge and any shallow basement structures are masked out to prevent the high velocities leaking into the sedimentary trend. Salt bodies are interpreted and flooded iteratively as required followed by a basement velocity stamp, including the Senja Ridge itself. A further two iterations of tomography are used to finalise the velocity model. The total velocity model building results are presented in Figure 2.

Conclusions

The complex structures contained within the Senja Ridge and surrounding salt provinces are addressed using a two-stage velocity model building approach. Diving-wave FWI is utilised to solve the shallow localised velocity anomalies, specifically related to the shallow gas clouds and channel features. High resolution image-guided tomography is used to update the deeper section, resolving structures both within and adjacent to the Senja Ridge, alongside constraining the salt bodies within the surrounding sedimentary basins.

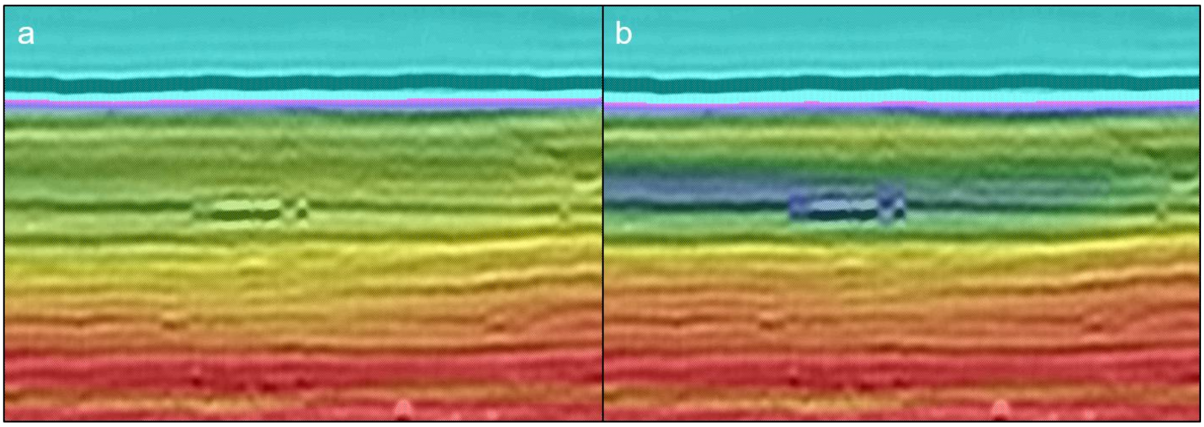

Figure 1 *(a) Input velocity field to FWI. (b) Updated velocity field after FWI. Velocity slowdown associated with shallow gas anomalies are represented within the velocity update.*

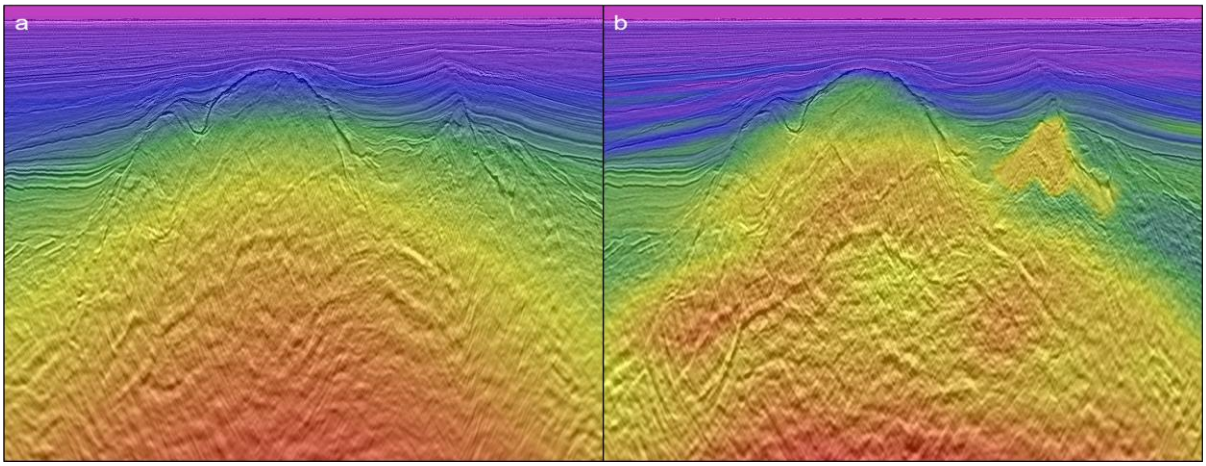

Figure 2 *(a) Initial velocity model prior to depth velocity model building, (b) final velocity model following FWI and high-resolution image-guided tomography.*

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