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Multi-Azimuth anisotropic tomography and PreSDM of a North Sea streamer survey

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***Keywords**: preSDM, MAZ, OVT, tomography, OBC*

Introduction

In conventional 3D seismic data processing, we typically sort the data in a number of 3D common-offset volumes, each offset volume comprising a limited range of offsets, but in doing so, we bin across any variation in azimuth that may exist in the recorded data (Williams and Jenner 2001). Ideally, it would be best not to bin across azimuth at all, and to work with fully sampled offset vector tile (OVT) data, as was demonstrated for OBC data over this field last year (Valler et al., 2012). One of several compromise solutions to full azimuth-offset sampling is the multiazimuth (MAZ) acquisition approach, where we collect a set of mono-azimuth surveys, each shot with a different orientation, and proceed to process each of these data sets in tandem, leading up to a MAZ velocity model building tomographic solution.

The study area

The field straddles the UK-Norwegian border, with the main reservoir at about 4km depth comprising tilted Jurassic fault blocks. These are overlain by a complex Tertiary and Cretaceous overburden with gas charged zones causing rapid lateral velocity variations, as well as a thin high velocity chalk layer and anisotropic Lower Cretaceous units between the chalk and the main target. The field is covered with several vintages of 3D seismic data, including a three azimuth MAZ marine streamer survey (Figure 1), and a full azimuth OBC multicomponent survey.

The main problem in this area is the poor quality of seismic data, due primarily to: low impedance contrasts in the PreCretaceous sequences, a large number of small faults, and minimal penetration of seismic energy below the Base Cretaceous level. Hence, the challenge is to better image the complex fault system at the Frigg (~1800-2000ms) and Upper Jurassic (~3200-3400ms) reservoir levels.

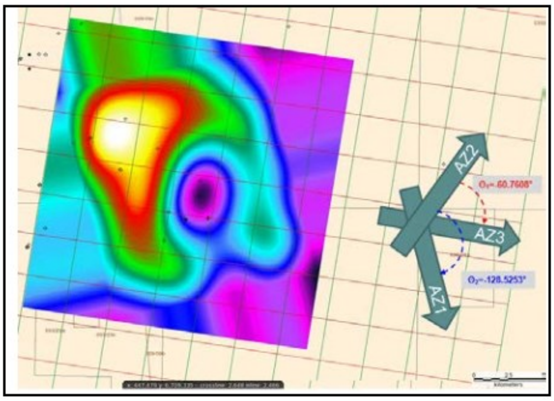

Figure 1: the directions of the three streamer surveys used in this study and a velocity model slice at 3km depth through the initial model.

MAZ tomography

Tomography updates the velocity model along raypaths, thereby taking into account the actual propagation path in the media. Conventional tomography measures velocity error at a CMP location for the available offset range, but having binned all azimuths into the same offset gather, hence no directional azimuthal dependence of velocity is retained (the TTI aspect is dealt with, but not azimuth itself). In the MAZ and OVT approaches, we preserve any observed azimuthal dependence on velocity, thus enabling the tomographic back-projection to better

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resolve localised overburden heterogeneities (e.g. Jones, 2012). The basic tomographic engine remains the same (all tomographic solvers back-propagate the observed error along ray paths) but for mono-azimuth tomography, we are essentially telling the solver that velocity error is the same for all azimuths at a given CMP location, which is an unnecessary restriction on its inherent abilities.

The CRP gathers were output on a 50m*50m grid for each iteration, and the tomographic update was solved for a 300m*300m*80m cell size. In total, four iterations of MAZ tomography were performed (remember that we were starting from a reasonable preSDM model from a previous study over the area, so perhaps fewer iterations than usual were required).

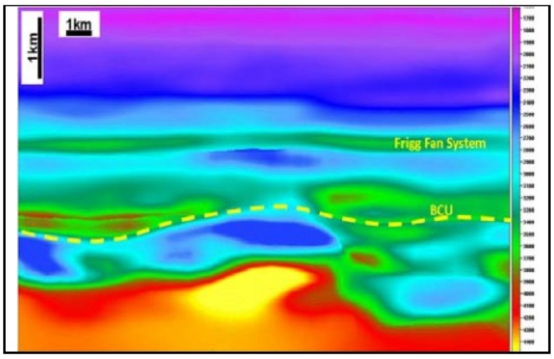

Figure 2: velocity model resulting from single azimuth tomography (the conventional approach)

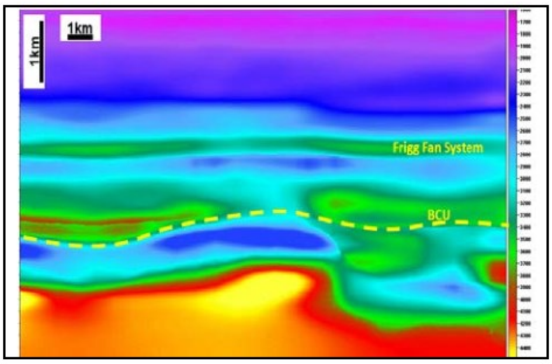

Figure 3: velocity model resulting from MAZ tomography: there is less apparent velocity variation ot reservoir level.

Results

Figure 2 shows a tomographic solution using the conventional approach of inverting only one azimuth class, whereas Figure 3 shows the corresponding MAZ tomography result. There appears to be more velocity variation in the mono-azimuth result, indicating that it is trying to reconcile unresolved local overburden heterogeneity incorrectly by assigning more velocity variation to the deeper structure. This is particularly obvious in the extent and shape of the low-velocity zone beneath the Chalk and in the more gentle varying velocity at Jurassic/Triassic levels.

Figures 4 and 5 compare a final image using one and three azimuths respectively. The main differences are a reduction in noise and a slight improvement at the top of the structure, improved continuity at Lower Cretaceous (Trygvasson) level and slightly better definition of the Jurassic fault blocks. The latter is achieved by better imaging of the bedding reflections, the fault planes being non-reflective.

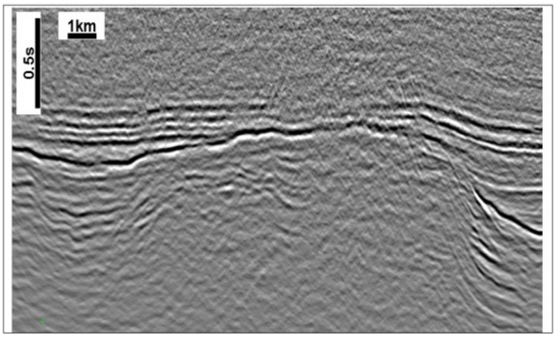

Figure 4: final iteration image from a single azimuth, converted to time

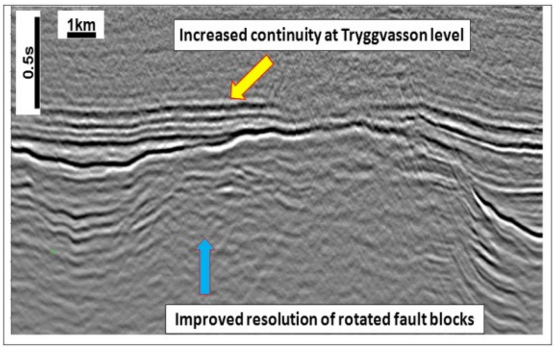

Figure 5: final iteration image combining all three azimuths, converted to time

Discussion

It is well understood that tomographic inversion is itself not inherently limited to ignoring azimuthal variation in velocity error. It is only the limitations in data sampling that limit our pre-processing and oblige us to bin the data across azimuths into common offset bins. Performing azimuth sectored MAZ processing and preserving azimuth information requires handling of increased data volumes, but does offer the possibility of enhanced resolution of overburden heterogeneity, and better imaging of deep targets.

Acknowledgements

Our sincere thanks to Total Norge and partners for permission to show these results, and to ION-GX Technology for permission to publish this work. We are also very grateful to Ian Jones for his hands-on support in producing this paper.

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