Optimum Stratigraphic Imaging with 3D Anisotropic Prestack Depth Migration

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Summary

We compare the results of applying 3D anisotropic prestack depth migration (3D ADM) to Southern Alberta plains seismic data with the industry-standard time processing approach. Until now, plains seismic data have not been commonly processed using 3D ADM because it has been argued that time migration handles vertical heterogeneity and that depth migration is not necessary due to the near-horizontal geological layering and lack of structural complexity. We found that the 3D ADM algorithm gave a superior image of the target beach barrier bar. The improvements in the focusing of the cross-cutting channel edges and the flanks of the beach barrier bar will result in better well placement, volumetric estimates and ultimate recovery.

Over 50 wells were available to constrain the depth-migration velocity model, and also to evaluate the final depth volume. The average mistie of the final migrated volume at the target zone was approximately 2 metres. Any individual well has a mistie of up to +/- 5 metres.

3D anisotropic prestack depth migration has the potential to become the migration of choice for the processing of plains data over development fields where better resolved, accurate depth volumes will permit more aggressive drilling programs.

Introduction

It is common practice to process Southern Alberta plains data in the time domain, interpret and then convert the interpretation to depth, tying the available wells. Depth conversion is necessary to verify the structure, which is then used for planning well trajectories, volumetric calculations and constructing reservoir models. There are several ways to depth convert the interpretation, each with their own limitations and pitfalls. Depending on the method used, critical features such as channel flanks may take on different geometries.

An alternative, one-step approach is to anisotropically depth migrate the pre-processed seismic gathers. Because this approach is relatively new, EnCana provided Veritas with a 24 km^2 Southern Alberta plains test volume for reprocessing using 3D ADM and comparison with the 1999 time processing. The objectives were to improve the overall image of the target zone and to get the most accurate depths possible.

Method

Most time migration algorithms are based on travel times derived from simple analytic expressions, typically based on a straight ray assumption and RMS type velocities. 3D prestack depth migration more accurately handles spatial velocity variations by ray tracing through an interval velocity model. ADM further compensates for the internal anisotropy of the layered clastic strata caused by their deposition and composition, based on the assumption that the tilt of the symmetry axis is normal to the dip within the strata. In areas of structural complexity, such as the Canadian foothills, 3D ADM is the migration algorithm of choice as it delivers the best image in terms of focussing and lateral positioning (e.g. Vestrum *et al.*, 2003). In principle, this should also be true in any situation where velocity varies spatially. We applied this technique to plains data and obtained a better image than that produced by less accurate time migration algorithms. Figure 1 shows a volume slice from the 3D ADM volume.

During 3D ADM processing, a velocity model is built with boundaries that follow geological horizons. An estimate of local dip and Thomsen's parameters, δ and ε, which describe how the velocities change with angle of wavefront propagation through the bedding layers (Thomsen, 1986), are defined at every grid point. An iterative process of model building and migration analysis, using proprietary interactive tomography software, is performed until the depths of migrated seismic events match depths from well tops and the migrated image gathers are flat.

The final 3D ADM stack tied the available tops well. The tie was analyzed by differencing horizons picked by snapping to the seismic, and tops supplied by EnCana. The average mistie of all horizons down to the deep Stettler horizon was less than 1 sample (4m). The seismic character matched synthetics generated using a zero degrees Ormsby wavelet (8/12 - 70/90 Hz), as shown in Figure 2.

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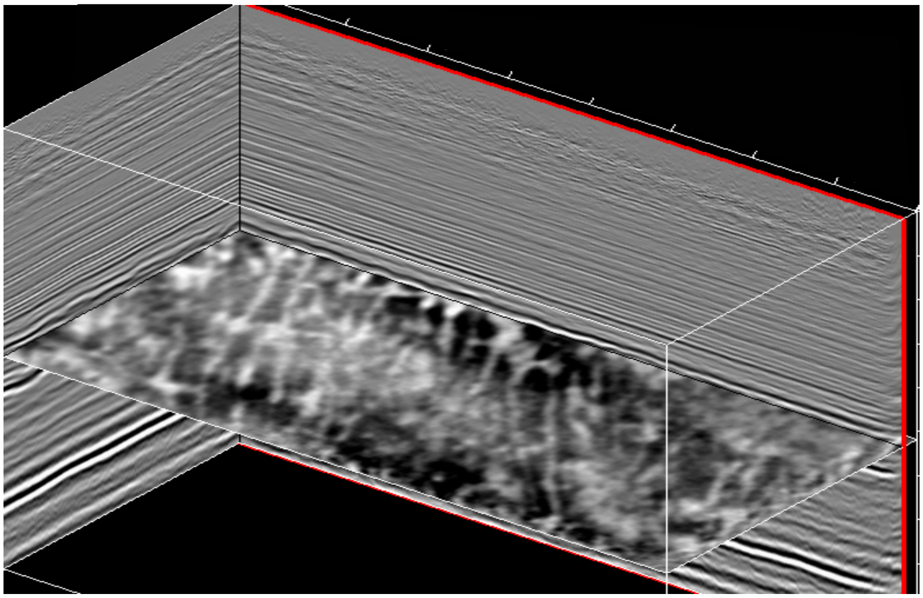
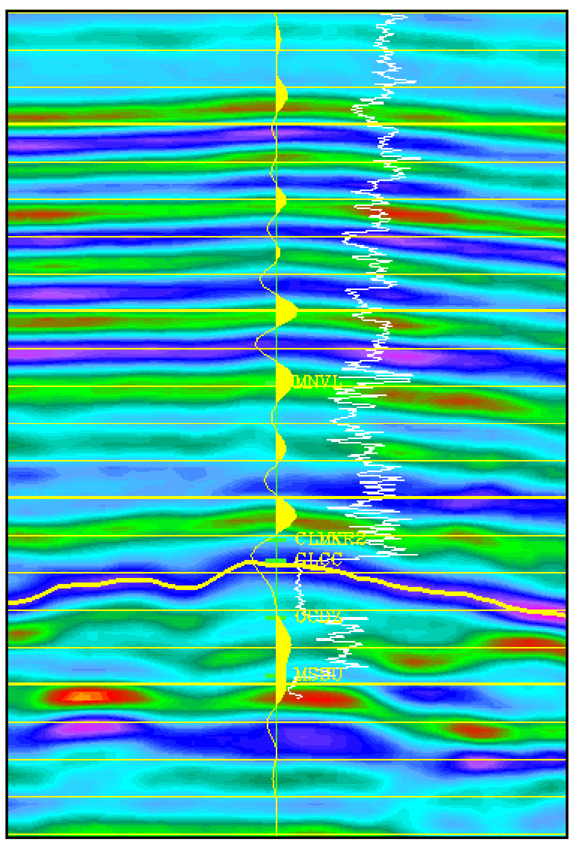


Figure 1. Depth slice from final 3D ADM stack.

Figure 2. Depth migration matches synthetic generated from well log.



Migration Comparisons

Comparison between the 1999 DMO-poststack time migration and the 3D ADM stack are given in Figures 3 - 5. A channel is examined in Figure 3. The channel flanks are clearer in the depth image than the time image. The amplitudes on either side of the channel are more continuous. In Figure 4, a timeslice and a depth slice are compared at a depth of 950m below datum. To help this comparison, a prominant shallower horizon was flattened in both datasets.

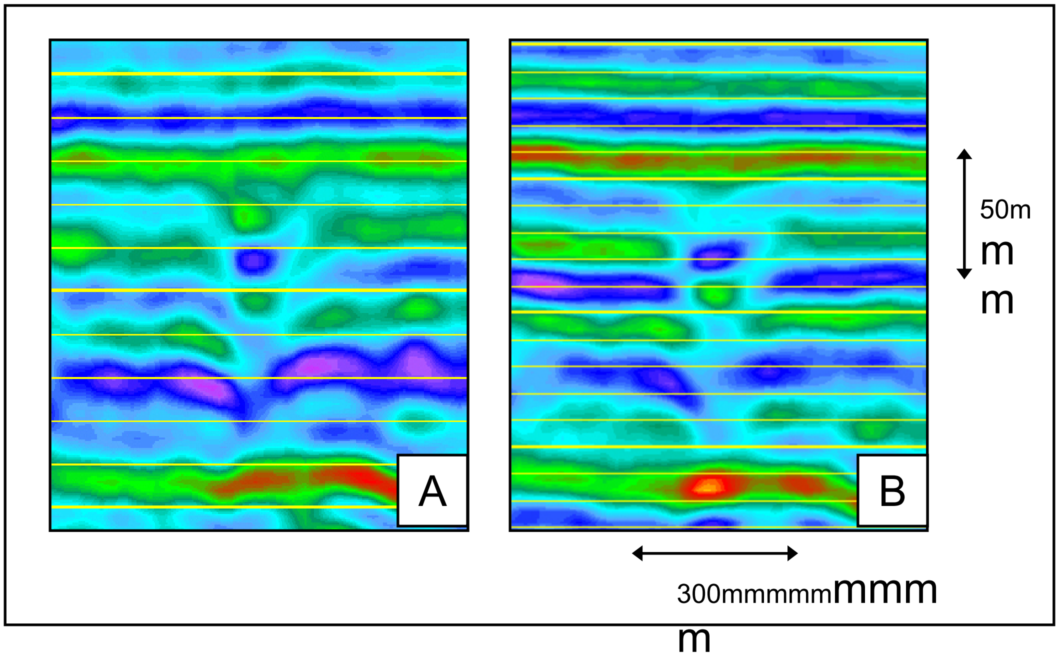
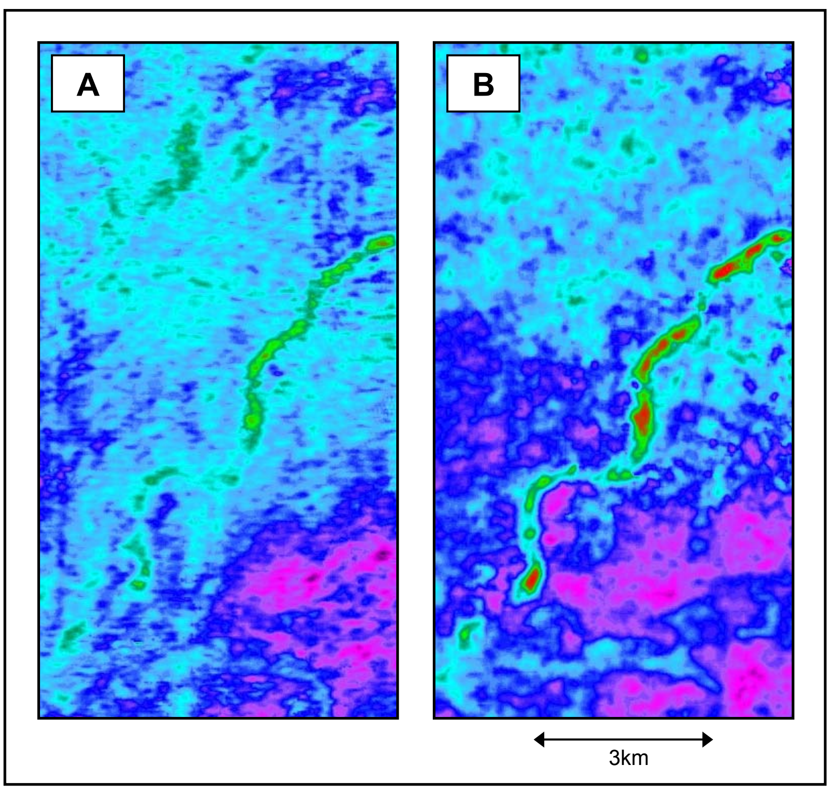


Figure 3. Comparison of (A) time migration and (B) prestack depth migration across channel.

Figure 4. Comparison of (A) time migration slice and (B) prestack depth migration slice.



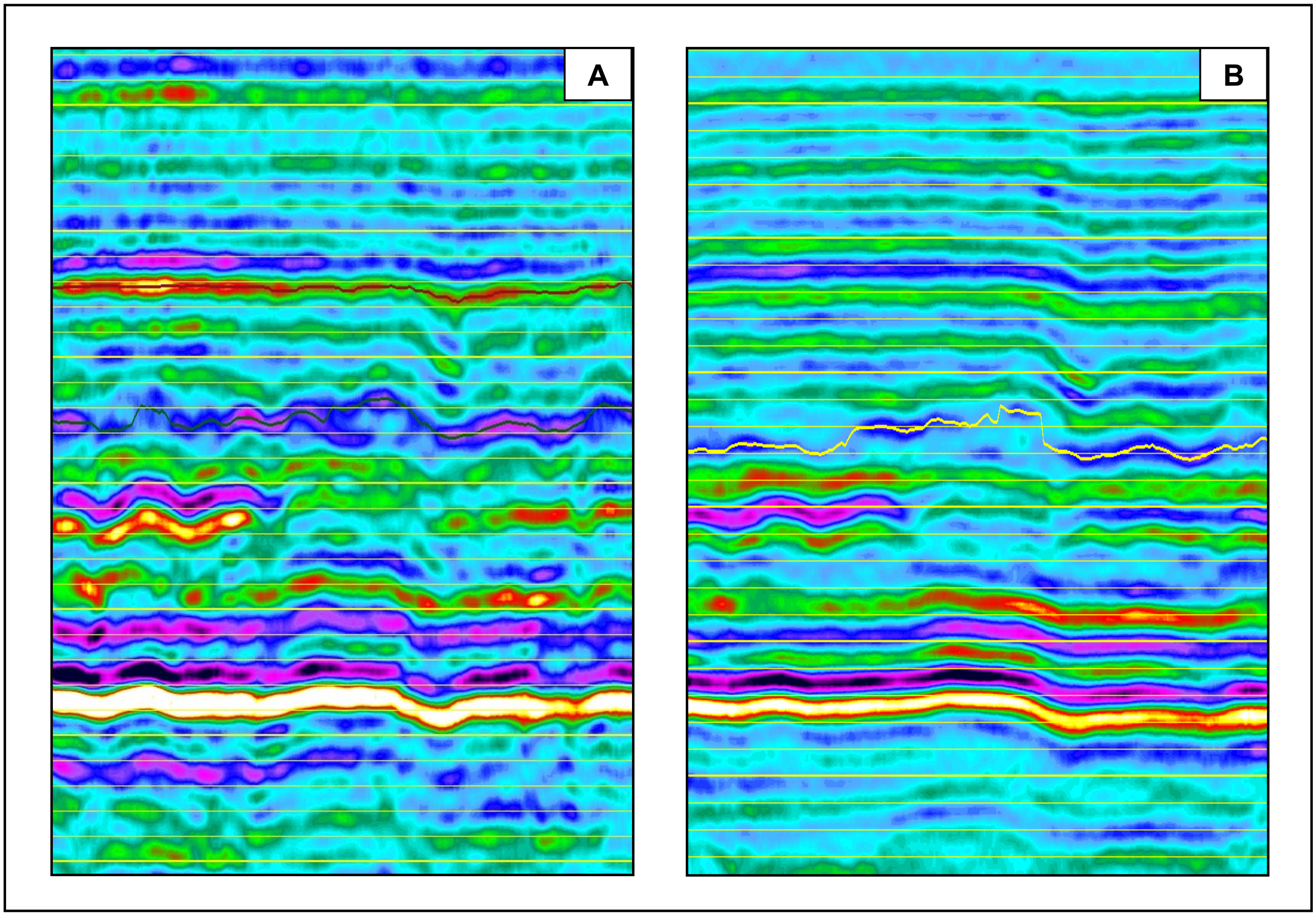


Figure 5. Comparison of (A) time migration and (B) prestack depth migration stretched to time. On this line, the reflector amplitudes and phase are significantly more continuous on the ADM volume.

Conclusions

This project tested the value of applying 3D anisotropic prestack depth migration to a Southern Alberta dataset. The results are better than the original time processing. Because the ADM algorithm properly handles wavefield propagation effects through a spatially variable velocity field, the imaging of the channel and other stratigraphic features are sharper and event amplitudes are more consistent and continuous than were achieved in the time domain. Depthing is also more accurate as imaging velocity analysis, seismic interval transit times and well tops are directly integrated during the process. Here the migration velocity model was well constrained due to the large number of well penetrations. Less work is required at the interpretation stage with a depth migrated volume, and a more focussed image has the potential to improve the placement of wells. In the Western Canadian Sedimentary Basin, the availability of a vast well log data base and the shift towards more detailed exploitation planning should see expanded use of ADM as the imaging tool of choice.

Acknowledgement

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