Depth Imaging through Surface Carbonates: A 2D example from the Canadian Rocky Mountains

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Summary

Depth imaging was conducted on a 2D line acquired over outcropping carbonates in the Canadian Rocky Mountains. Through integrated velocity model biulding, global velocity model refinement and careful consideration of migration parameters, a plausible depth section was achieved that was an improvement over time migration.

Introduction

Lawton (2007), Vestrum et al. (2004) and Gray et al. (2002) overviewed the challenges and strategies to improve seismic imaging in structurally complex environments such as the Canadian Rocky Mountains. Prestack depth migration (PSDM) is necessary to resolve complex structures with lateral velocity variations. The integration of all available sources of geophysical and geological data in consultation with interpreters is the key factor to develop geologically realistic velocity models for optimizing seismic imaging using PSDM. Many case studies in the Canadian Rocky Mountains (e.g. Isaac 2007, Robinson et al., 2006 and Charles et al., 2006) demonstrate the encouraging outcomes of 2D or 3D PSDM using either an isotropic or anisotropic velocity models coupled with geologic constraints. Kirtland Grech (2002) and Newrick (2004) summarized and analyzed detailed processing sequences incorporating both time processing and depth imaging in order to achieve plausible depth migration results in thrust-belt environments. However, to date, it is still a challenge for the seismic method to image subsurface structures through the surface carbonates in the Canadian Rocky Mountains.

Following previous work on time imaging on a 2D seismic line (Hua and Lawton, 2007), depth imaging was conducted in an attempt to improve subsurface imaging beneath outcropping carbonates in mountainous terrain as indicated in Figure 1. Figure 2 shows the image after prestack time migration (PSTM) that did not produce and interpretable section below the surface carbonates. Velocity pull-up on deeper events is also apparent.

Time pre-processing procedures with careful quality control was undertaken prior to subsequent PSDM processing from topography using a Kirchhoff approach.

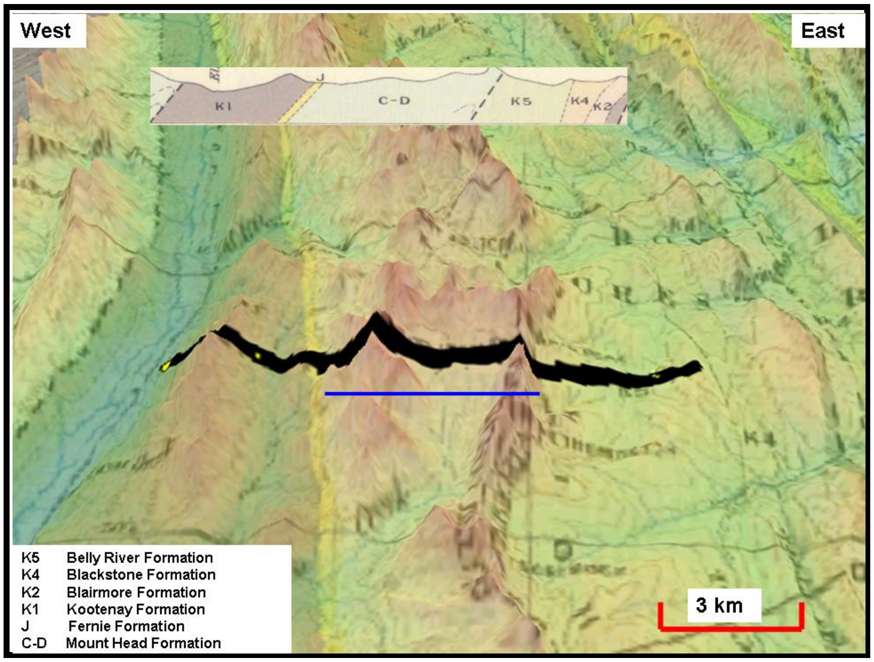

Figure 1: Geological bedrock map and geological cross section with the topographic profile. The black strip indicates the the seismic line location. This line crosses high velocity carbonate rocks in the middle portion, named as central carbonate bow l(the range is indcated by blue line), and clastic strata occurs at the surface in the western and eastern areas (after Marshall, 1920).

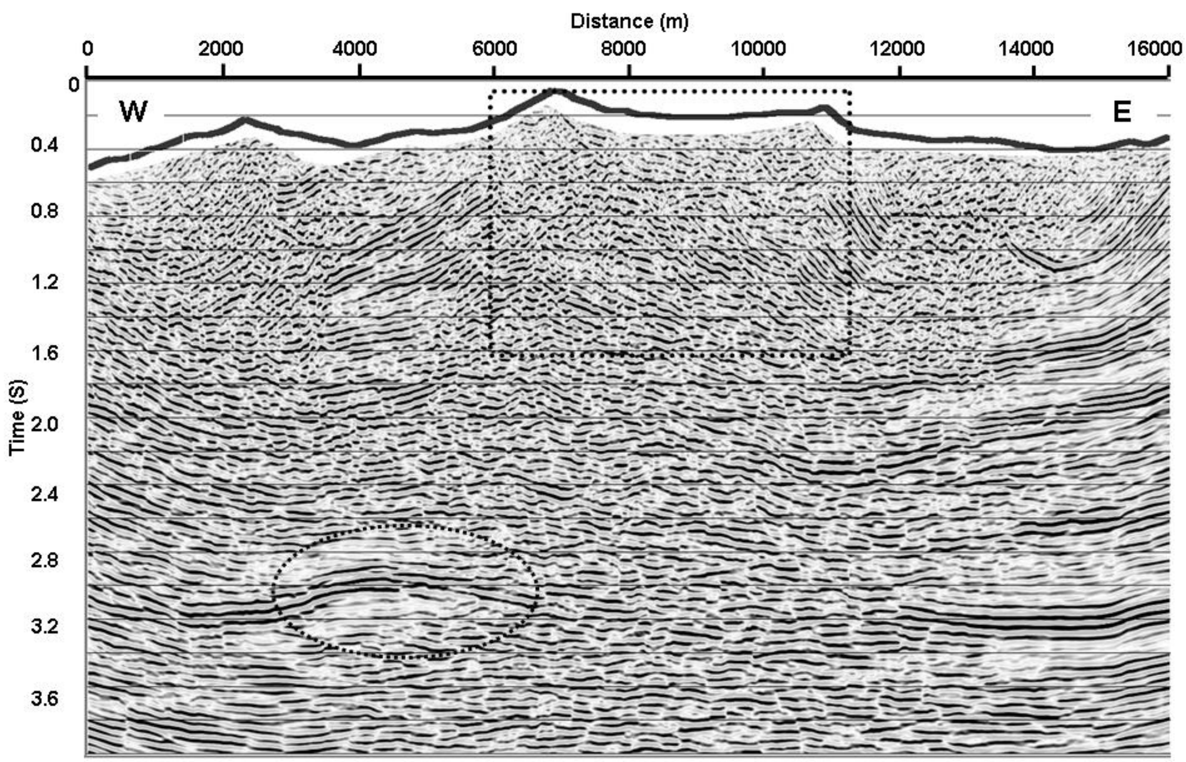

Figure 2: PSTM section. The box outlines poor imaging below the surface carbonates and the ellipse denotes velocity pull-up of a later reflection.

Depth Imaging Scenarios

Initial Velocity Model Building

Figure 3 outlines the strategy applied to build the initial isotropic velocity model. All available geologic and geophysical data were used to guide the initial model building. The velocity values were assigned from constant velocity scans and coherence inversion.

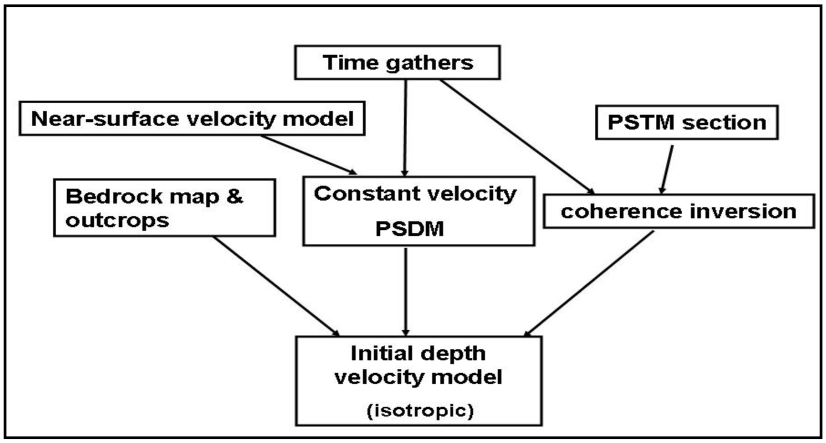

Figure 3: Workflow utilized to generate initial PSDM velocity model.

Velocity Model Refinement

Since the data has low S/N and there are no well constraints along the line, grid tomography was chosen and applied to refine the initial velocity model using common image gathers (CIGs) and segments picked on the resulting depth section. Four iterations were conducted using the procedure described by Kosloff et al., (1997). The layer stripping approach was also applied during this process. In first iteration, the velocity model of the shallower layers down to 3500m was updated with a grid size 200 m x 200 m and then in the second iteration, we updated the velocity model down to 6000m with a grid size 300 m x 300 m. In the third and forth iteration , whole velocity model was updated with coarse grid of 500 m x 500 m.

Depth Migration

Once the plausible velocity model achieved, Kirchhoff depth migration code developed by Lawton (2005) was used to produce the final CIGs and migrated section. This code undertakes raytracing honouring Snell' Law from surface (topography) that is implicit solution to the shortest time path. Optimal migration parameters were chosen: 1) half-aperture: 3500m and 2) asymmetrical angular aperture with dip pass: 65^o (west) and 80^o (east).

Final PSDM Result

After final migration, two mute functions were applied on the CIGs; one focussed on abnormal amplitudes in shallow part of the gathers; another was used to remove long offset traces on the CIGs located on the western and eastern sides to mitigate edge effects on the survey because those long offset traces content more swing noise rather than reflection signal.

Figure 4 demonstrates the final PSDM stacked section at a 1:1 scale. Obviously, the quality of PSDM image is generally better than PSTM stacked section shown in Figure 2 since the PSDM inherently drives the seismic data to match the geologic frame assigned in the velocity model. The anomaly caused by velocity pull-up was removed and more continuous deep marker can be identified in the PSDM stacked section. Imaging below the carbonates has been improved.

Conclusion

A successful isotropic Kirchhoff PSDM was implemented to produce the optimal depth image beneath surface carbonates. Integration of geologic bedrock data, outcrop photographs, time processing results, constant velocity PSDM and coherence inversion showed the possibility to build a reasonable initial velocity model as the starting point. Grid tomography guided by layer stripping was able to produce a globally refined velocity model to improve the flatness of CIGs from seismic data with low S/N. With the specific goal of interest in mind, careful selection of main PSDM parameters achieved the optimal depth image. Spatially various mute function applied on the CIGs also was benefit of imaging quality of lowest structures.

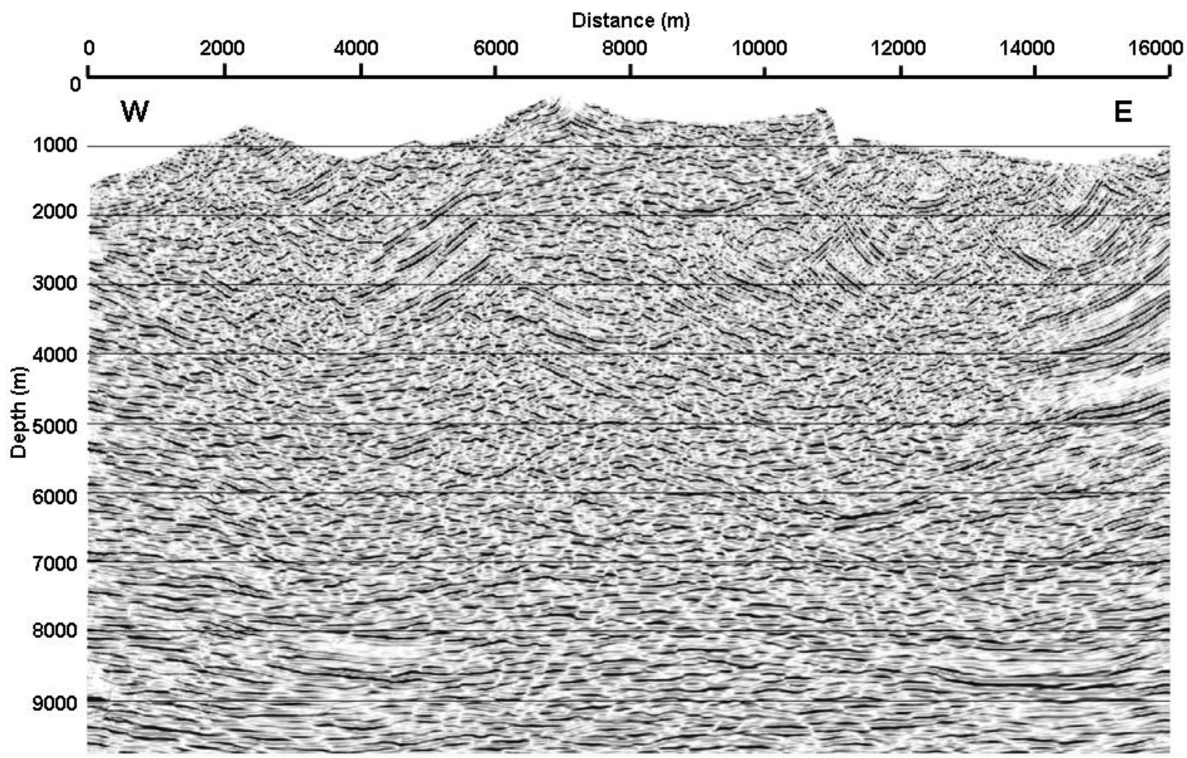

Figure 4: Final Kirchhoff PSDM stacked section (scale 1:1)

Acknowledgments

We thank Norcen Energy (now CNRL) for providing the seismic data, Dr. Helen Isaac for technology support and all of the sponsors of the FRP for financial support. We are grateful to Paradigm for providing GeoDepth software and P-Wave Imaging Ltd helpful advice.

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