Effective Multiple Attenuation and Depth Imaging with Thousands Well Ties for Montney Reservoir Characterization: A Western Canada Wembley Valhalla Land Case Study

Hui Zhang, Dmitri Skorinski, Patty Evans, Ahmed Mouaki Benani Chebihat, Kelsey Stannard, Patrick Fothergill, Homayoun Gerami

Schlumberger WesternGeco

Summary

Both surface-related and interbed multiples affects the Montney target reservior characterization located in the Western Canada Basin. In addition, azimuthal anisotropy is also important for characterizing stress and fractures in the Montney formation. This case study presents a cascaded demulitple workflow which optimally attenuates surface-related and interbed mulitples to reveal the true reflection of the Montey formation. We will also demonstrate the derivation of a detailed depth velocity model including the ability to obtain a highly variable near surface zone using diving wave tomography and well/horizon constrained reflection tomography. The final depth image obtained was consistent with the true depth of the structure as it sucessfully tied thousands of wells and resolved false azimuthal anisotropy anomalies.

Introduction

The study area is located in the west of the Alberta Basin. Eighteen seismic surveys were acquired from 1999 through 2007 covering approximately 4,400 km^2. Due to the benign and layered geology, the key target Montney formation was contaminated by strong multiple energy interfering at the target level and as a result was one of the main imaging challenges. The multiple contamination included surface-related and interbed multiple.

The regional geological structure is relatively flat, however significant amount of azimuthal 'anomalies' were observed on pre-stack time migrated common offset common azimuth (COCA) gathers. In order to capture true azimuthal anisotropy in an amplitude versus azimuth (AVAz) inversion, any apparent anomalies must be resolved. Apparent azimuthal anisotropy can occur if the overburden velocities are not fully resolved or if simplistic time imaging assumptions are chosen over depth imaging. More than 7,000 wells were drilled in the past 50 years in this case study area. Another objective of this project, was to derive a depth image that tied with thousands of wells in the area.

In this abstract, we will describe in detail, the methodologies for effective multiples attenuation and depth velocity model building and imaging, that was carried out during the execution of this project.

Multiple Attenuation

1. Pre-migration surface-related multiple attenuation

It was recognized that the key target interval was mainly contaminated by internal multiples. However, any surface related multiple energy must be removed prior to the modeling of interbed multiples. A land adaptation of the well-known true azimuth 3D surface related multiple elimination (SRME) algorithm used in marine processing was utilized to remove surface-related multiples prior to interbed multiple attenuation.

The 3D data driven surface multiple prediction was performed on prestack dataset, the predicted multiples were subtracted from input dataset using an adaptive subtraction technique. Irregular and sparse spatial sampling geometry in this land dataset limited the effectiveness of the surface multiple attenuation application. The majority of the eighteen surveys had similar acquisition geometry parameters. In order to provide a better spatially sampled dataset as input to the multiple attenuation step, a 5D anti-alias Fourier interpolation was adopted to regularize source and receiver spacing. Extra source and receiver lines were interpolated to provide denser sampling. The surface-related multiple attenuation process was validated through a semblance spectrum analysis and well synthetic match with the surface seismic.

2. Pre-migration interbed multiple attenuation

The algorithm chosen for modeling internal multiples required prior knowledge of the multiple-generating horizons or intervals. This information can be obtained from VSP information or from the analysis of well logs. In this project, multiple modelling was performed using well logs to identify multiple generating horizons. Six key multiple generators (Puskwaskaum, Cardium, 2nd Whitespecks, Gething, Nordegg and Belloy) were identified for use in the interbed multiple prediction process. It was determined that the interbed multiples affecting the target Montney layer reflection were mainly generated between Gething, Nordegg and partially Cardium layer. All the six multiple generating horizons were interpreted on pre-migrated stack volume and the data-driven 3D, true-azimuth internal multiple prediction algorithm was adopted to predict the multiples. Predicted interbed multiples were subtracted adaptively in OVT (offset vector tile) domain. The results show that significant amount of multiple energy was removed by the combination of both algorithms. The key target events previously masked by interfering multiples energy were separated into three distinct layers, providing better resolution and the target and also provided better correlation with the primary-only synthetics seismic generated from well logs data.

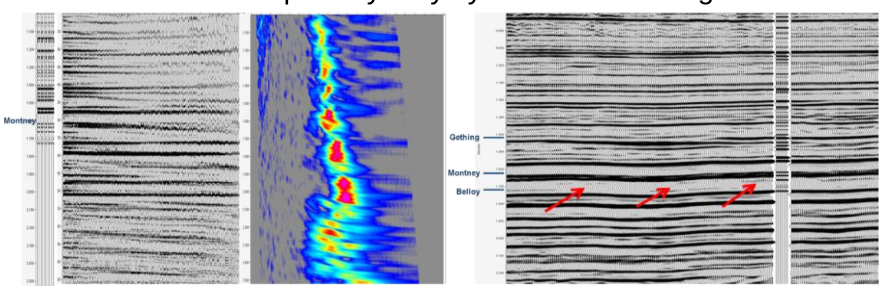

Figure 1-A *Left: CMP gather and velocity spectrum before demultiple, Right: Stack before surface related and interbed multiple attenuation.*

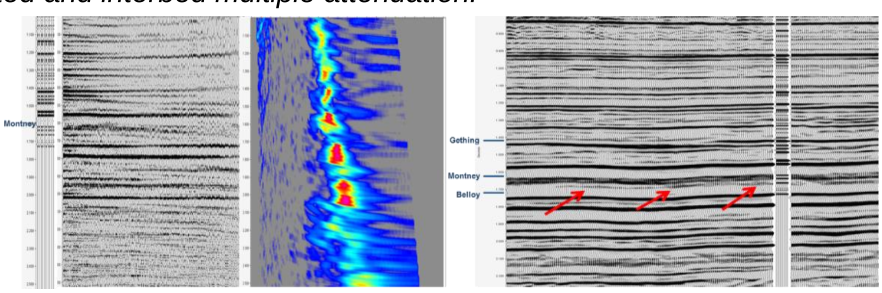

Figure 1-B *Left: CMP gather and velocity spectrum after demultiple, Right: Stack after surface related and interbed multiple attenuation.*

3. Post-Migration Residual multiple attenuation:

High-resolution radon demultiple was used to attenuate residual multiple after pre-stack migration. The migrated cmp gathers were sectored into eight azimuth bins for the radon demultiple application in order to preserve any azimuthal variation.

Depth Imaging

1. Near surface modeling and Initial model building

In general, land seismic data doesn't have sufficient near offsets density. As a result, obtaining reliable moveout picks to run reflection tomography updates to derive a near surface model poses a challenge.

Diving wave tomography (DWT) was used to derive near surface model from abundant first break information. High frequency velocity details were derived by the inversion process using DWT. frequency statics were applied to the data prior to migration. Some degree of smoothing was applied to the DWT model to be incorporated into the initial velocity model for the shallow velocities. Twenty-five wells were used to create a smoothed sonic log model for the deeper velocities. The shallow DWT velocity model was then merged with the deep sonic log model to build an initial isotropic velocity model.

2. Isotropic velocity update

A layer-striping approach was applied to obtain velocity updates since the main layers are relatively flat in this area. The first step was focused on updating the shallow velocities necessary to flatten the gathers in the shallow section before moving to deeper updates. High density residual moveout (RMO) was picked on pre-stack depth migrated gathers that were migrated using the initial model. Grid based reflection tomography inversion was used to update velocity model that would minimize the RMO. Steering filters were also employed to enable velocity updates to conform to the geological layer changes. After two iterations of tomography, the isotropic migrated gathers were generally flat.

3. Initial anisotropic parameters derivation

Despite VSP and checkshot information were not available in this survey, there were abundant well top information from shallow to deep, which could be used to perform the anisotropic calibration. First, a scaled vertical velocity was derived to match key seismic horizons to corresponding well top depths and Thomson anisotropy parameter delta was estimated layer by layer for each well. Based on a regional ratio, Thomson epsilon was derived with the understanding that it was approximately two times that of delta. Initial anisotropy parameters were estimated at ten wells locations and propagated throughout the whole survey along geological surfaces. The initial VTI anisotropy model was therefore created and used subsequently to perform further tomography updates and depth migrations.

4. Well constrain anisotropic velocity update and depth migration

Several key seismic horizons were used for the mis-tie analysis. Approximately eighty wells were used to obtain seismic-well mistie from shallow to bottom. Five anisotropic tomography update iterations were constrained by the well top information with shallow horizons/markers being weighted more than the deep markers for the first two tomography iterations. Vertical velocity and Thomsen epsilon were updated simultaneously by well constrain tomography. Figure 2 shows the final raw PSDM stack image crossing wells with markers. Overall, the key seismic horizons tied well markers within 1% mistie error for most wells.

5. Horizon constrain tomography for residual depth mistie correction

Ten seismic horizons were interpreated over the full depth migrition volume, and the mistie error was analyzed between seismic horizons and well markers for thousands of wells. In order to further reduce the residual depth mistie error, an iterative workflow which adopted horizon constrained tomography to update the velocity was performed. The workflow included : 1) seismic horizons interpretated and used as the ‘image’ horizons 2) target seismic horizons that was consient with the well measurements and referred to as the ‘well’ horizons, 3) horizons constrained tomography in order to invert for a velocity model which reduced the mistie between ‘image’ horizons and ‘well’ horizons, 4) the depth volume was stretched to time domain using pre-updated velocity model, 5) and re-streched to depth domian using the updated velocity model.

Examples

Figure 3 shows that significant amount of false VVAZ anomalies have been reduced on PSDM gathers, providing more accurate results that correlated to known azimuthal anisotropy, and events on the PSDM gathers are more coherent and continuous. The reprocessed PSDM stack has an improved structure, details and coherency compared to the PSTM stack. Figure 4 shows that the seismic mistie error after residual depth mistie corretion. For most wells, the shallow layer mistie was within approximately +/- 8m based on the analysis of over three thousand well tops. The montey layer mistie was approximately at +/-16m in error due to limitations of it being a relatively weak reflection event.

Conclusions

This case study highlights that the multiples were properly attenuated in this flat geological setting. Seismic data after demultiple provided better correlation with synthetics. The final seismic depth cube tied thousands of wells and provided a more reasonable subsurface structure and better coherency, which may help reduce drilling uncertainties. The depth migration image minimized apparent azimuthal anisotropy anomalies after accurately and sucessfully resolving the complex velocity changes in the overburden. This case study demonstrated how process technologies can help the Montey resveroir characterization and and aid in optimizing production.

Acknowledgements

The authors thank Gregory Rogers, Jay Joseph Vickers, Alexander Zarkhidze, Bruce Hootman, Saeeda Hydal, Qinglin Liu, Steve Wiseman and Bartosz Szydlik for advice and discussions. The authors would also like to thank Schlumberger WesternGeco for permission to publish these results.

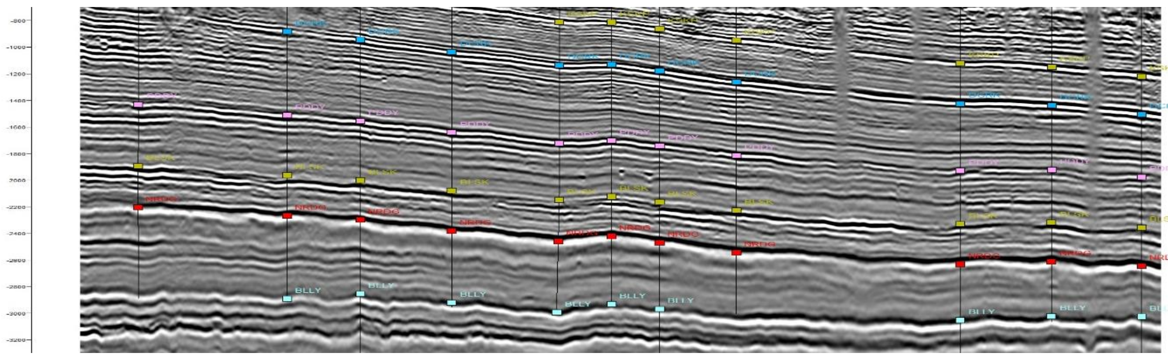

Figure 2: *PSDM raw stack (before residual depth correction) crossing well with markers.*

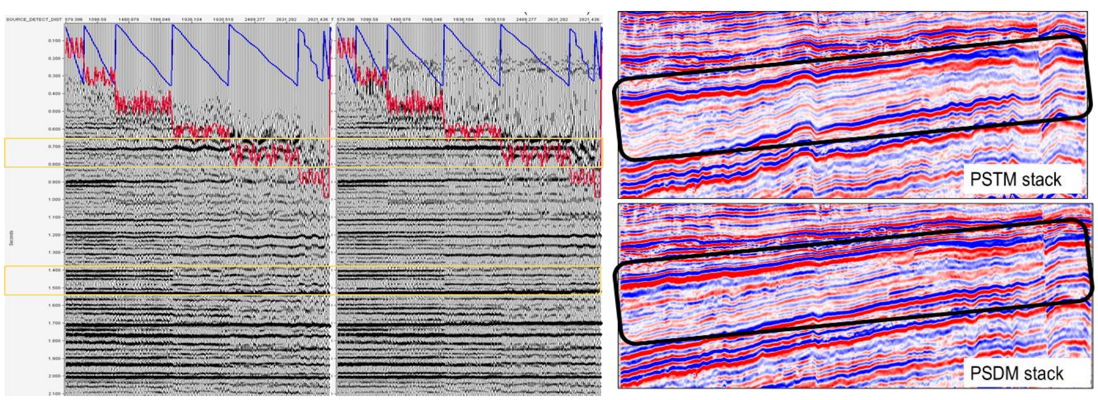

Figure 3 *Left: PSTM COCA Gather Middle: PSDM COCA Gather in time, Right top: PSTM raw stack in depth, Right bottom: PSDM raw stack*

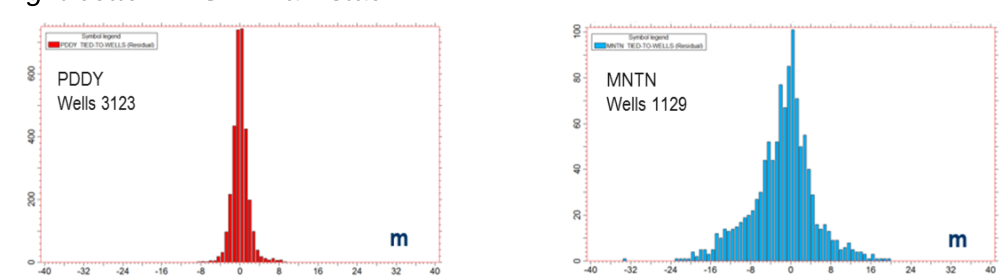

Figure 4 *Left: Mistie error distribution for shallow Paddy layer of 3123 wells, Right: Mistie error distribution for Montney layer of 1129 wells.*

References

[1] Goodway, B., G. Purdue, S. Y. Looi, L.J. Du, and M. Rowland, 2016, Depth Imaging for Unconventional Reservoir Characterization: Canadian Plains Case Study. GeoConvention 2016.

[2] Charles, S., J.W. Lin, L.J. Du, A. Mouaki and B. Chebihat, 2016, Constraining a 3D anisotropic tomography inversion with hundreds of well ties – A Canadian Oil-Sand case history: GeoConvention 2016.