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Horn River Converted Wave Processing Case Study

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Summary

Converted wave processing has come a long way in the last 15 years since the advent of the modern Micro-Electro-Mechanical Systems (MEMS) accelerometers. With this jump in acquisition technology, shear wave measurement became much more economical and robust. Processing technology has evolved to the point where some of the earlier holdbacks can now be rectified post-acquistion. This abstract reviews the current state of that technology applied on a survey collected in the Horn River basin.

Introduction

The Horn River basin covers 1.1 million hectares of land in north-eastern British Columbia. Current efforts are focused towards unconventional recovery of natural gas in the Muskwa, Otter Park and Evie shale units which in a study commissioned by the BC Oil and Gas Commission (2014), are believed to contain ~500 Tcf, with 11.1 Tcf of this total currently believed recoverable. This basin will be a key part of supplying proposed LNG (Liquefied Natural Gas) exports off the Pacific Coast.

Canada has had a strong multicomponent processing track record. Continuing that tradition, we present a recent exploration study in one the country's key basins, the Horn River play in northern British Columbia. This paper focuses particularly on the results obtained from the converted-wave data processing.

Converted-Wave Processing

Like most converted-wave processing, the first step involved the rotation from the field orientation of the geophone to radial/transverse (aligning horizontal components in the direction of the source). Although care is taken by field crews to properly orient receivers, deviations can occur and can be difficult to detect. To confirm the orientation of each receiver, an analysis was performed on the first breaks to confirm and potentially adjust the initial orientation to perform the correct rotation. The expected orientation was approximately 22° (relative to true north). Figure 1 shows that ~84% of the receivers were measured to within 10° of this value but outliers did exist. The measured values were applied with the constraint threshold of +/- 45° from the expected field value. Properly correcting these orientation values is critical to not only obtaining the best quality radial/transverse rotation but also serves as a basis for future splitting analysis and compensation.

The processing proceeded through several iterations of noise attenuation in various sorting domains and was then followed by surface-consistent deconvolution. Because signal strength was very good, a simple method of matching horizons between PP and PS common receiver stacks was used to compute the receiver statics. The source statics were provided via the p-wave processing refraction and residual solutions. Several iterations of residual statics were employed to finalize the statics derivation.

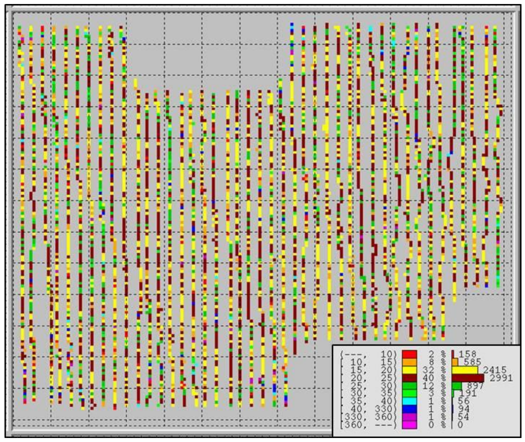

Figure 1 *Results of the field orientation analysis (colours represent measured value of orientation) show that while most values from the histogram are close to what was expected some deviations need to be accounted for.*

Once the signal processing was deemed satisfactory, interpolation was performed on the dataset to regularize and improve data density. Converted waves often suffer because p-wave modelling is often only employed in deriving the acquisition parameters. Particularly, inlines or crosslines running perpendicular to the receiver direction can suffer from a “saw tooth” effect in the shallow section as time-variant binning shifts the mid-points closer to the receiver in correlation with higher Vp/Vs ratios (Figure 2a). Matching Pursuit Fourier Interpolation (MPFI), as defined by Schonewille et al. (2013) was performed on sectored asymptotically binned gathers to preserve birefringence. This result effectively filled in the data holes maintaining relative amplitudes and the sectoring preserved azimuthal signatures (Figure 2b).

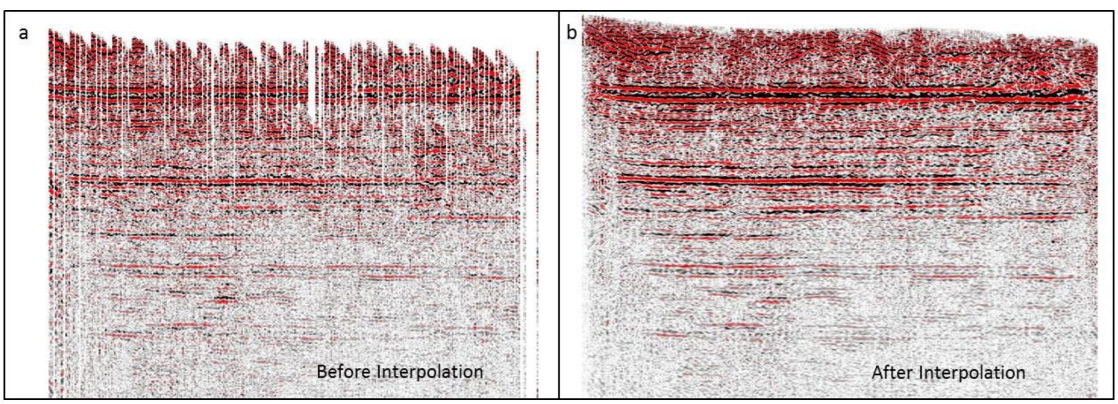

Figure 2 *Single sector ACP stacks before (a) and after (b) interpolation.*

The next stage of the project involved an analysis of the splitting response using the 2C by 2C method devised by Alford (1986) and adapted to C-waves by Gaiser (1999). The data was pre-stack time migrated into azimuthally sectored radial and transverse components to optimally position and bin the data prior to analysis. Careful testing of window sizes in a layer stripping approach showed that two-windows (Figure 3) accurately capture the splitting scenario. The majority of the splitting appears to be influenced by a shallow carbonate aquifer; water from this aquifer is being used for drilling and completion in an economic and environmentally responsible manner (CAPP, 2011). Figure 3 displays the results before and after correction. Performance of the rotation was deemed effective as the majority of the signal has been removed from the off-diagonals.

Examination of the fast direction and splitting magnitude attributes reveals a defined trend (Figure 4). The top window is dominated by the effect of the previously mentioned aquifer. The fast azimuth histogram displays a dominant stress direction of approximately 75° from true north, which matches well with published values from The World Stress Map database.

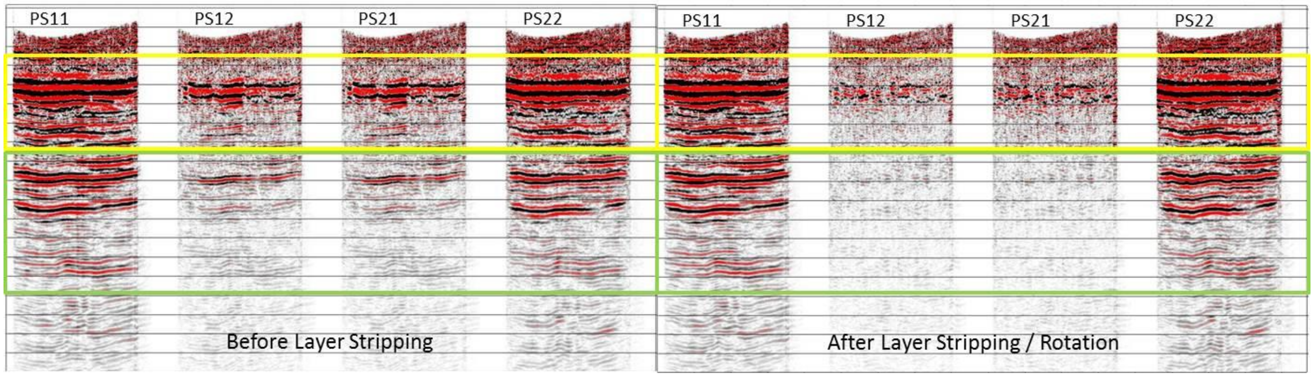

Figure 3 *After sectored prestack time migration (PSTM), the gathers are reorganized into primary (PS11, PS22) and off-diagonals (PS12, PS21). Data is then rotated off the off-diagonals onto the fast (PS1) and slow (PS2) orientations. The coloured boxes represent the two analysed layers for Alford rotation.*

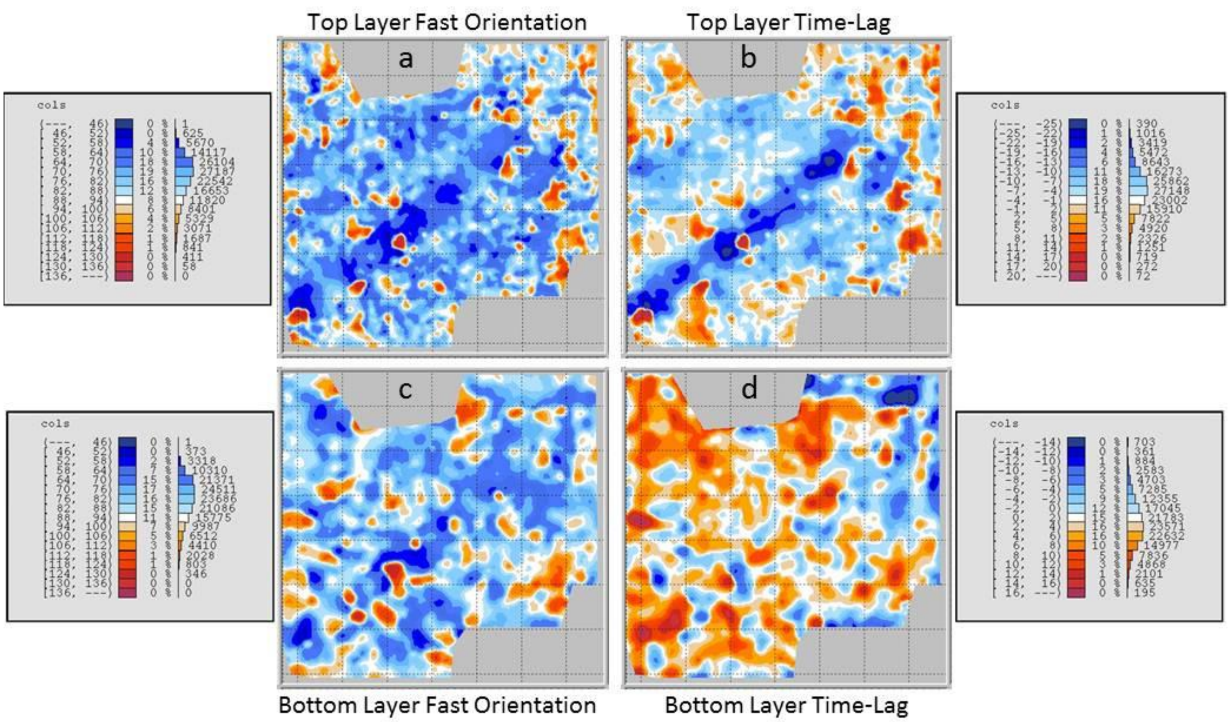

Figure 4 *Attribute maps derived from splitting analysis. Top images are from the upper window and the lower two from zone of interest. Images (a) and (c) are the measured fast-direction orientation and (b) and (d) are the time-lags between the fast and slow shear wave modes measured in milliseconds.*

The last stage of the processing portion involved a PSTM of the fast and slow orientations using the results as detailed above to derive the final stacked images and gathers for inversion. The PS1 and PS2 sections show distinct amplitude variations which may prove to be very interesting in the subsequent inversion analysis. Figure 6 displays an example of the final PS1 and PS2 stacked sections and a comparison to a corresponding filtered P-wave section. The p-wave section is filtered to the same frequency content of the c-wave (6-40 Hz.). A manual initial registration has been performed to align corresponding horizons; a detailed registration is on-going.

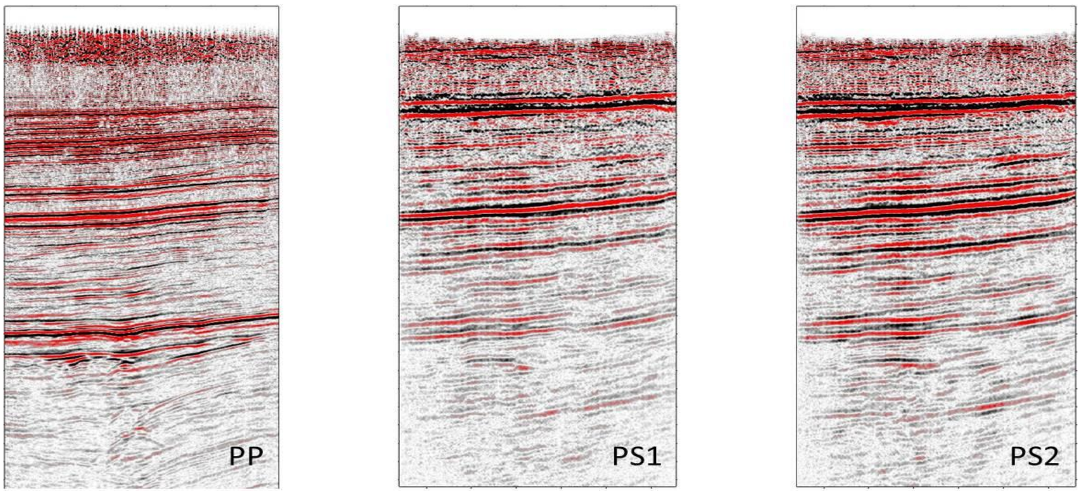

Figure 6 *The final PSTM stacked sections show a good structural match and amplitude variations which hint at the complimentary lithological information the converted-waves can add to a study.*

Conclusions

This paper has shown that processing technology has evolved to deal with several of the key issues from early surveys. Firstly is the reliance of proper field orientation; the data can now be analysed to determine the correct orientation with reasonable robustness. Secondly is non-optimized survey design with p-wave response the only planning consideration, 5D interpolation can to some extent, fill in some of those gaps which can be exacerbated by asymptotic mid-points. Finally, it gives a greater understanding of splitting response and being able to analyse and compensate both laterally and temporally. Land converted-wave processing is still evolving and advancing through the promising aspects of ground-roll inversion for a near-surface S-wave model and PS-PSDM which mostly removes the lack of refractor-based receiver statics. Analysis is continuing and is expected to yield much more valuable attribute information.

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References

Alford, R.M., 1986, Shear data in the presence of azimuthal anisotropy: Dilley, Texas: 56th Annual International Meeting, SEG, Expanded Abstracts, 476-479.

Canadian Association of Petroleum Producers, 2011. Water Stewardship in Practice – The Debolt Water Treatment Project, http://www.capp.ca/energySupply/innovationStories/Water/Pages/debolt.aspx

Gaiser, J.E., 1999, Applications for vector coordinate systems of 3-D converted-wave data: *The Leading Edge*, 18, 1290-1300.

Government of British Columbia. BC Oil and Gas Commission, 2014. Horn River Basin Unconventional Shale Gas Play Atlas

Heidbach, O., M. Tingay, A. Barth, J. Reinecker, D. Kurfeß, and B. Müller, 2008. The World Stress Map database

Schonewille, M., Z. Yan, M. Bayley, and R. Bisley, 2013. Matching pursuit Fourier interpolation using priors derived from a second data set. 83rd Annual International Meeting, SEG, Expanded Abstracts, 3651-3655