Pre-stack (AVO) and post-stack inversion of the Hussar low frequency seismic data

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Abstract

Pre-stack (AVO) and post-stack and inversions were performed for the Hussar data to study the role of using very low frequencies on seismic inversion. Another objective is to investigate the accuracy of the resulting acoustic and elastic properties from the inversion. Seismic data conditioning applied to the common image gathers, CIGs, has improved the signal to noise ratio considerably, and facilitated extraction of source wavelets for different angle stacks. The lengths of the angle-dependant wavelets were chosen to be long enough to ensure consistent matching of source and seismic spectrums at the low-cut end of frequency band limit. The experiments proved that inverting of very low frequency seismic data is feasible and reduces the residual error between measured and inverted attributes. The inverted elastic attributes managed to discriminate different lithologic layers, and resolved the lateral extension of the Glauconitic sand, hard shale of Ostracod, Ellerslie formations and other geological markers of the survey area.

Introduction

Broadband seismic data is vital for detailed AVO inversion as well as full waveform inversion (FWI). The survey site is located at Hussar, Alberta, where the low frequency experiments were carried out to record very low frequencies using a variety of source and geophone types (Margrave et al., 2012).. The Glauconitic sand channel and Ellerslie formations are the two prospects, which are hydrocarbon bearing formations.

We use the common image gathers, CIGs, of the pre-stack Kirchhoff migration of the dynamite source recorded with 10Hz geophone (Saeed et. al., 2014) to invert for elastic rock properties. The objective is to study the role of low frequencies on inverted elastic attributes of the Hussar seismic data. Another objective is to delineate and map the lateral extension of the Glauconitic sand channel and Ellerslie prospects as well as the hard shale of the Ostarocd formation that separate the two prospects.

Well-to-seismic tie

Prior to performing well-to-seismic tie, seismic data conditioning processes include creating super gathers to improve the S/N ratio and then applying trim statics to further flatten the reflected events at far offsets. Well to seismic tie was then performed, and angle-dependant wavelets for the near, mid and far angle stacks were extracted for the wells intersected with the survey line. Inverting of very low frequency data required source wavelets whose temporal lengths are long enough in order to tie the low frequency end of the wavelet spectrum to the spectrum of the associated angle stacks. However, this requirement may cause the noise to leak into the real spectrum of the source wavelet, thus affecting the accuracy of the extracted wavelet. Therefore, extra attention is needed in determining optimal source wavelets used in inverting very low frequency data. Figure 1 shows well to seismic tie for well 14-35, where a good cross-correlation >0.80 between synthetic and field seismic gathers near the well is achieved.

Seismic inversion of Hussar data

The inverted zone is limited to the Base Fish Scale (BFS) – Pekisko formations. Post-stack and pre-stack inversion analyses were conducted, and the inversion parameters were calibrated to minimize residual between inverted and measured attributes. The inversion analysis shows that with low cut filter of 1-3Hz, we still obtain reasonable inverted results with minimal residual between measured and inverted results. The scaled pseudo Poisson ratio section from the AVO analysis in Figure 2 is a good lithology attribute indicator whereby the top sand layer can be easily distinguished from hard shale bottom layer. Figure 3, shows the post-stack P-impedance section while Figure 4, shows P-impedance section from the AVO inversion. The AVO P-impedance section (Figure 4) shows better lateral mapping for the Medicine-coal marker and the Glauconitic sand and a reasonable lateral extension of the Ellerslie formation, as the reflector of the Ellerslie formation was not clearly seen and disappear beyond well 1-34. The hard shale of the Ostracod formation separates the two prospects is clearly mapped in the S-impedance section (Figure 5) as a continuous high-impedance layer separating the Ellerslie formation form the Glauconitic sands. This is because, the S-impedance attribute is a measure of rigidity and is not influenced by fluid contents of the two prospects separated by a hard shale.

Conclusions

Conditioning of the CIGs aids in extracting the angle-dependant wavelets used in the inversion. Calibration of seismic inversion parameters minimizes the residual error between measured and inverted results. The pre-stack (AVO) and post-tack seismic inversion of the Hussar experiments proves that inverting of very low frequency data is manageable. The inverted sections were delineate the spatial and temporal extents of the hydrocarbon bearing formations (Glauconitic channel sand and Ellerslie), hard shale of the Ostracod formation and other significant geological marker of the survey area.

Acknowledgements

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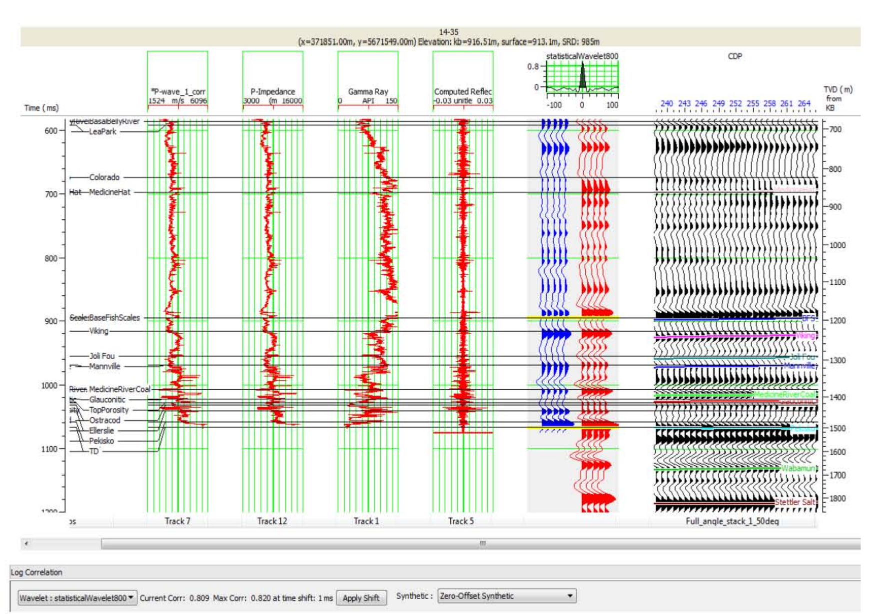


FIG.1. Well to seismic tie for well: 14-35

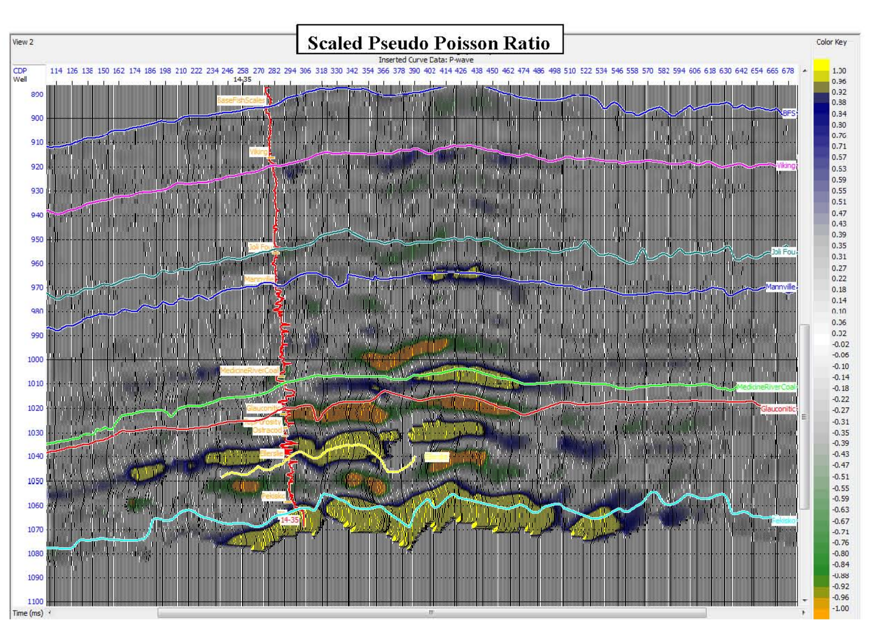
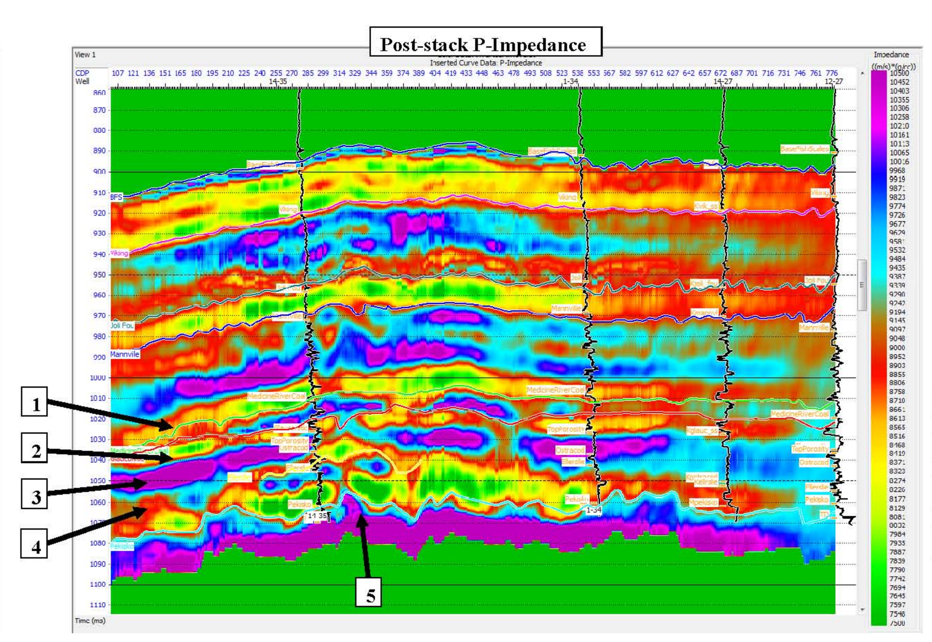
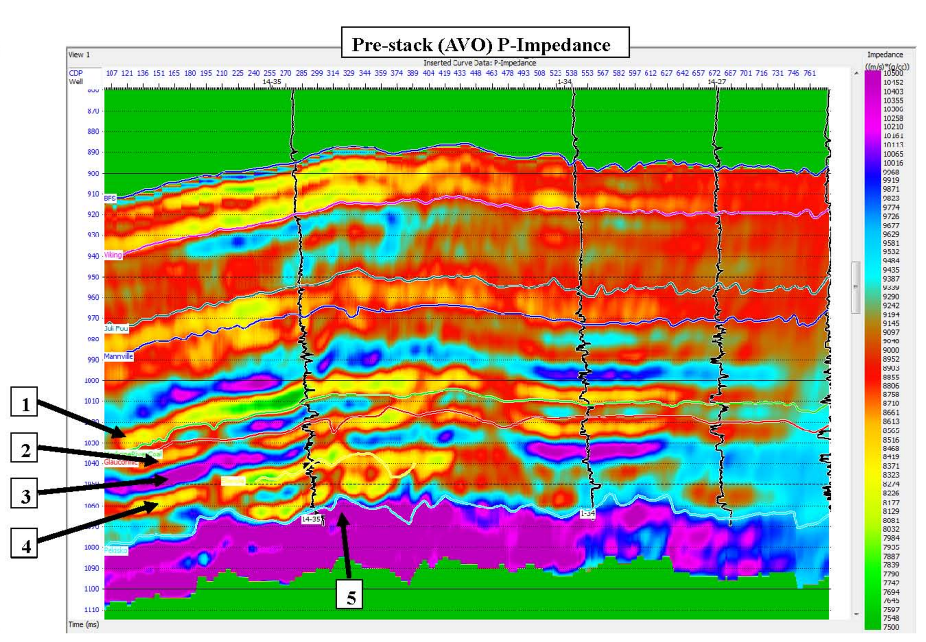
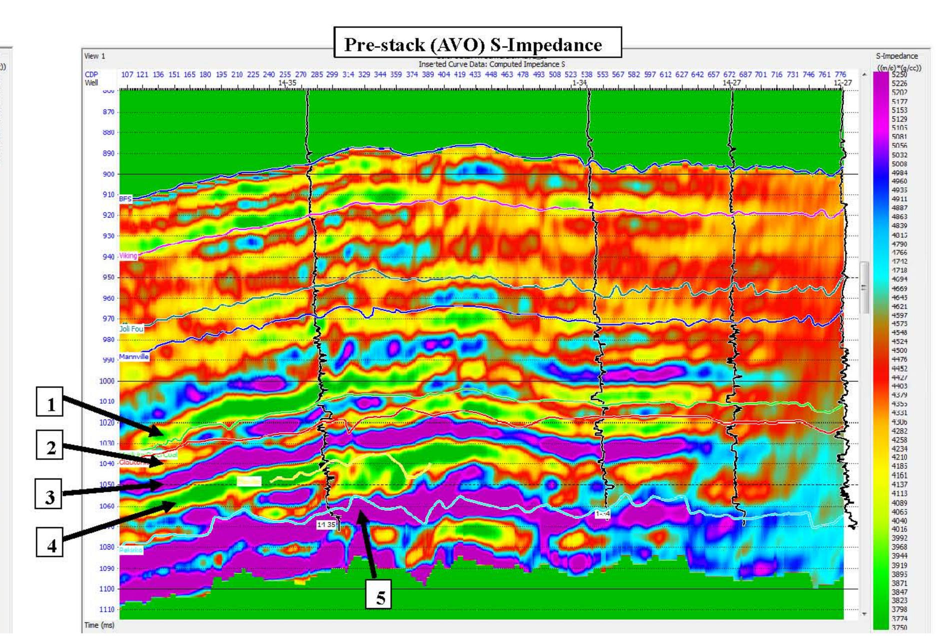


FIG.2. Scaled pseudo Poisson ratio from the AVO analysis.

The negative values (orange in color) reflect the top sands of Glauconitic channel and Ellerslie FM, while positive values (bright yellow) reflects the base of the reservoirs where shale layers manifest.







(1) Medicine River Coal. (2) Glauconitic sand. (3) Hard shale of Ostracod. (4) Ellerslie. (5) Pekisko.

FIG.3. Post-stack P-Impedance section.

FIG.4. Pre-stack (AVO) P-Impedance section.

FIG.5. Post-stack S-Impedance section.

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