Pre-stack Simultaneous Inversion: A Case Study of The MississpPian Limestone of North Oklahoma

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Summary

The purpose of prestack seismic inversion is to obtain a reliable estimate of P-wave velocity, S-wave velocity and density from which to predict the fluid and lithology properties of the subsurface. The zone of study is the Mississippi Lime in north Oklahoma. We used a lithology template proposed by Katherine along with P-impedance, Vp/Vs and Lame parameters in an attempt to map the different formations through the study area. We used the probablity distribution based on the cross plots to relate the derived volumes back to the well logs.

Regional Geology

The study area is located in Anadarko shelf in north Oklahoma (figure 1). The formation of interest is the Mississippian Lime, a thick limestone thinning to the north. The Mississippian formation in the Anadarko shelf consist of limestone, chert with strings of shale and sandstone.

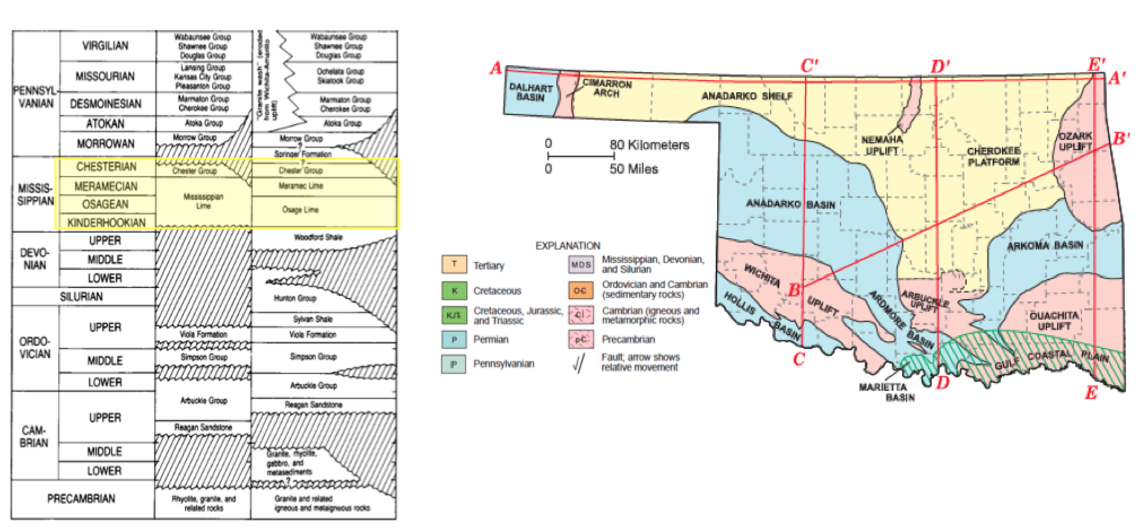

Figure 1: Left: A stratigraphic column showing the sequence in the area of interest. MISS-system is highlighted in yellow. Right: Geologic provinces of Oklahoma

Data Conditioning

The time migrated gathers used for inversion have been processed using the flow in blue. However, The data is contaminated with linear noise (ground roll) and insufficient NMO correction in the far offset. Therefore, we applied the conditioning flow (in red) to enhance the data and suppress the noise (figure 2).

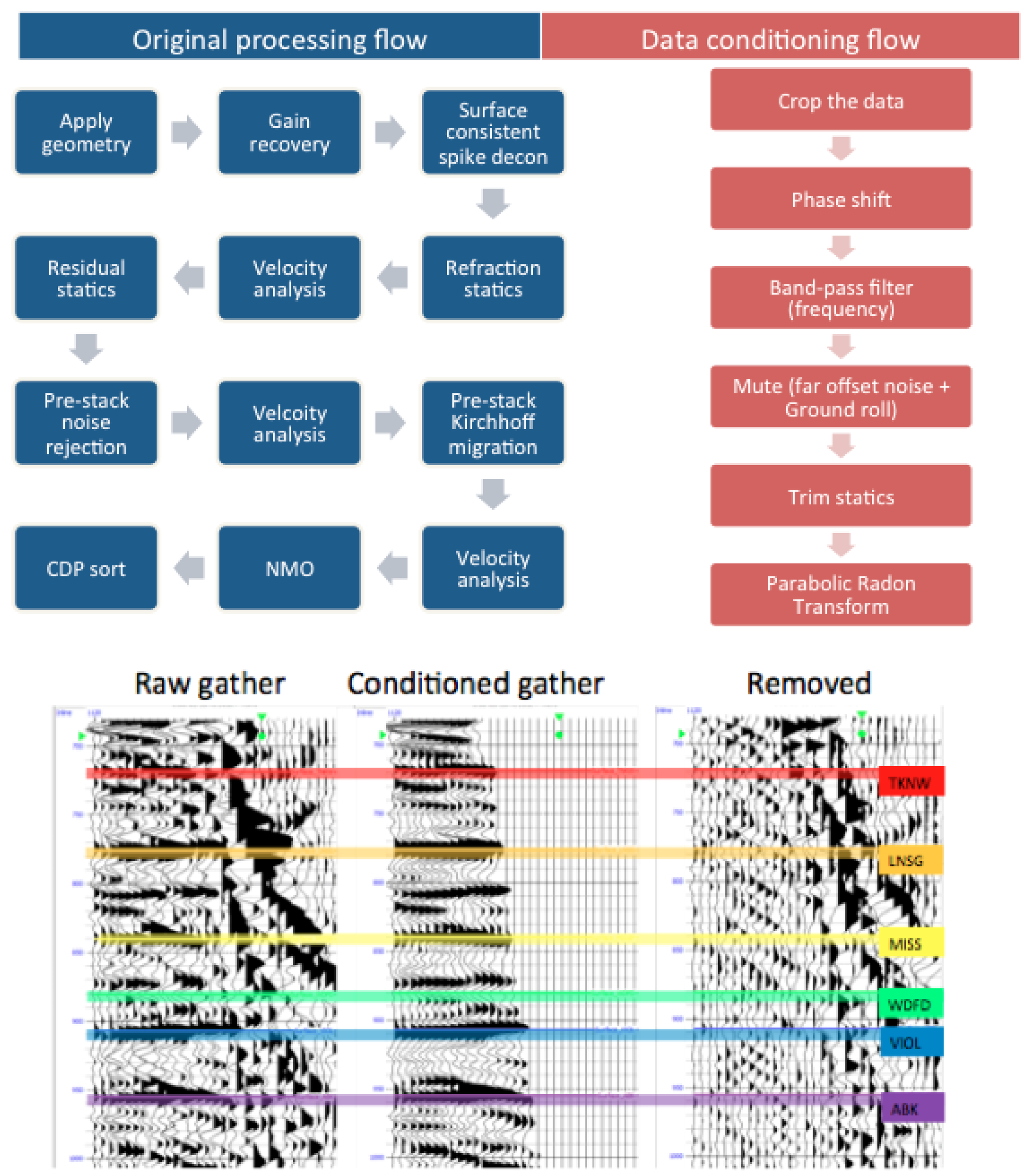

Figure 2: Left: Seismic time migrated gathers. Right: Seismic gathers after data conditioning. A decent improvement have been achieved along all the horizons. The horizons of interest are labeled in different colors. The mute applied has got rid of the ground roll and other linear noise on the far offset. The Woodford Horizon (green) is more continuous. The Arbuckle (purple) horizon has improved but a better NMO correction might improve the far offset. After the conditioning we were left with 37 degrees of incident angle data.

Prestack Simultaneous Inversion

A total of 18 P-sonic and Density well have been used, and a single S-sonic to run the inversion. To verify that our model was good enough, we computed the relative error using :

$$RE = \frac{(Gathers_{angle} - Gather_{Syn})^2}{RMS(Gathers_{angle})}$$

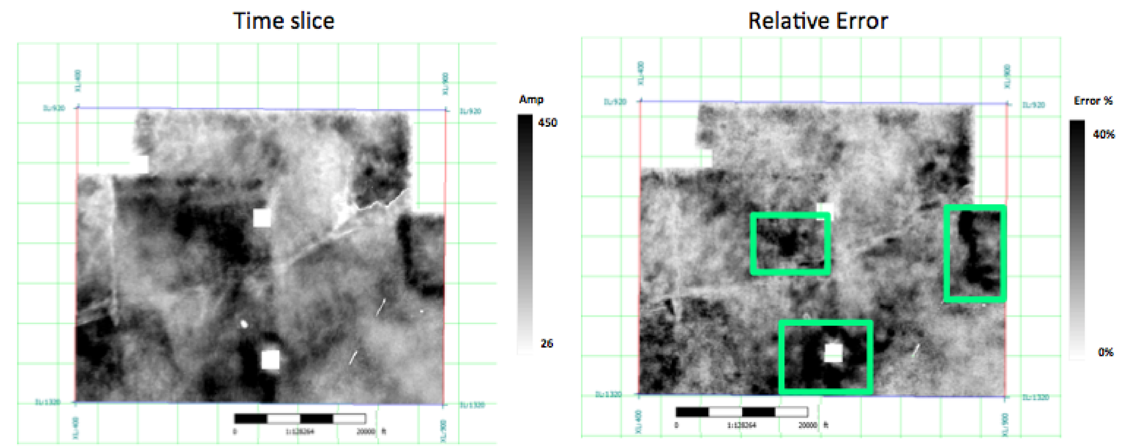

Figure 3: Left: Amplitude time slice along the Mississippian horizon showing the range of values. Right: the relative error between inverted synthetic seismic and original gathers. The error is larger in the areas highlighted with green squares and this could be linked to the quality of the gathers used in this inversion.

Hampson Russell (LithoSI)

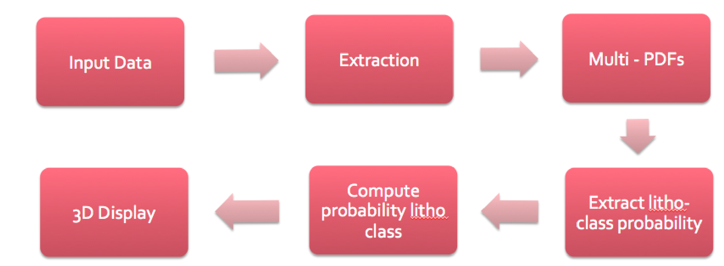

Figure 4: LithoSI workflow overview. $p(c/X) = \frac{p(c)p(X/c)}{p(X)}$

Results

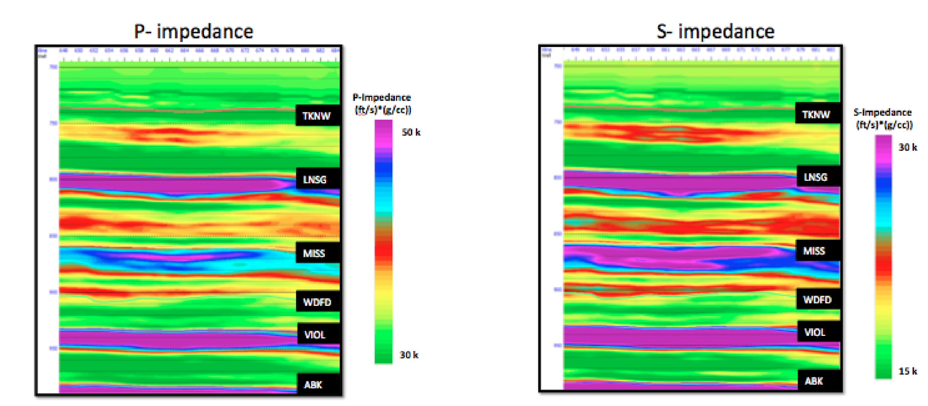

Figure 5: Left: Profile through the inversion result for the P- impedance. Right: Profile through the inversion result for S- impedance.

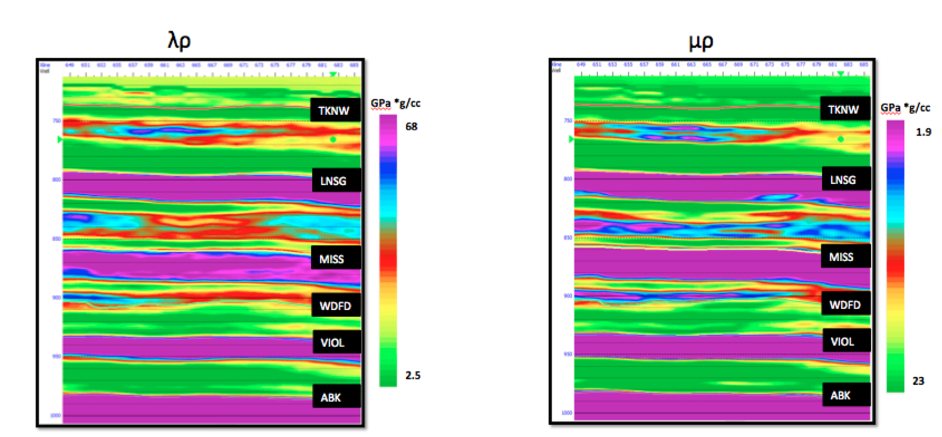

Figure 6: Left: Lame parameter, $\lambda\rho$. Right: Lame parameter, $\mu\rho$.

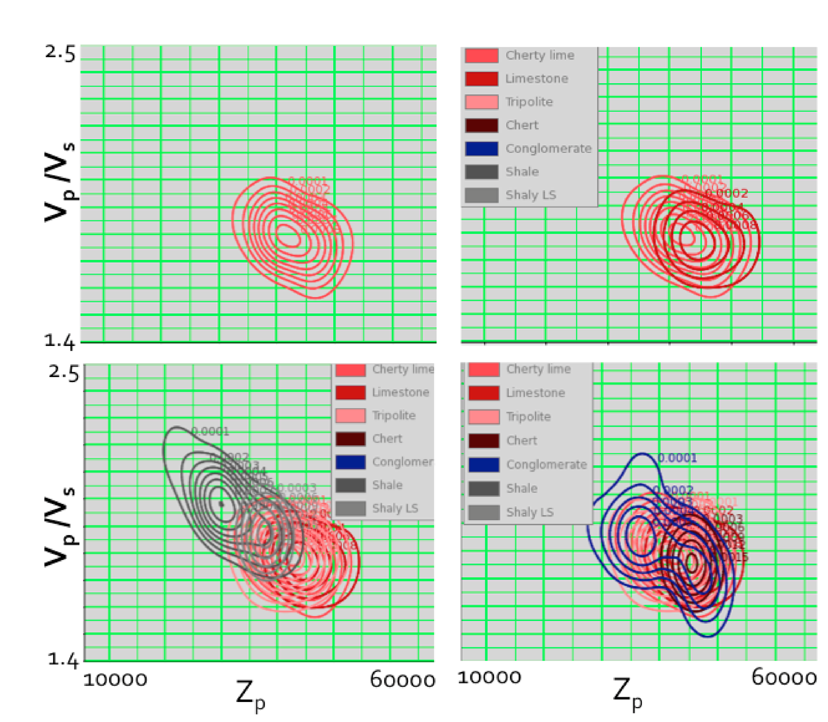

Figure 7: Multivariate probability distribution for different lithologies.

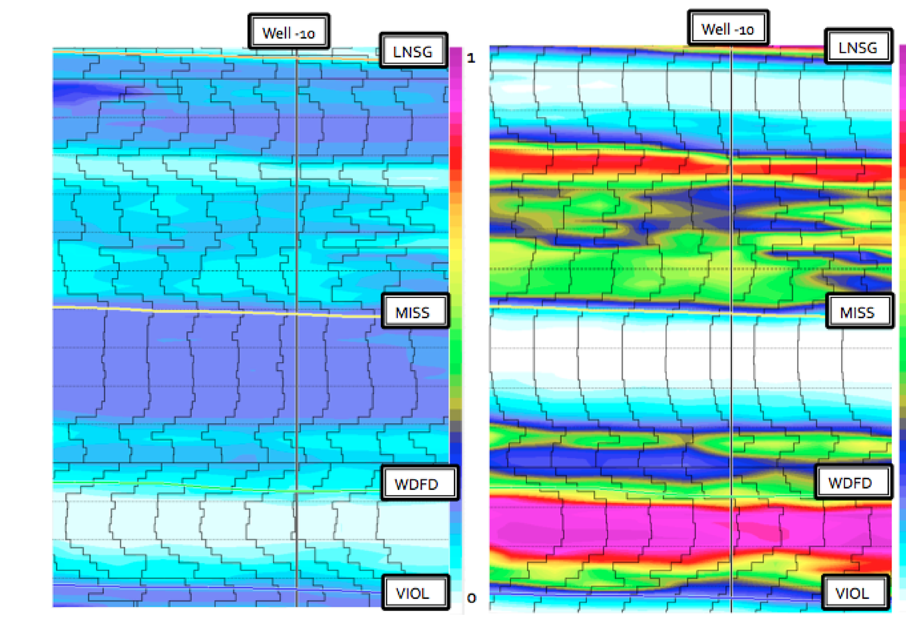

Figure 8: Left : Probability of Cherty Limestone. Right: Probability of Shale. Higher probablity of finding Shale at the bottom of the Mississippian formation.

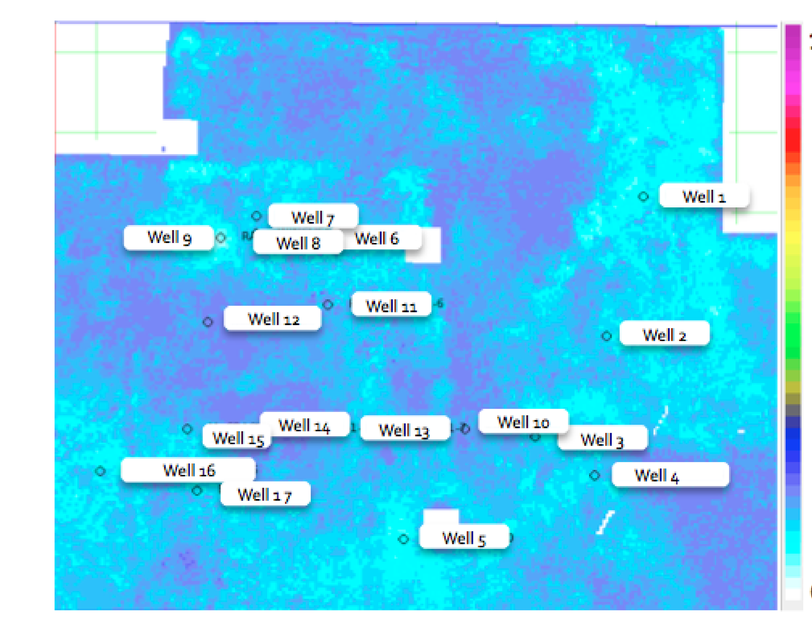

Figure 9: Probability of Chert at the top of the Mississippian formation

Conclusion

1. Data quality (30 degrees incident angle and noise level) limit the inversion accuracy.
2. A single shear sonic is used.
3. High mismatch percentage between the predicted and real lithology on wells.
4. Currently, we are re-processing the data and re-running the inversion to obtain more reliable results.

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