# An integrated study of a Mississippian tripolitic chert reservoir - Osage County, Oklahoma, U.S.A.

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AASPI


## Abstract

With the advent of horizontal drilling and hydraulic fracturing in the Midcontinent, U.S.A., fields once thought to be exhausted are now experiencing renewed exploitation. However, traditional Midcontinent seismic analysis techniques no longer provide satisfactory reservoir characterization for these plays; new seismic analysis methods are needed to properly characterize these radically innovative play concepts. Seismic attributes such as impedance inversion are sensitive to lithology while coherence and curvature are sensitive to lateral changes in waveform and structure.

Our objective is to map highly porous tripolitic chert "sweet spots" within a highly fractured Mississippian siliceous lime reservoir, located in Osage County, Oklahoma. In addition to the tripolitic chert facies, a tight, fractured chert facies is also present. In order to discriminate between these lithologies, we use impedance inversion and correlate with post stack seismic attributes and well log information.


## Geologic Setting

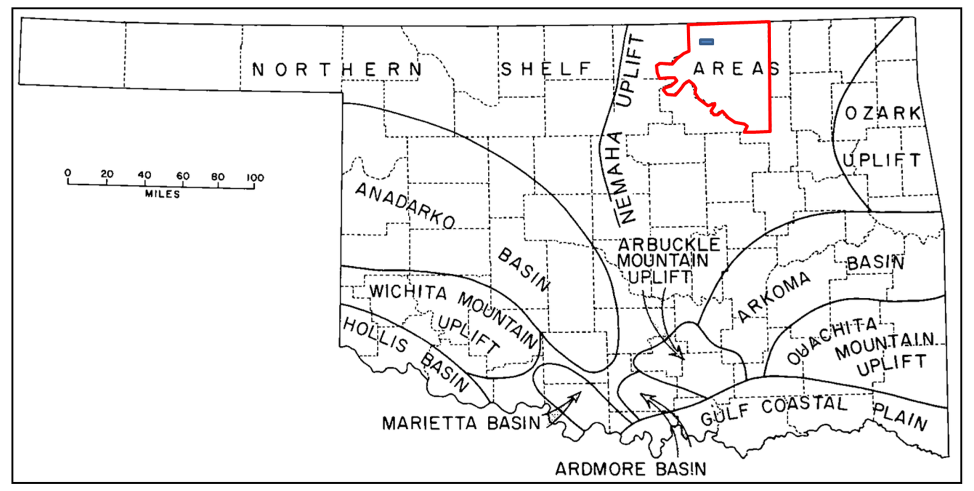



**Figure 1.** Geologic provinces of Oklahoma. Osage County is outlined in red, and the bounds of the survey are designated approximately by the blue box (Johnson and Cardott, 1992).

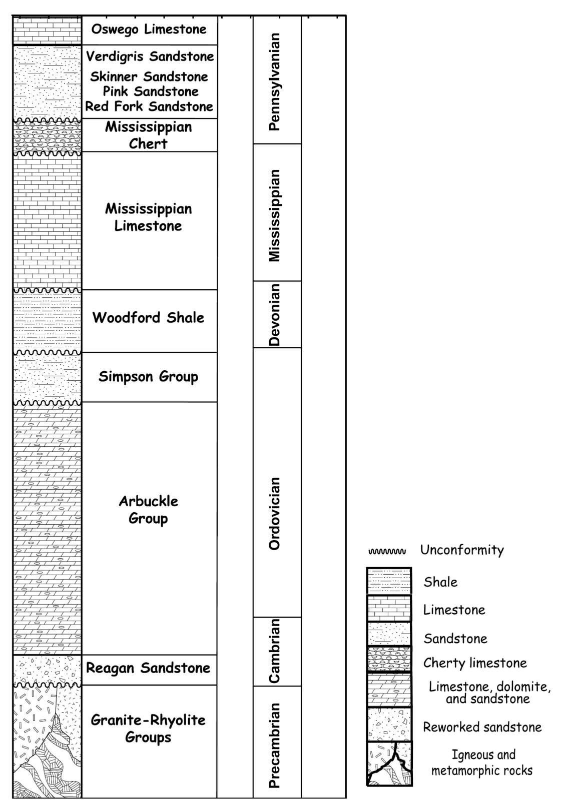



**Figure 2.** Generalized stratigraphic column for Osage County, Oklahoma (from Elebiju et al., 2011)

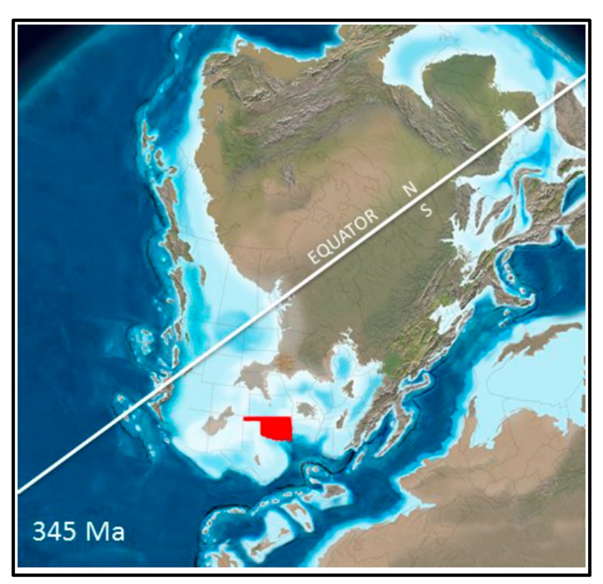
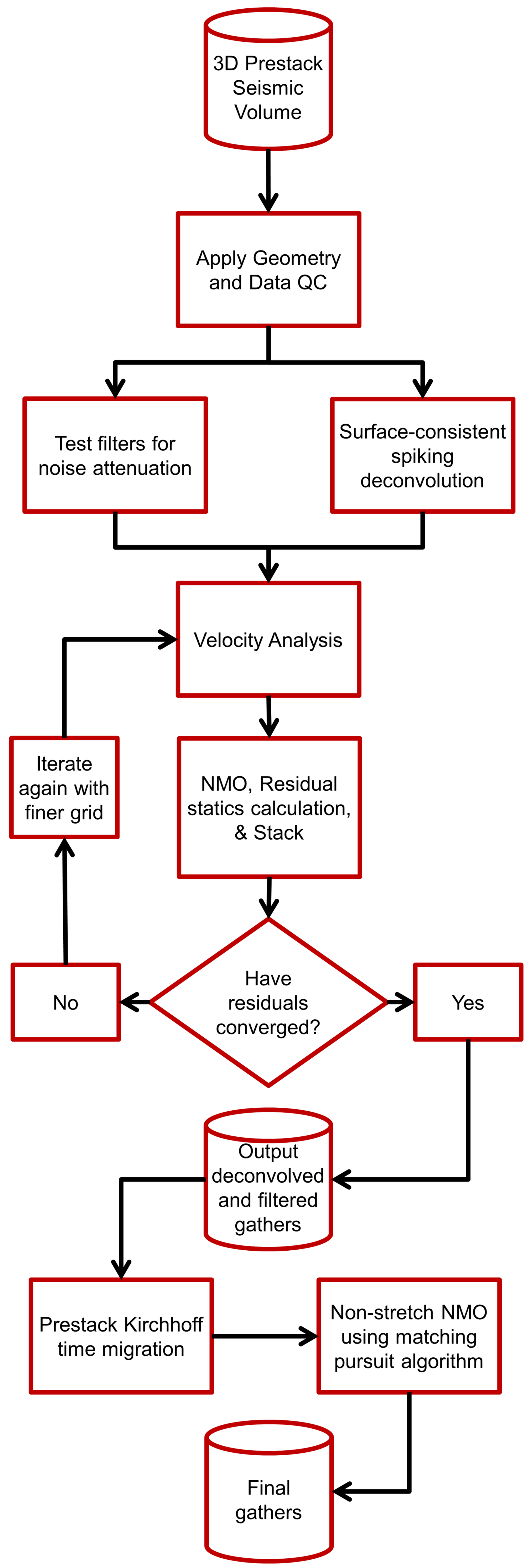



**Figure 3.** Paleogeographic map showing the location of Oklahoma during the Osagean, ca. 345 Ma (modified from Blakey, 2011).

## 3D Prestack Seismic Processing Workflow




## Preliminary prestack processing results compared to post stack data

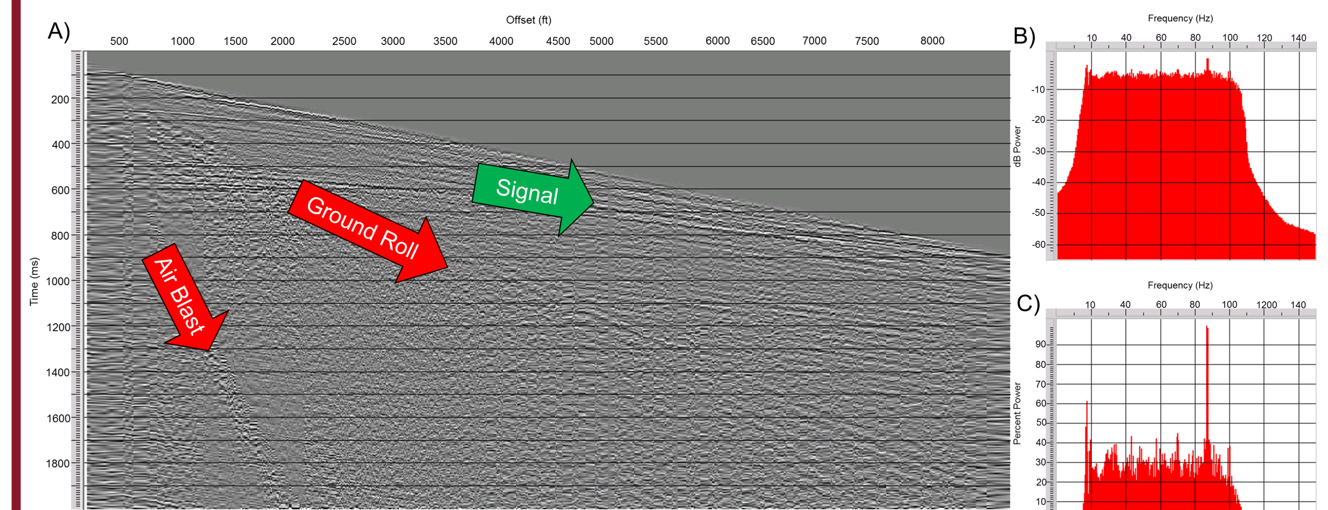



**Figure 4.** (A) Shot gather after surface-consistent spiking deconvolution, top mute, air blast attenuation, time-variant spectral whitening (10-18-100-110 Hz), & time-variant scaling. (B) dB power spectra and (C) percent power spectra.

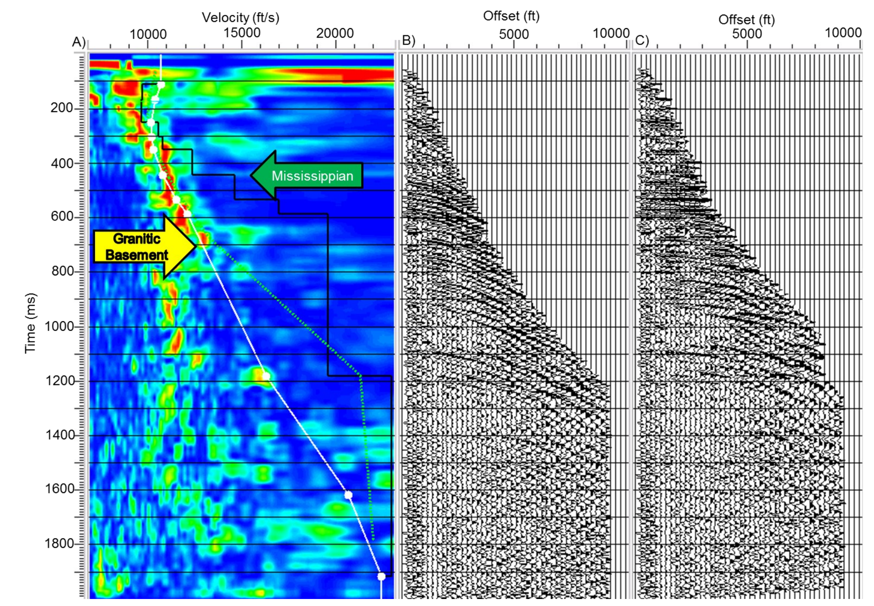



**Figure 5.** Final velocity analysis pass before prestack time migration. (A) Semblance panel, (B) CDP super gather before NMO correction, and (C) CDP super gather after NMO correction. The granitic basement is shallow (~700 ms), and we are able to resolve some basement structures.

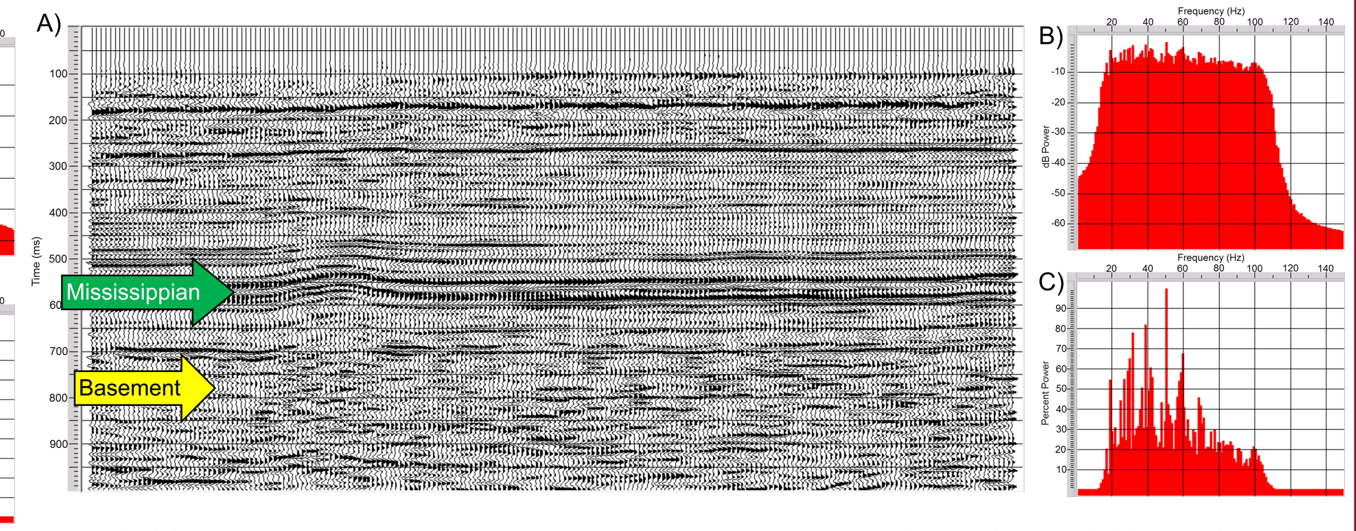



**Figure 6.** (A) Vendor-provided post stack time migrated 3D seismic survey. Time displayed is from 0 to 1000 ms. Below 700 ms is granitic basement. Notice the effect of FX deconvolution. (B) dB Power spectrum and (C) Percent Power spectrum for the vendor-provided post stack time migrated survey.

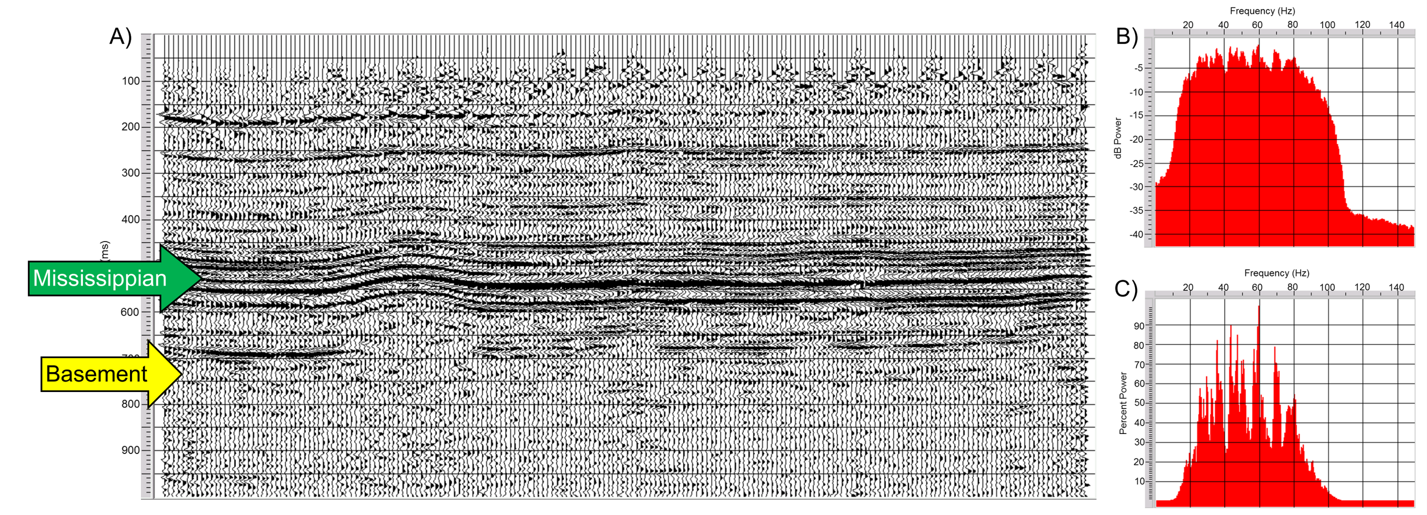



**Figure 7.** (A) Prestack processing after multiple iterations of velocity analysis and prestack structure-oriented filter. Time displayed is from 0 to 1000 ms. Lack of FX deconvolution does not create false layering in granitic basement below 700 ms. (B) dB Power spectrum and (C) Percent Power spectrum show similar shape to post stack processed data, but are more flat, evenly distributed, and contain higher frequency content.

## Post Stack Seismic Attributes

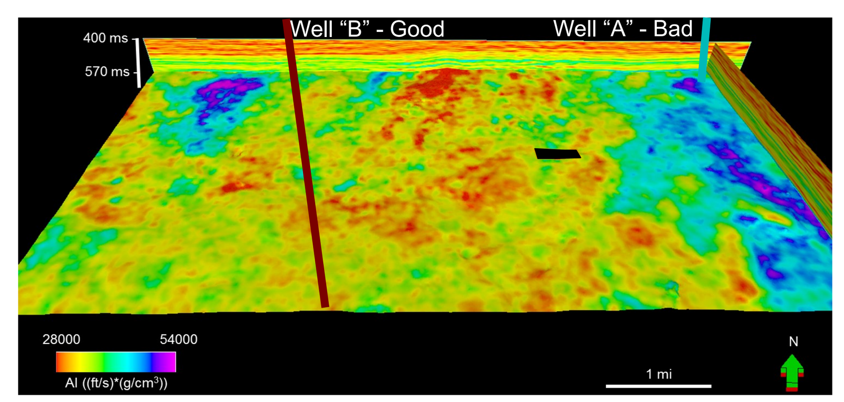



**Figure 8.** Post stack acoustic impedance (AI) inversion extracted along the top of the Mississippian surface. Potential pockets of tripolitic chert correspond to low (warm colors) AI values. The tripolitic chert is highly porous, with low density, hence, the expectation for low AI, while the tight, dense limestone and tight chert will exhibit high AI values.

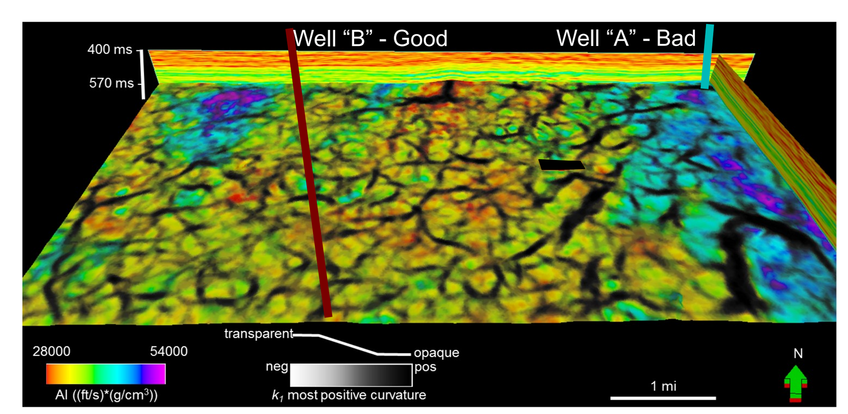



**Figure 9.** Post stack AI inversion co-rendered with $k_1$ most positive curvature. Potential tripolitic chert "sweet spots" occur where pockets of low AI values correspond with curvature anomalies. Curvature is an indicator of strain and is a proxy for areas of high fracture density.

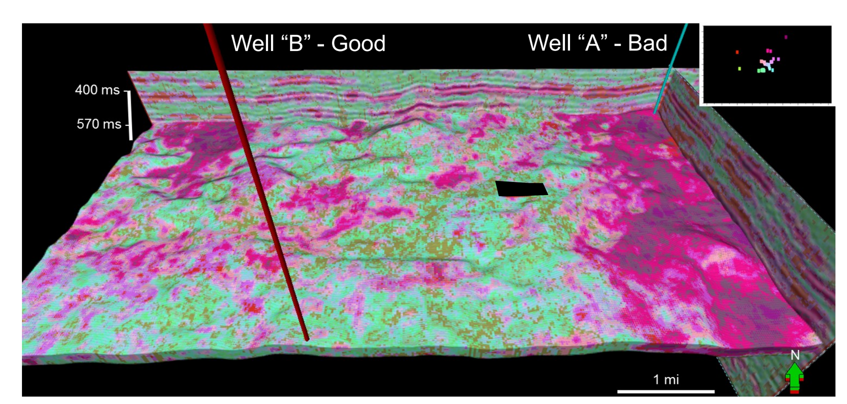



**Figure 10.** Facies volume from unsupervised 3D self-organizing maps (SOM3D). Input amplitude attributes are Coherent Energy, Spectral Bandwidth, GLCM Energy, GLCM Entropy, and GLCM Homogeneity. Here, greens correspond to potential tripolitic chert facies, while pink and magenta correspond to potential

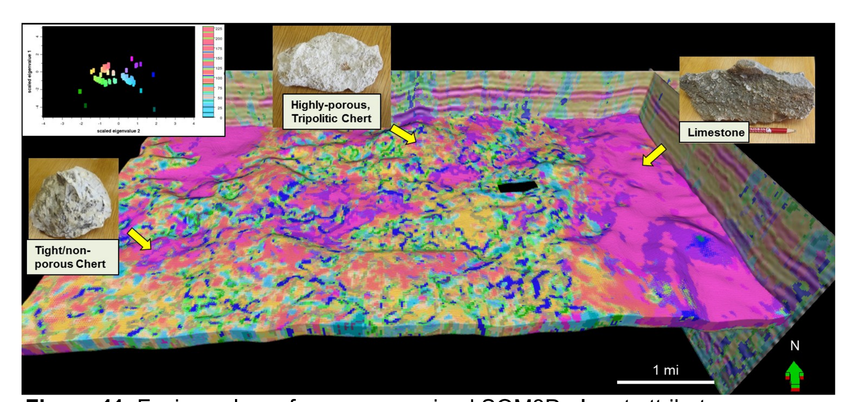



**Figure 11.** Facies volume from unsupervised SOM3D. Input attributes are Coherent Energy (amplitude measure), Coherency (structural), Dip Magnitude (structural), and Reflector Convergence (structural). Greens and yellows correspond to potential tripolitic chert facies, while pinks and magentas correspond to potential limestone and tight chert facies.

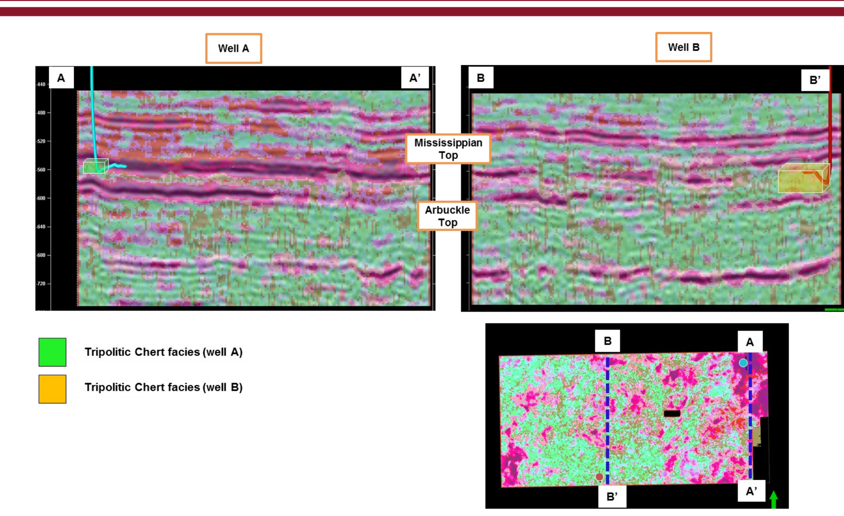



**Figure 12.** Wavelet extraction from wells A and B for supervised multi-attribute clustering and facies classification. Input attributes are Coherent Energy, Peak Frequency Magnitude, GLCM Entropy, and GLCM Homogeneity.

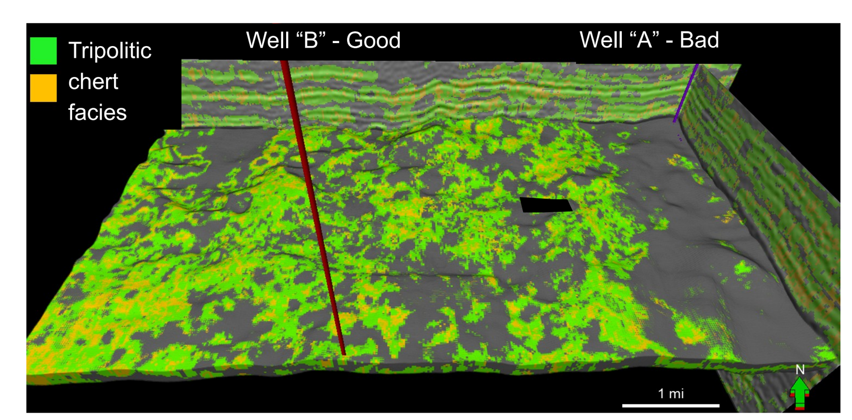



**Figure 13.** Facies volume from supervised multi-attribute clustering comparing the most representative wavelets around each well. Well A is very tight, while Well B is a decent producer.

## Cross plots

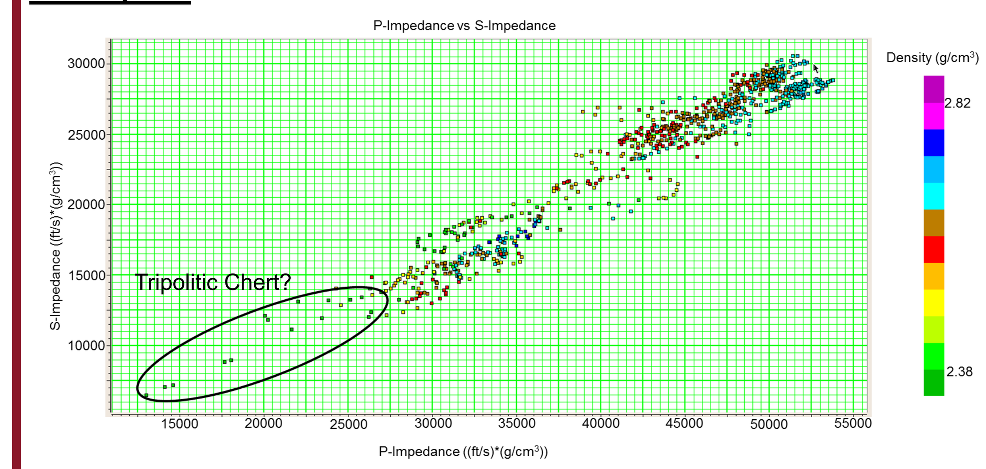



**Figure 14.** Crossplot of P-Impedance vs S-Impedance, colored by density. The lowest density points correspond to the lowest impedance values, and fall within the correct depth range for potentially being Tripolitic chert.

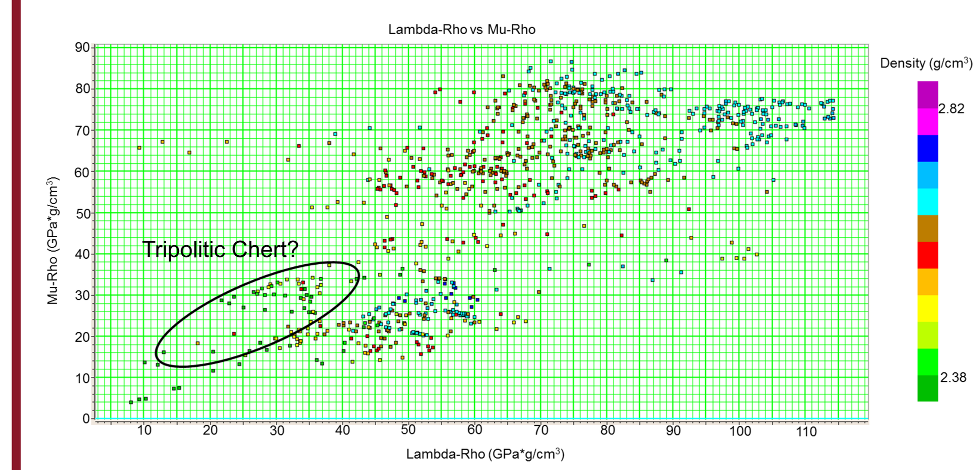
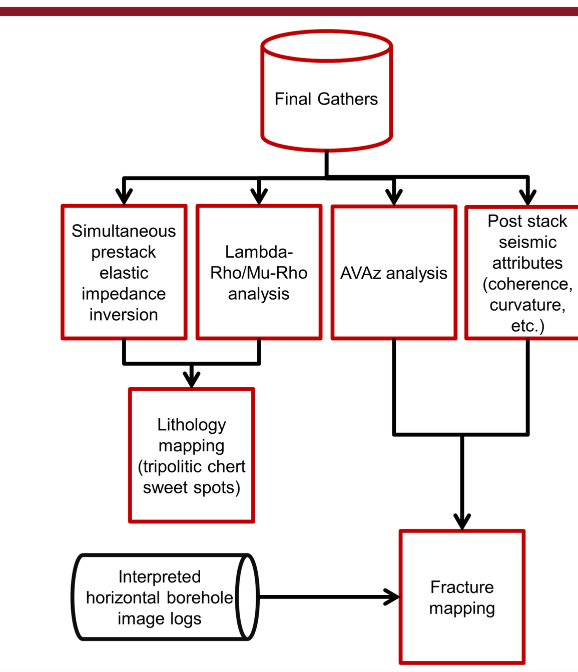



**Figure 15.** Crossplot of Lambda-Rho (λρ) versus Mu-Rho (μρ). Tripolitic chert is highly porous and is expected to exhibit low rigidity and low incompressibility.

## Next steps




## Conclusions

Prestack seismic analysis, while time-consuming, definitely provides better quality seismic data. Although the prestack results shown here have not yet been prestack time-migrated, the stack section shows better vertical and lateral resolution, exhibiting more layering and higher frequency content. We observe qualitative relationships between post stack attributes that allow us to map potential tripolitic chert "sweet spots", but quantitative results can only be accomplished through prestack analysis.


## Acknowledgements

We wish to thank first and foremost the Osage Nation and Spyglass Energy, LLC, for their interest in this research project and providing our dataset. We also wish to thank the sponsors of the Attribute Assisted Seismic Processing and Interpretation (AASPI) Consortium for their continued support and interest in our research. We thank the ConocoPhillips School of Geology & Geophysics and The University of Oklahoma for providing an environment in which scientific enquiry is nourished. We also wish to thank Mark Aisenberg, Oswaldo Davogustto, Dr. J. Tim Kwiatkowski, Trey White, and Bo Zhang for their input and ideas, as well as Halliburton/Landmark and TameCat for the use of their software.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