# Direct 3D Seismic Determination of Dolomitization and Associated Reservoir Quality Using Supervised Bayesian Classification and Probabilistic Neural Network (PNN): Lower-Middle Permian Carbonates of The Midland Basin

Abidin B. Caf & John D. Pigott
*School of Geosciences*
*Email: berkcaf@ou.edu*

## 1.Summary

Extensive dolomitization is prevalent in platform and periplatform carbonates in the Lower- middle Permian (Wichita-Clearfork) strata in the Midland and greater Permian basin (Mazullo, 1994). Early works (Saller et al., 1998, Mazullo et al., 1994) state that the platform and shelf-top carbonates were dolomitized while slope and basinal carbonates were remained calcitic. They conclude that Reflux Dolomitization is the possible diagenetic mechanism. More importantly, they underline that this dolomitization pattern controls the porosity and forms updip seal. There are numerous studies focused on Lower-Middle Permian dolomites in the Midland Basin, but they had been mostly conducted using well logs , cores and outcrops. Though they exhibit high resolution vertically, they are laterally sparse.

Aim of this study is to use Supervised Bayesian Classification and Probabilistic Neural Networks (PNN) to create estimation of the most probable distribution of dolomite and calcite, and combine this lithology information with porosity to illuminate the diagenetic effect in the seismic scale. Workflow begins with deriving lithology classifications from well log cross-plots of Neutron Porosity and Acoustic Impedance to determine a priori proportions of lithologies, and Probability Density Functions (PDF) calculation for each lithology type. This probability distributions and a-priori proportion then applied to full seismic volumes of Acoustic impedance and predicted NPHI volume to create lithology volume and their probabilities. To create these input seismic volumes Model based Post-Stack Inversion and Probabilistic Neural Network (PNN) was performed.

Results tie with the regional Reflux Dolomitization model, in which the porosity is increasing from shelf to slope, while dolomitization is decreasing. This work also suggest that diagenesis in the Leonardian strata and corresponding reservoir quality can be mapped in seismic scale, by quantitative seismic interpretation and supervised classification methods which will help to reduce uncertainty.

## 2. Background Geology

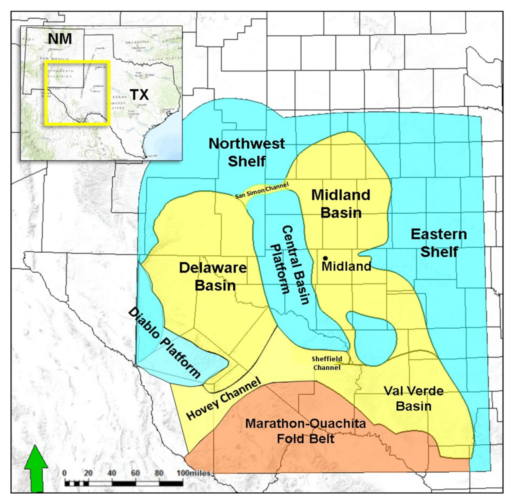



**Figure 1:** Geologic provinces of Greater Permian basin. (Modified after The University of Texas at Austin, Bureau of Economic Geology, 2008).

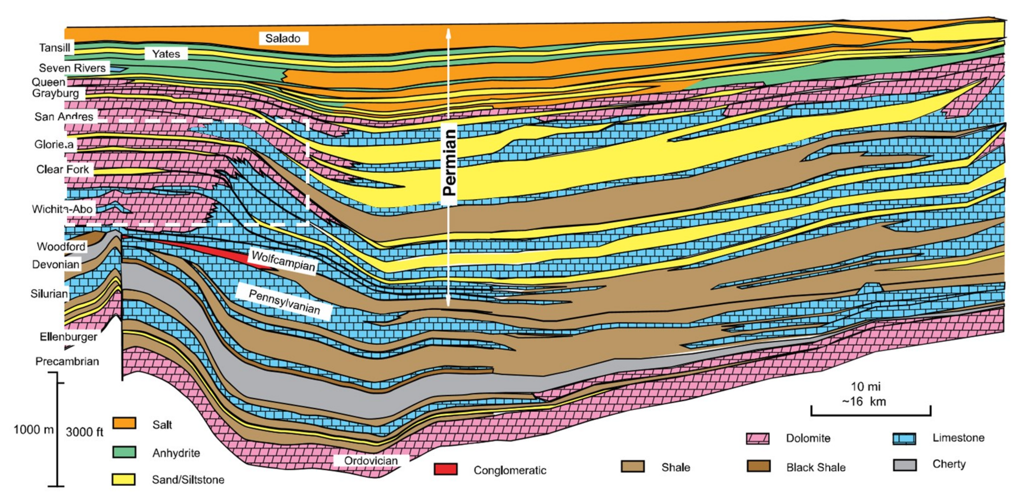



**Figure 2:** Schematic cross–section showing the generalized stratigraphy of the Midland Basin (Modified after Saller et al., 2011). This study was focused on the Lower Permian Clearfork interval (White dashed box). Note that Shelf is Mainly dolomite while slope is Limestone.

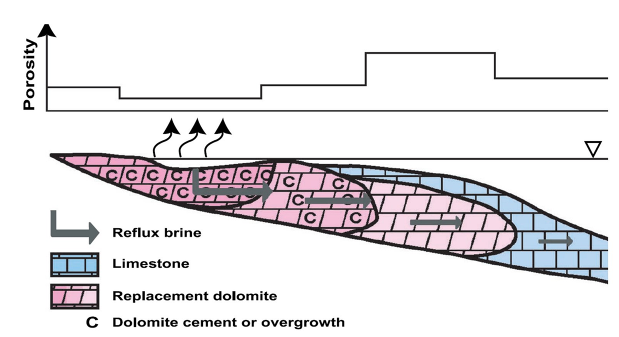



**Figure 3:** Conceptual model of reflux dolomitization. Note that porosity increases basin ward because of dolomite cementation proximal to the brine source ( Xiao et al., 2015 after Saller and Henderson, 1998).

## 3. Workflows

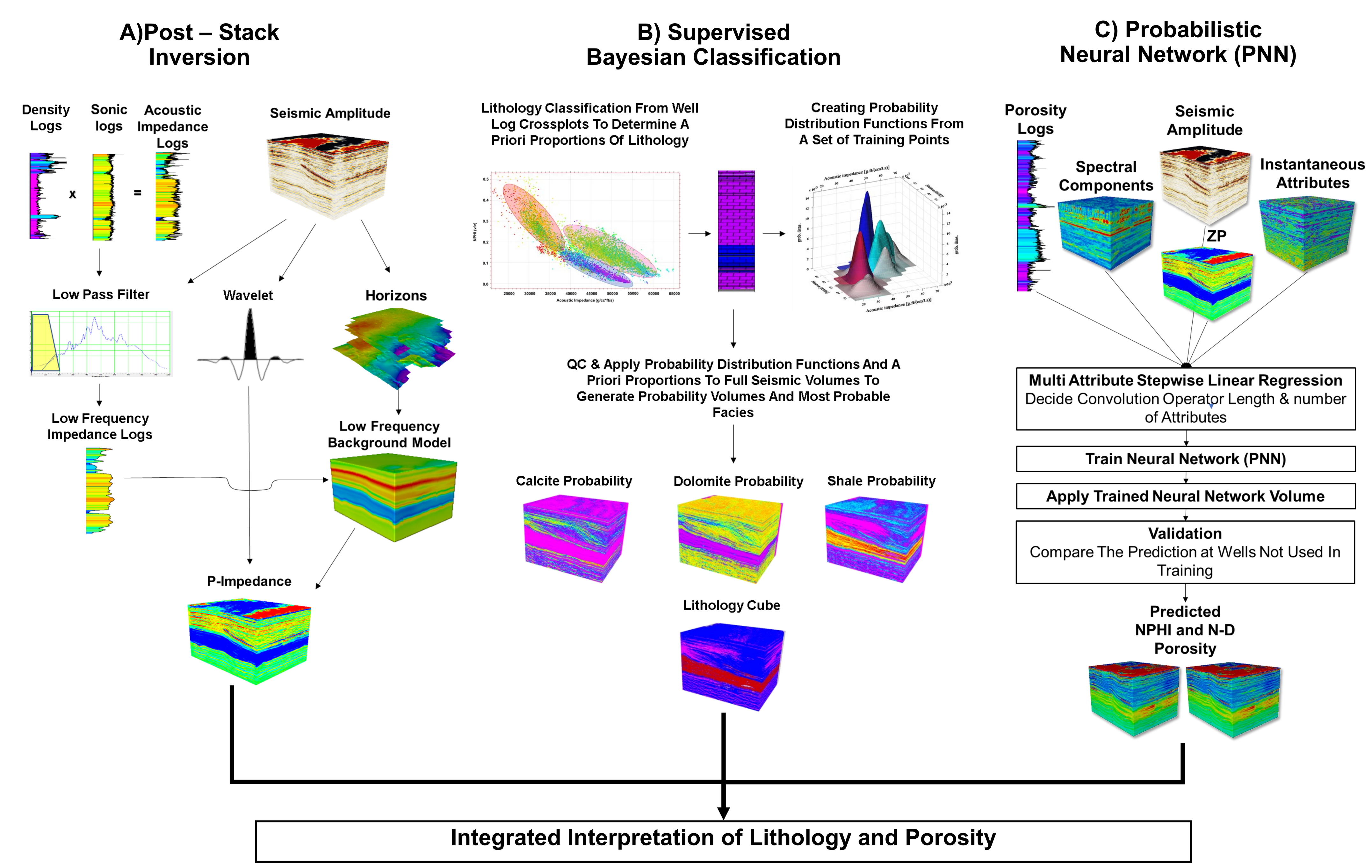



**Figure 4:** Generalized Workflow showing three main steps followed in this study. These steps are: (Left) Model-Based Post-Stack Inversion (After Russel et al., 2006), (middle) Bayesian Supervised Classification (after, Nieto et al., 2013), and (Right) Probabilistic Neural-Network (PNN) for porosity prediction (After Verma, 2015) .

## 4. QC & Application

### A) Post-Stack Inversion QC

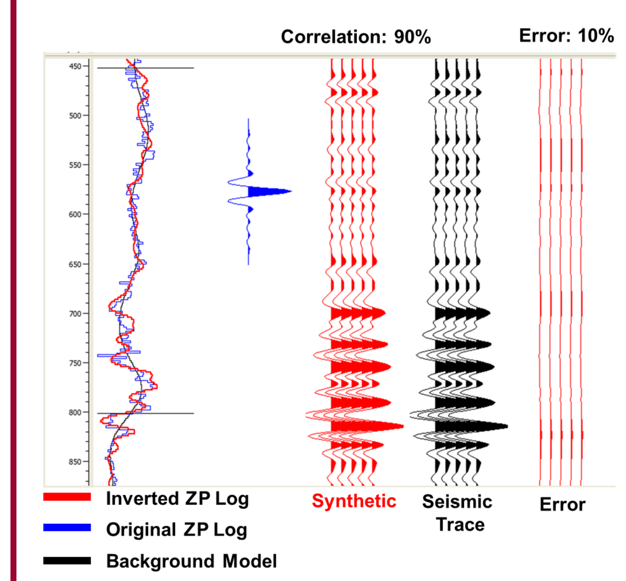



**Figure 5:** Post–Stack Inversion QC on the Well #1. Correlation is 90%.

### B) Neural Network Training And Validation

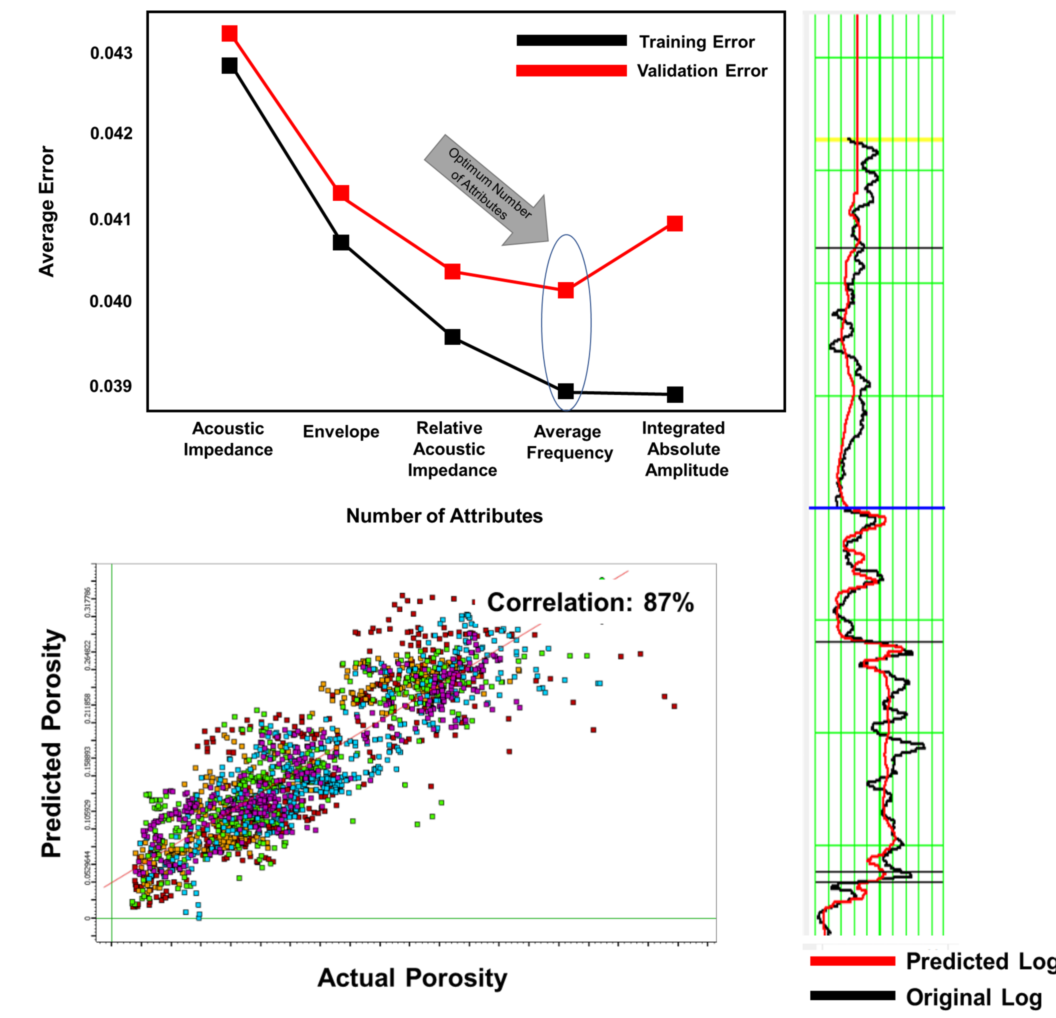
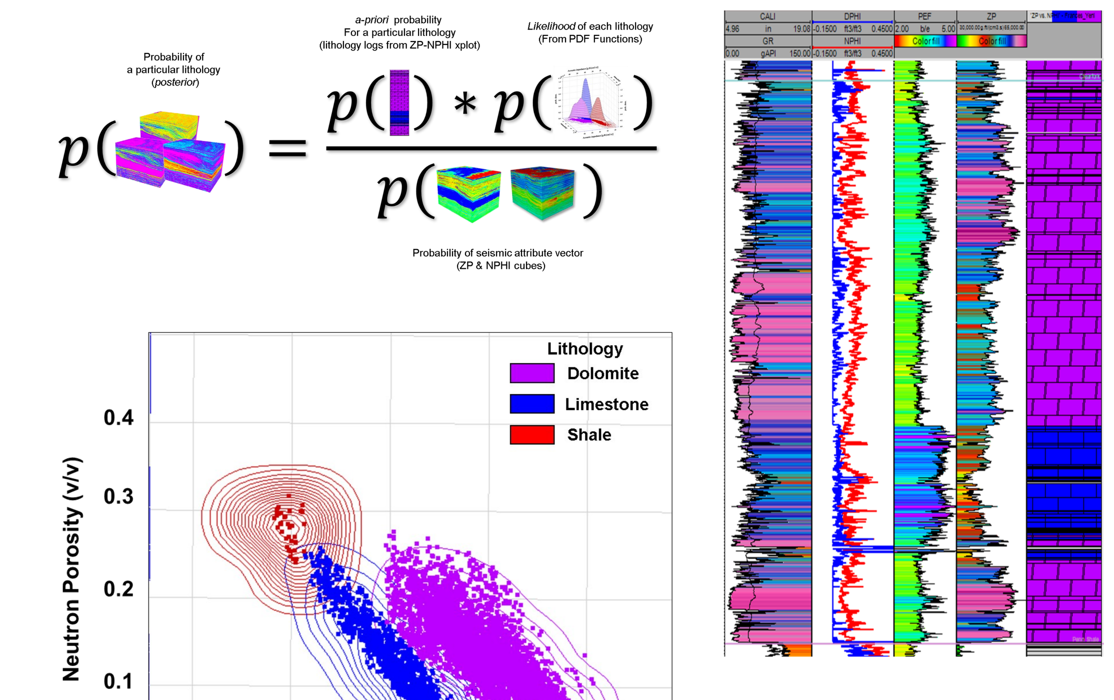



**Figure 6:** Selection of optimum number of attributes (top) and validation result of Neural Network at the . Cross-plot of predicted and actual porosity shows 87% correlation (left). Blind well which was not used in the training (right).

### C) Bayes' Theorem, PDF's And Confusion Matrix




| | | Predicted Lithology | | |
|---|---|---|---|---|
| Lithology Logs | | Dolomite | Limestone | Shale |
| | Dolomite | 84.22% | 11.43% | 04.35% |
| | Limestone | 13.42% | 81.95% | 04.63% |
| | Shale | 05.19% | 0.04% | 94.85% |

**Figure 7:** Simplified Bayesian Theory for lithology classification (top left). Lithology Determination by cross-plotting ZP vs NPHI logs and calculation of Probability Density Functions (PDF) for each lithology type (bottom left). Resulting lithology logs are shown with the suite of well logs on well #2 ( top right). Confusion Matrix showing the match between Well log lithology and predicted (classified) lithology (bottom right).

## 5.Results

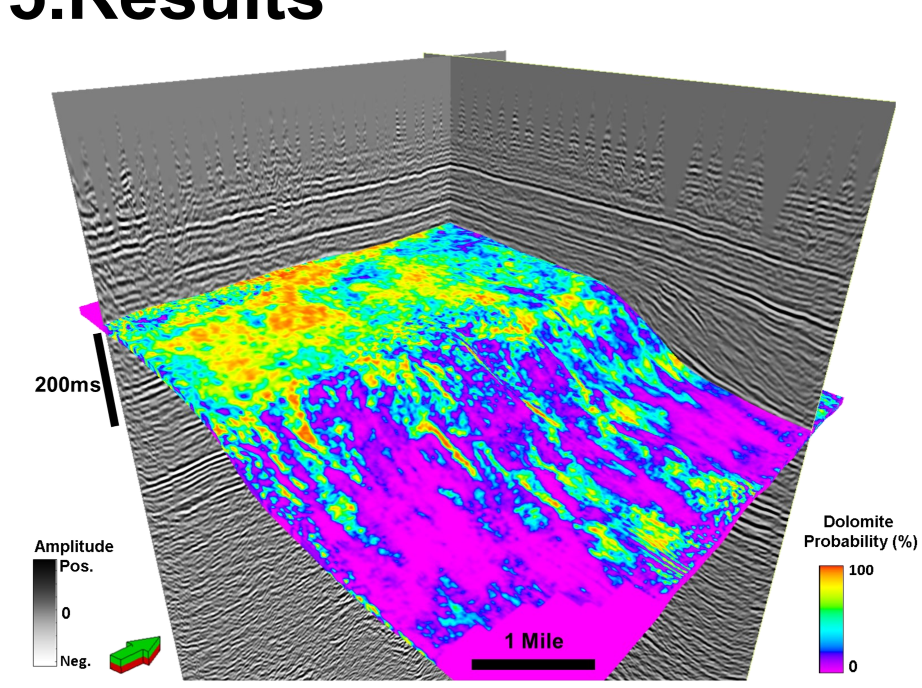



**Figure 8:**Dolomite Probability extracted on the Middle Clearfork interval. Note the decreasing dolomite probability from shelf to slope.

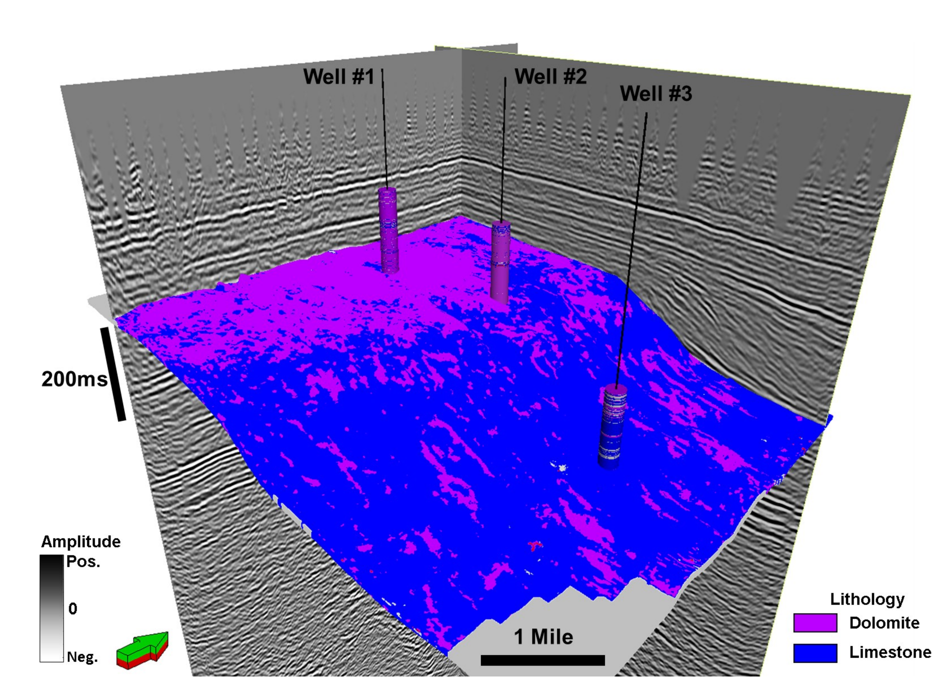



**Figure 9:** Predicted lithology extracted from the Middle Clearfork Interval. Platform is dolomitized, while shelf and slope are remain calcitic.

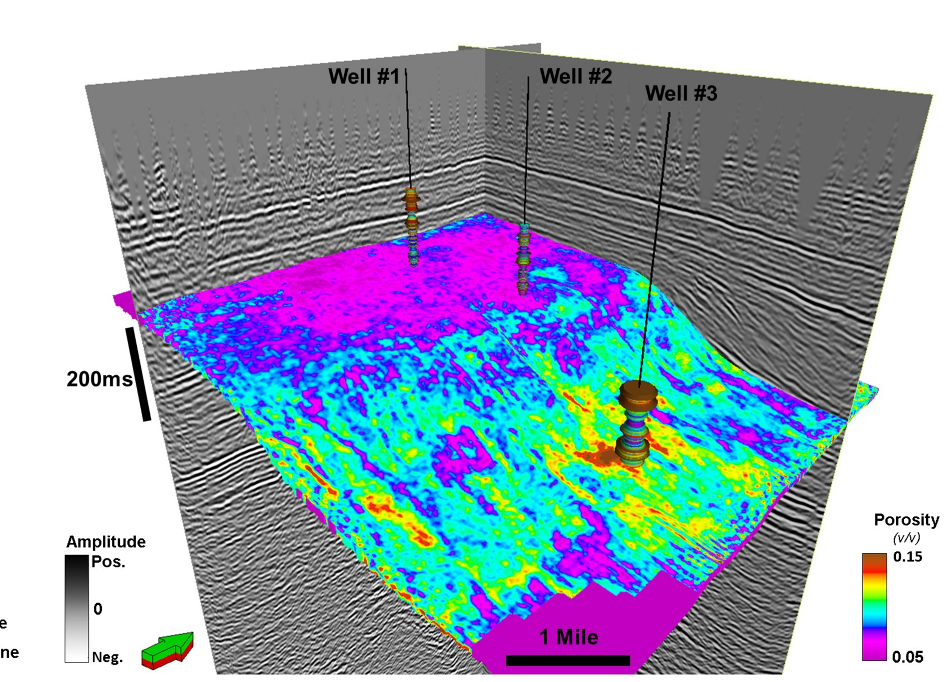



**Figure 10:** Predicted porosity extracted on the Middle Clearfork interval. Porosity increases from shelf to slope. Well #2 is a blind well which was not in the Neural-Network Training.

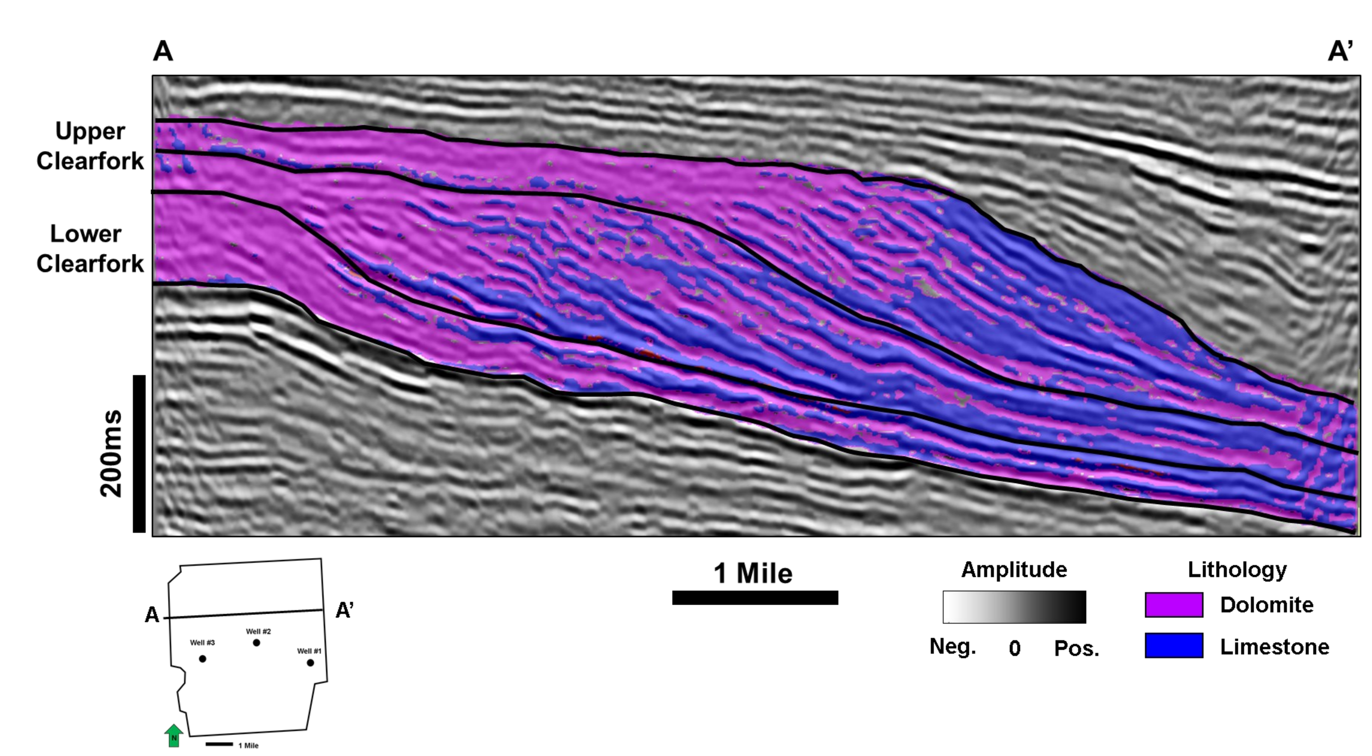



**Figure 11:** Arbitrary line (A-A') showing predicted Lithology co-rendered with seismic amplitude. Note that platform top is dolomite, while slope is limestone.

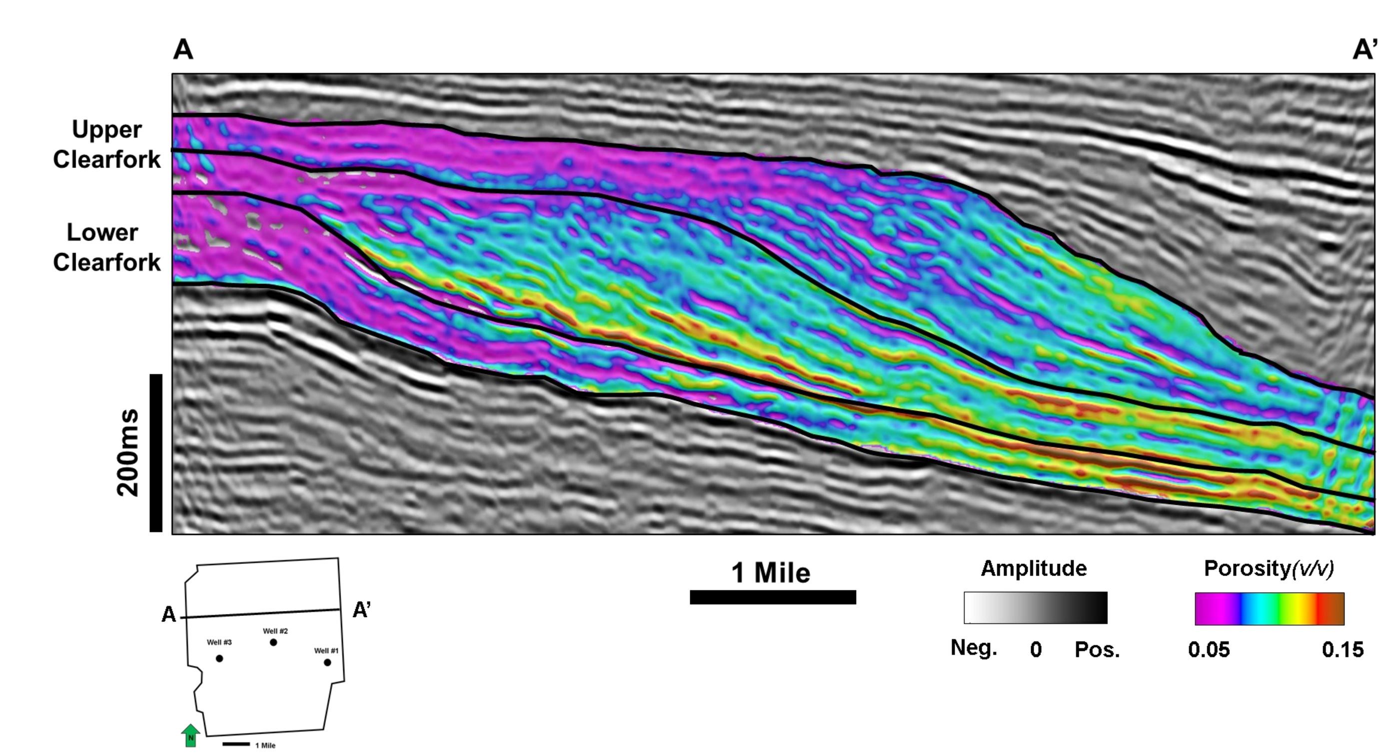



**Figure 12:** Arbitrary line (A-A') showing predicted porosity co-rendered with seismic amplitude. Porosity is increasing from shelf to slope.

## References

Mazullo, S., J., 1994, Dolomitization of periplatform carbonates (Lower Permian, Leonardian), Midland basin, Texas, Carbonates and Evaporites, 1994, 9, 1, 95.
*Nieto et al., 2013, Seismic Lithology Prediction: A Montney Shale Gas Case Study, CSEG Recorder* Special Edition, 2013.
Saller, A. H., and N. Henderson, 1998, Distribution of porosity and permeability in platform dolomites: Insight from the Permian of west Texas: AAPG Bulletin, v. 82, p. 1528– 1550
Russell, B., Hampson, D., Bankhead, B., 2006, An inversion primer, CSEG Recorder Special Edition, no. 1, 96-103.
Saller, A. & Dickson, J., 2011, Partial dolomitization of a Pennsylvanian limestone buildup by hydrothermal fluids and its effect on reservoir quality and performance. AAPG Bulletin. 95.
Saller, A., 2014, Late Pennsylvanian and Early Permian Sedimentation on the Central Basin Platform and Implications to the Wolfberry Deposition in the Western Midland Basin, APG 2014 Southwest Section Annual Convention, Midland, Texas, May 11-14, 2014
Verma, S., 2015, Seismic data conditioning for quantitative interpretation of unconventional reservoirs, Ph.D. dissertation, University of Oklahoma, Norman, Oklahoma.
Xiao, Y., Jones, G., D., 2015, Dolomitization, anhydrite cementation, and porosity evolution in a reflux system: Insights from reactive transport models. *AAPG Bulletin* ; 89 (5): 577–601.

## Conclusions & Future Work

Integration of Supervised Bayesian Classification and Probabilistic Neural Network (PNN) study in the Midland Basin showed that the dolomitization and corresponding reservoir quality can be extracted from seismic data. Results tie with the regional Reflux Dolomitization model, in which the porosity is increasing from shelf to slope, while dolomitization is decreasing. For the next step in this study, CDP gathers will be utilized to perform pre-stack inversion. Additionally, Results of this study will be compared to unsupervised classification methods.

## Acknowledgements

*Thanks to CML Exploration for their seismic data. Also I would like to thank to Schlumberger for providing Petrel© Software, And CGG for providing Hampson & Russell© Software, and Thanks to AASPI members and sponsors. For AASPI software.*