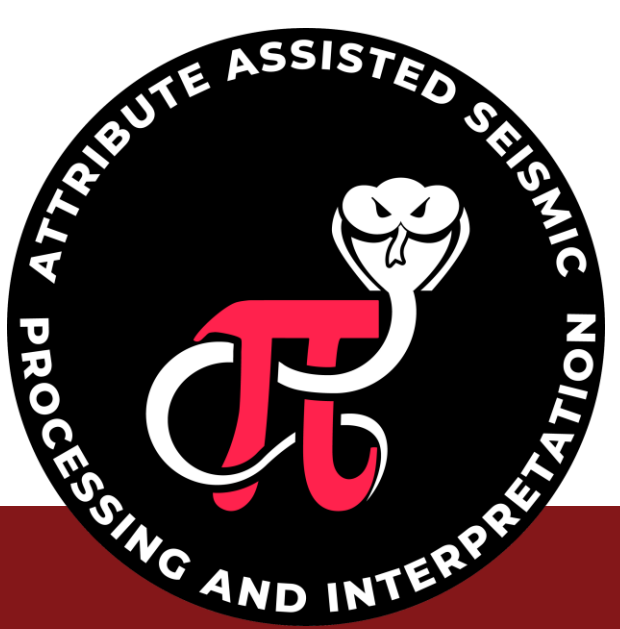




# Integrating Seismic Inversion Products into Multi-Attribute Analysis and Unsupervised Machine Learning for Reservoir Characterization

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## INTRODUCTION

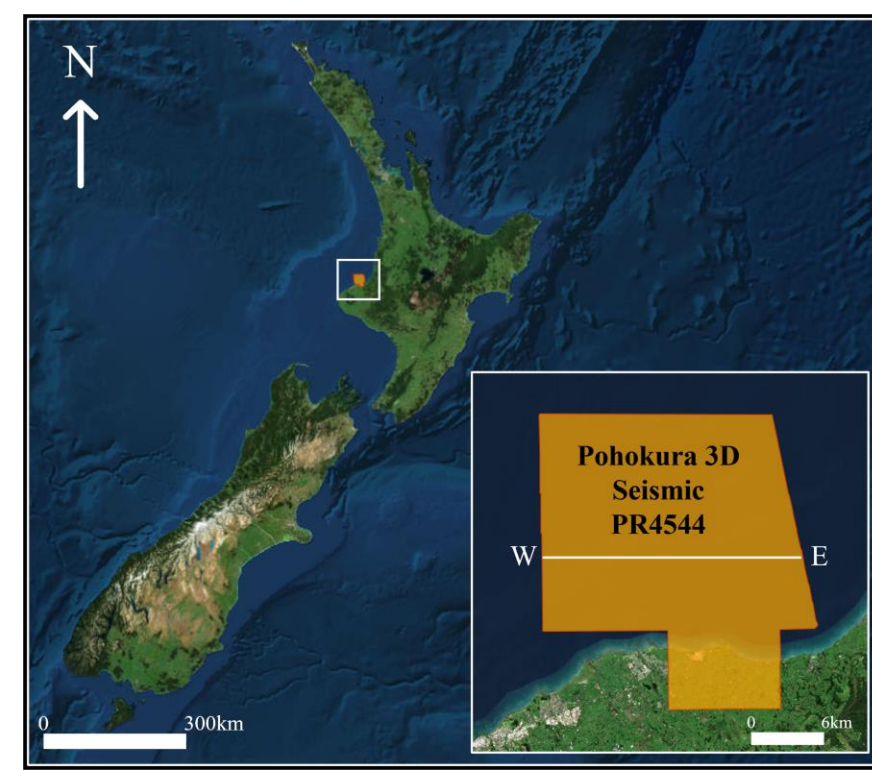


Figure 1: Location of the Pohokura Field

Multi-attribute analysis and machine-learning applications have proven highly effective in reservoir characterization and facies classification. However, the ability of multi-attribute analysis to yield geologically meaningful results is strongly conditioned by the diversity and extent of the input data. We hypothesize that including inversion products in multi-attribute analysis enriches the dataset with low-frequency information.

Accordingly, this study investigates how this integration can improve reservoir characterization. For this cause, we selected the Pohokura hydrocarbon field (New Zealand) as a case study, given its comprehensive datasets, pronounced reservoir heterogeneity, and clear structural elements.

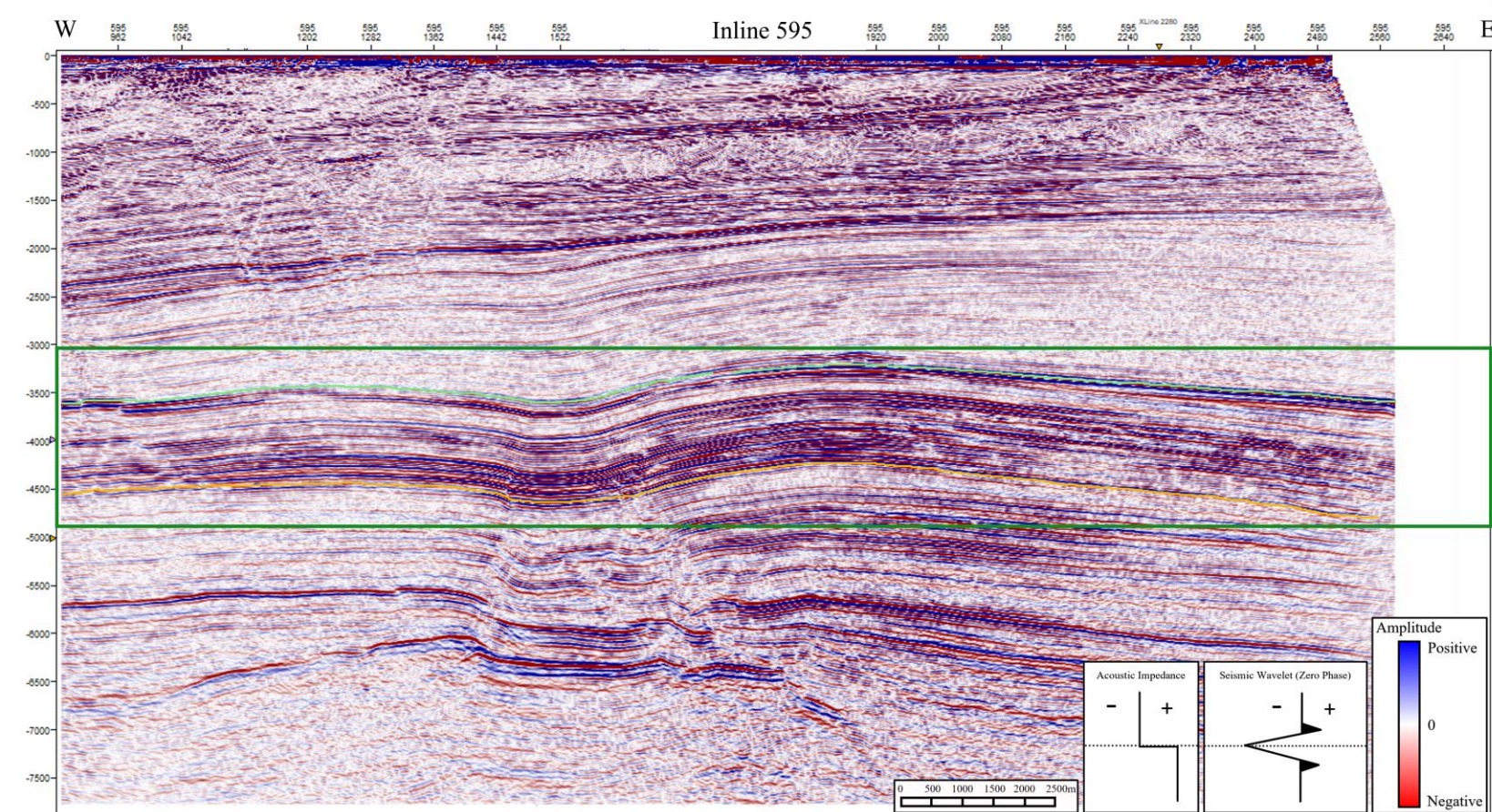


Figure 2: Seismic amplitude section along inline 595 (W-E)

Due to acquisition limitations, attenuation, and common processing steps (e.g., low-cut filtering, deconvolution, noise suppression), seismic amplitude volumes contain energy only within a restricted frequency band (typically ~ 5-80 Hz).

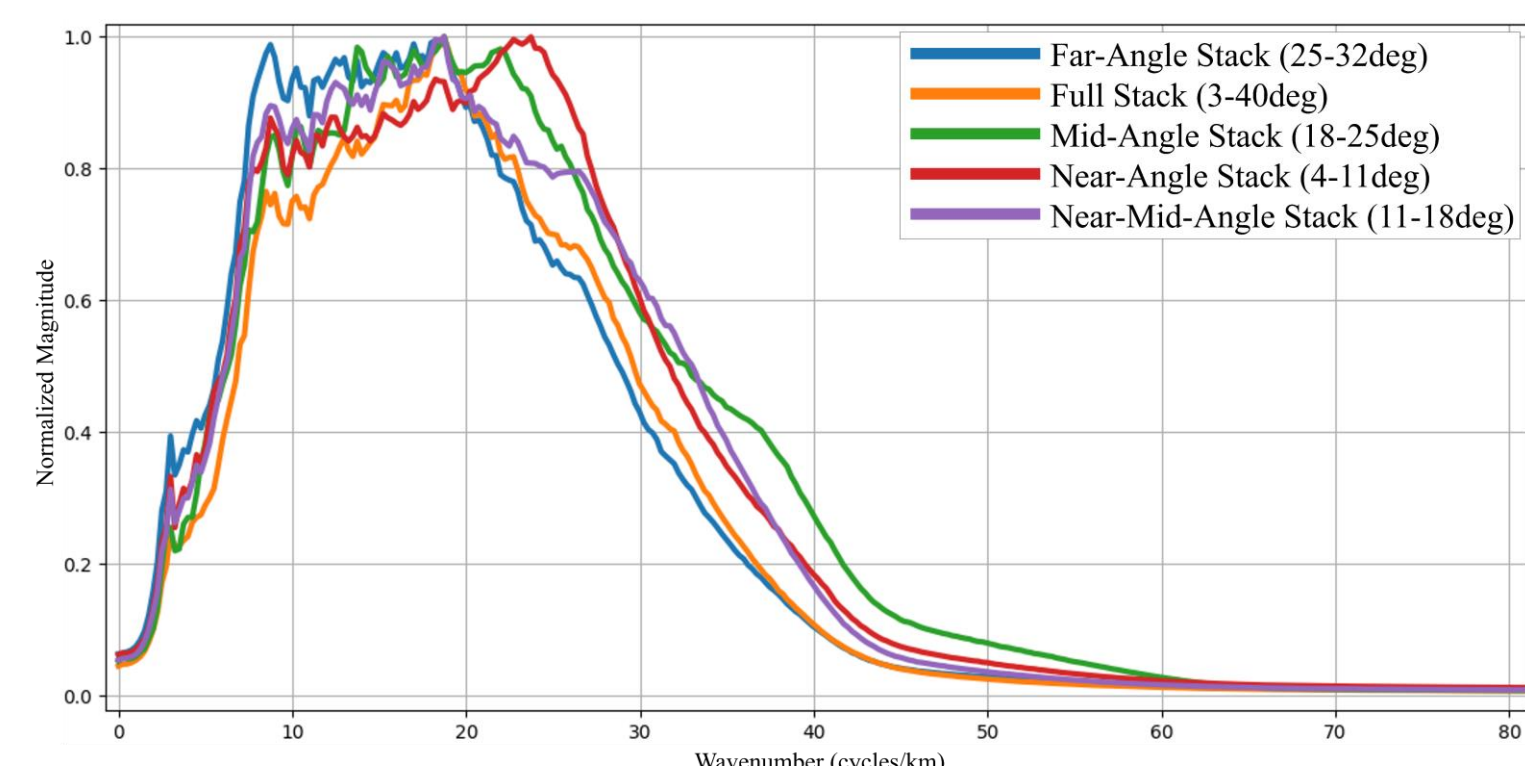


Figure 3: Amplitude spectrum comparison of different angle stacks

## METHODOLOGY

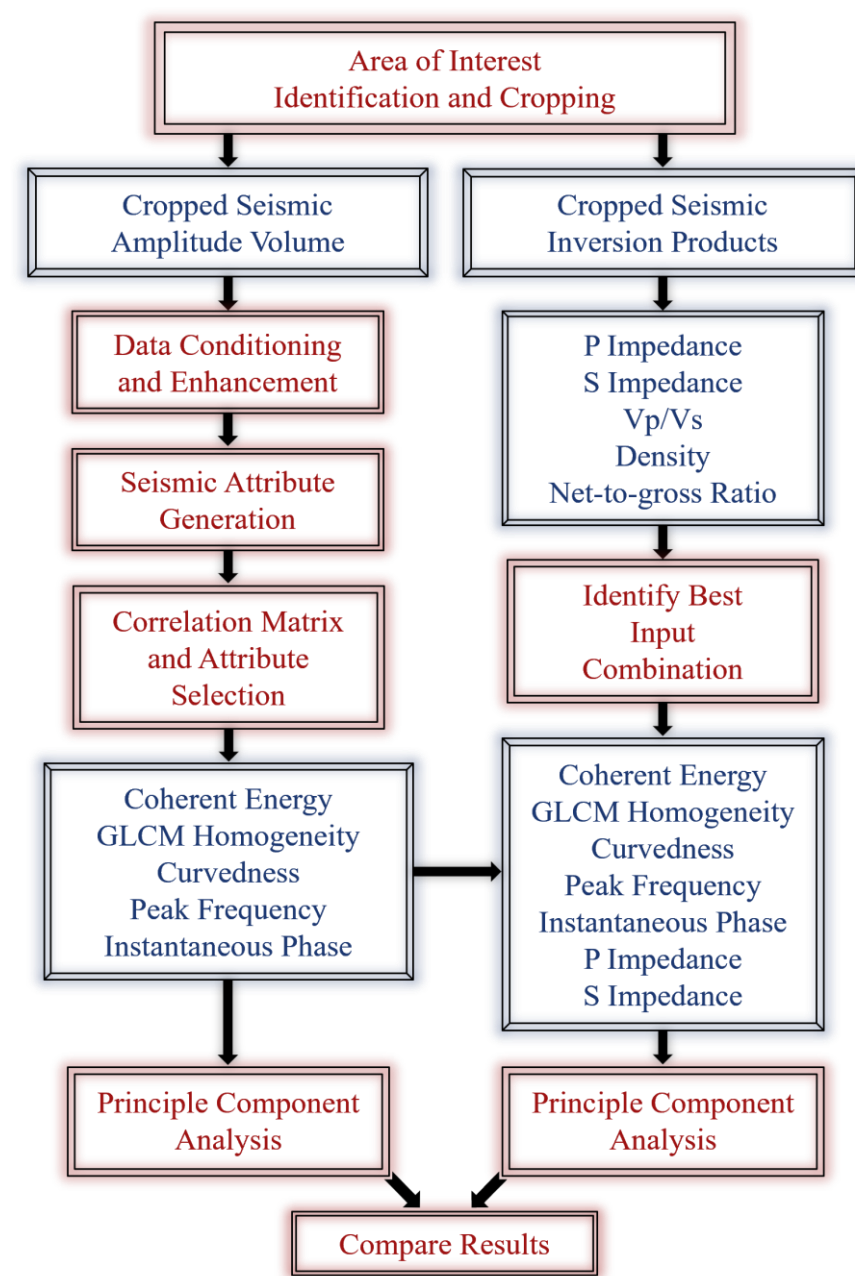


Figure 4: Generalized workflow chart

Seismic amplitude data and inversion products were cropped to the 3000-5500 m interval to encompass the reservoir and associated geological features.

Footprint suppression, and spectral balancing were applied to the full-stack seismic volume to enhance signal quality, reduce acquisition-related artifacts, and ensure a balanced frequency spectrum prior to attribute generation.

Using the selected attribute set, two PCA scenarios were constructed: one without inversion products (attributes only) and one with inversion products included. For each scenario, two principal components (PC1 and PC2) were generated, and the resulting components were cross plotted.

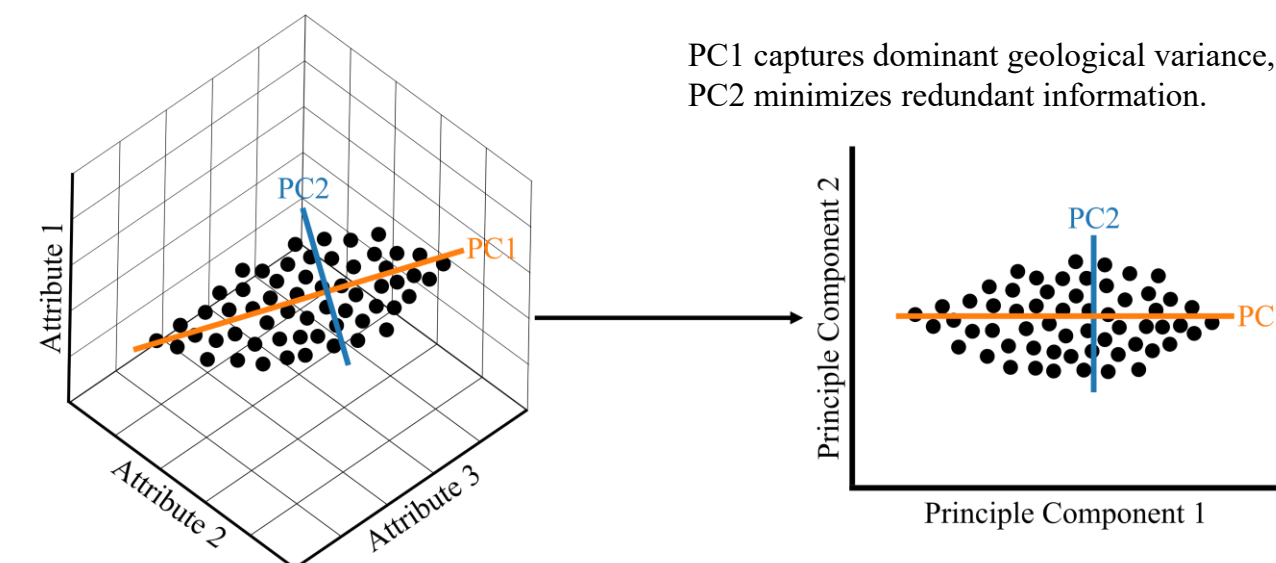


Figure 5: PCA concept illustration

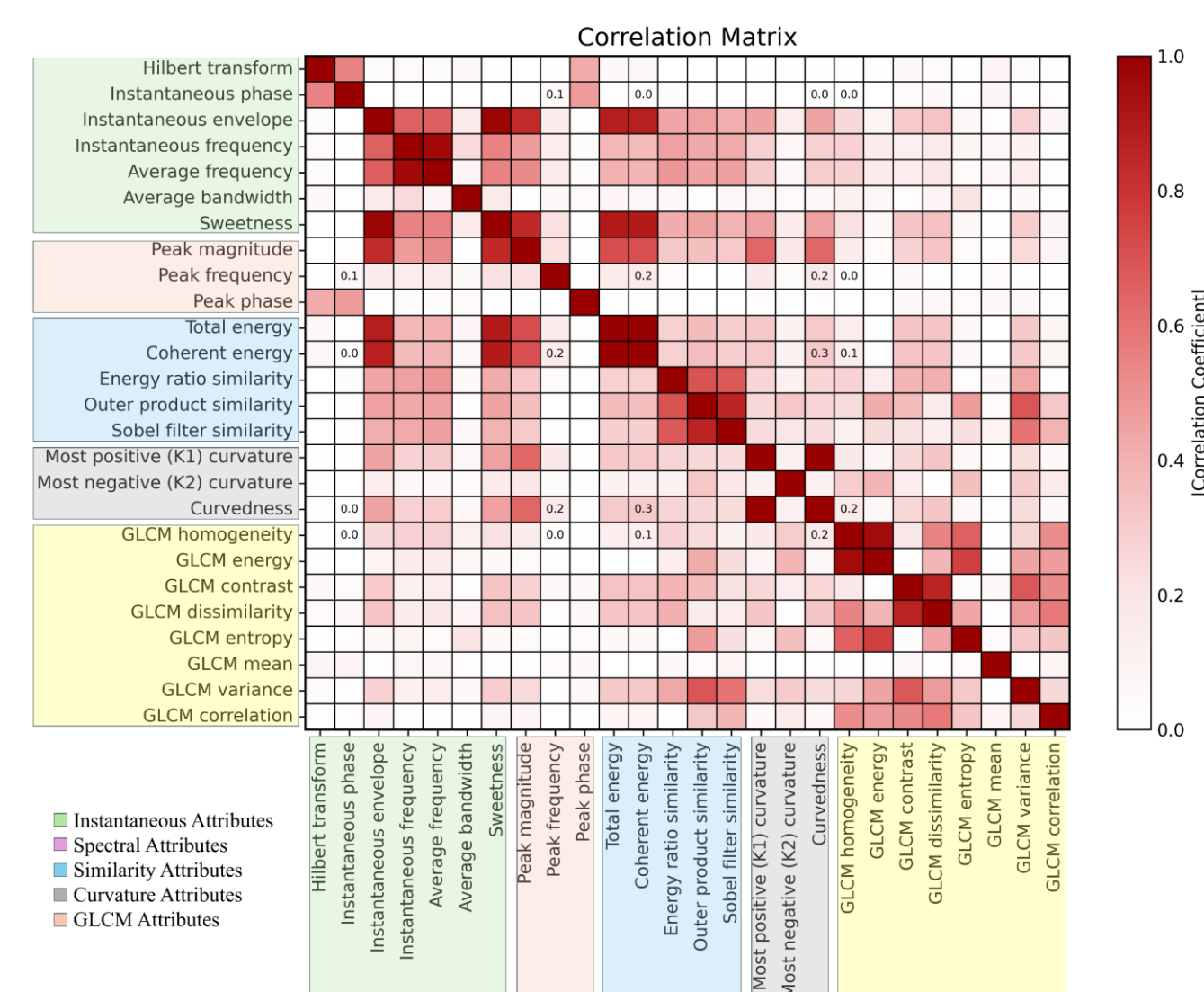


Figure 6: Correlation matrix of the seismic attributes

## PCA INPUTS

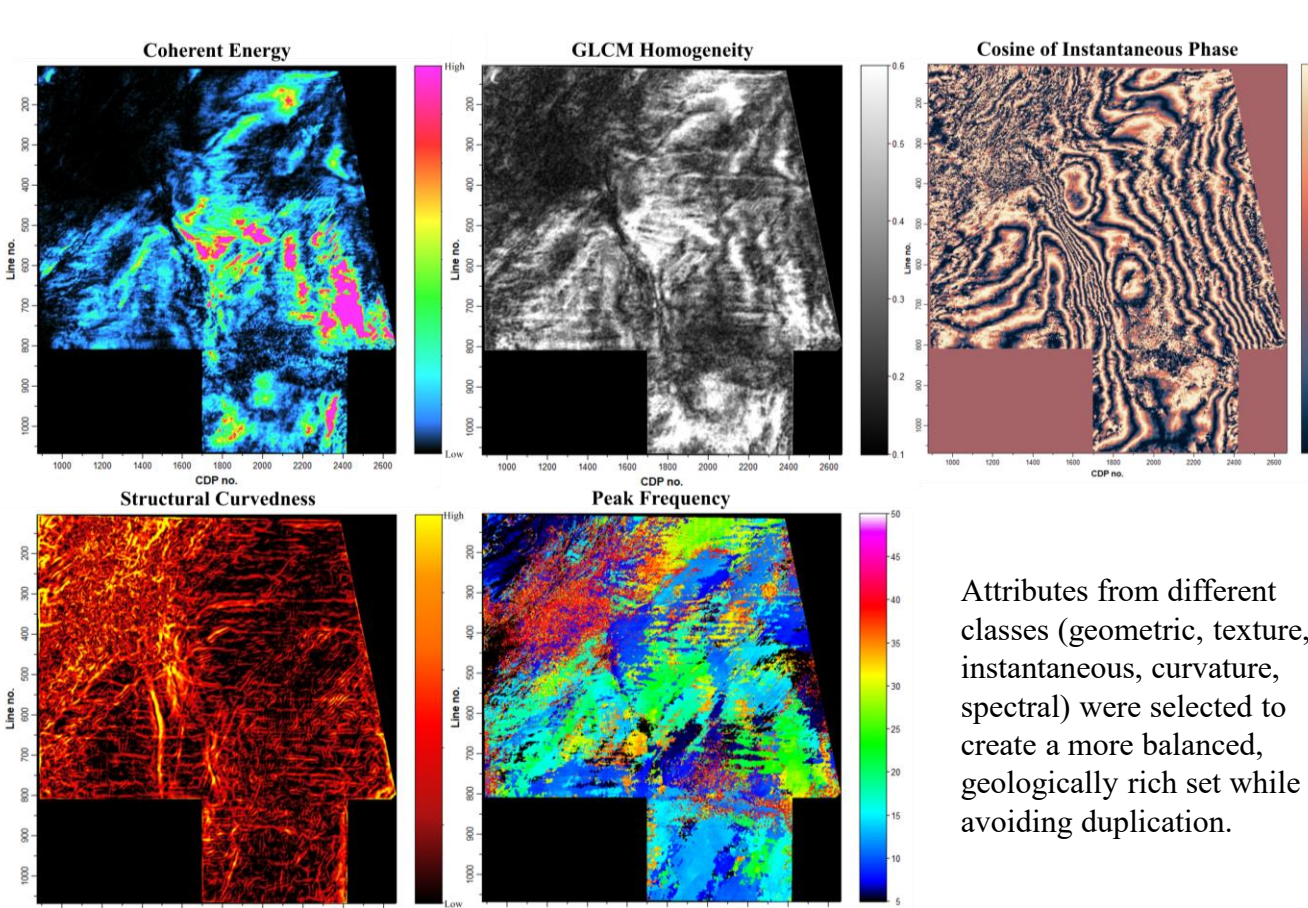


Figure 7: Seismic attributes selected for PCA

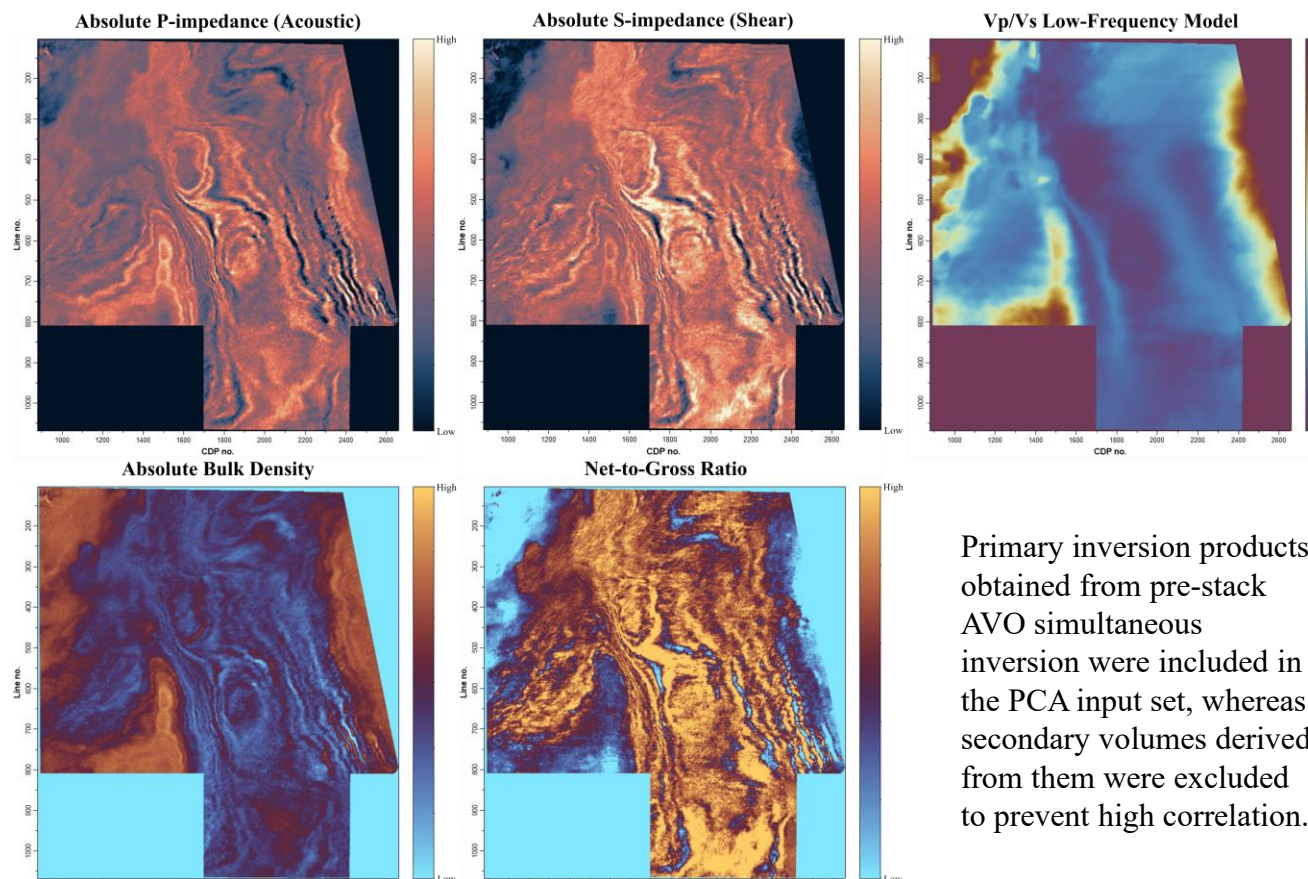


Figure 8: Inversion products

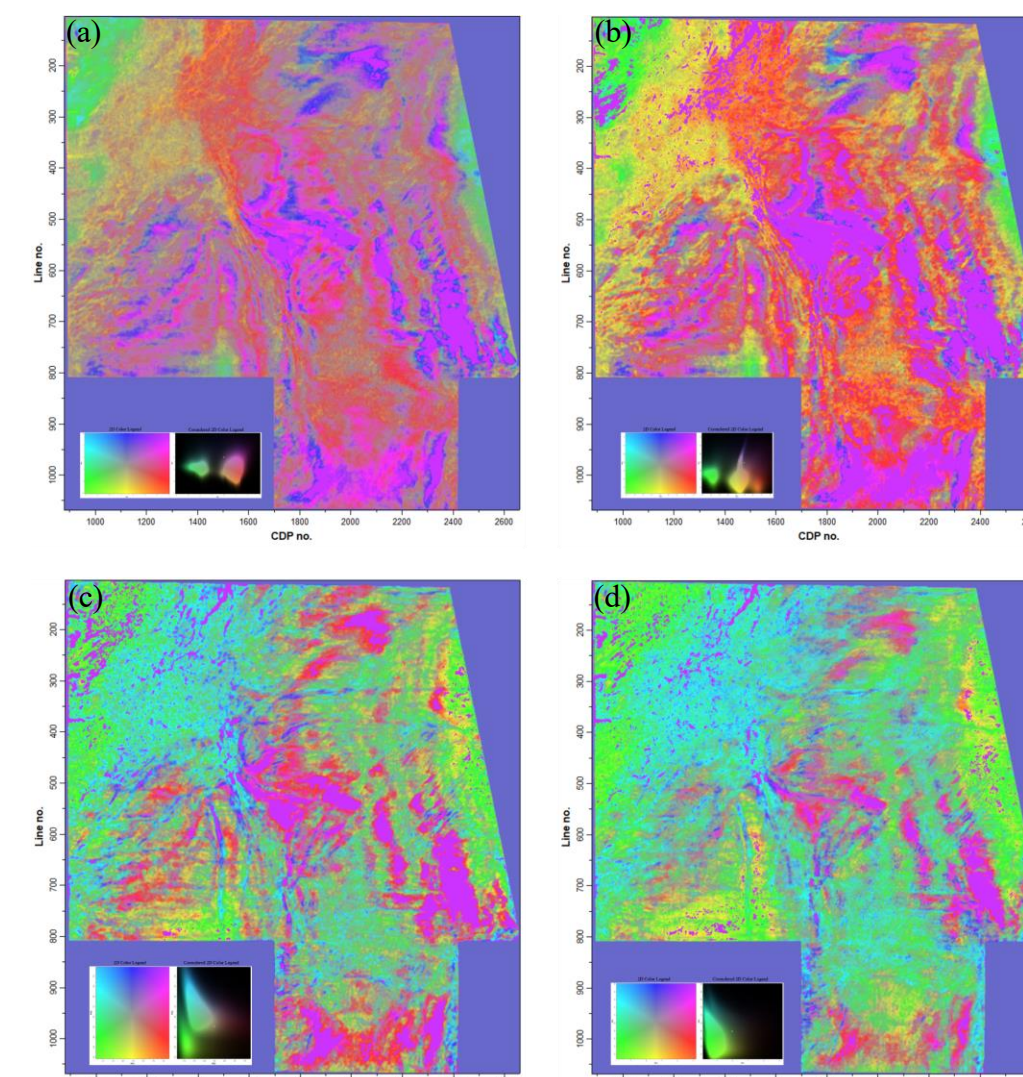


Figure 9: Comparison of PCA results using different inversion product inputs (a) P & S-impedance, LFM (b) P & S-impedance, Density (c) LFM (d) Density

## RESULTS

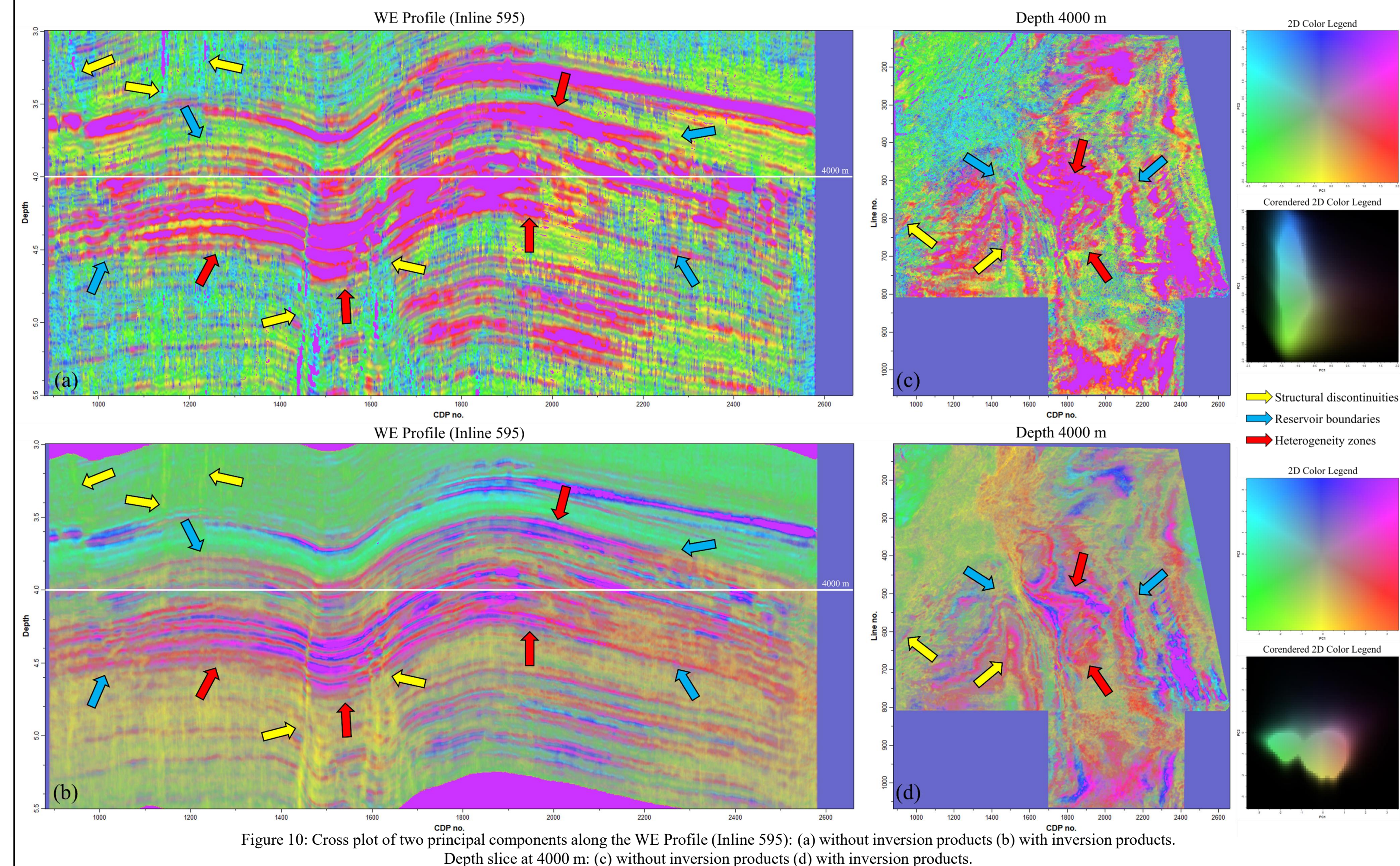


Figure 10: Cross plot of two principal components along the WE Profile (Inline 595): (a) without inversion products (b) with inversion products. Depth slice at 4000 m: (c) without inversion products (d) with inversion products.

## DISCUSSION

In PCA results incorporating inversion products, notable enhancements are observed. First, structural discontinuities are resolved with greater clarity, allowing clearer delineation of continuous features. Second, the representation of stratigraphic layers and reservoir boundaries has significantly improved. Third, inter- and intra-formational heterogeneities are distinguished at higher resolution; reduced color homogeneity associated with lithologic variation leads to more accurate identification of heterogeneity zones. Collectively, these improvements yield a more robust reservoir characterization. By contrast, PCA results and co-rendered displays generated using only seismic attributes perform well in detecting structural elements but provide limited ability to distinguish heterogeneity zones and reservoir boundaries.

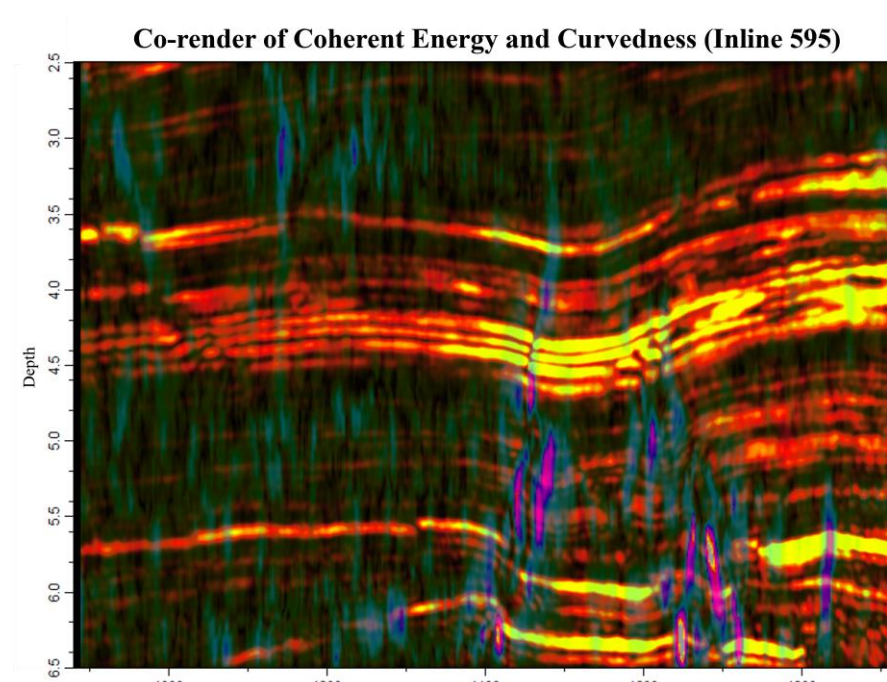


Figure 11: Co-render of coherent energy with curvedness

## CONCLUSIONS

In conclusion, this study demonstrates that integrating seismic inversion products with multi-attribute analysis significantly improves the characterization of the Pohokura hydrocarbon reservoir. Our findings reveal three key improvements: (1) enhanced clarity of structural discontinuity boundaries, (2) improved recognition of reservoir heterogeneity, and (3) more definitive identification and characterization of reservoir zones.

## ACKNOWLEDGEMENTS

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