[PS]Detailed Stratigraphic Architecture of the Mesaverde Group Determined from Principle-Component Analysis of 3D Seismic Data, Mamm Creek Field, Piceance Basin, Northwest Colorado*

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Abstract

Windowed principle component analysis (PCA) of seismic data can be used to delineate significant changes in seismic reflection character. PCA is a method that statistically derives the attributes (components) of the seismic waveform which contribute to the most significant variations of the signal. These components are used to break the signal into seismic classes that are able to delineate geologically significant surfaces and features.

The method reveals much of the stratigraphic detail of the Mesaverde in Mann Creek Field of the Piceance Basin. Stacking patterns of both marine and fluvial deposits in the Mesaverde Group indicate varying rates of accommodation. Shorelines prograde, and fluvial channels amalgamate during periods of low accommodation. Shorelines transgress or aggrade, and fluvial channels form isolated sand bodies in low net-to-gross intervals during periods of high accommodation. The different stacking patterns of fluvial sandstones can be identified on the PCA-classified seismic data. Amalgamated channel intervals have numerous discordant internal surfaces. Intervals with isolated fluvial channel sandstones have more regular layering and contain pods with different OCA-classes that appear to represent preserved individual meander belts.

References

Johnson, R.C., 1989, Geologic history and hydrocarbon potential of Late Cretaceous age, low-permeability reservoirs, Piceance basin, western Colorado: U.S. Geological Survey Bulletin, v. 1787-E, 51 p.

Yurewicz, D.A., 2005, Controls on gas and water distribution, Mesaverde basin center gas play, Piceance Basin, Colorado (extended abstract): Search and Discovery Article #90042 (2005) http://www.searchanddiscovery.net/documents/abstracts/2005hedberg_vail/abstracts/extended/yurewicz/yurewicz.htm).

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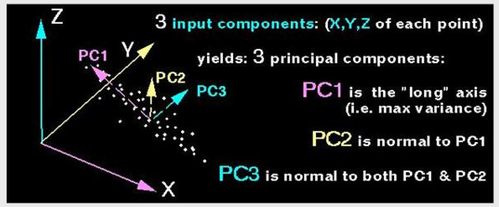
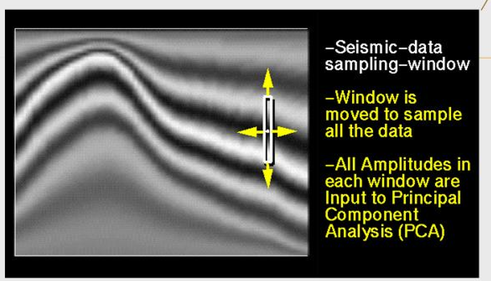
What are Principal Components?
What is Principal Component Analysis (PCA)?

- Principal Components (PC's) are unique linear combinations of a multivariate dataset.
- PCA first finds the linear combination (direction in input-variable space) that is parallel to the highest variance, as defined by all input datasets (This is the long dimension of the data cloud below). This direction is defined as the PC1 direction (eigenvector).
- PCA also uniquely determines the mutually orthogonal directions, in order of decreasing variance and these are called as PC2, PC3,….



How do we apply PCA to 3D Seismic Data?

•Normally we capture many randomly sampled vertical windows of amplitude values for Input to PCA As shown below. This process creates many multivariate input datasets, where each sample from the window is treated as a unique element of each input.



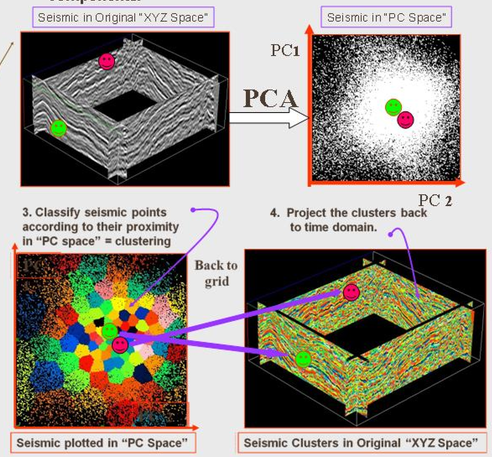
Why PCA on 3D Seismic Data?

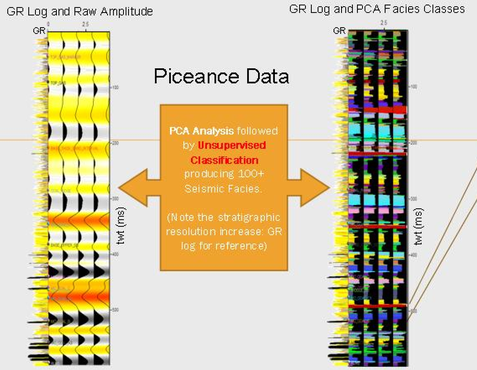
Primary Reason:
Enhanced resolution (using *two* techniques).

1. **Unsupervised Seismic Facies Calibration** *(below)*
2. **Vertical Seismic Facies Pattern Calibration** *(at right)*

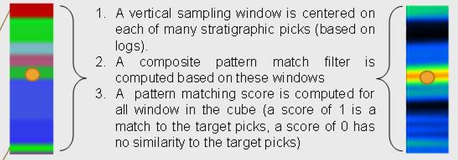
Seismic Facies Calibration
Unsupervised Signal Classification

2. From window-sampled amplitudes, compute the principal components.

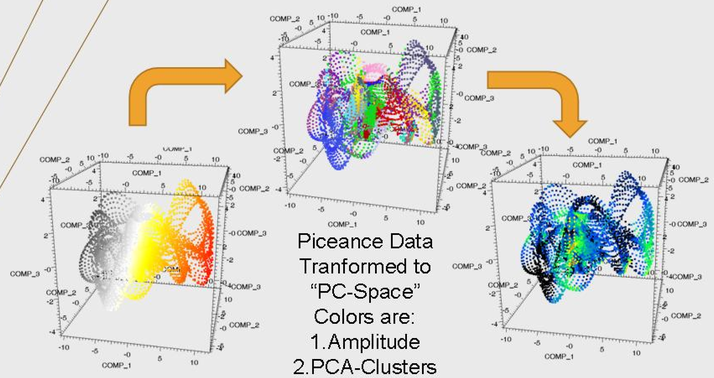


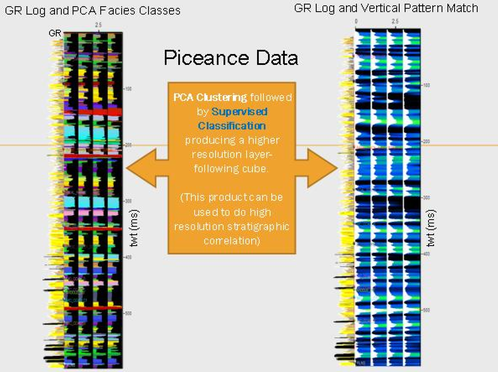


Vertical Pattern Calibration (Supervised)

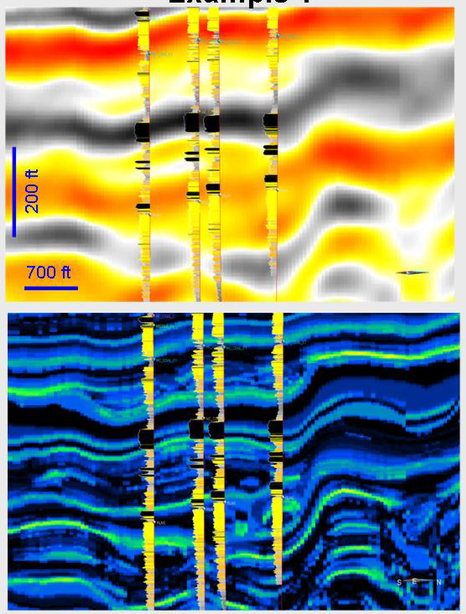


1. A vertical sampling window is centered on each of many stratigraphic picks (based on logs).
2. A composite pattern match filter is computed based on these windows
3. A pattern matching score is computed for all window in the cube (a score of 1 is a match to the target picks, a score of 0 has no similarity to the target picks)

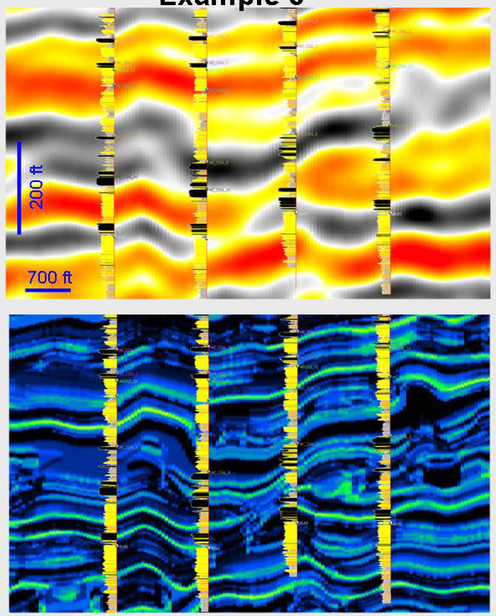




Example 1



Example 3



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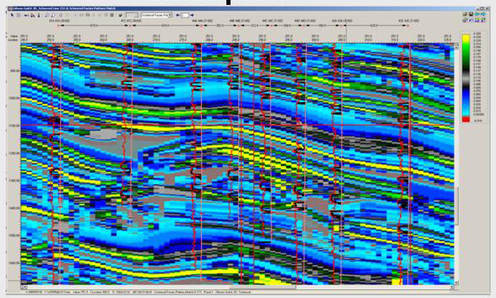
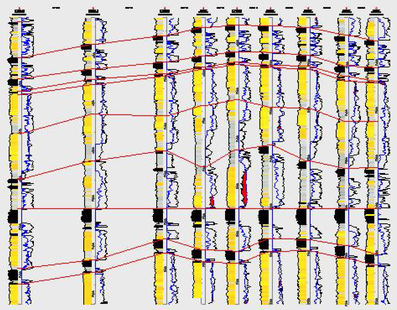
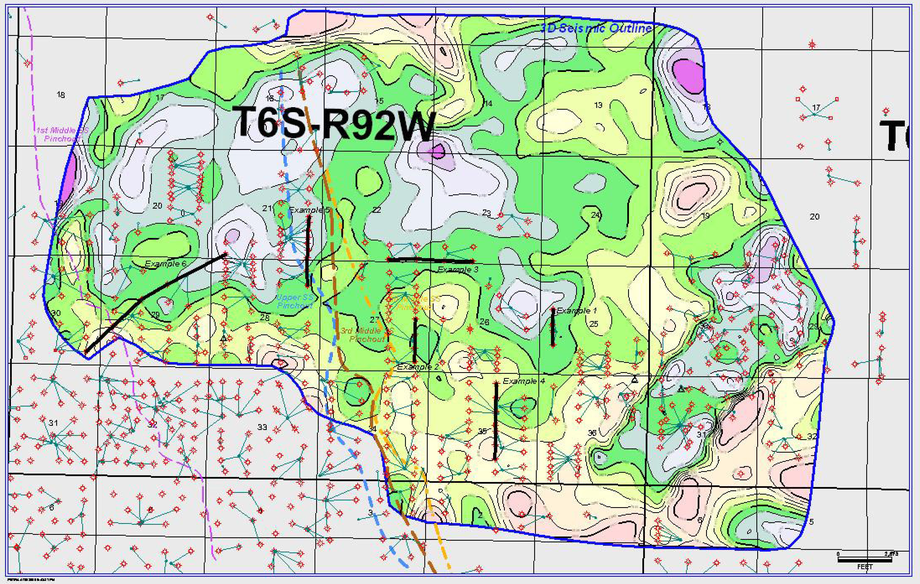
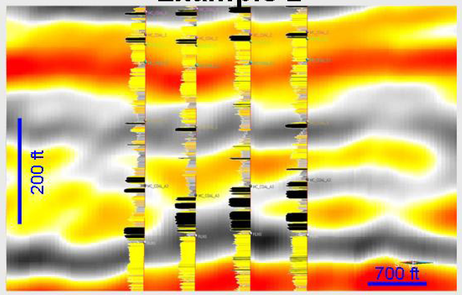
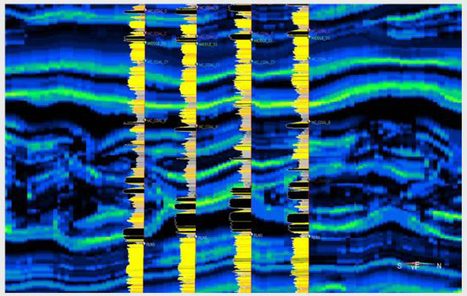






Example 2





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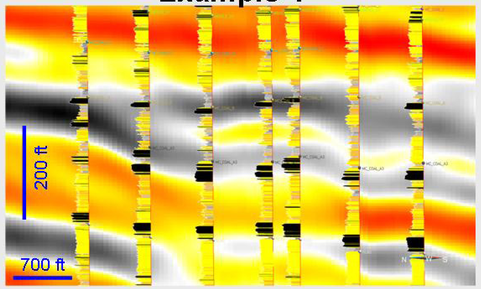
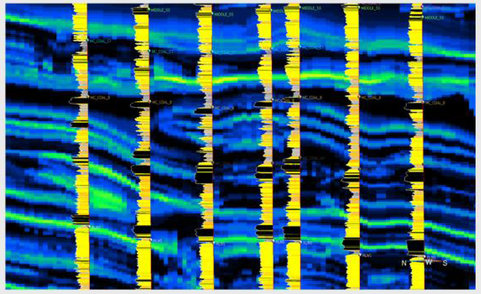
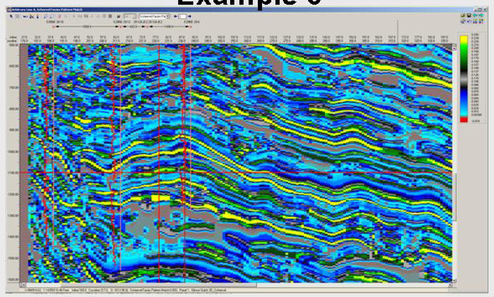
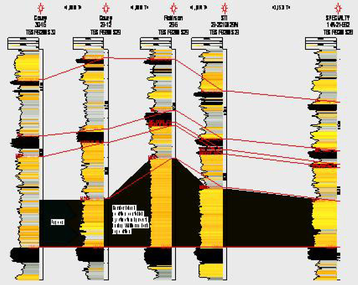




Example 6





Based on discussions with Paul Devine.

Lines of section for cross sections and PCA seismic lines are shown on map. Contours shown are the isochron from Price Coal to Rollins. Many stratigraphic features in the Williams Fork show evidence of structural growth during deposition. Landward pinchouts of marine shoreface units in the Upper and Middle Sandstone intervals are shown on map.

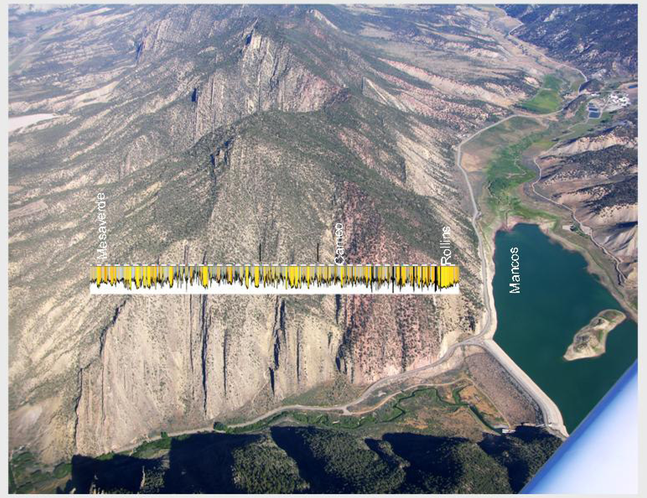
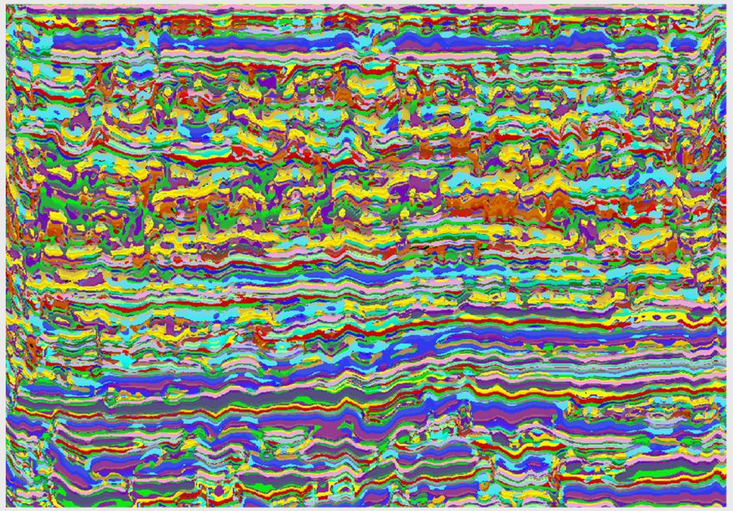
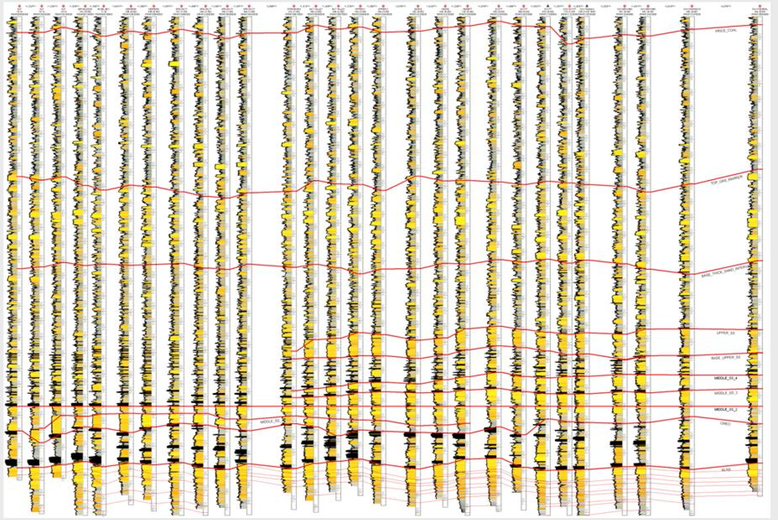


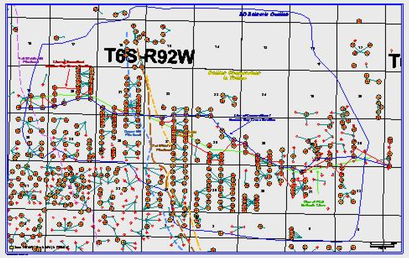
Photo of Rifle Gap with nearby well log superimposed. Located 7 miles northwest of 3D survey.



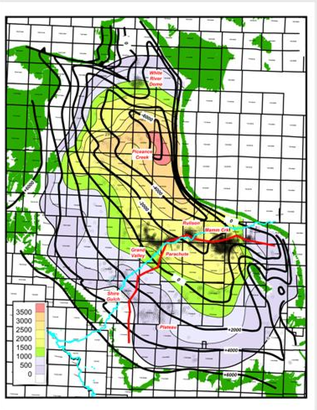
Same line of section for two different PCA displays. Line of sections for PCA seismic sections and cross section lines are shown on map.

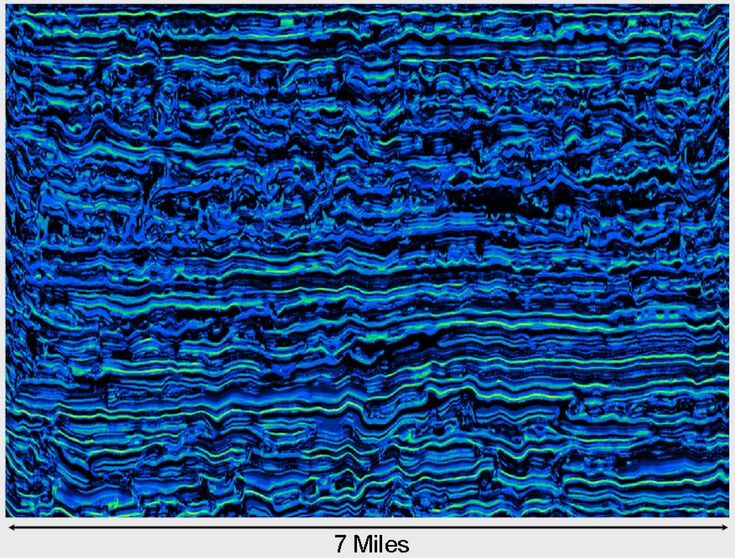


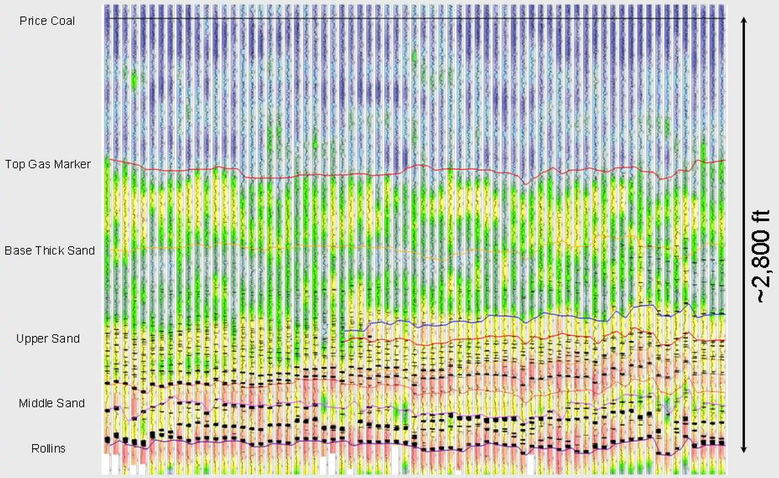
Line of cross section shown in blue on map.



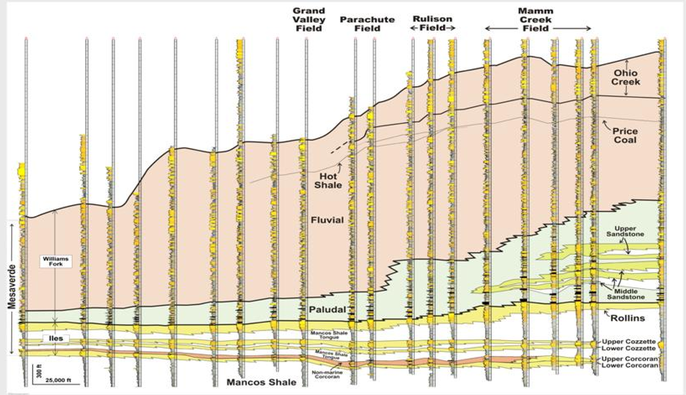
Piceance Basin is located in northwest Colorado. Structure contours are top of Rollins (Johnson, 1989). Color-filled contours are thicknesses of continuous gas column in the Williams Fork (Yurewicz, 2005). Cross section line of cross sections below is shown in red.







Line of cross section shown in red on map.



Smoothed gamma ray cross is color filled using smoothed gamma ray curves as shown below. Low gamma ray values have warm colors and high gamma ray values have cool colors. Conventional gamma ray curves are shown in black.