Jay Scheevel

Jay Graduated from University of Illinois with a BS in Geology in 1979, from Texas A&M (Center for Tectonophysics) with an MS in 1981 then worked for Chevron from 1981 to 2002.

Jay has worked in the US Rocky Mountains, Permian Basin, California, and internationally in West Africa, the Middle East, Indonesia, Australia, Papua New Guinea, the North Sea, Canada and South America. For Chevron, he worked as a geologist and geophysicist in both exploration and production/development and in research at Chevron's research facility. Jay has served worldwide and as an instructor in the Reservoir Characterization, Geostatistics and Structural Geology.

Since 2002, Jay has operated a consulting and technology company in Grand Junction, Colorado which specializes in advanced geophysics and reservoir description, 3D geological/geophysical modeling, complex well design and geosteering, well supervision and wellsite geology. Jay also provides onsite training and mentoring in all areas of geology, geophysics, and reservoir characterization.

Detailed Stratigraphic Architecture of the Mesaverde Group Determined from Principal Component Analysis of 3D Seismic Data, Piceance Basin

Jay Scheevel – Scheevel Geo Technologies LLC., Steve Cumella – Bill Barrett Corp.

Mamm Creek field produces from sands of the Mesaverde that are part of a pervasive gas accumulation in the deeper part of the Piceance Basin. Most production is from discontinuous fluvial sands in the Williams Fork Formation, but marine sands in the Corcoran, Cozzette, and Rollins members of the Iles Formation and middle and upper sands of the Williams Fork Formation also contribute. Coals are present in the lower third of the Williams Fork and are believed to be the primary source of gas for the Williams Fork production. The sands of the Mesaverde have permeabilities in the 1-100 microdarcy range and have average porosities of about 9%. Abundant natural fracturing has been documented in core and image logs and is critical to providing permeability for commercial production.

The primary limitation of 3D amplitude data employed in evaluation of stratigraphic and structural features lies in the fact that its resolution is limited by the frequency content of the data. This is not a new problem. The long-standing goal of all acquisition and processing flows to achieve the maximum resolution of the final product while minimizing noise. Despite the advanced state of modern signal processing, the signal content still limits the effective resolution of amplitude data.

Our goal has been to push the resolution limit significantly higher by departing from standard approaches to signal processing of seismic amplitude data. We recognize that the final migrated 3D seismic dataset is, by virtue of its uniformity of signal character and spatial distribution and because of its excessive statistical mass, ideally suited for purely statistical analysis. Any analysis that is performed on large seismic dataset has sufficient sampling multiplicity to reveal details that may be filtered or rejected by standard signal-processing- or physical-response-based approaches commonly used in standard geophysical analysis.

We have chosen to apply a common linear statistical approach, principal components analysis (PCA), to the analysis of seismic amplitude data (Scheevel and Payrazyan, 2001). PCA is a method used to extract the significant information from multivariate datasets of unknown redundancy. The PCA linearly recombines multivariate input vectors into a few principal components (PCs) that contain the most significant signal content of the original dataset. The result is a more compact description of the original signal compressed into the fewest possible independent attributes (the most significant PCs). PCA has no presumptions about the signal character, so all elements of statistically significant signal content are revealed.

To begin, we apply PCA to a large number of randomly sampled vertical windows of amplitude data from within a given 3D amplitude cube. The PCA algorithm isolates statistically valid variations within the population of individual amplitude windows. Small changes in signal that may be very subtle but statistically significant can identify sub-bandwidth features within the original amplitude data. The statistical variations are clustered into similar categories and rendered onto the seismic cube as “seismic facies”. These seismic facies are indicative of changes in seismic signal rather than being a quantification of the underlying petrophysics. Nevertheless, the geometry of the facies classes reveals details of the stratigraphy and structure that are difficult or impossible to interpret from the original amplitude data alone.

Overall, the improvement in the vertical and lateral resolution of stratigraphic features is dramatic.

These windowed, PCA-based seismic facies are an "unsupervised" facies classification that simply subdivides the seismic amplitude signal (Figure 2a) into an arbitrary number of facies, based on significant changes in the PCs computed from windows of amplitude data and clustered by proximity in PC n-dimensional space. The facies are presented in the form of a cube of colored regions, each color representing a distinct seismic facies (Figure 2b).

The second product is "supervised" stratigraphic horizon mapping, which we refer to as a pattern match (PM) cube. This product is created by computing a vertical pattern-matching filter based on a set of target points. The vertical pattern is defined by the ordered sequence of unsupervised seismic facies within the seismic facies cube. The supervision is provided manually interpreting a few points along a geologic horizon of interest, such as a flooding surface or sequence boundary. A vertical pattern-matching filter designed from the interpreted points, that highlights the seismic facies pattern most similar to the interpreted points. The PM filter is applied to the entire facies cube, resulting in a horizon-specific PM cube. The PM cube is a high-resolution attribute cube designed to specifically for identifying and mapping anything similar to the interpreted feature. (Figure 2c). By adding or removing target points, and recomputing, the PM cube can be iteratively improved as interpretation proceeds.

A PM cube can be computed for any number of target horizons, with each PM cube used as a high-resolution tool that is unique to the reflection character of the horizon of interest. Any PM cube can be combined with those of several other horizons can be to create a hybrid-attribute cube that allows more complete high-resolution visualization of the entire stratigraphic section. Such a hybrid cube is shown in Figure 2d.

Validation of the methods described above has been proven for a number of locations worldwide. The dataset available at Mamm Creek field in the Mesaverde Formation provides a unique test case to compare the seismic method to dense well control. The Mesaverde contains a variety of lithologies, lateral thickness and facies changes, and small faults. This part Mamm Creek field has been actively developed at 10-acre density and consistent evaluation, and completion technologies have applied. Detailed prediction of reservoir variations in the field will allow better understanding of stratigraphic and structural control of production. Figures 2d shows the PM hybrid cube with high well density superimposed. Details of geometries of the paludal interval and the presence of faulting are particularly striking in this example. Comparison with the original amplitude for this section (shown in Figure 2a) demonstrates the higher resolution of the PCA-based products.

PCA facies for petrophysical predictions are also possible but are beyond the scope of this presentation. We continue to research the best methods for producing statistically validated petrophysical and stratigraphic predictions using the high-resolution capabilities of PCA analysis techniques.

The authors would like to thank the generosity of Bill Barrett Corporation for making the data for this study available and for permission to present it.

References

Scheevel, J.R., Payrazyan, K., 2001 Principal Component Analysis Applied To 3D Seismic Data for Reservoir Property Estimation. Paper 56734., SPE Reservoir Evaluation & Engineering, February 2001.

Scheevel, J and S.P. Cumella, 2009, Extracting sub-bandwidth detail from 3D amplitude data: An example from the Mesaverde Group, Piceance Basin, Colorado, U.S.A.,: SEG The Leading Edge, v.28 no. 11, November 2009. pp. 1362-1367.

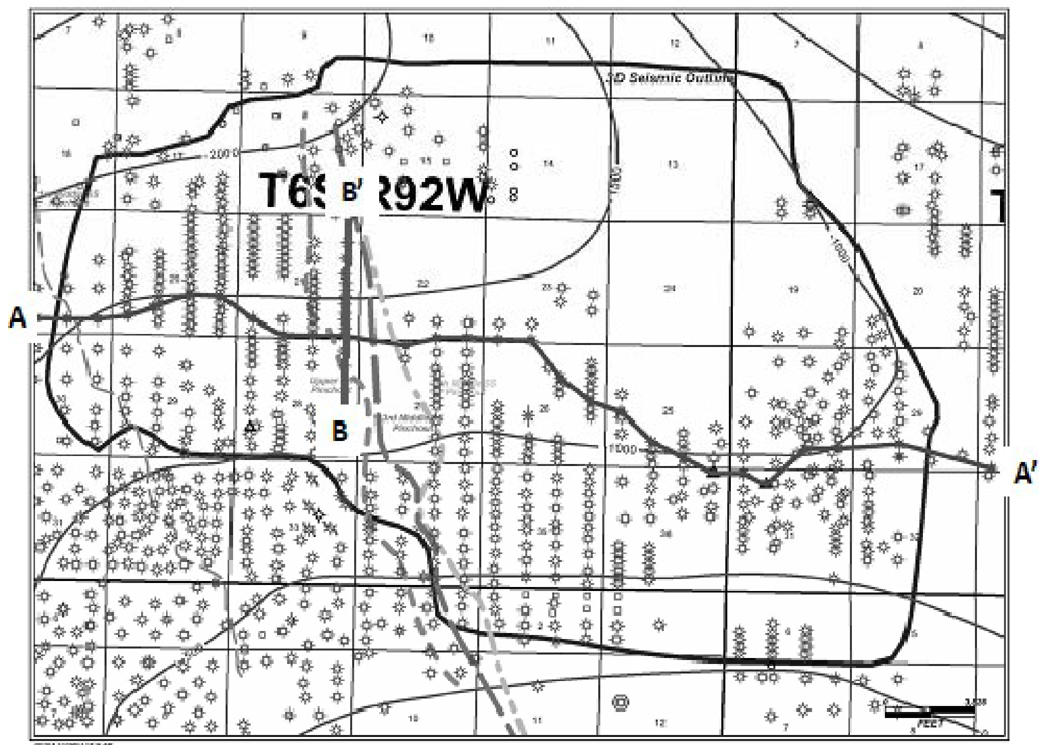

Figure 1. Map of northeastern part of Mamm Creek field. Structure contours on top of Rollins Member of Iles Formation. Line of cross section A-A' shown in Figure 3b is heavy black line running roughly E-W. The N-S line B-B' is the line of section shown in Figure 2 a-d. Landward pinch outs of marine sandstones in lower part of Williams Fork are shown with dashed lines near section B-B'.

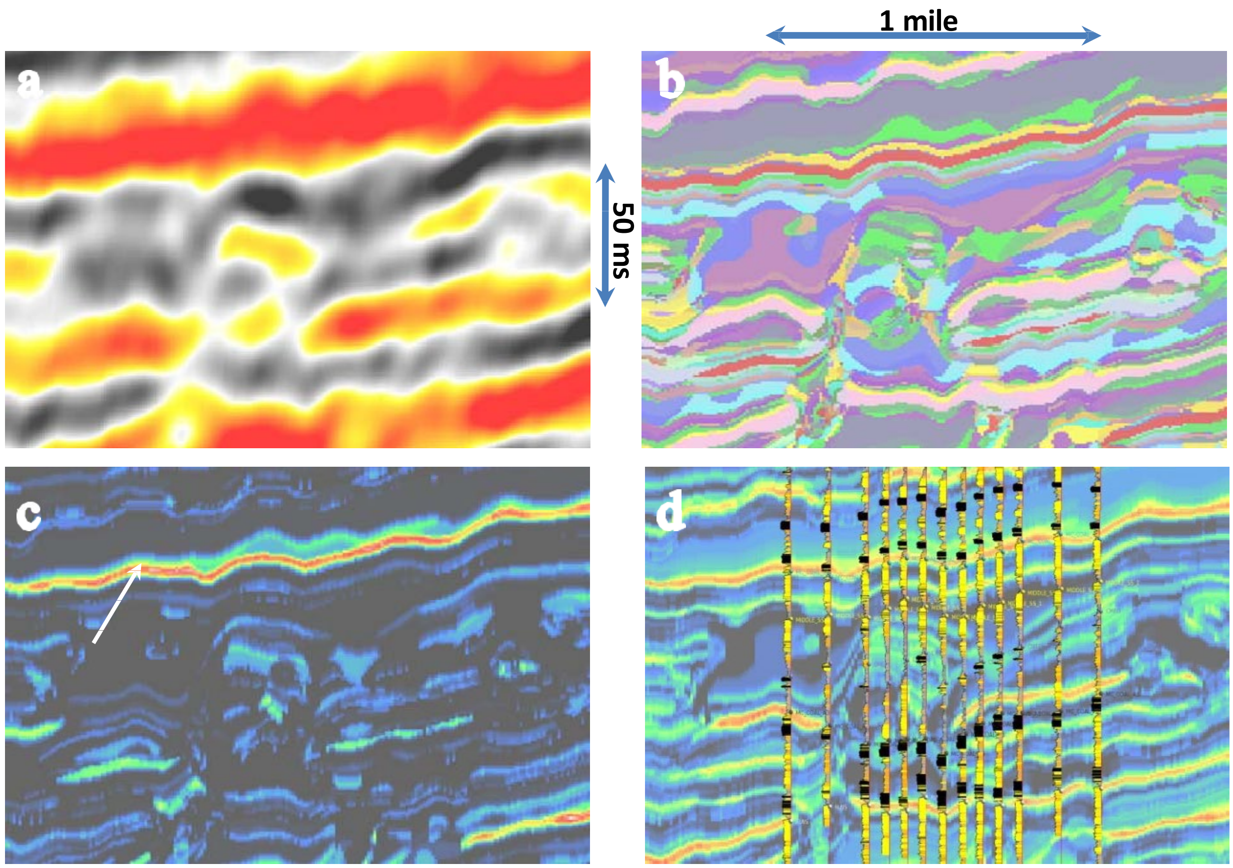

Figure 2. A two way time section showing: **(a) Original** migrated amplitude section. **(b)** PCA facies computed with 22ms window, **(c)** PM cube computed with target points for a single horizon (white arrow). **(d)** Hybrid PM cube with 10 -20 acres spacing well control over posted. Well log trace is GR, with color fill identifying coal as black, sands as yellow and shale as gray.

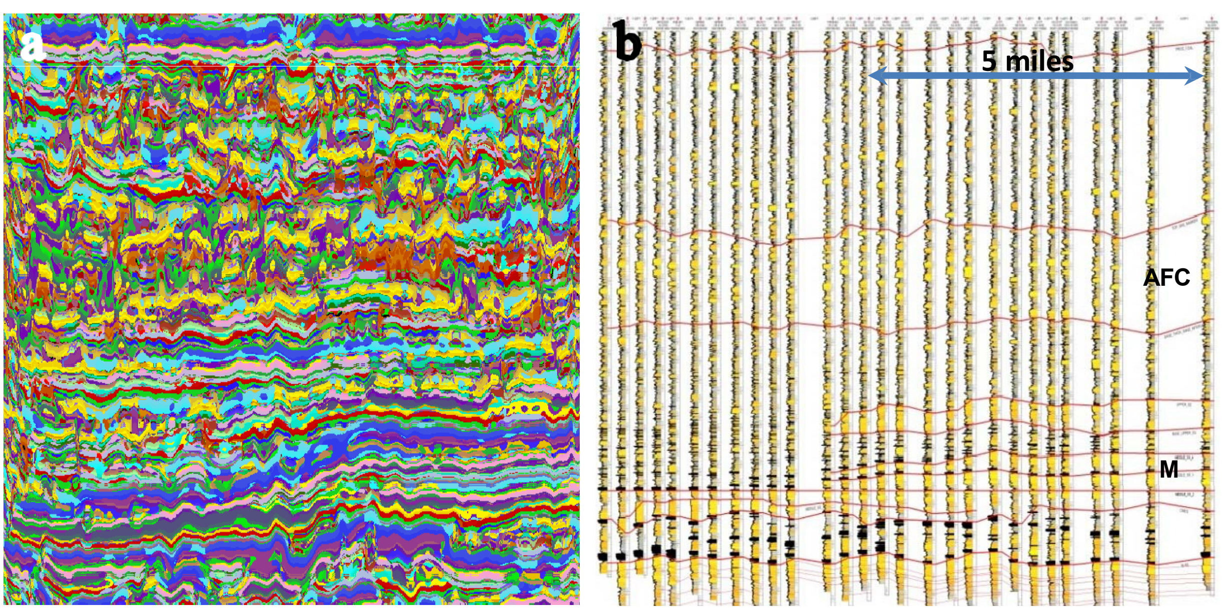

Figure 3. (a) PCA facies regional section from Price Coal at top to Rollins near base. **(b)** Well section closely following the PCA facies section in (a). Line of cross section shown on Figure 1. Note the facies transition of the thick marine sand (M) in the from right to left in the lower half of the section and how these geometries are reflected in the PCA facies in (a). The chaotic facies in (a) in the upper half of the section corresponds to the amalgamated fluvial channel sand interval (AFC) in the upper half of the well section in (b).