Seismic Attributes - from Interactive Interpretation to Machine Learning

Kurt J. Marfurt

Multiattribute Analysis using Visual Decision Making

Multiattribute Analysis Tools

Interpreter-Driven Multiattribute Analysis

Visual Decision Making

- Crosscorrelation Maps
- Corendering
- Spreadsheets
- Crossplotting and Geobodies
- Connected Component Labeling

Projection Techniques

- Principal Component Analysis
- Independent Component Analysis

Statistical Analysis

- Analysis of Variance (ANOVA, MANOVA)
- Multilinear Regression
- Kriging with external drift
- Collocated co-kriging

Machine Learning Multiattribute Analysis

Unsupervised Learning

- K-means
- Gaussian Mixture Models
- Kohonen Self-Organizing Maps
- Generative Topographical Maps

Supervised Learning

- Probabilistic Neural Networks
- Multilinear Feedforward Neural Networks
- Support Vector Machines
- Random Forest Decision Trees
- Generative Adversarial Networks

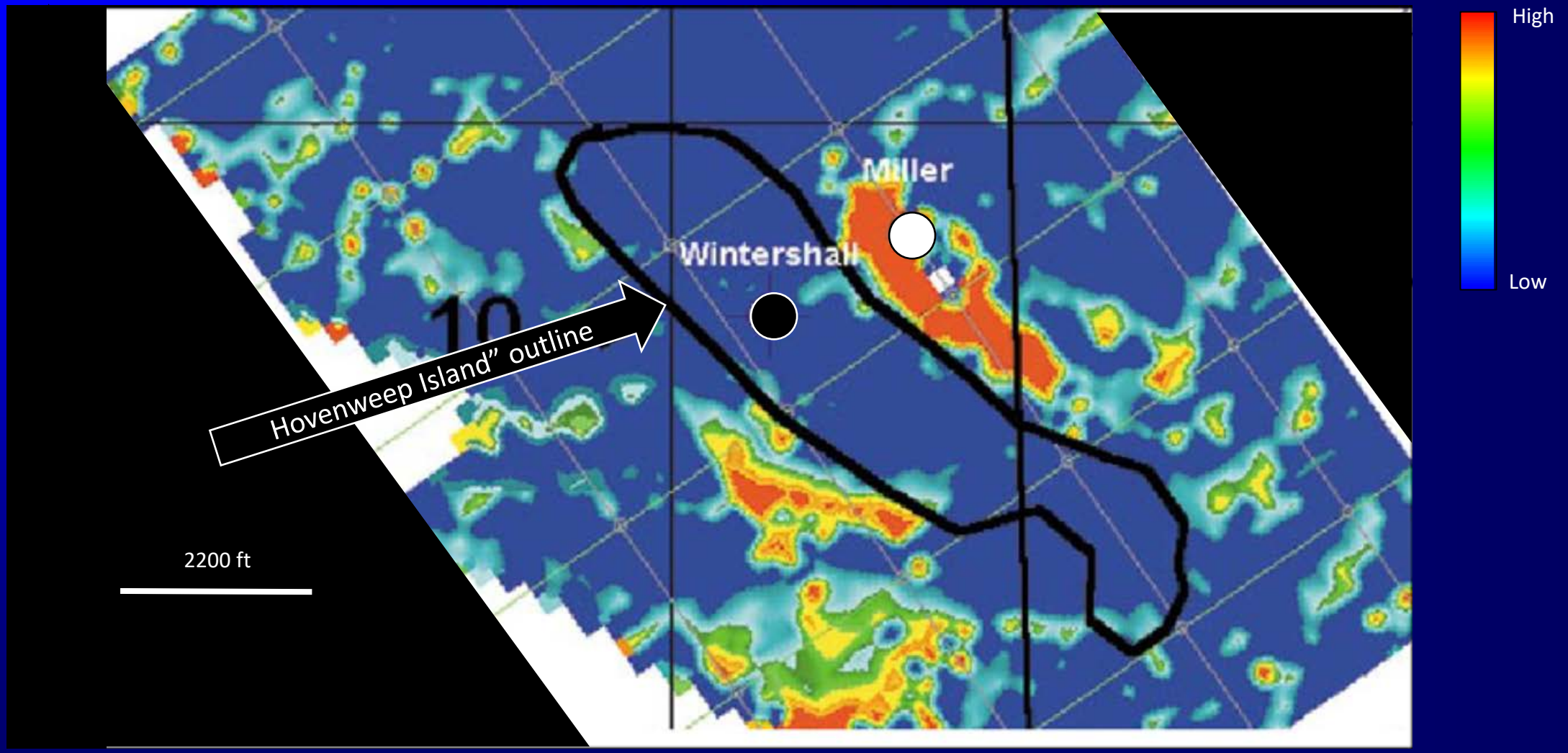

Figure 5.39 (Johnson et al., 2002)

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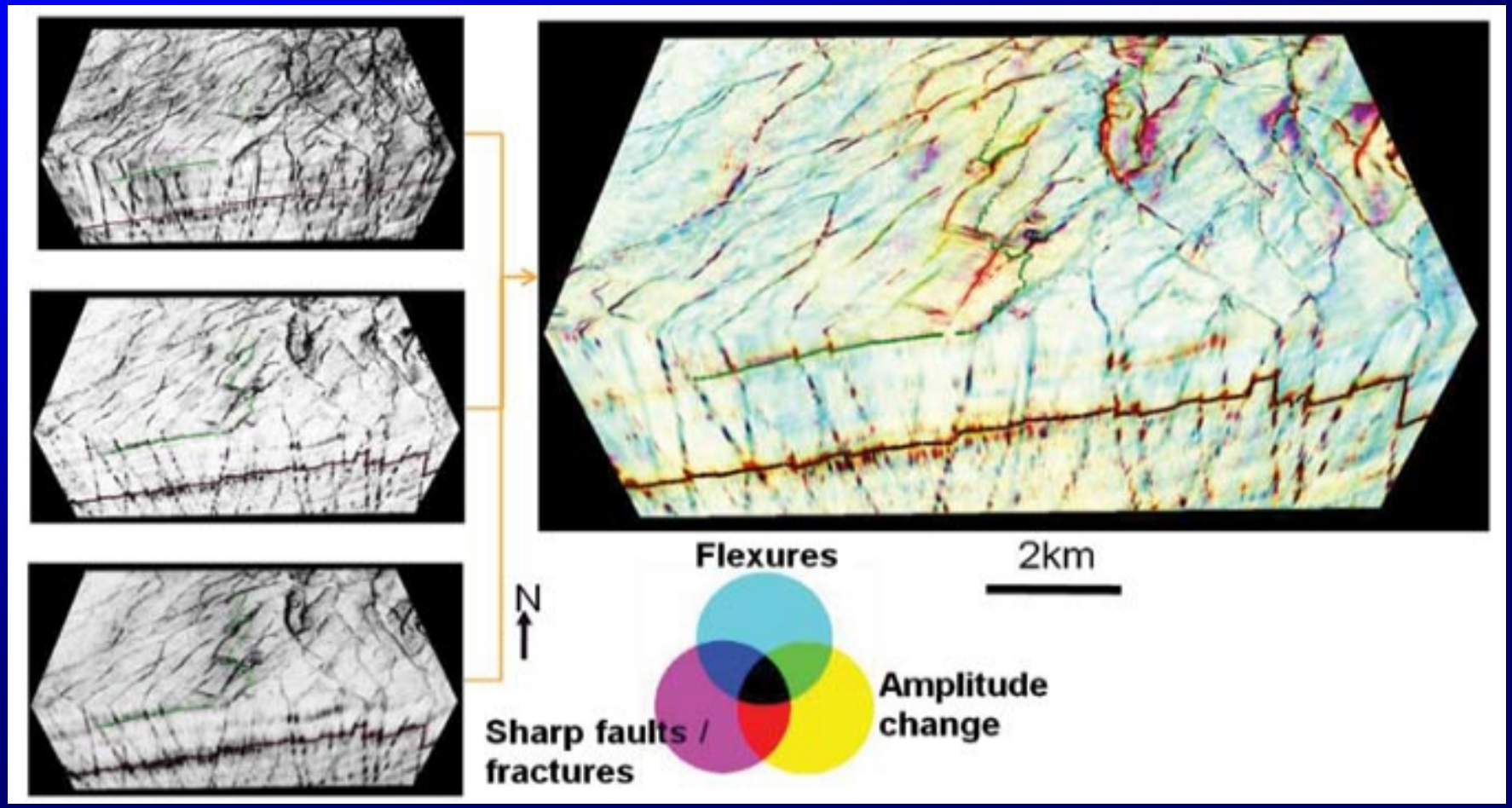
Corendering three fault-sensitive attributes using CMY

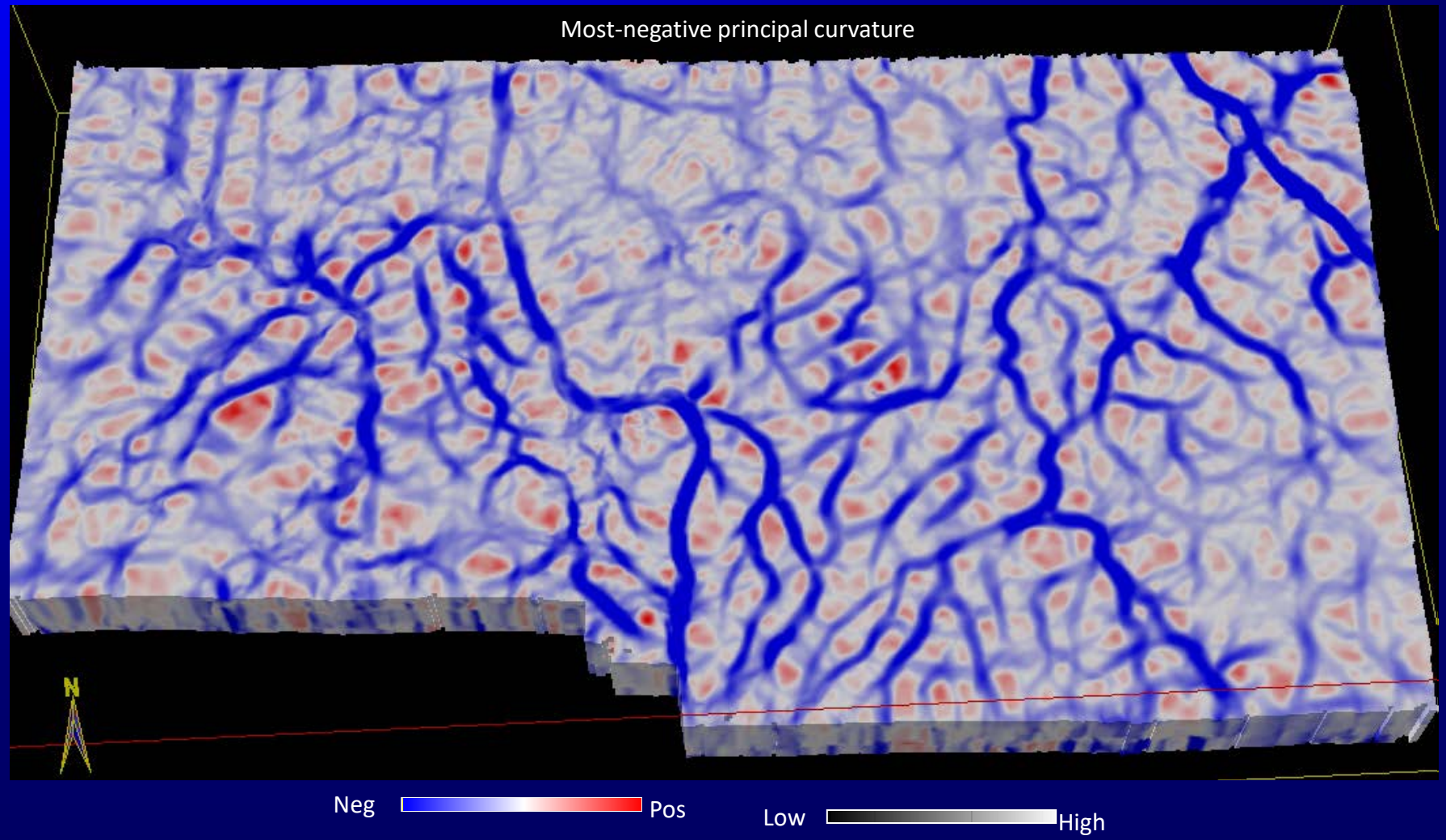


(Henderson, 2012)

Corendering coherence and most-negative curvature

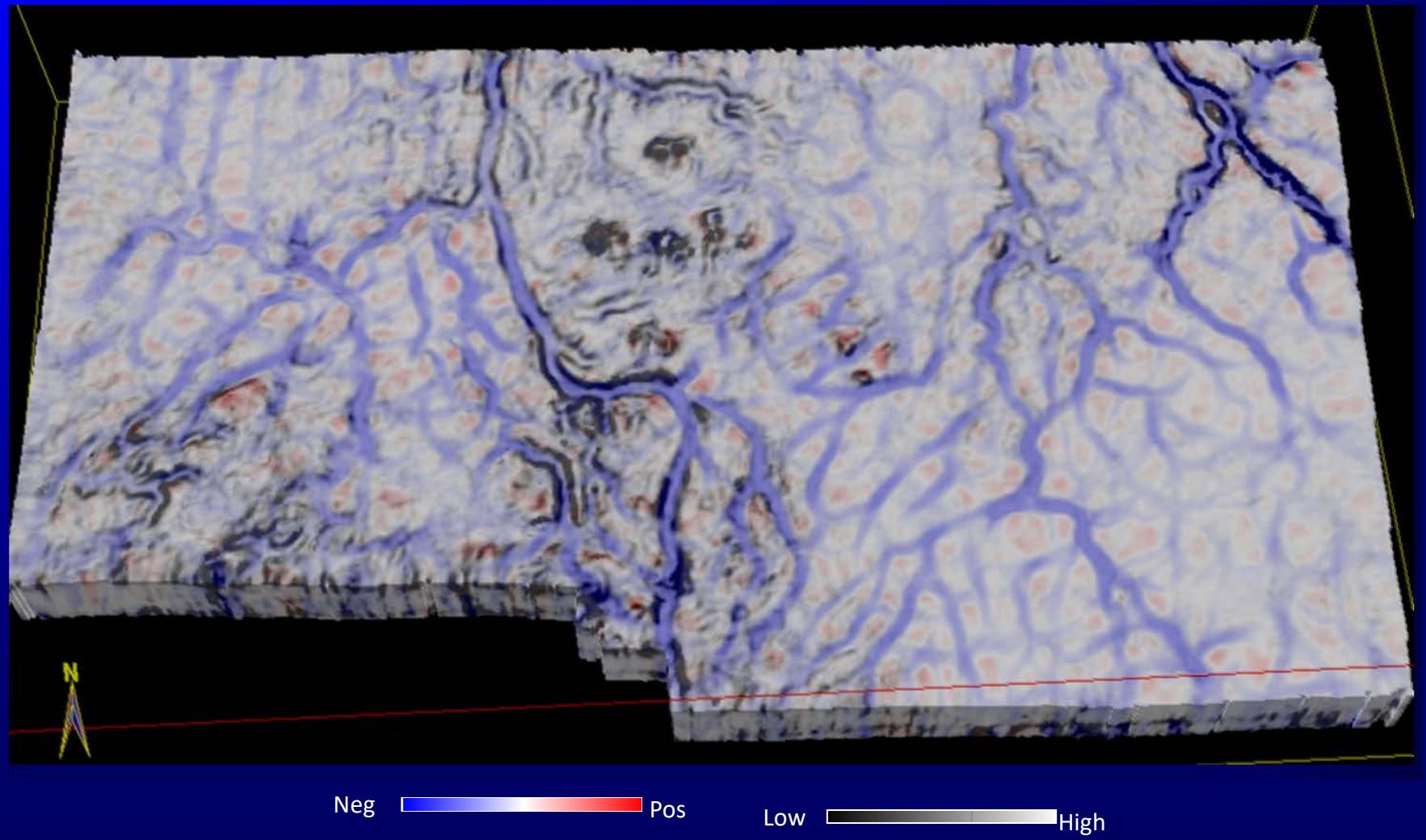
Coherence: highlights lateral discontinuities

Most-negative curvature: highlights synclinal features



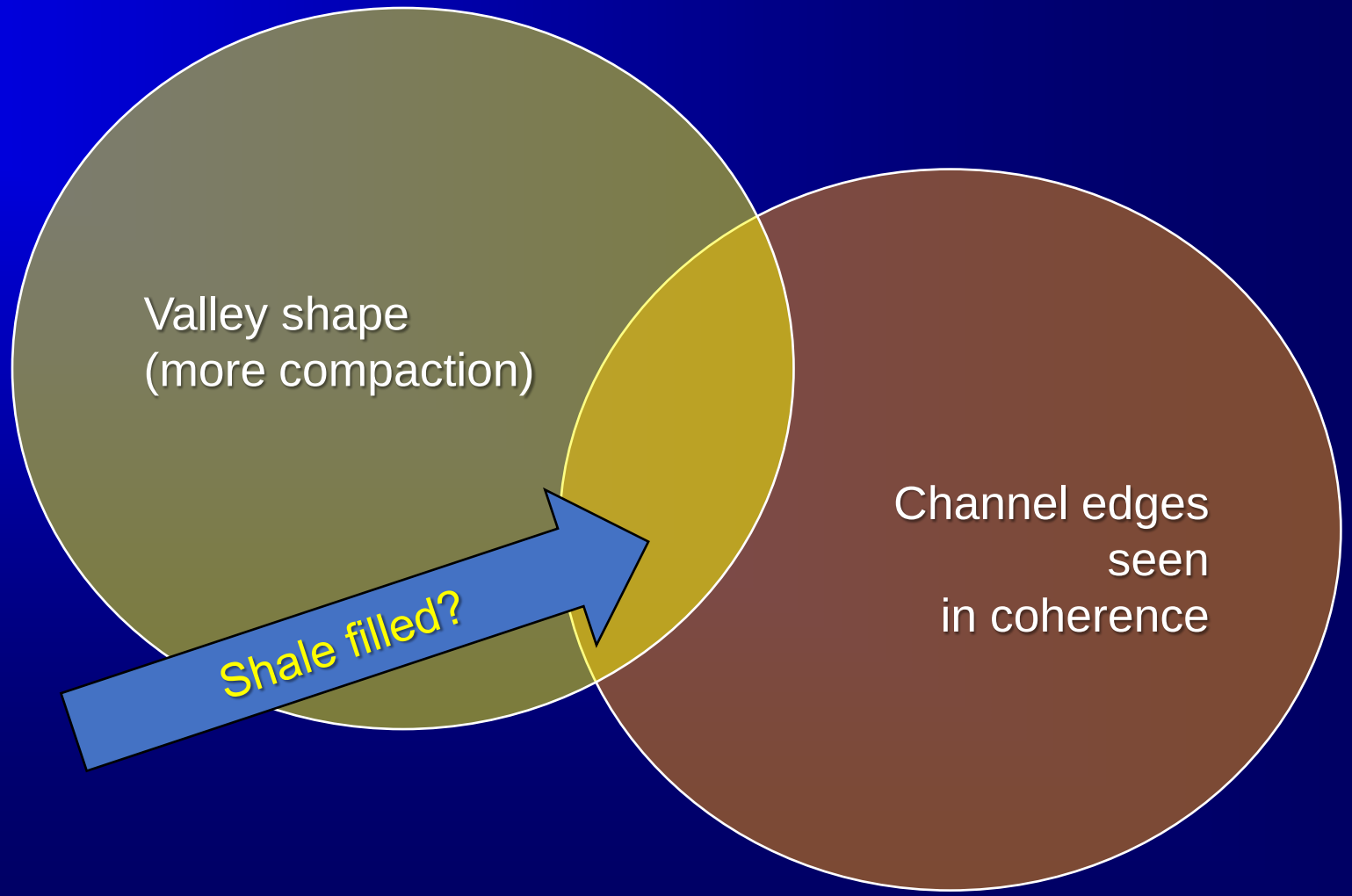
(Data courtesy Arcis; Chopra and Marfurt, 2008)

Corendering coherence and most-negative curvature

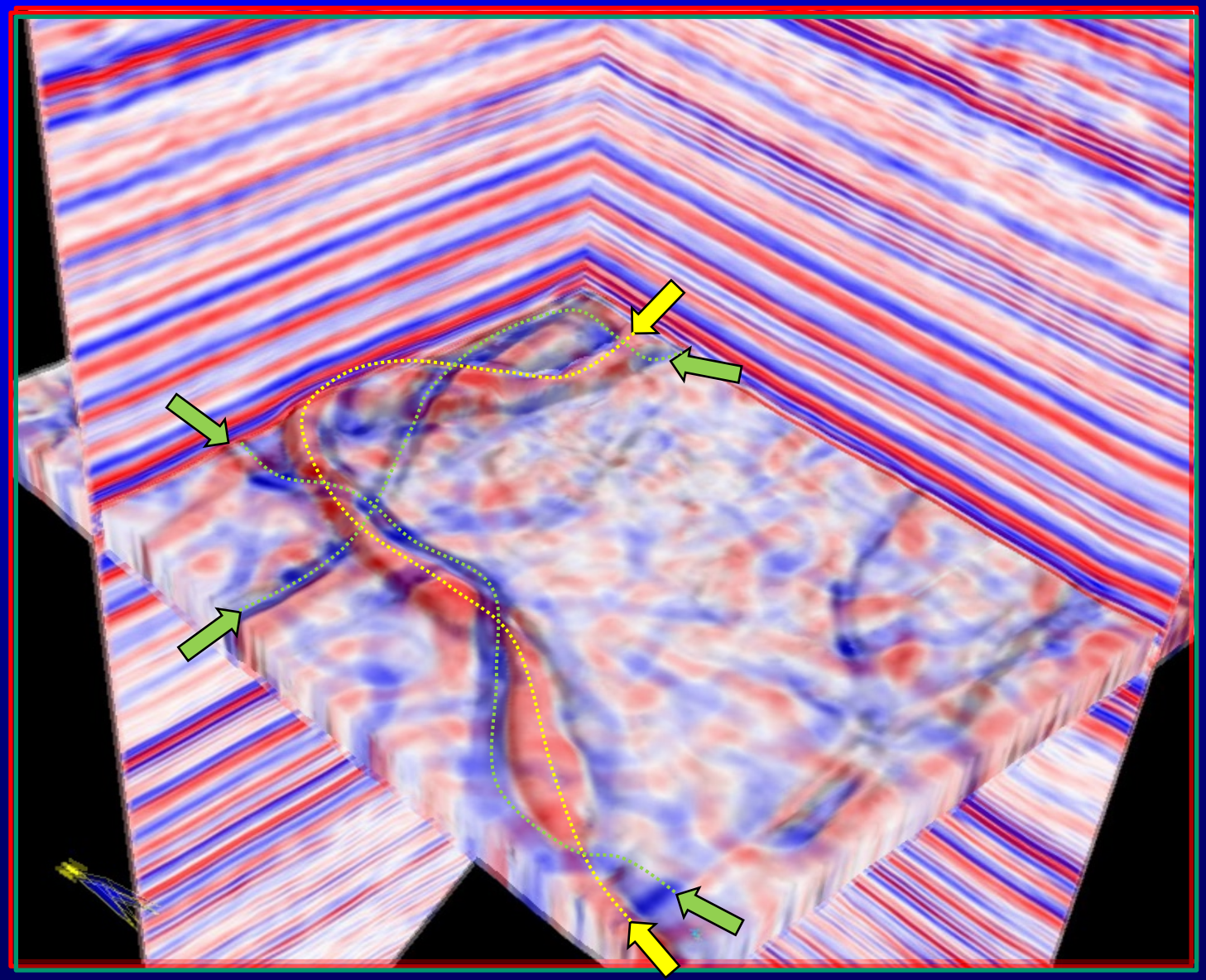


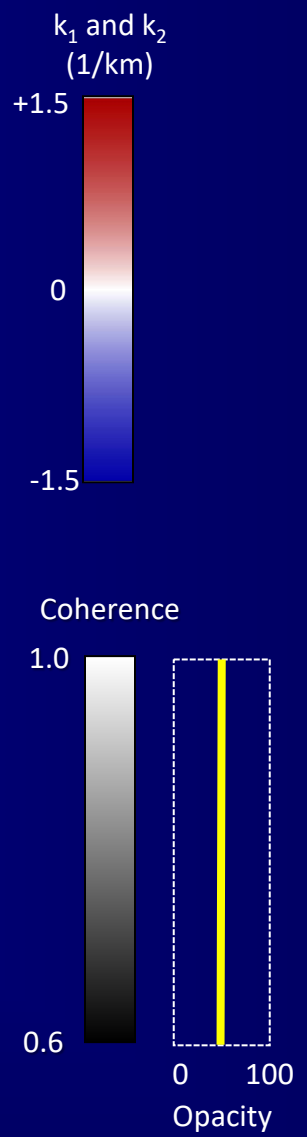
(Data courtesy Arcis; Chopra and Marfurt, 2008)

Interactive clustering using visualization



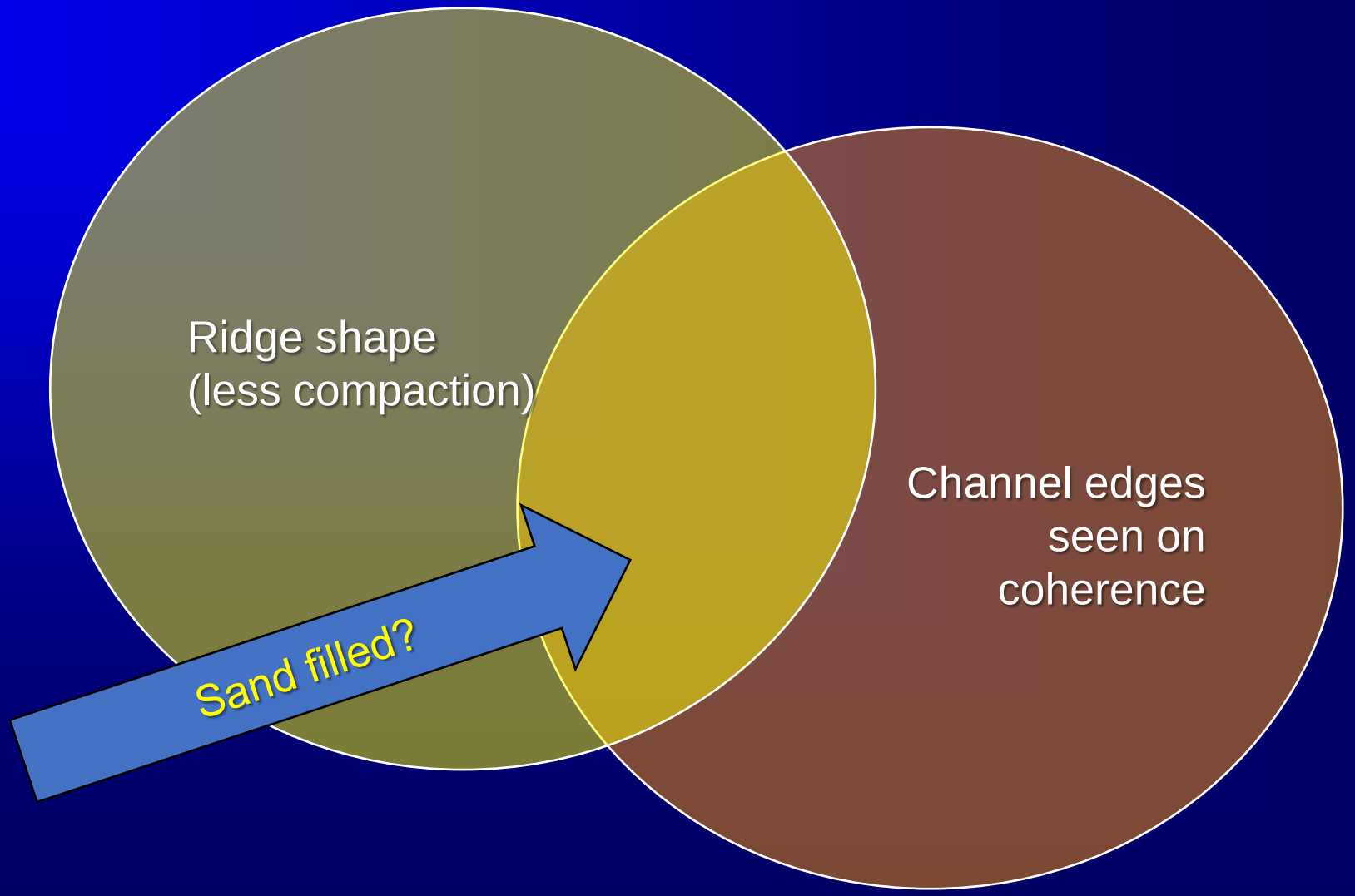
Corendering coherence, most-positive, and most-negative curvature



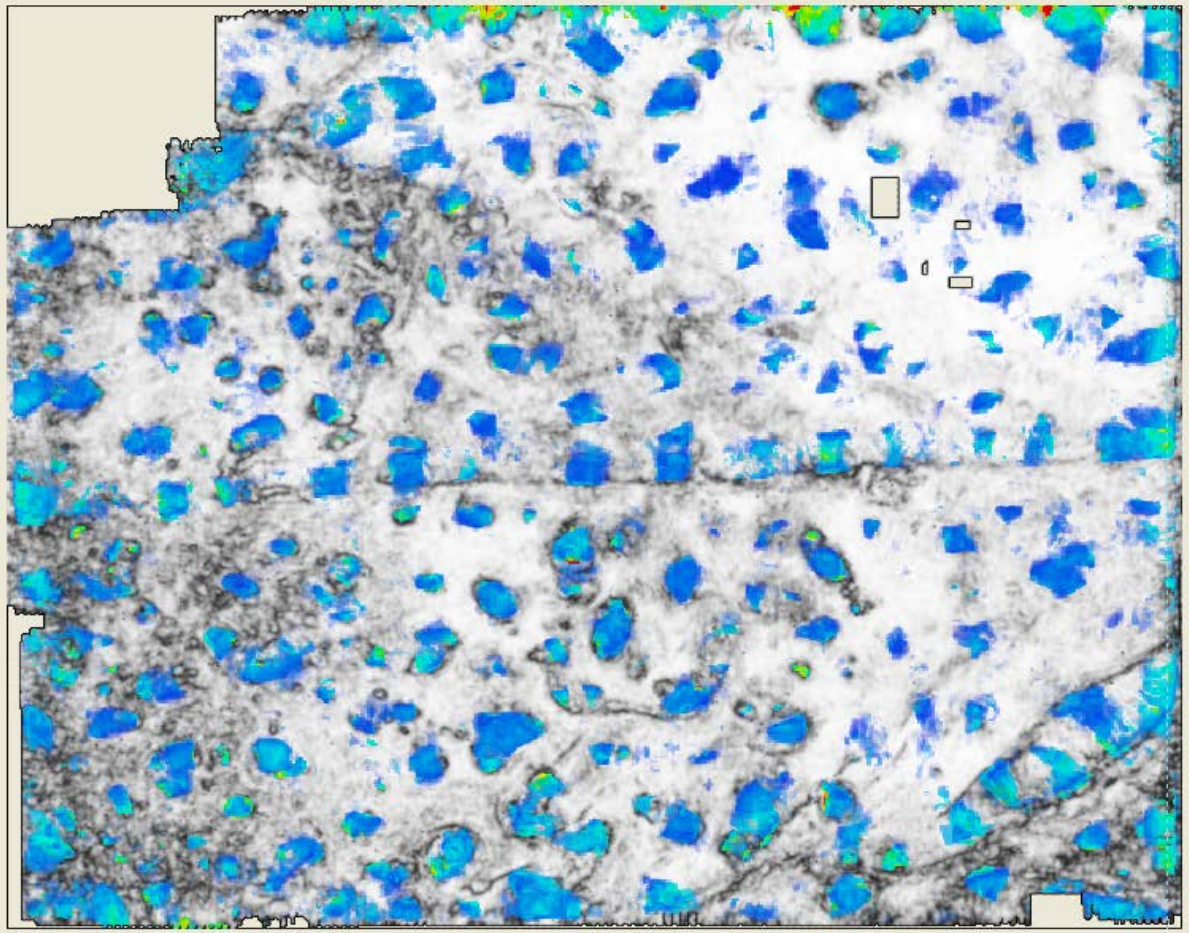


(Chopra and Marfurt, 2015a)

Interactive clustering using visualization



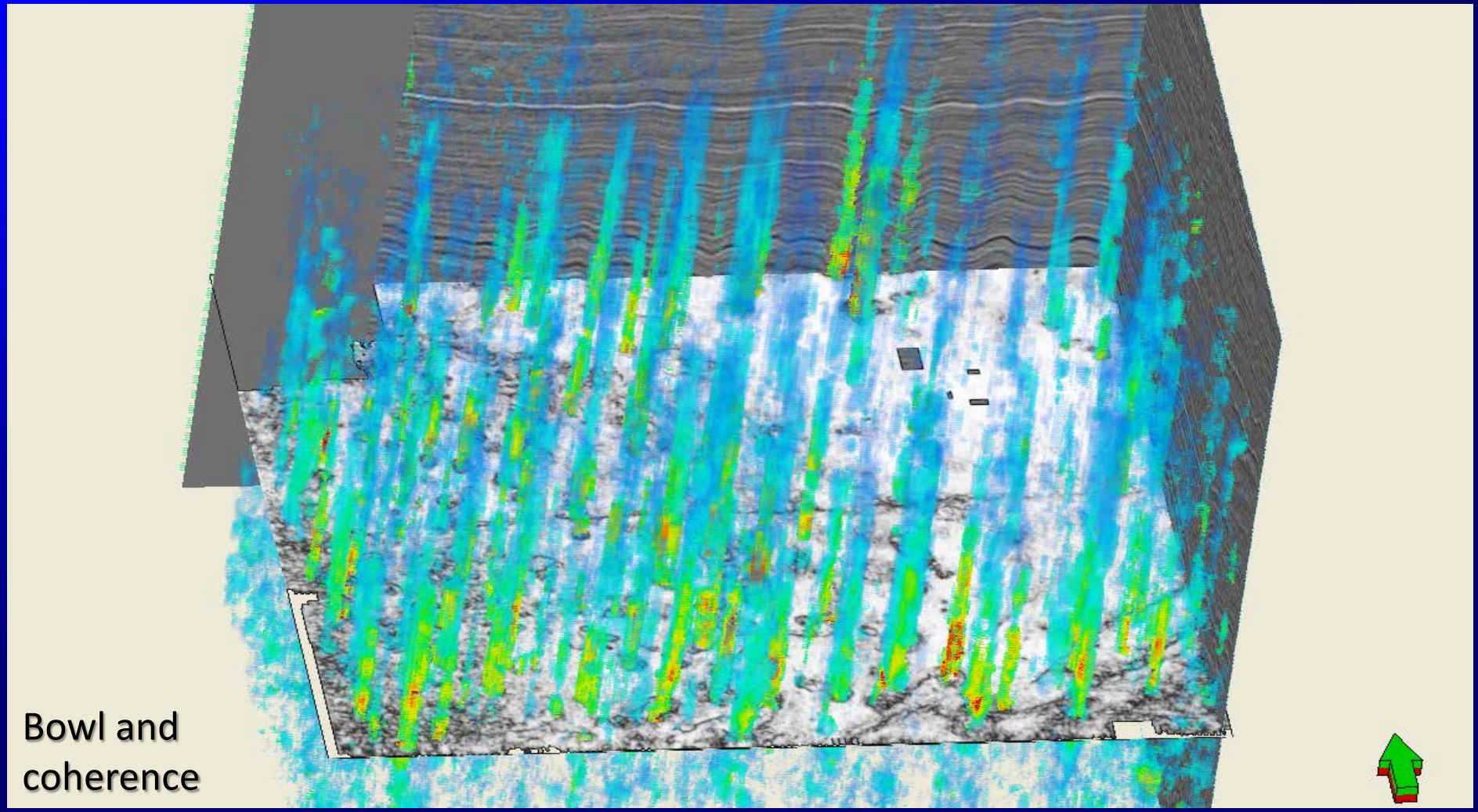
Correlation of bowl shape component with collapse features



Bowl and coherence

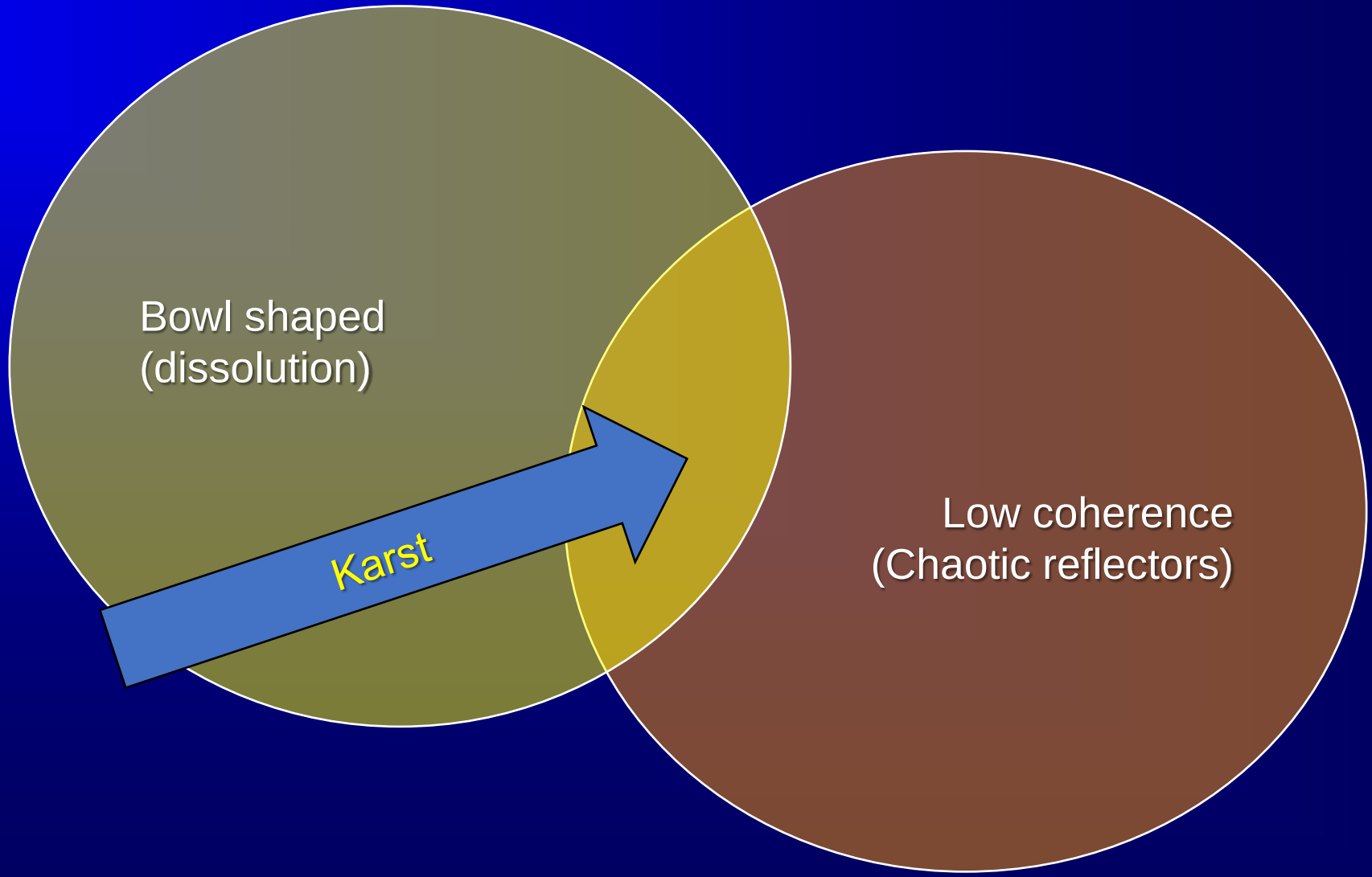
(Marfurt, 2010)

Correlation of bowl shape component with collapse features



(Marfurt, 2010)

Interactive clustering using visualization



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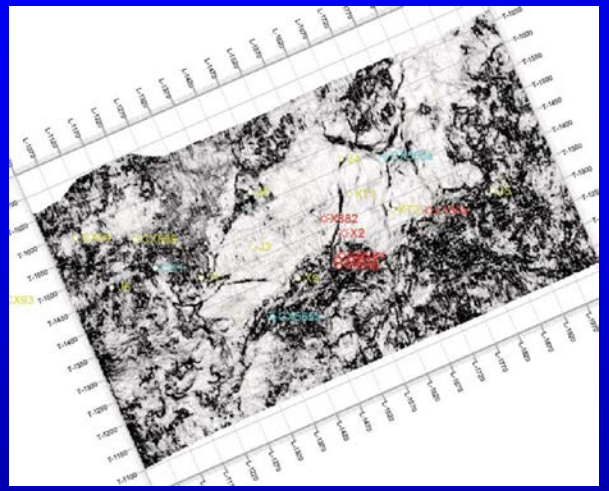
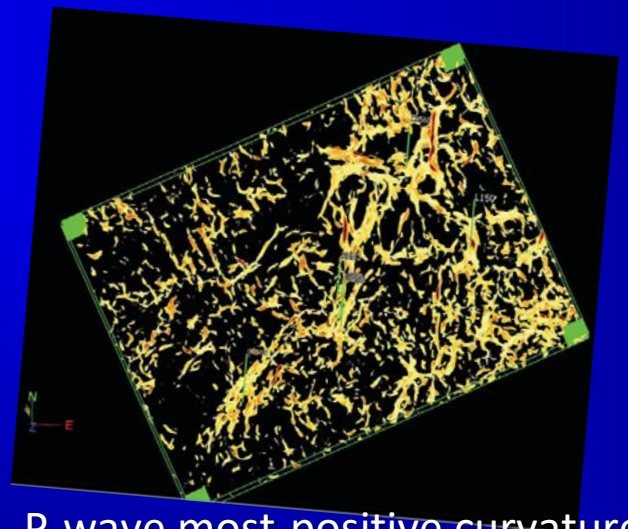
Clustering using a spread sheet (common exploration risk analysis)

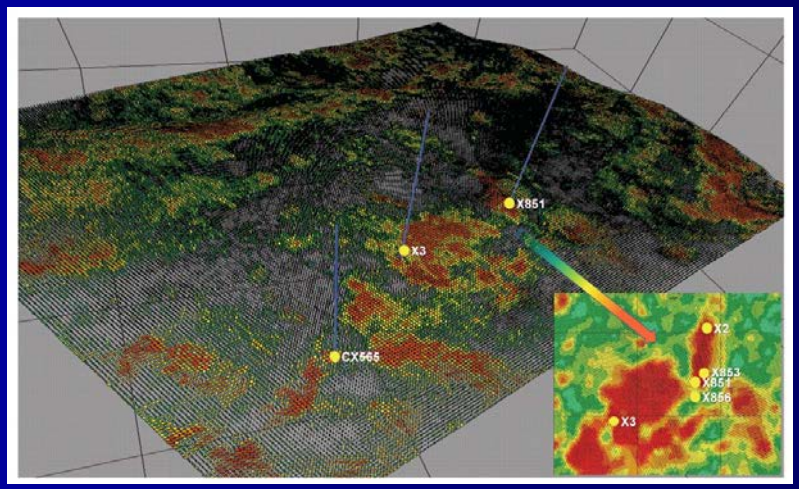
Mapping fractures in a Sichuan carbonate reservoir



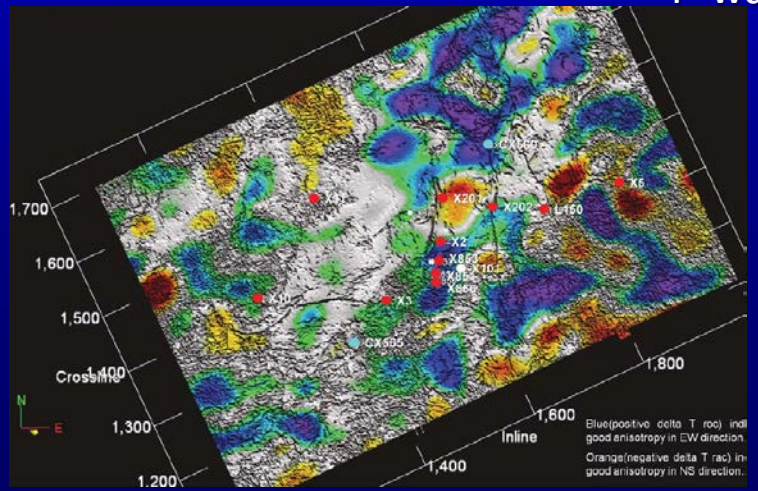
P-wave coherence



P-wave most-positive curvature



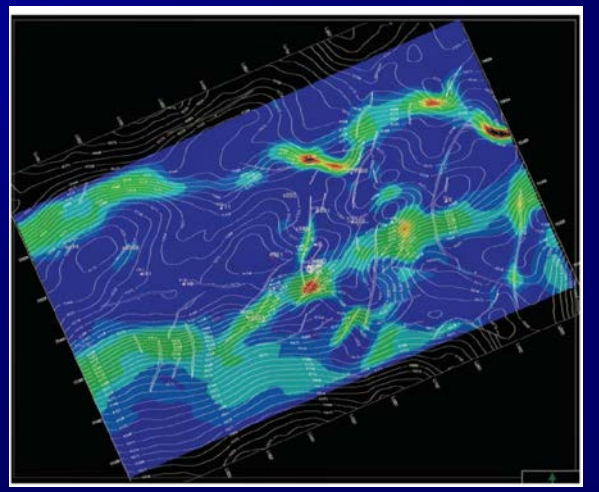
P-wave AVAz anisotropy



Shear wave time thickness difference

Section	Sand	Curvature Attribute		S-wave Splitting		P-wave Azimuthal Anisotropy	Coherency
		Class 1	Class 2	Class 1	Class 2		
Xujiahe Member 4	TX_4^8	>5	>7				<60
	TX_4^9						
Xujiahe Member 2	TX_2^2	>3	>2.6	Blue zone	Blue + green zone	>1.06	<50
	TX_2^3	>3	>2.6				
	TX_2^4	>3	>2.6	Blue zone	Blue + green zone		
	TX_2^5	>3.6	>3			>1.09	
	TX_2^6	>4.6	>4				
	TX_2^7	>6	>5				

Risk analysis table



Multiattribute fracture prediction

(Jianming et al., 2009)

Multiattribute Analysis Tools

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Visual Decision Making

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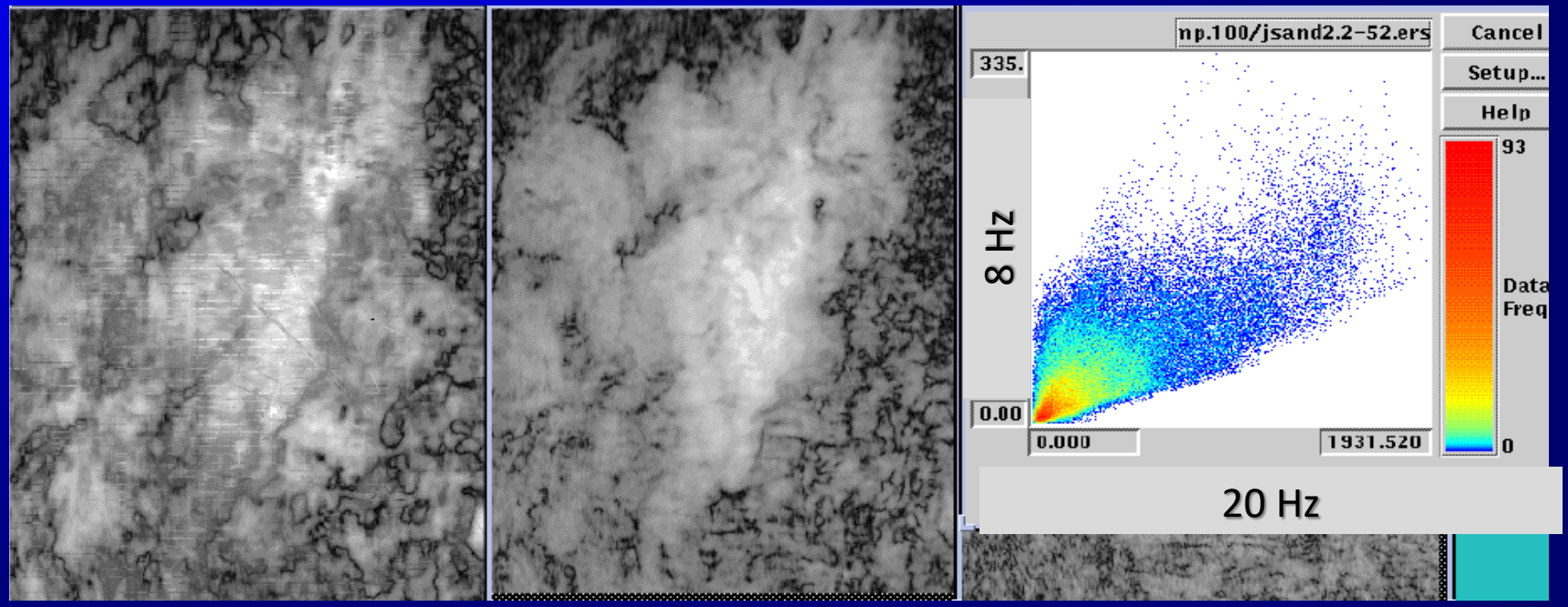
Scatterplots of spectral decomposition extractions



8 Hz

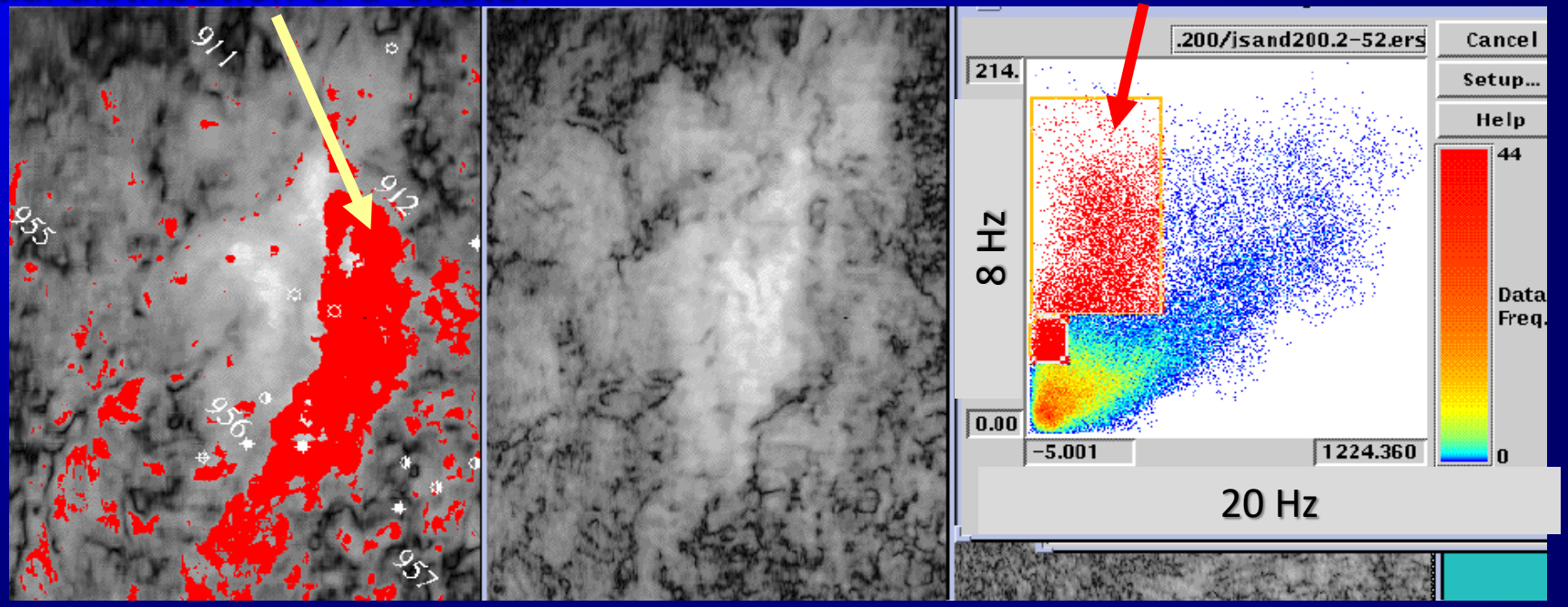
20 Hz

(Wessels et al., 1996)

Interactive clustering (good for 2 at a time!)

Spatial distribution of a ‘cluster’

User highlighted ‘cluster’

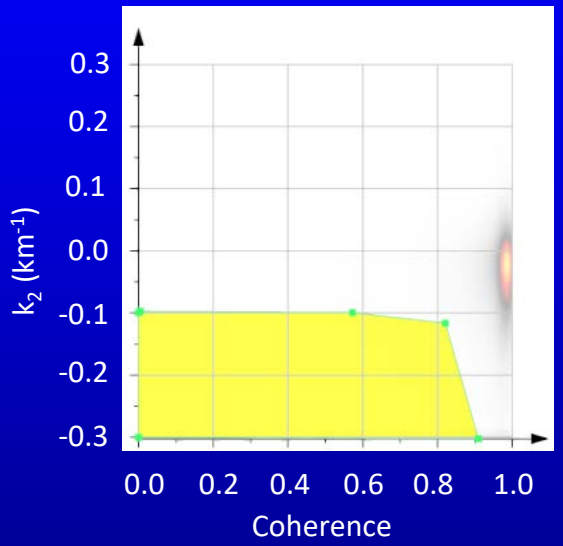


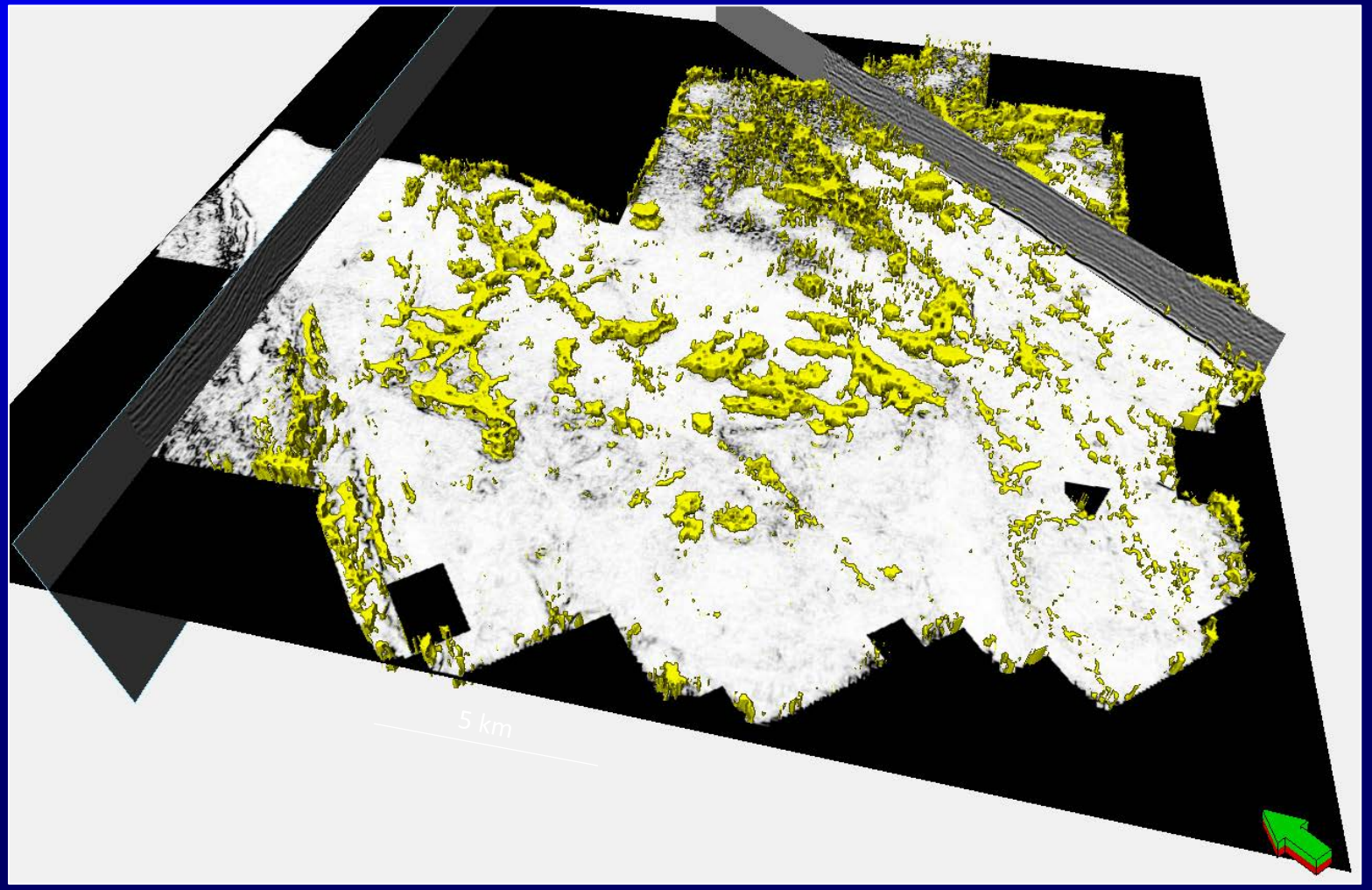
8 Hz

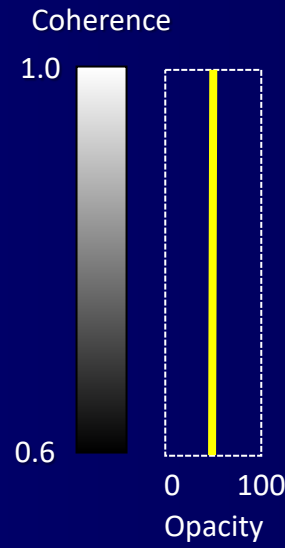
20 Hz

(Wessels et al., 1996)

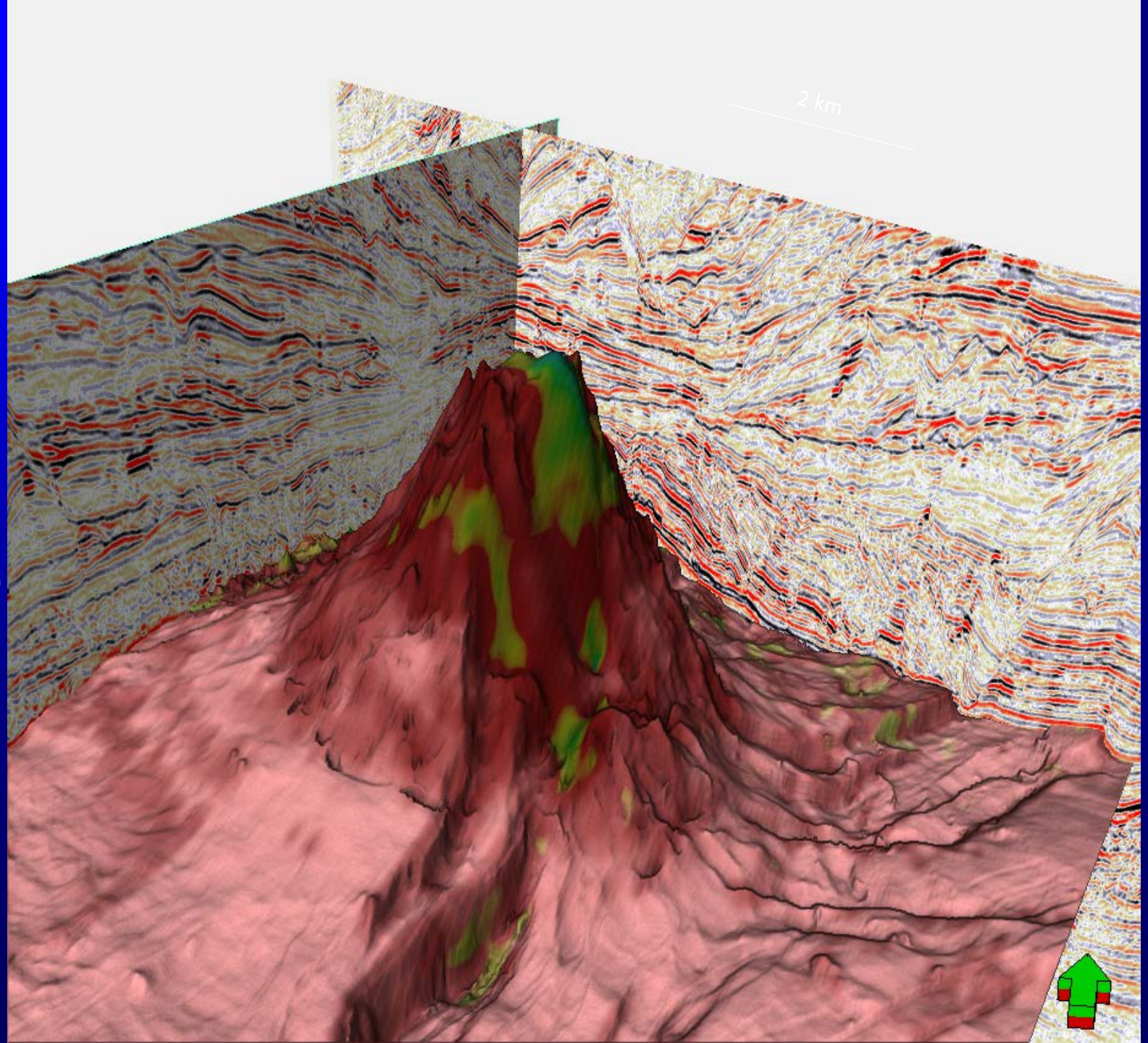
Crossplotting 2 attributes using a 2D histogram





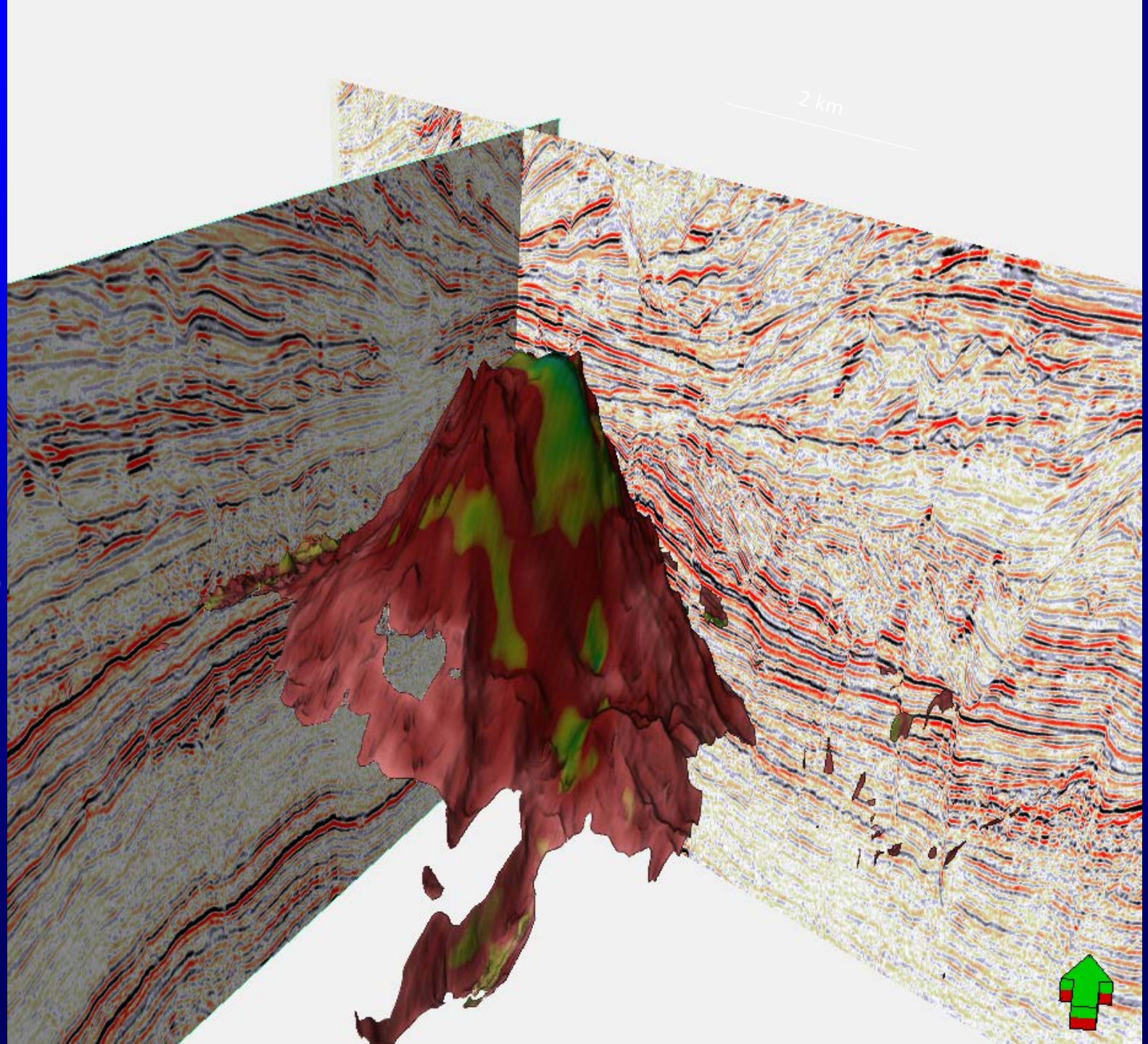


(Marfurt, 2018)



Crossplotting 3 attributes by applying opacity to each histogram

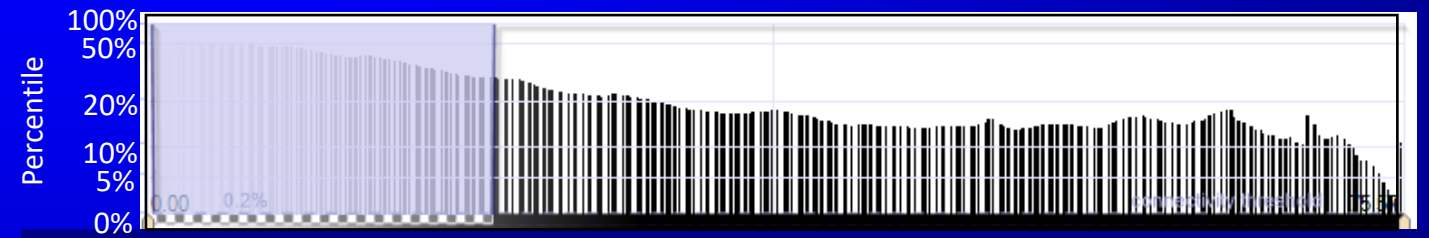
(Marfurt, 2018)



Crossplotting 3 attributes by applying opacity to each histogram

(Marfurt, 2018)

Crossplotting 3 attributes using by applying opacity to each histogram

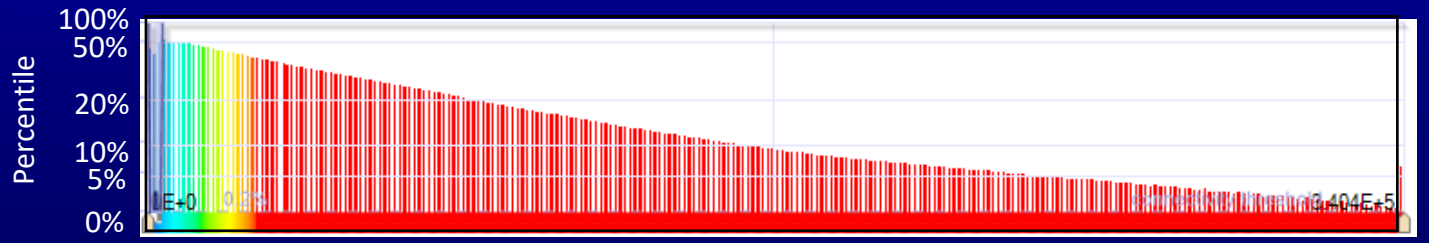


0° Dip magnitude 70°

Reject 0°-25° dips

0 Entropy 0.2

Reject 0.0-0.15 entropy

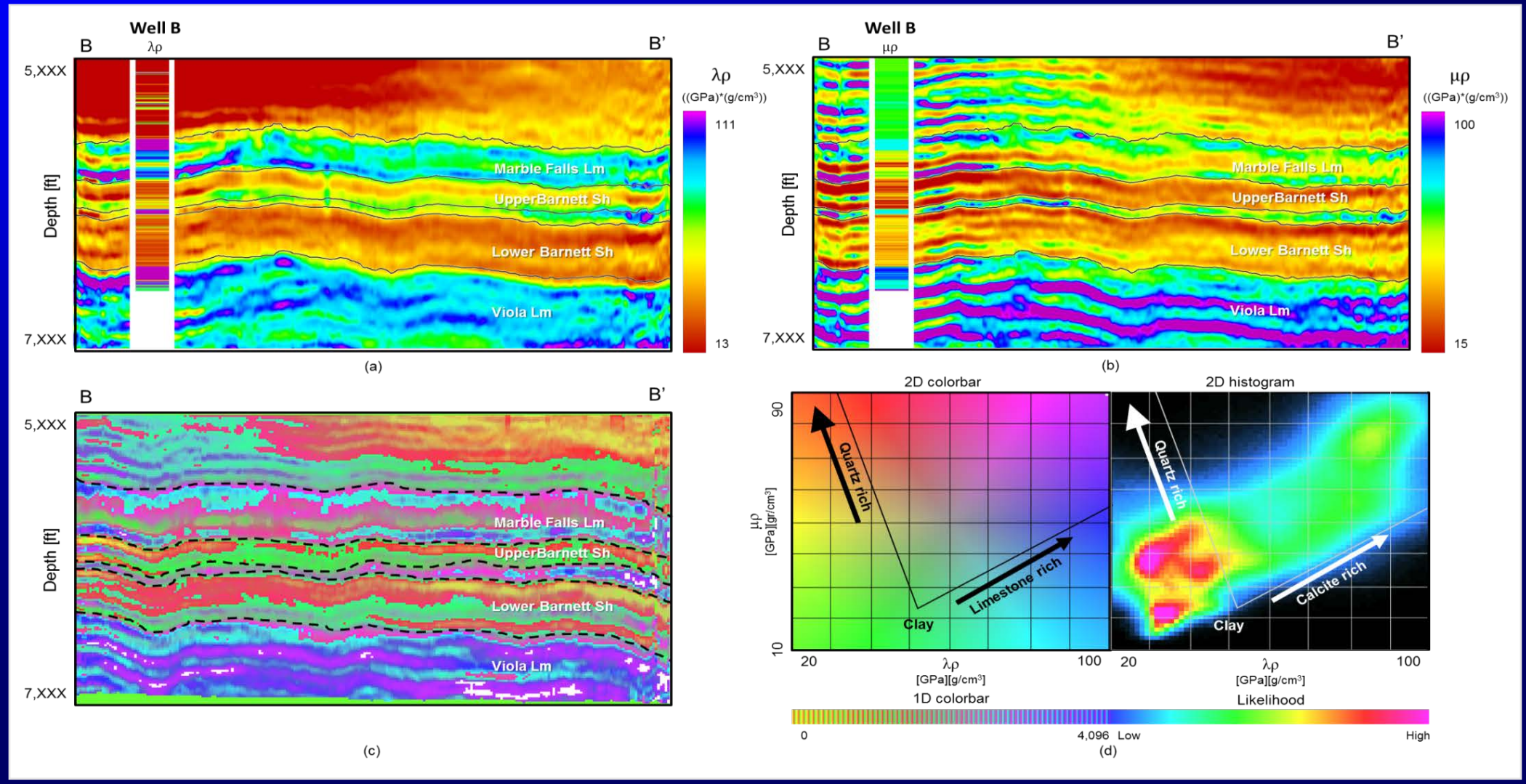


0 Peak magnitude 10000

Reject 0-1000 peak spectral magnitude

Figure 4.22c (Courtesy Lennon Infante, SU) (Marfurt, 2018)

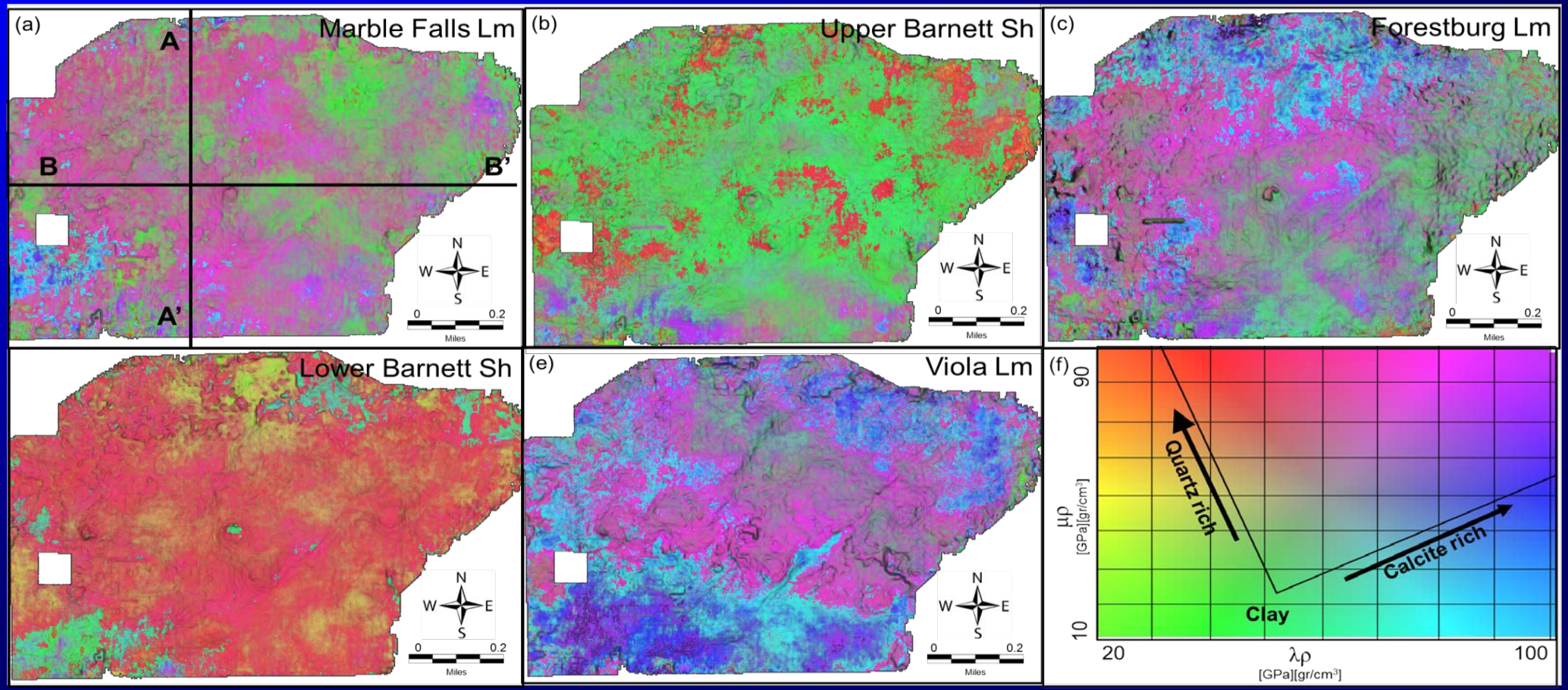
Using a 2D color bar to crossplot $\lambda\rho$ vs. $\mu\rho$ to estimate mineralogy



Vertical slices through the Barnett Shale sequence

(Perez and Marfurt, 2015)

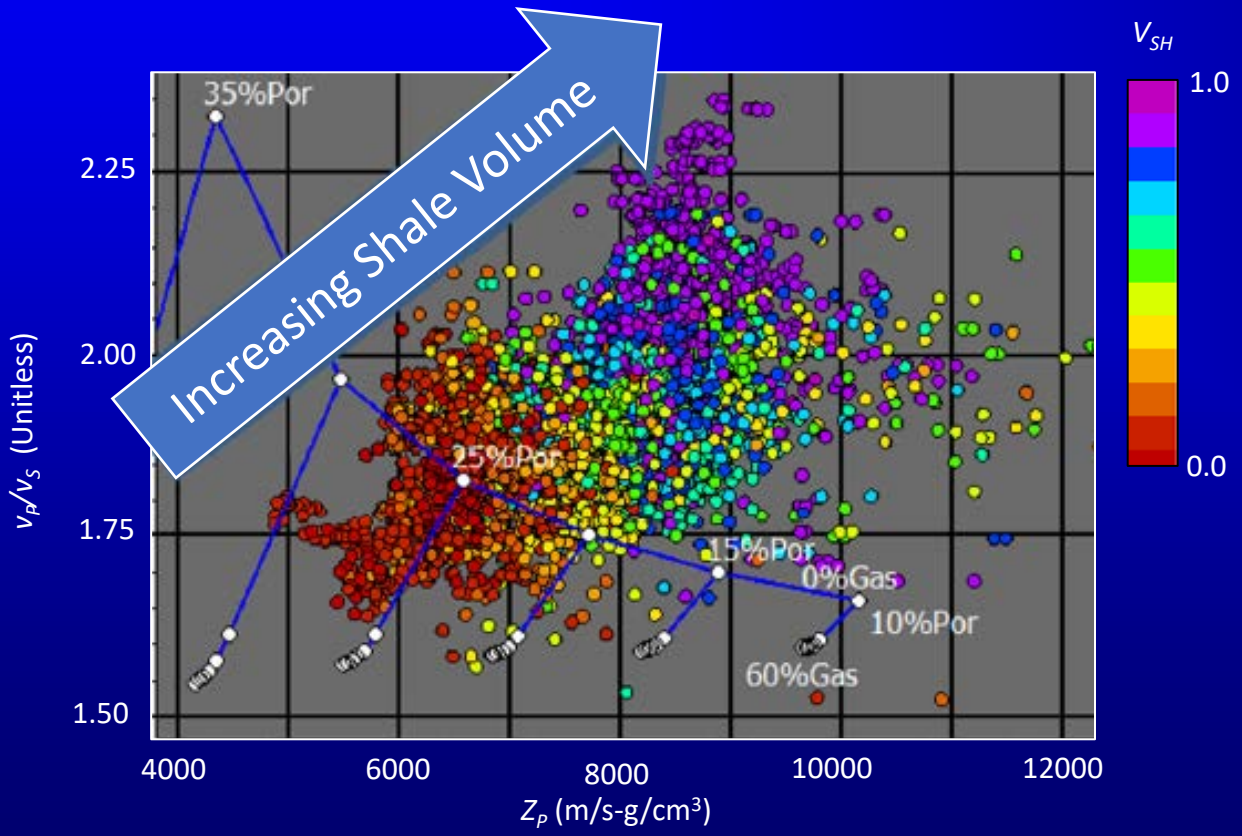
Using a 2D color bar to crossplot $\lambda\rho$ vs. $\mu\rho$ to estimate mineralogy

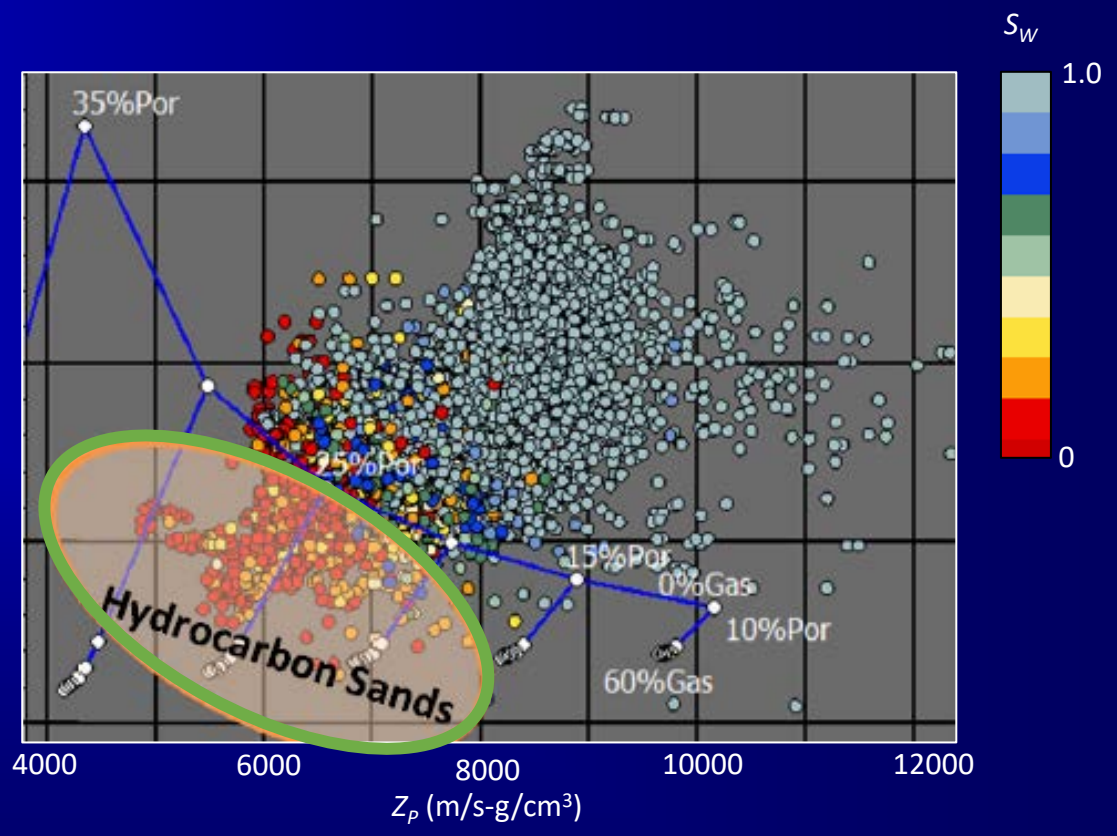


Stratal slices through the Barnett Shale sequence

(Perez and Marfurt, 2015)

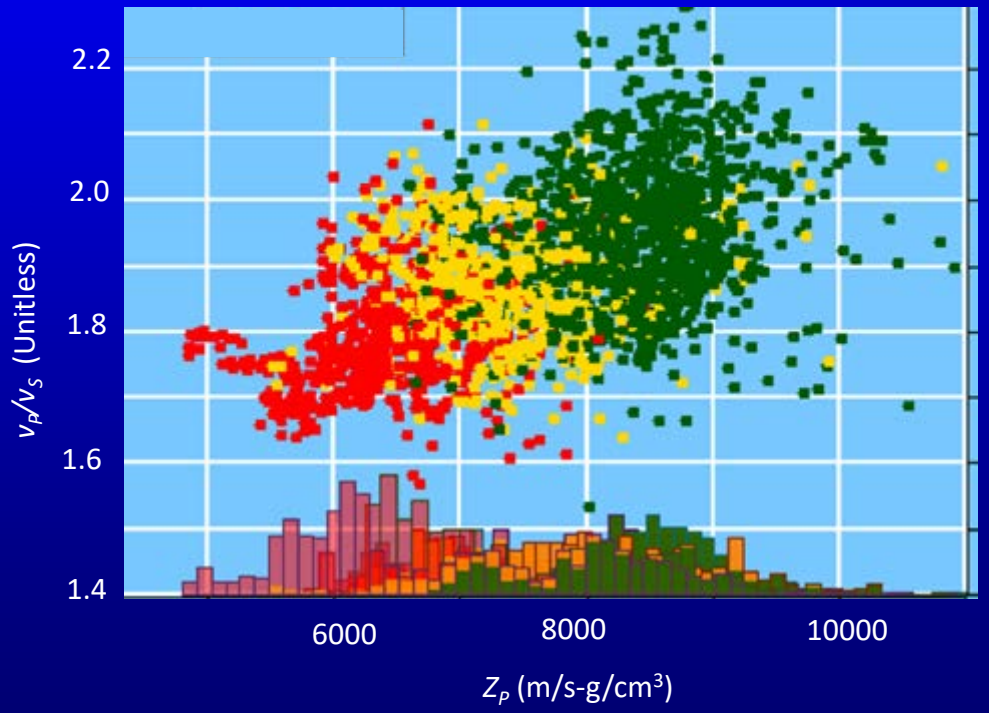
Building a petrophysical template using well log control

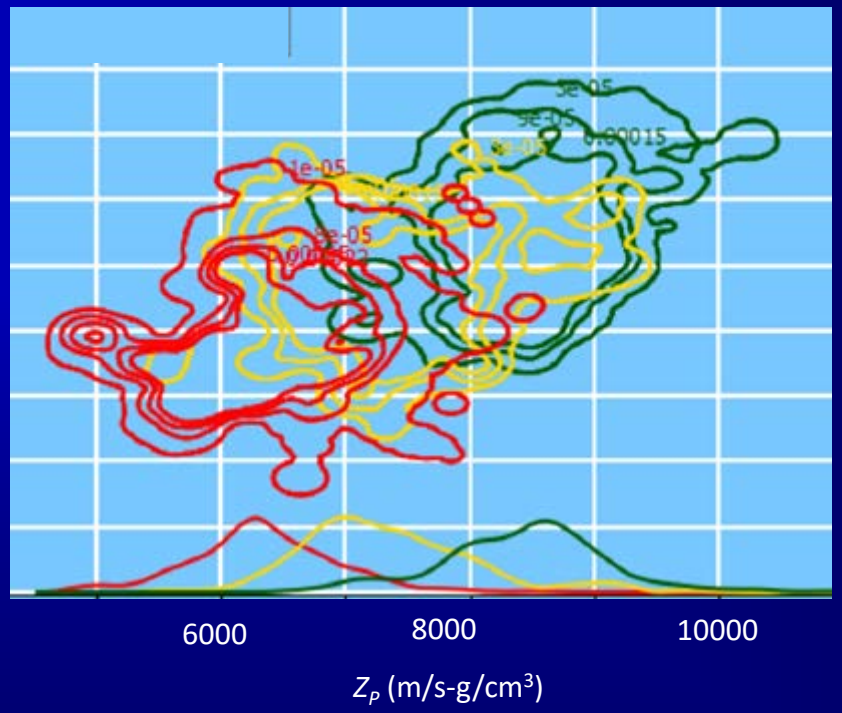




(Yenwangai et al., 2017).

Building a petrophysical template using well log control





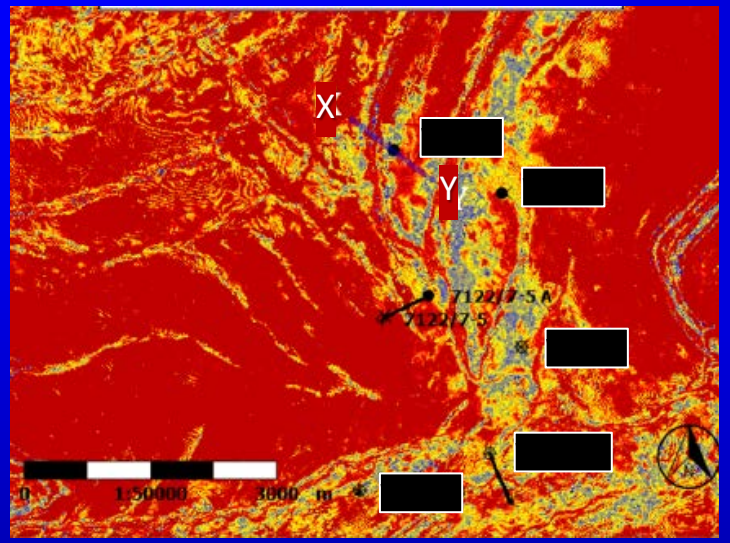
Background

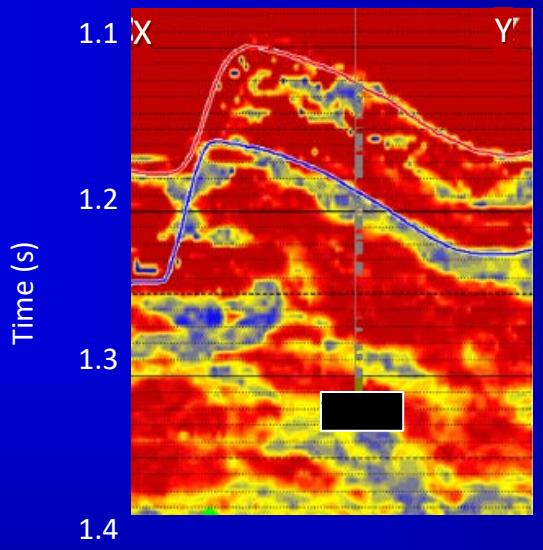
Brine sand

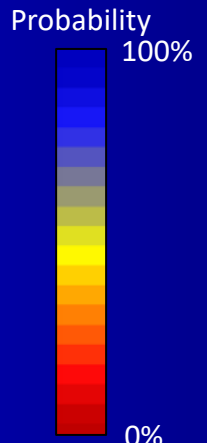
Hydrocarbon sand

(Yenwangai et al., 2017).

Brine sand probability

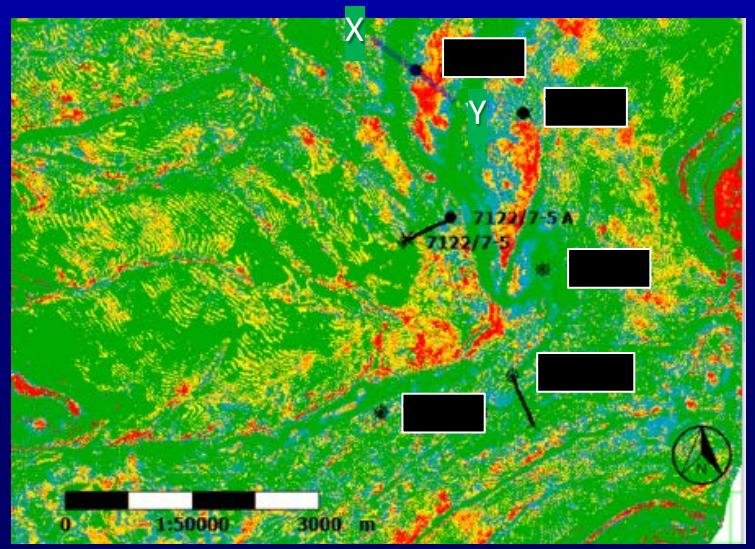


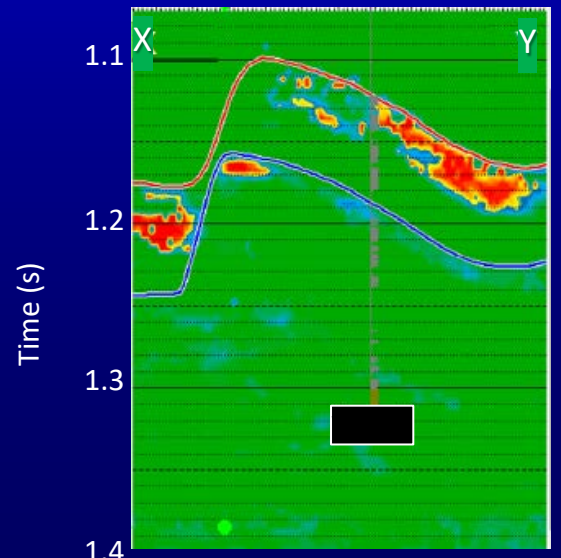


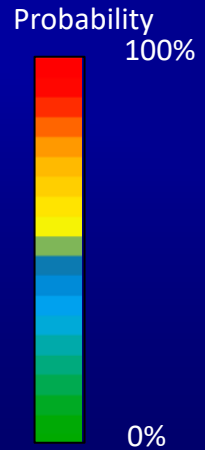


Using Bayesian classification to predict lithology and fluid facies

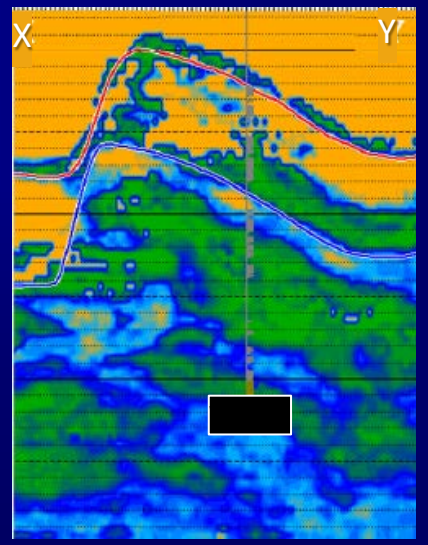
Hydrocarbon sand probability

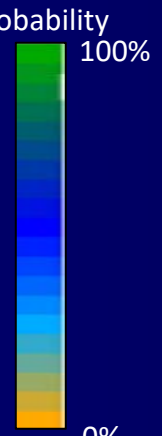






Shale probability





(Yenwangai et al., 2017)

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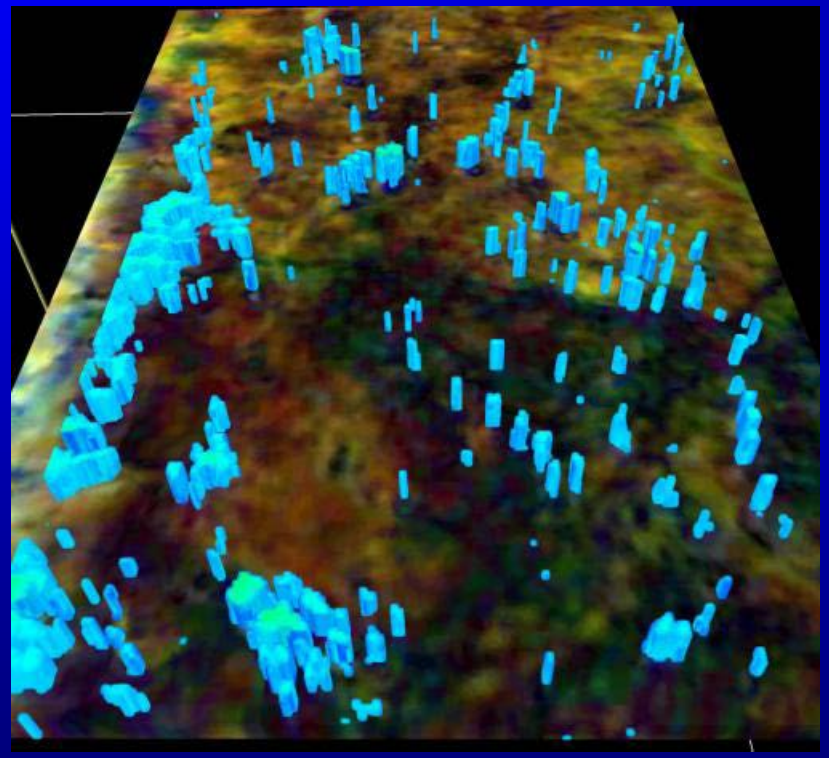
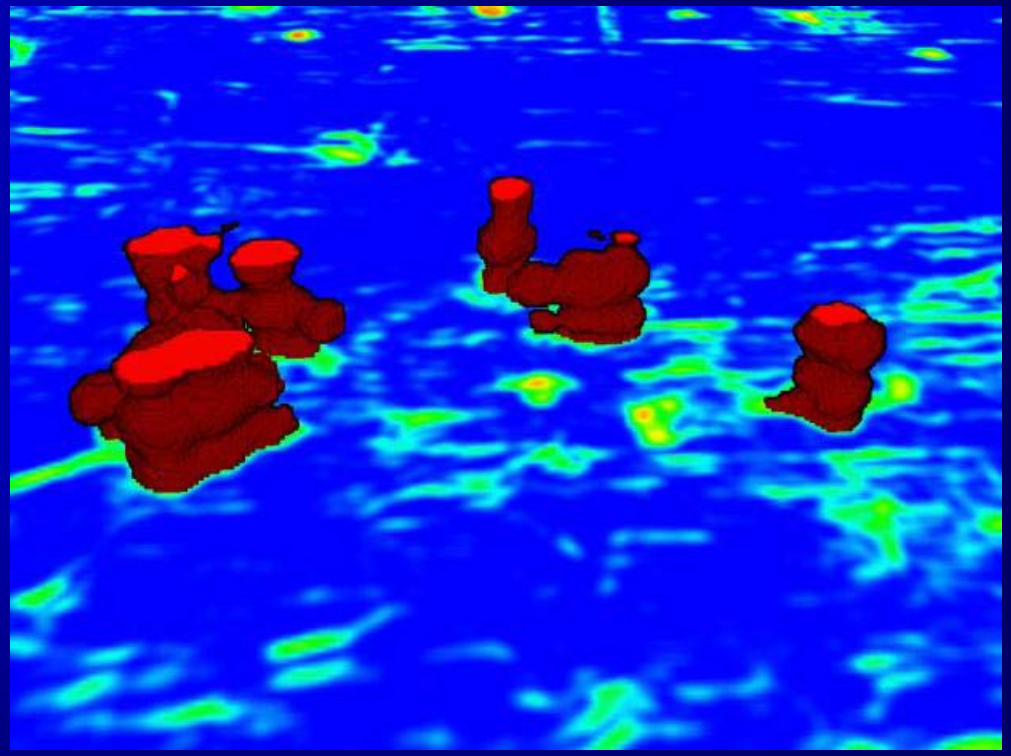
Connected Component Labeling (CCL)
(Karst dissolution)

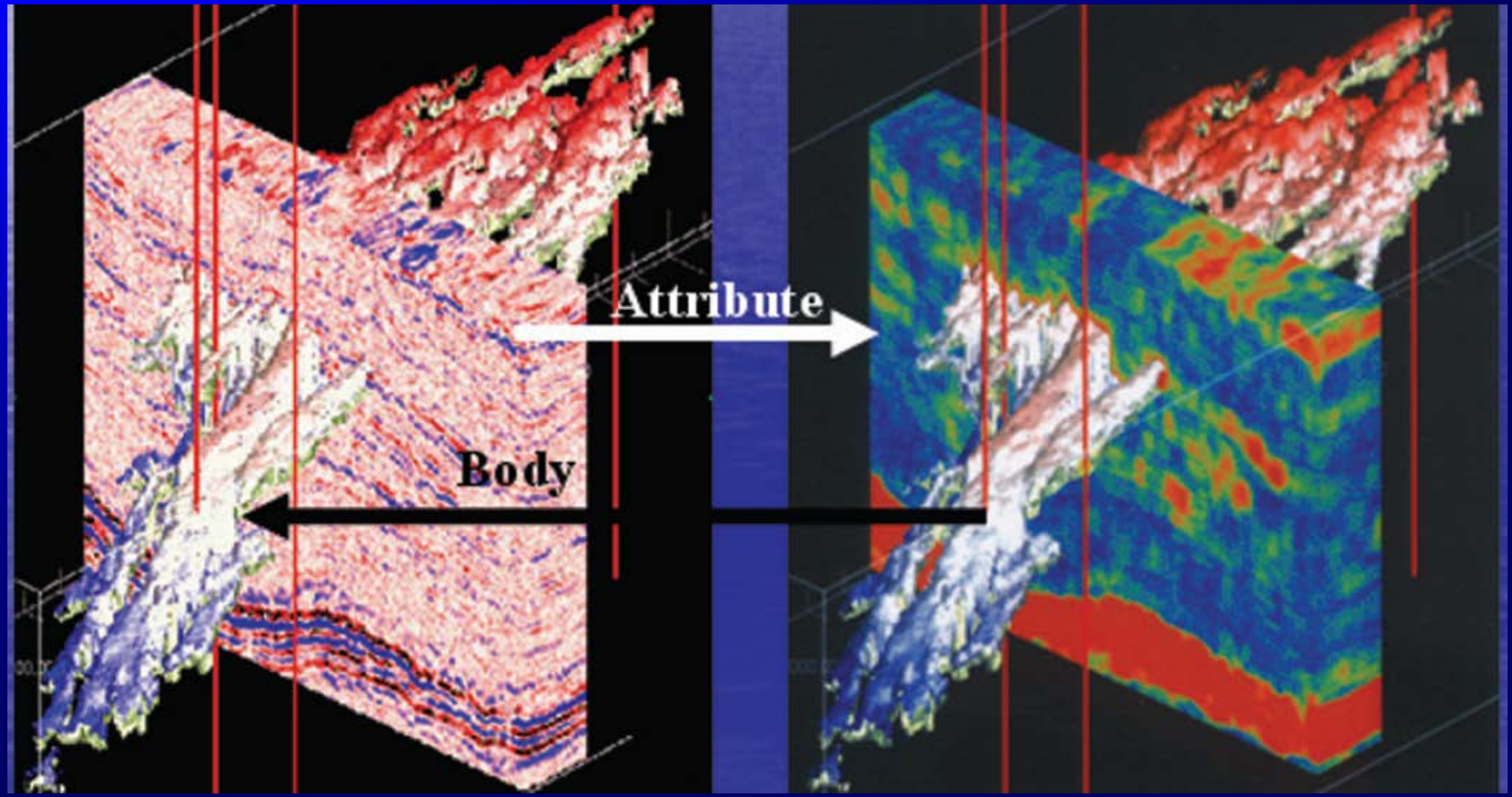




Input attributes include coherence , spectral components, and conformity of vector dip.

(FFA – EAGE 2008)

Connected Component Labeling (CCL)
(A turbidite flow)



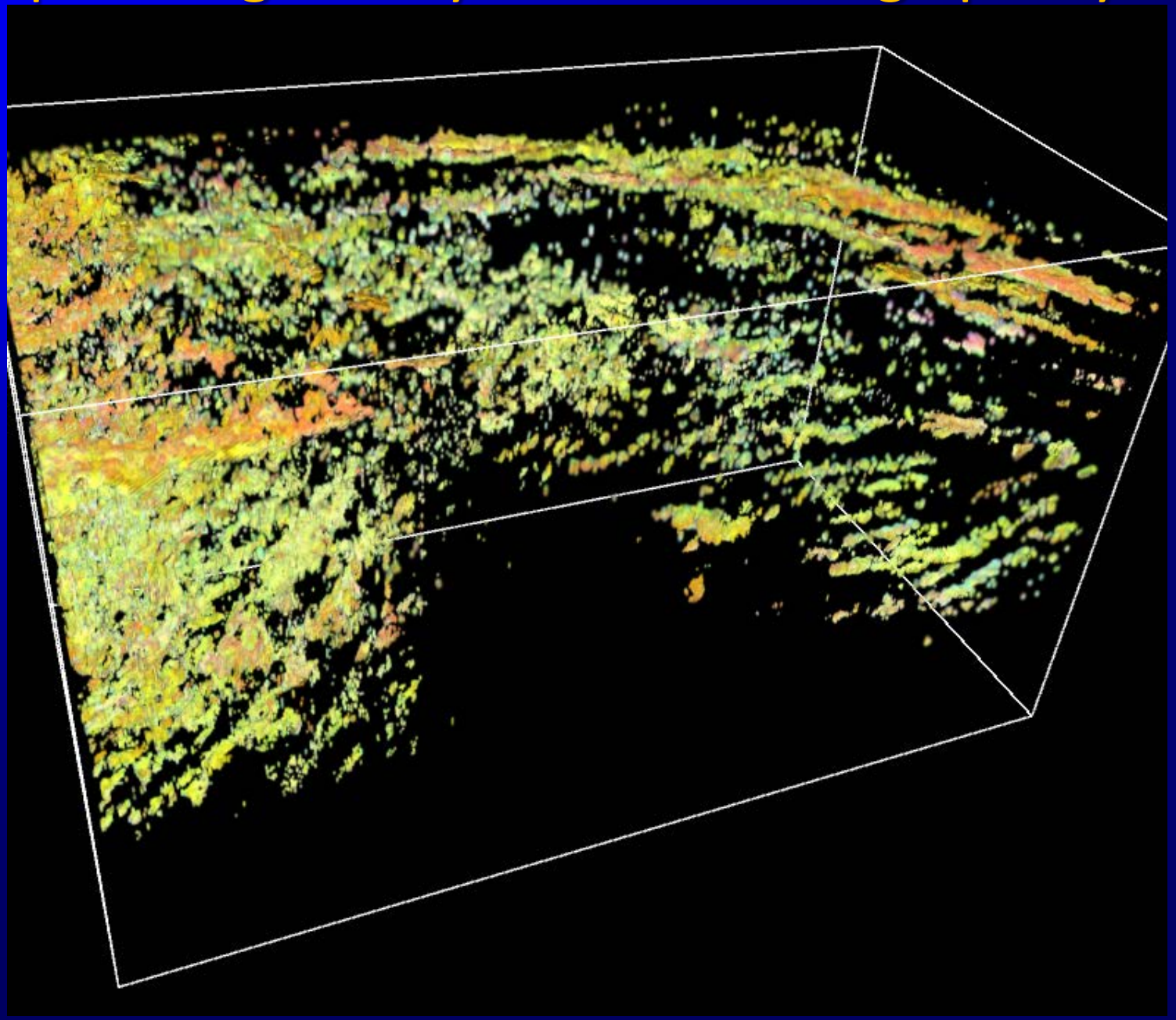
(Dalley, 2008)

3 spectral component geobody detection using opacity

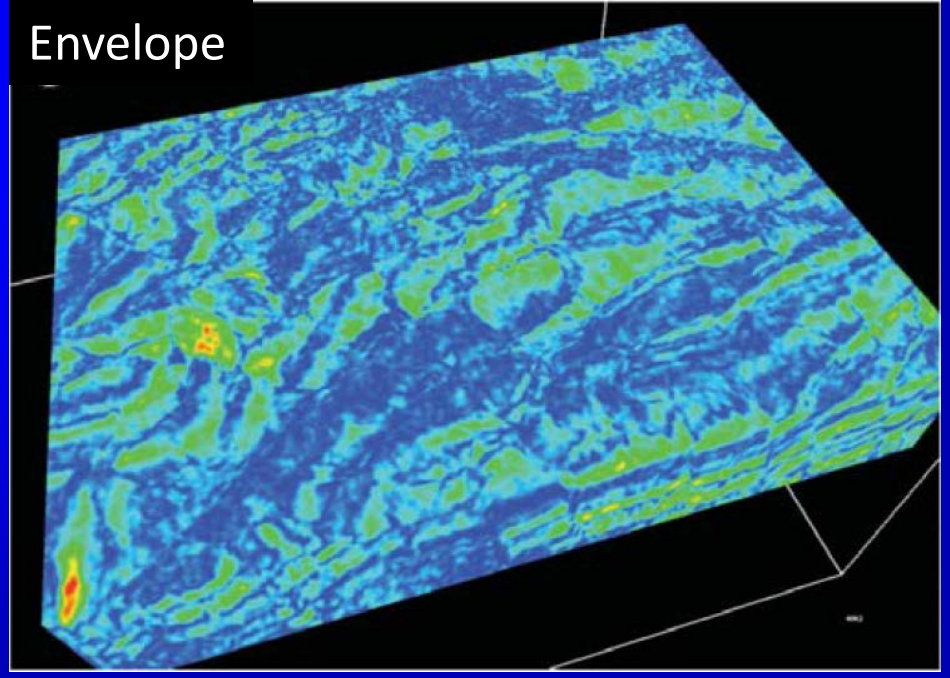
1. Co-render 3 attributes against RGB
2. Draw a polygon on a 2D slice to define a region of interest
3. Interpolate colors with the polygon using a diffusion operator
4. Set all colors in the polygon to be opaque, all others to be transparent

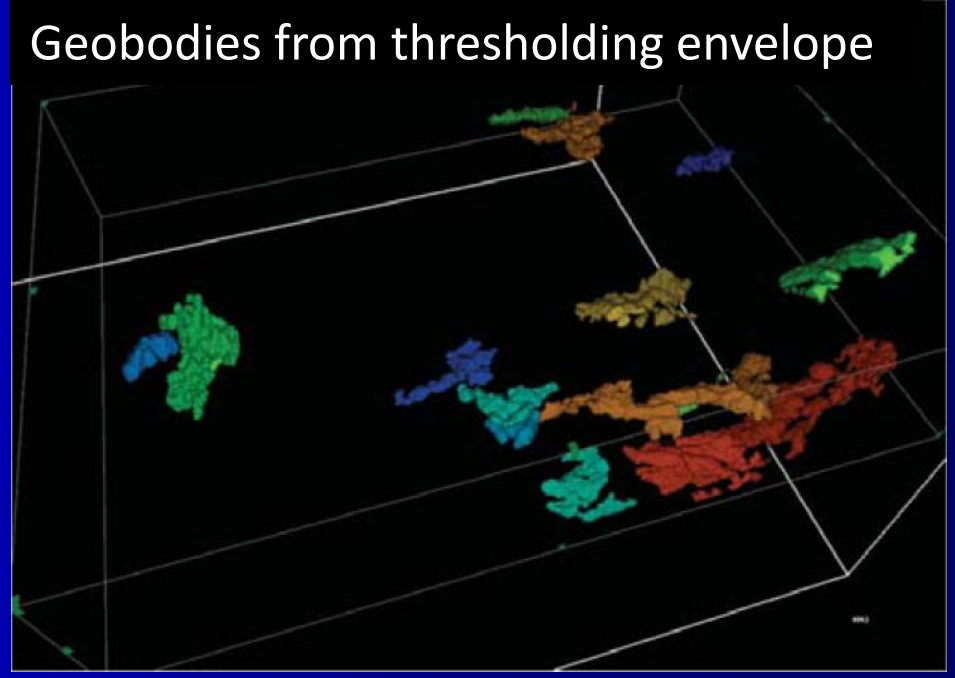
(Henderson et al., 2008)

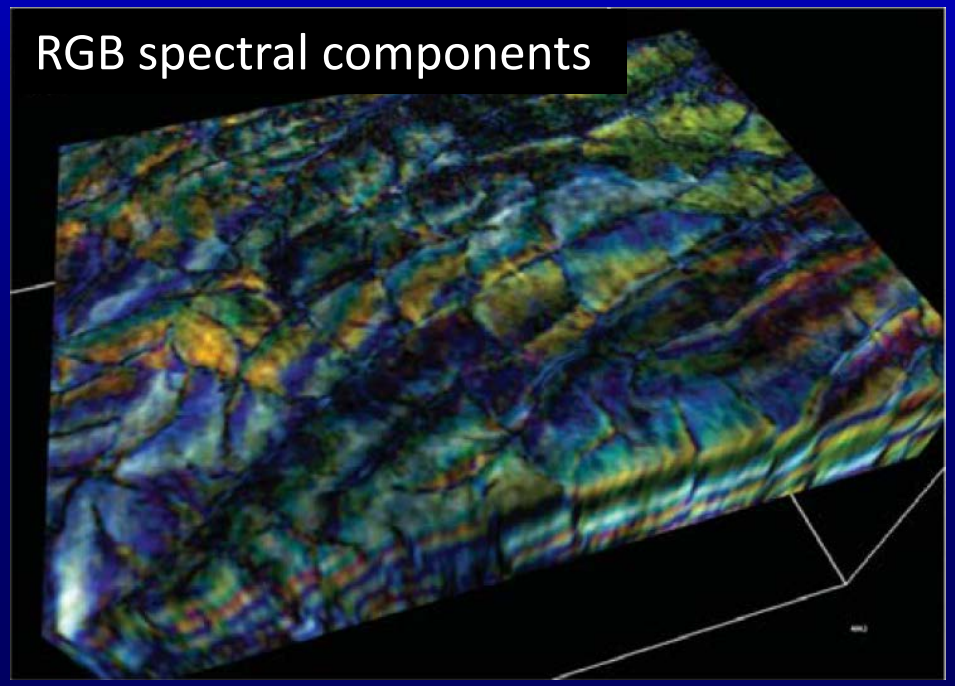
3 spectral component geobody detection using opacity

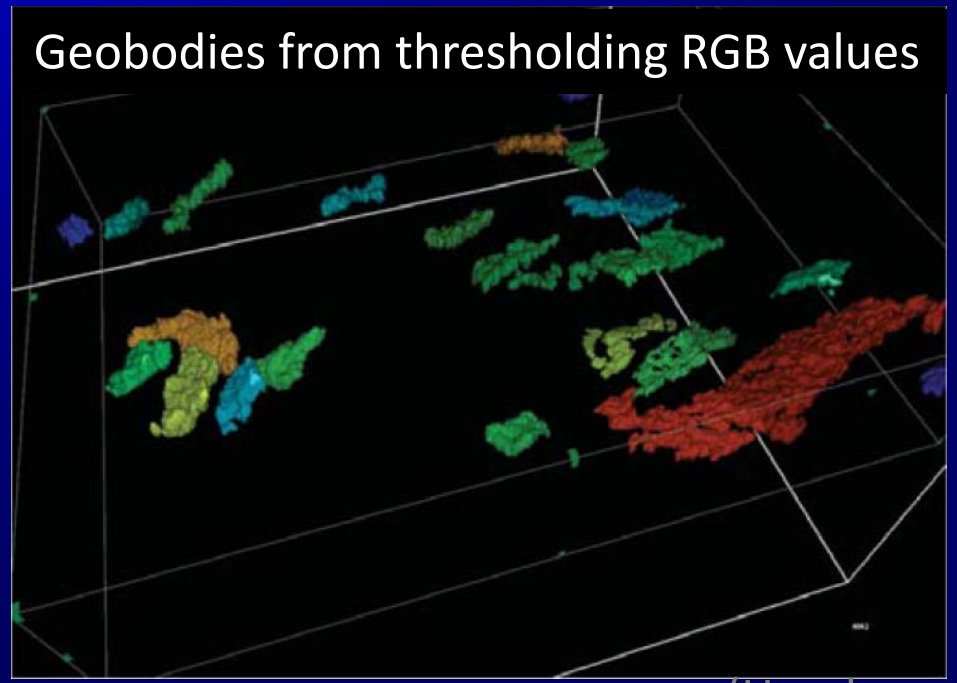


(Henderson et al., 2008)





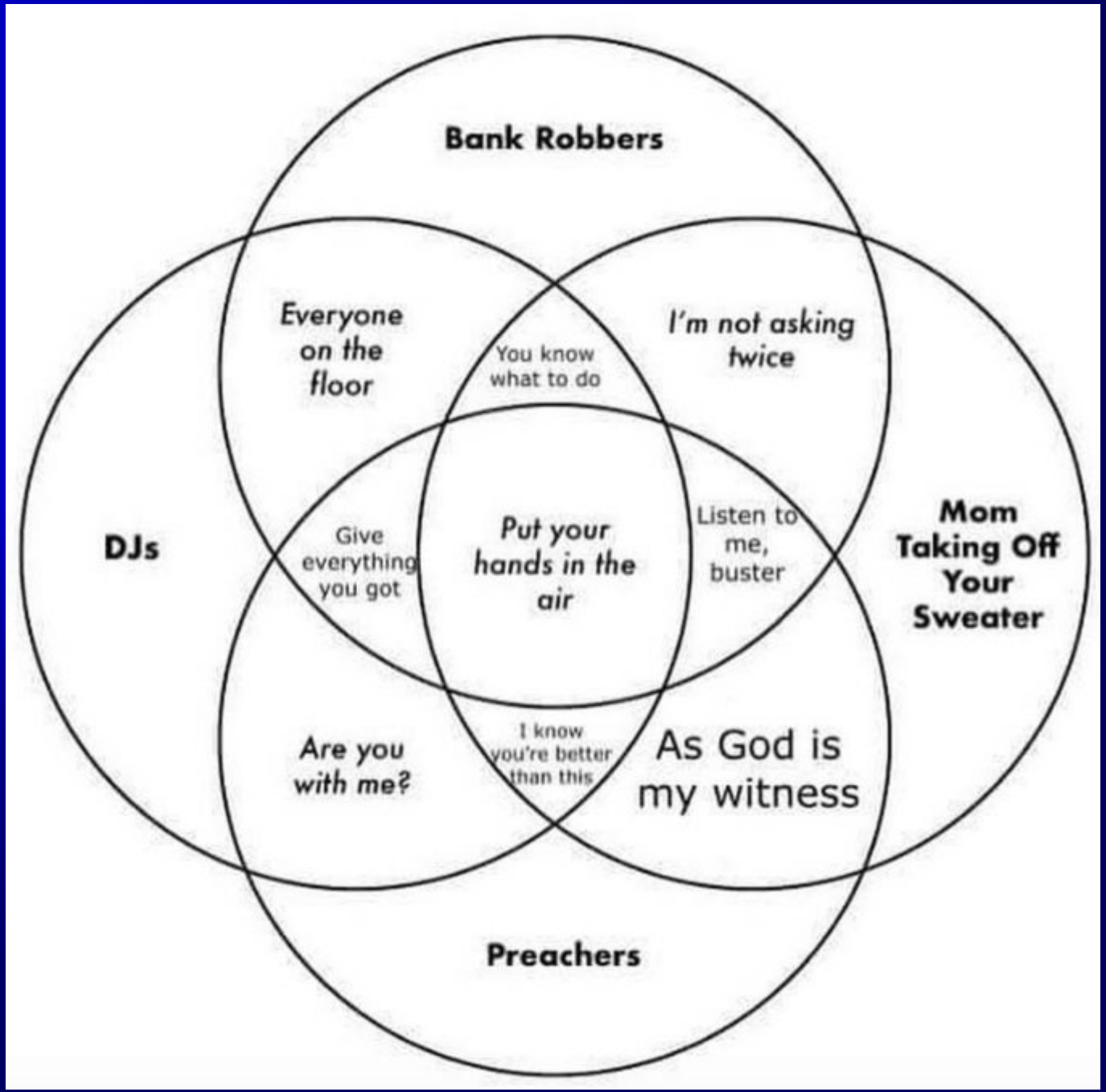




(Henderson et al., 2008)

Machine learning using visual decision making

In Summary:

- Combining attributes can provide information that exceeds that of each attribute viewed separately.
- Simple clustering can be achieved through color blending and opacity.
- Modern interactive cross-plotting tools allow human-driven clustering of 2 or 3 attributes with well control.
- Interactive clustering is a key component of ‘exploratory data analysis’, which is the first step in more quantitative analysis techniques.

Similar results from DJs, bank robbers, preachers, and Mom