Seismic Attributes

H. Roice Nelson, Jr.

Day 2 Session 4

- Attribute details
  - Definitions
  - Instantaneous attributes
  - Wavelet attributes
  - Geometrical attributes
  - Reflective attributes
  - Curvature attributes
    - Semblance attributes
    - Energy attributes
    - Shape attributes
    - Dip and azimuth attributes
    - Gradient attributes
  - Coherence attributes
- AVO (Amplitude vs. Offset)
- AVA (Amplitude vs. Angle)
- Attributes and structural interpretation
  - Coherence
  - Dip
  - Derivatives
- Attributes and stratigraphic interpretation
  - Slices and windows
  - Frequency enhancement
  - Amplitude display options
- Attributes and reservoir delineation

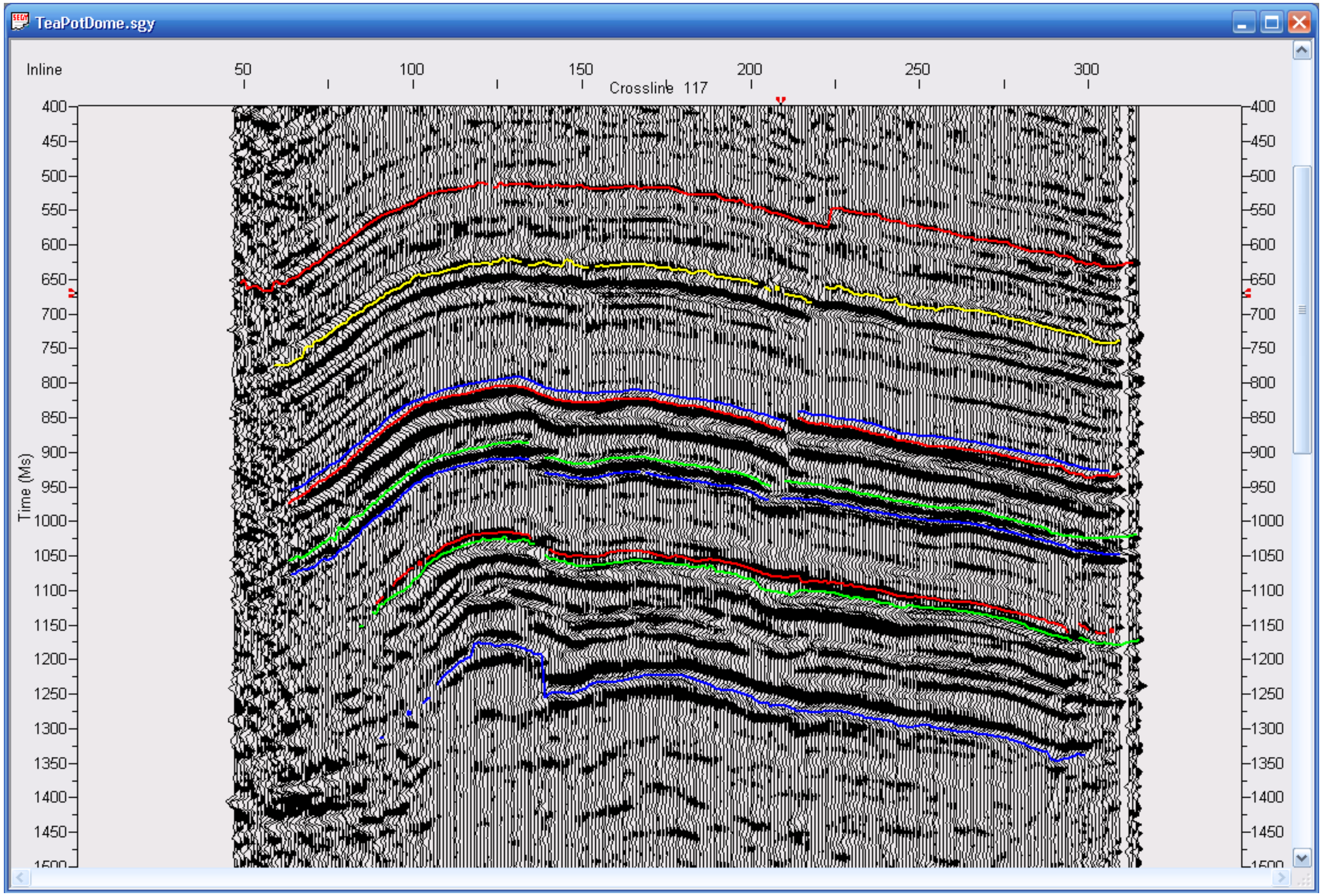
Seismic Attributes Definition

Seismic Attributes are all the information obtained from seismic data, either by direct measurements or by logical or experience based reasoning.

Tury Taner, **Attributes Revisited**, *www.rocksolidimages.com/pdf/attrib_**revisited**.htm*.

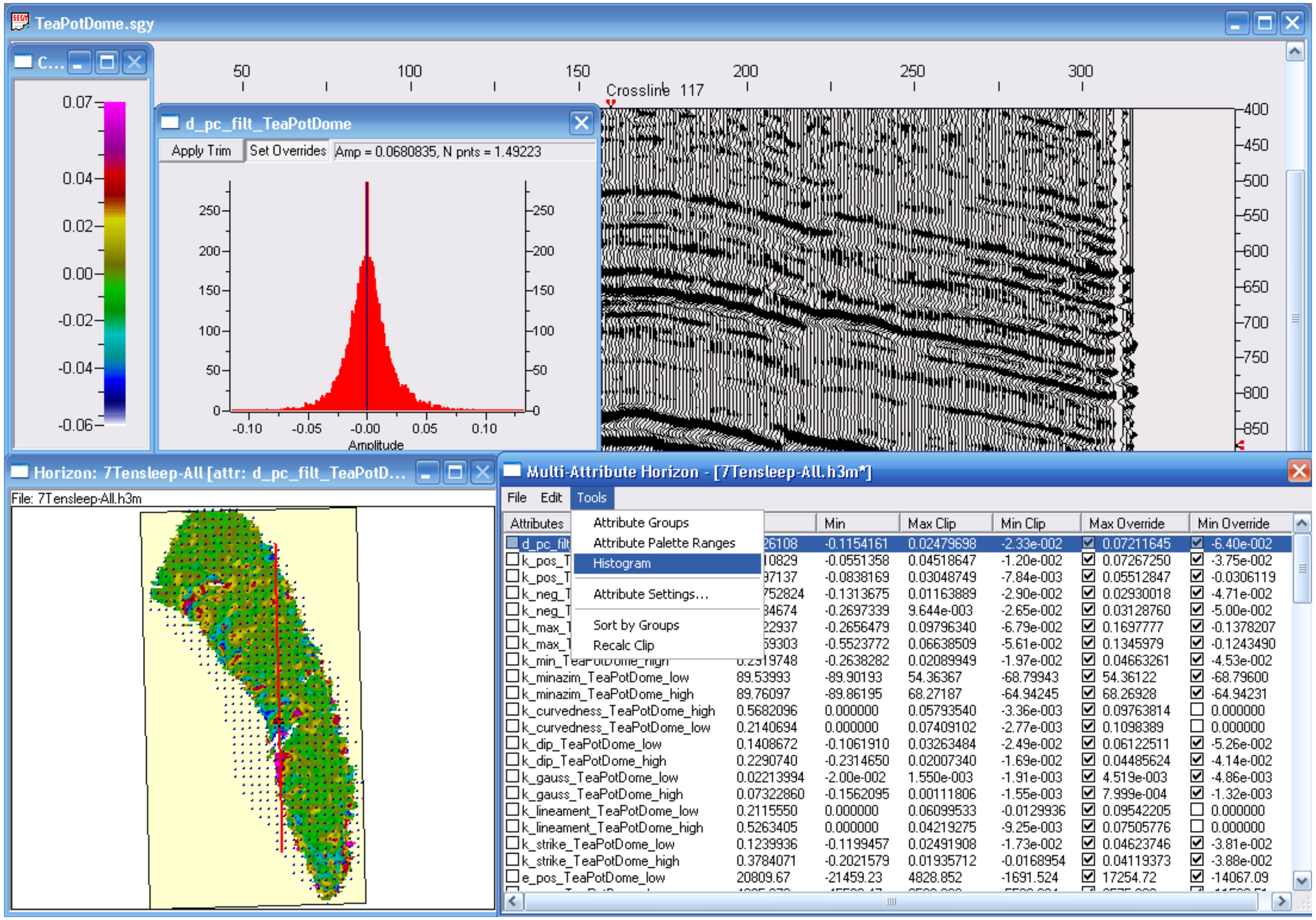
Amplitude Section

Teapot Dome



Don Robinson, **ResolveGeo**, http://www.resolvegeo.com, Data from The Rocky Mountain Oil Testing Center and the U.S. Department of Energy

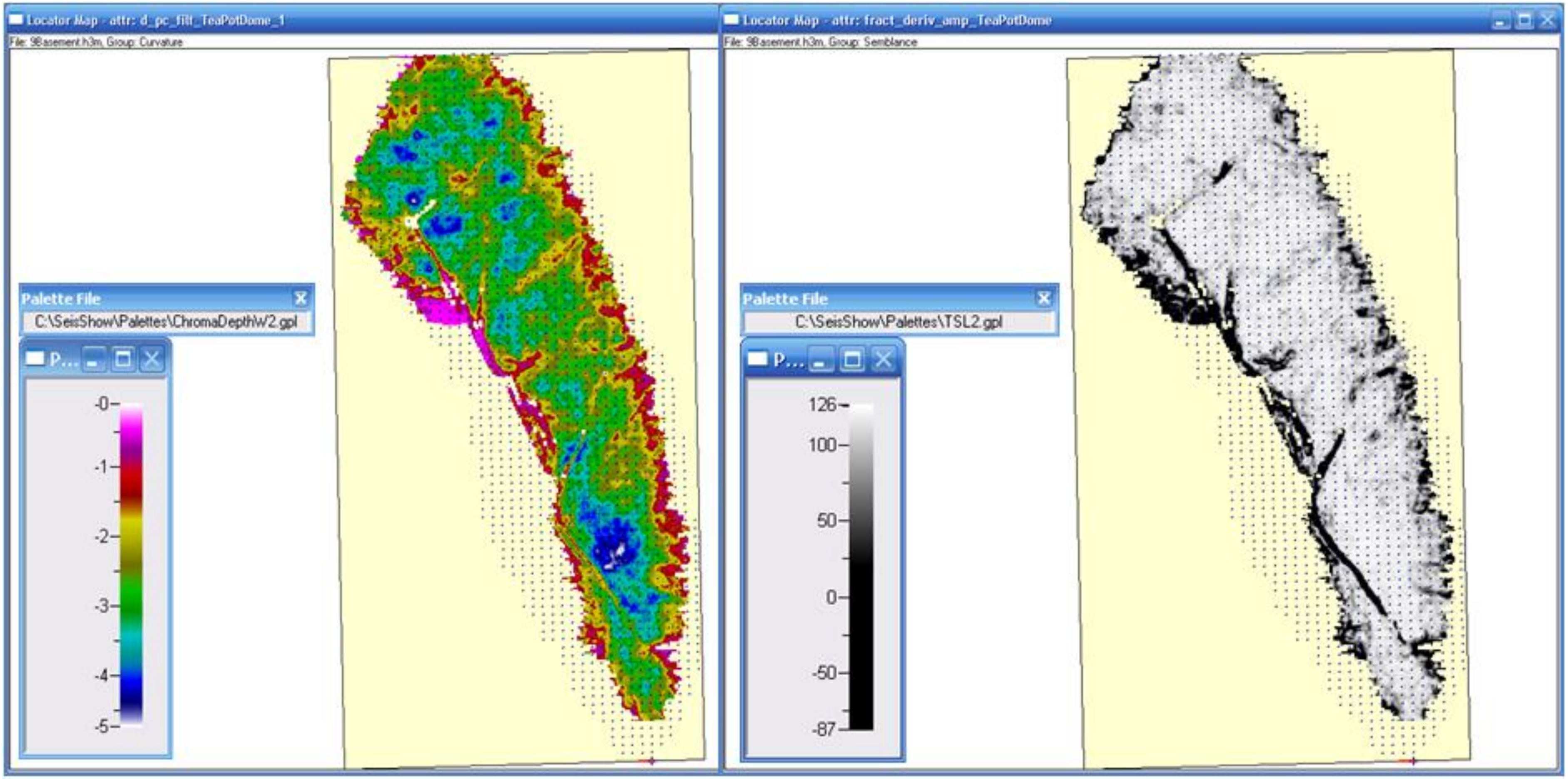
Grouping and Palletes
Teapot Dome



Don Robinson, **ResolveGeo**, http://www.resolvegeo.com, Data from The Rocky Mountain Oil Testing Center and the U.S. Department of Energy

PC_Filt & Fractional Derivative

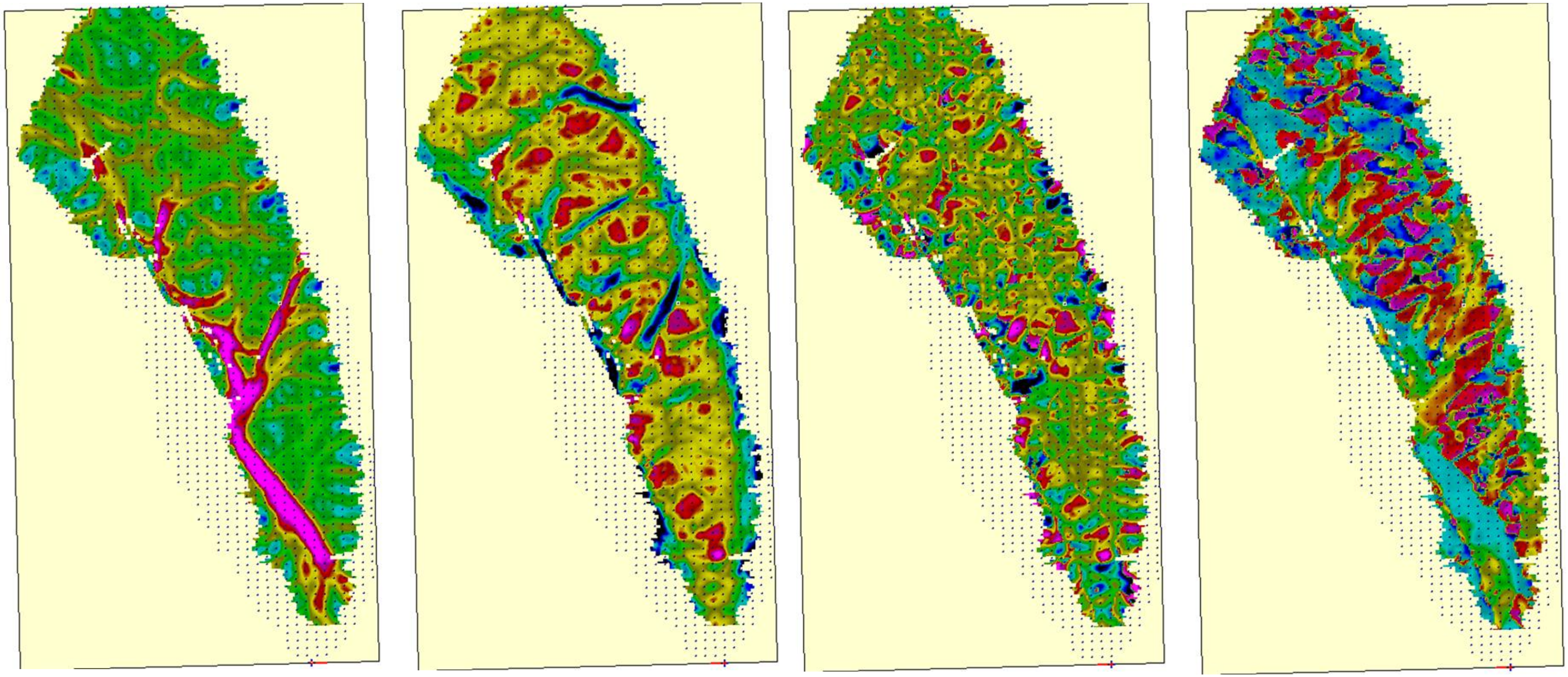
Teapot Dome



Don Robinson, **ResolveGeo**, http://www.resolvegeo.com, Data from The Rocky Mountain Oil Testing Center and the U.S. Department of Energy

K_Pos, K_Neg, K_Min, & K_min_azim

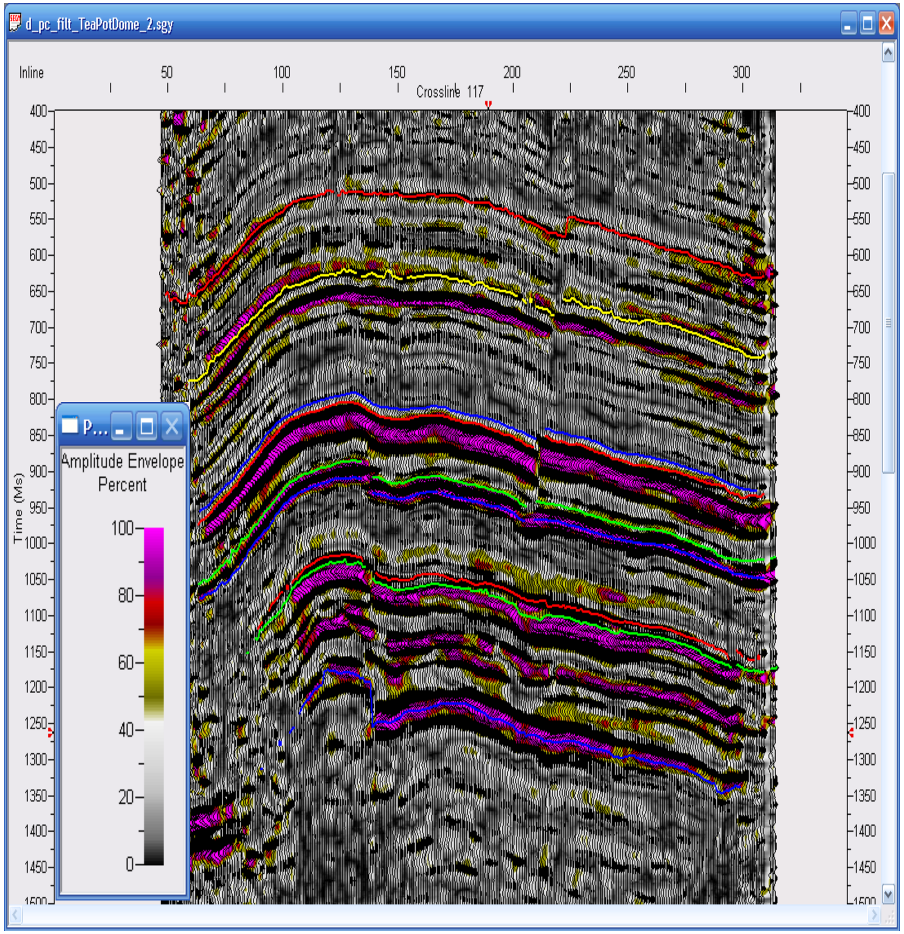
Teapot Dome

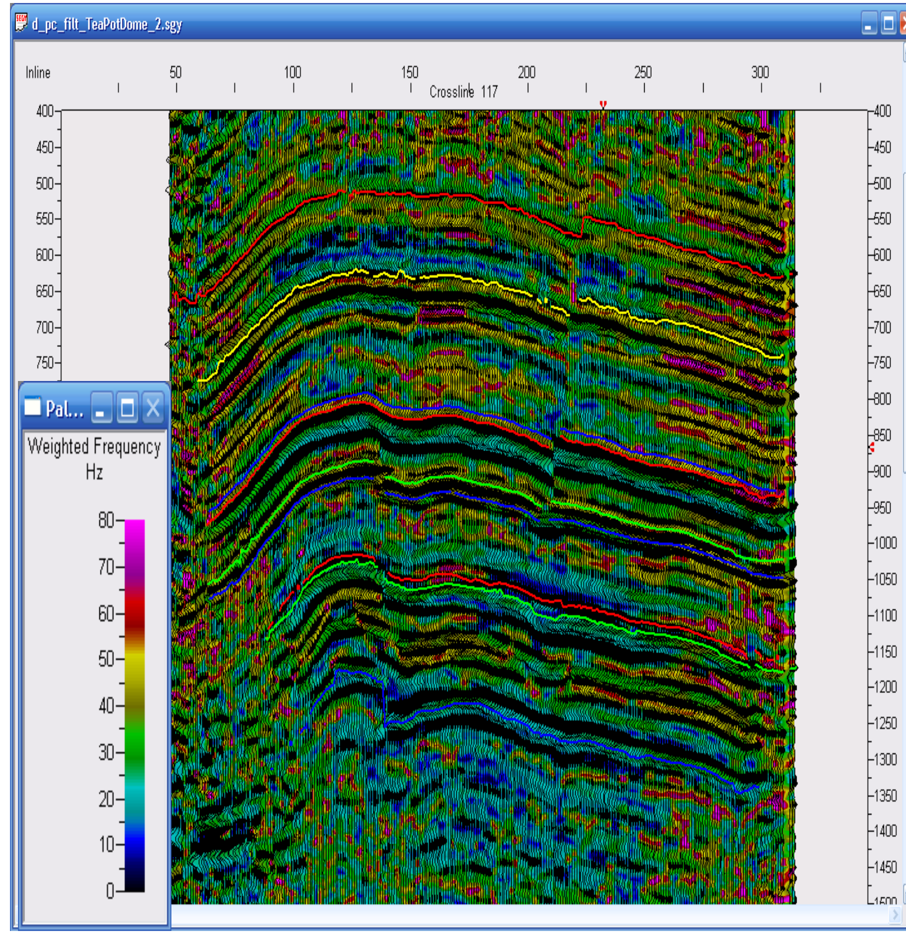


Don Robinson, **ResolveGeo**, http://www.resolvegeo.com, Data from The Rocky Mountain Oil Testing Center and the U.S. Department of Energy

Amplitude Envelope & Instant Frequency

Teapot Dome

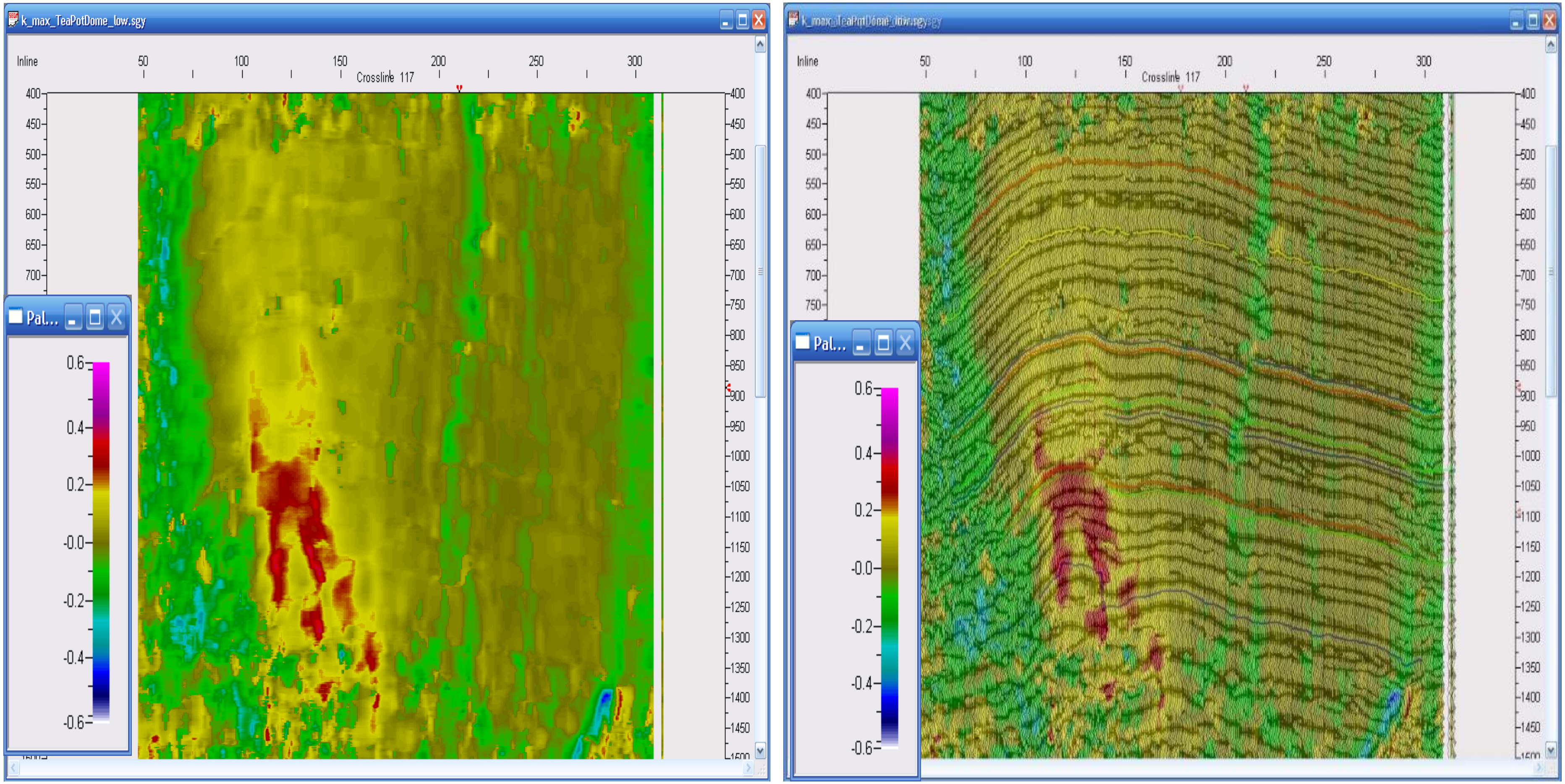




Don Robinson, **ResolveGeo**, http://www.resolvegeo.com, Data from The Rocky Mountain Oil Testing Center and the U.S. Department of Energy

K_Max_Low & with Amplitude Section

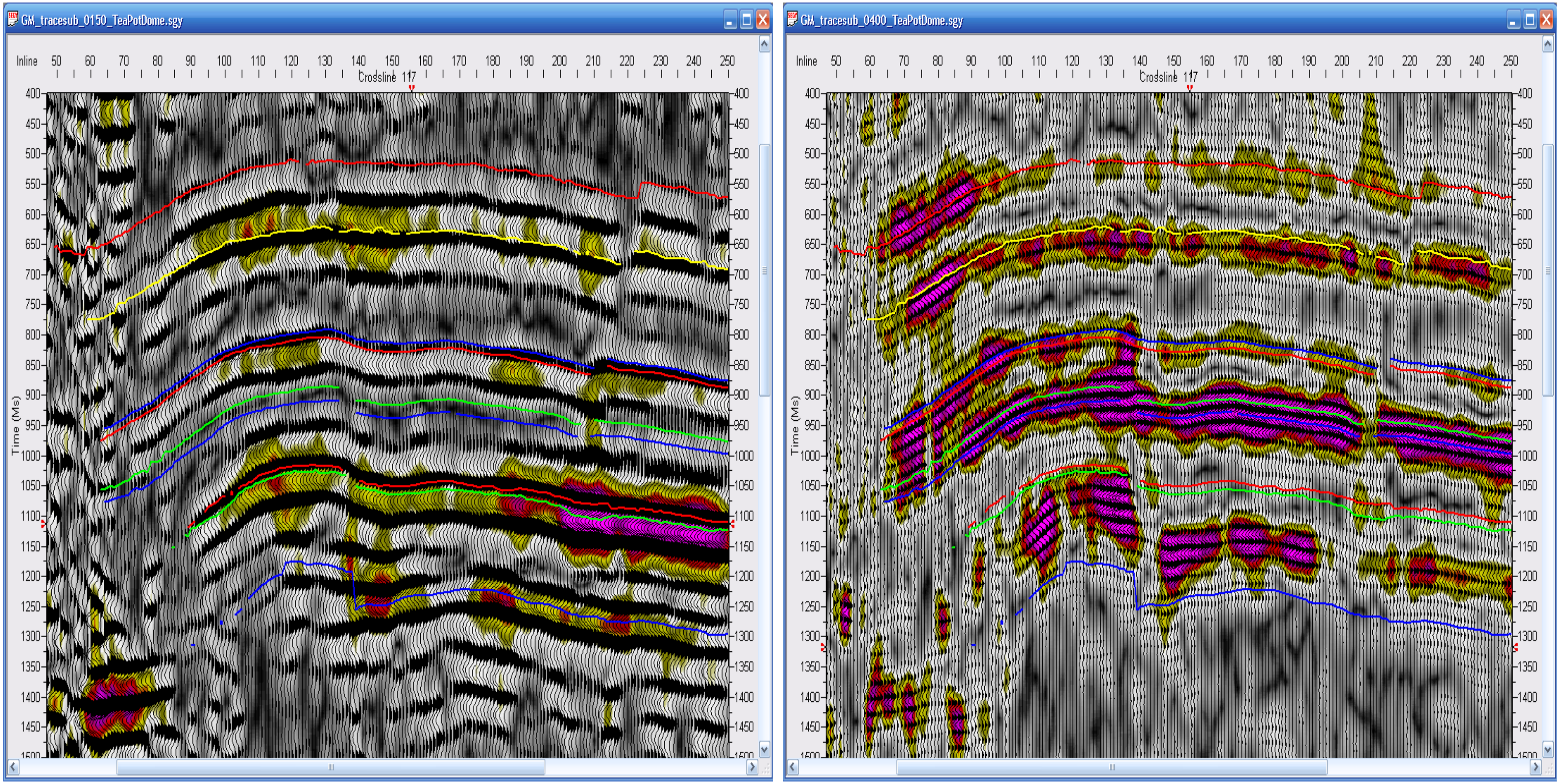
Teapot Dome



Don Robinson, **ResolveGeo**, http://www.resolvegeo.com, Data from The Rocky Mountain Oil Testing Center and the U.S. Department of Energy

Spectral Decomp 15 hz & 40 hz

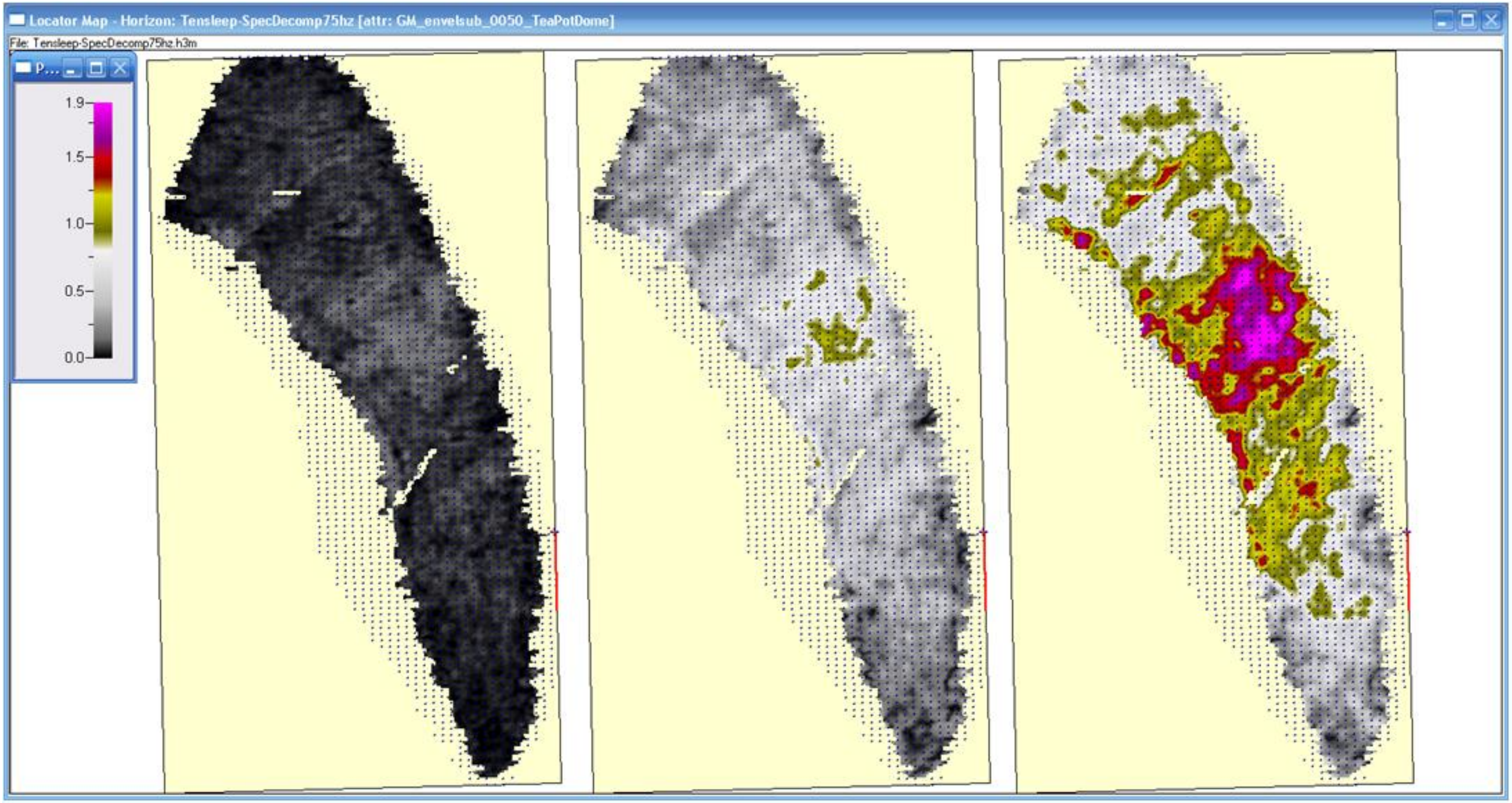
Teapot Dome



Don Robinson, **ResolveGeo**, http://www.resolvegeo.com, Data from The Rocky Mountain Oil Testing Center and the U.S. Department of Energy

Spectral Decomposition

Teapot Dome



Don Robinson, **ResolveGeo**, http://www.resolvegeo.com, Data from The Rocky Mountain Oil Testing Center and the U.S. Department of Energy

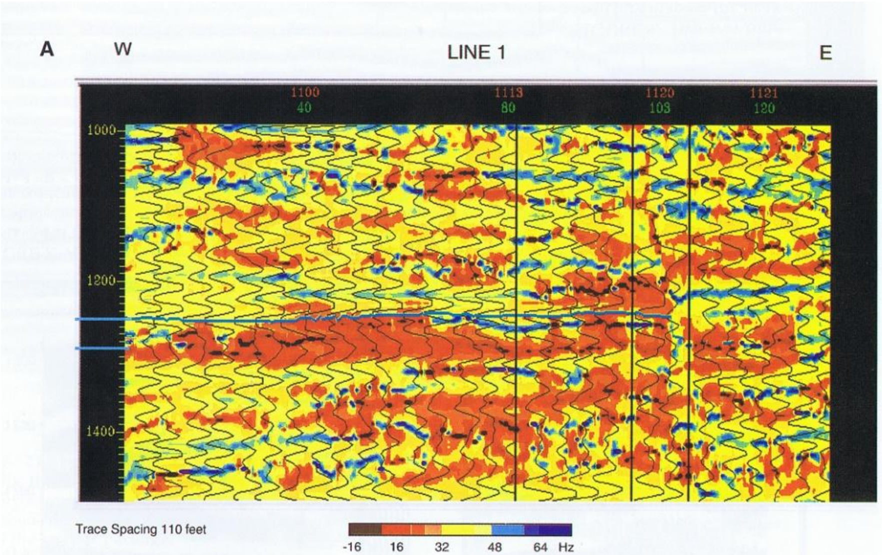
Attributes - Instantaneous

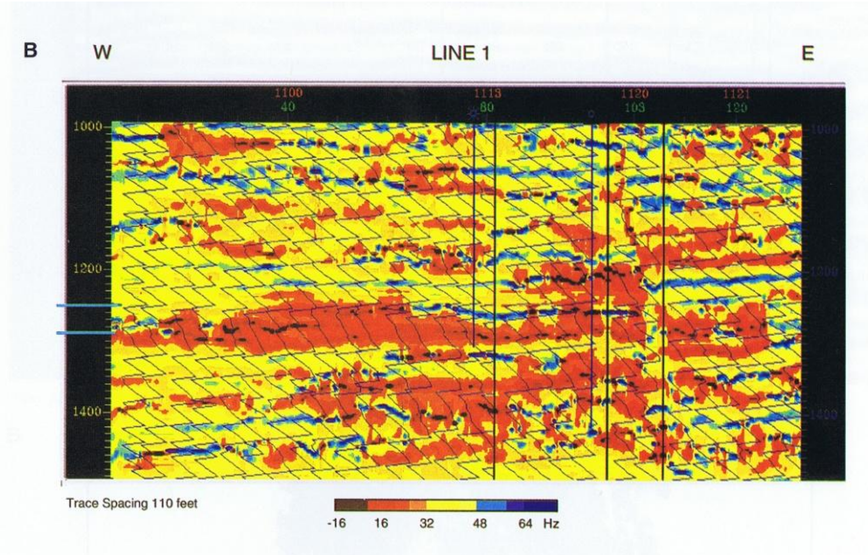
Instantaneous attributes are computed sample by sample, representing instantaneous variations of various parameters. Instantaneous values of attributes such as trace envelope, its derivatives, frequency and phase may be determined from complex traces.

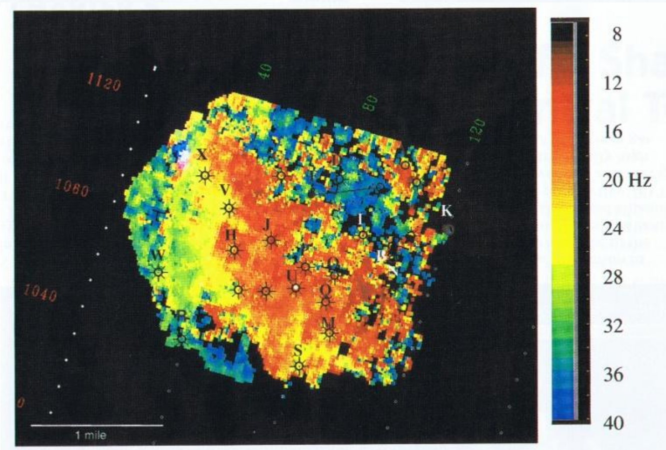
1) **Real part of Complex Trace**
2) **Imaginary part of Complex Trace**
3) **Trace Envelope**
4) **Time Derivative of the Envelope**
5) **2nd Derivative of Envelope**
6) **Instantaneous Phase**
7) **Instantaneous Frequency**
8) **Env. Weighted Inst. Frequency**
9) **Thin Bed Indicator**
10) **Acceleration Phase**
11) **Dominant Frequency**
12) **Band Width**
13) **Instantaneous Q factor**
14) **Normalized Amplitude**
15) **Env. Ampl. Modulated Phase**
16) **Relative Acoustic Impedance**

Tury Taner, **Attributes Revisited**, *www.rocksolidimages.com/pdf/attrib_**revisited**.htm*.

Instantaneous Frequency – Thin Sands



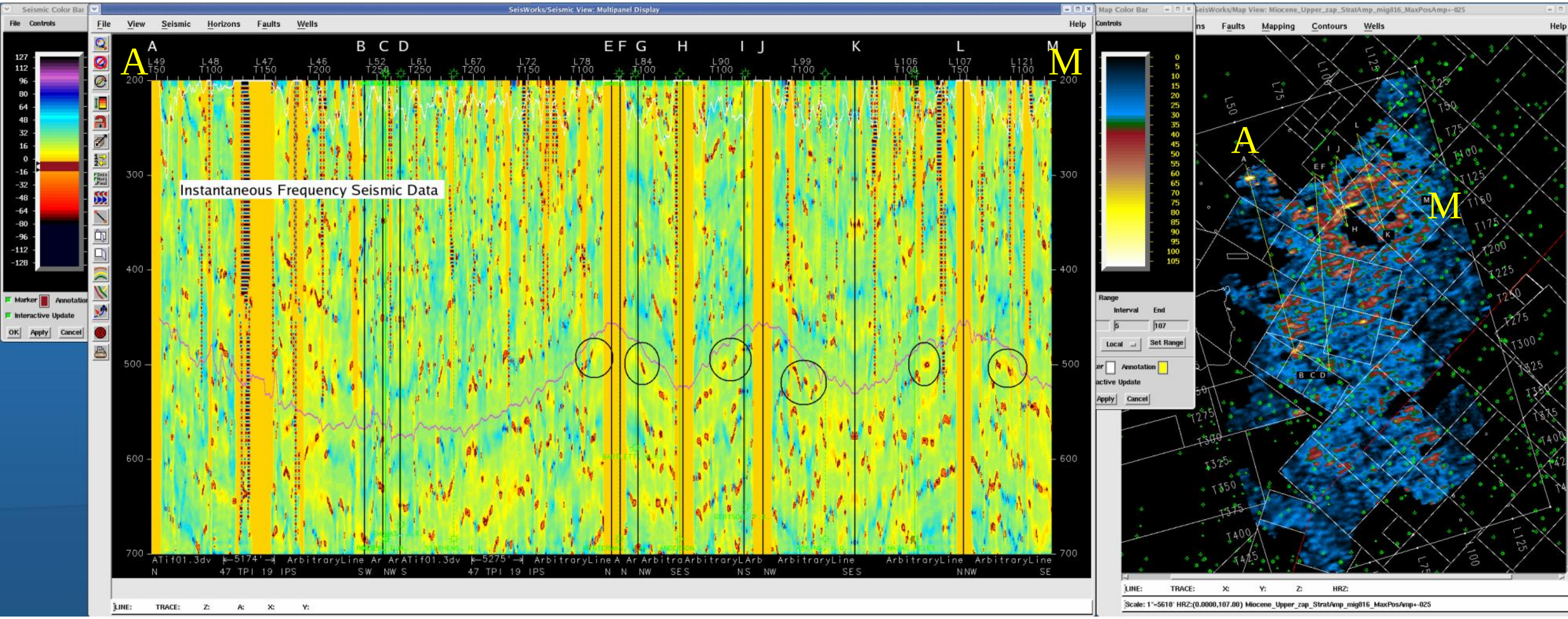




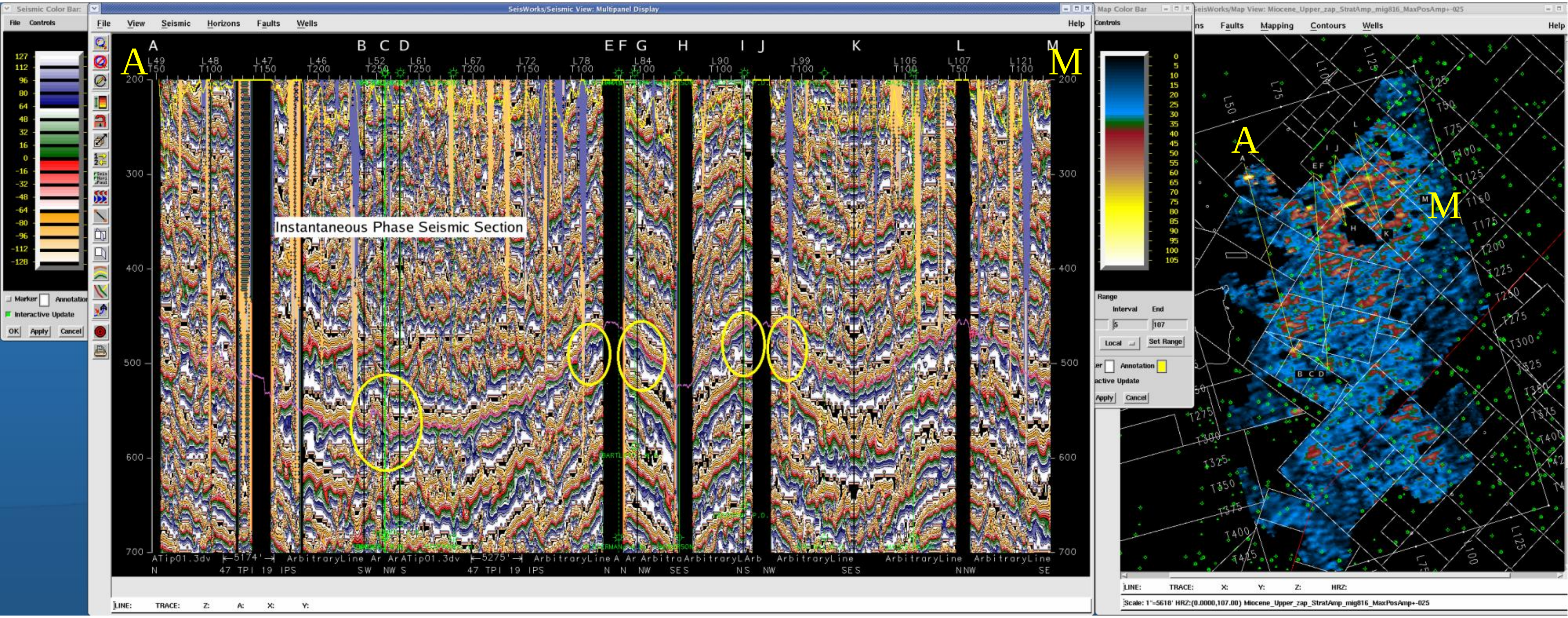
A-A’: Instantaneous Frequency with seismic overlay.
B-B’: Instantaneous Frequency with phase overlay.
Map: Instantaneous Frequency over 40 ms target interval shown in blue on A-A’.

Horkowitz and Davis in **Application of 3-D Seismic Data to Exploration and Production**, pages 42-43, data from Sanchez-O-Brien Oil and Gas, Kennedy County, TX.

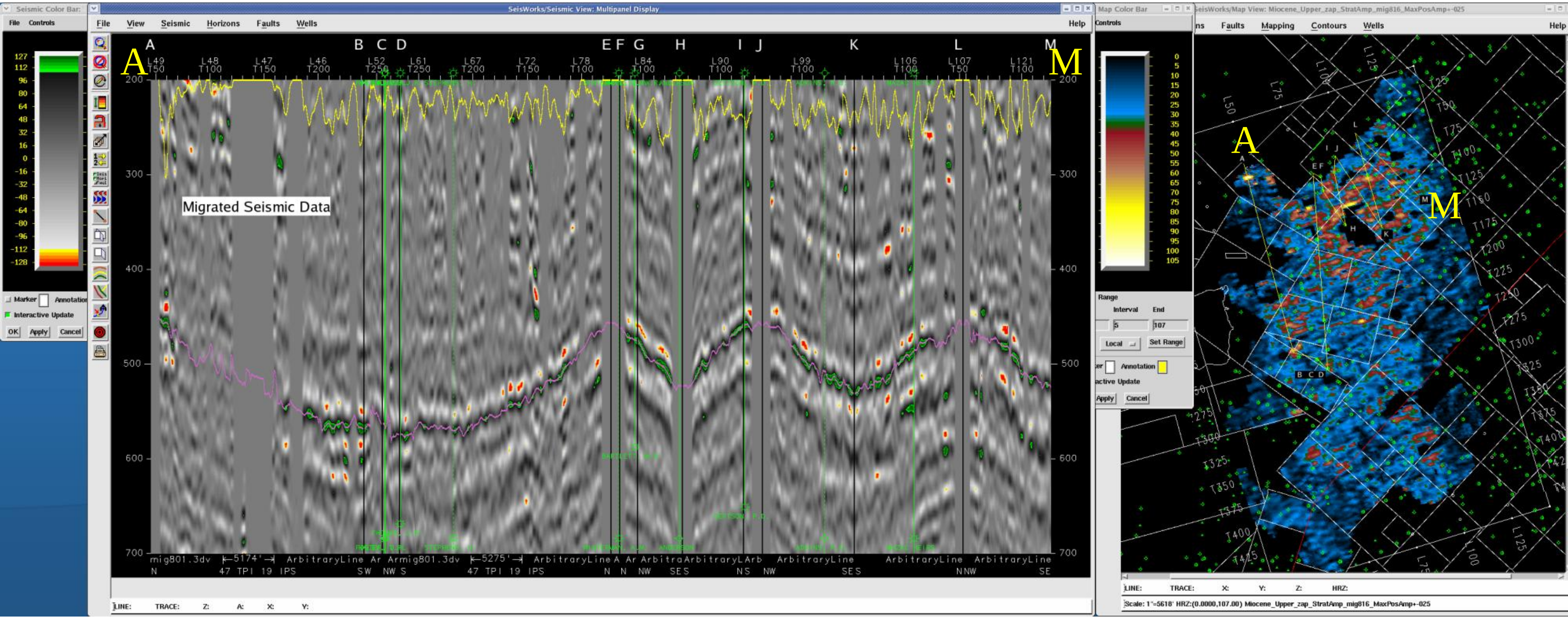
Instantaneous Frequency South Texas



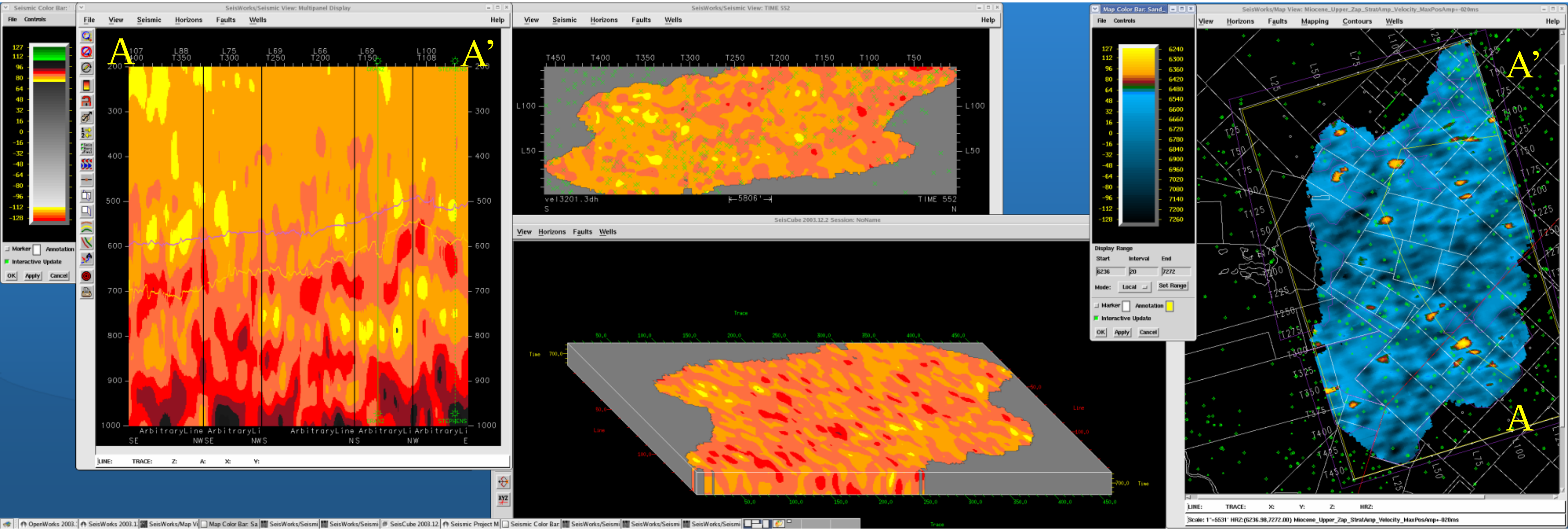
Instantaneous Phase South Texas



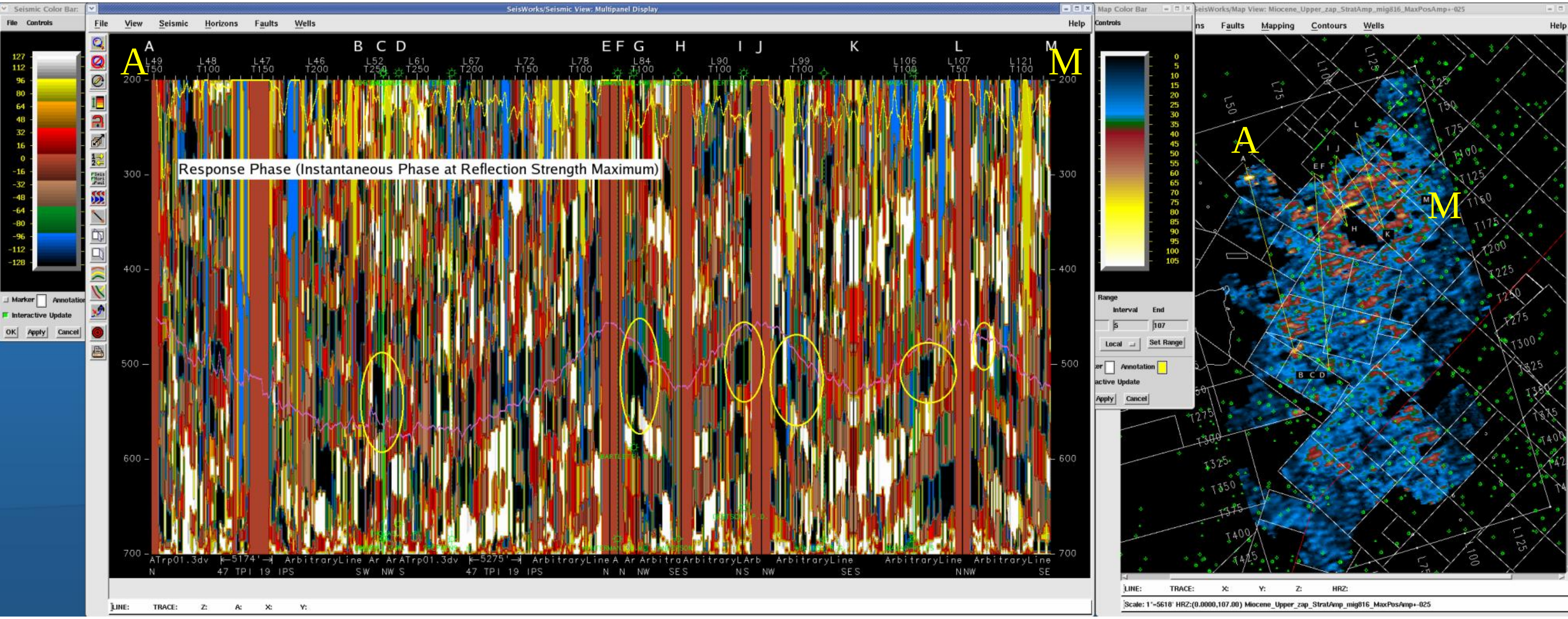
Instantaneous Phase South Texas



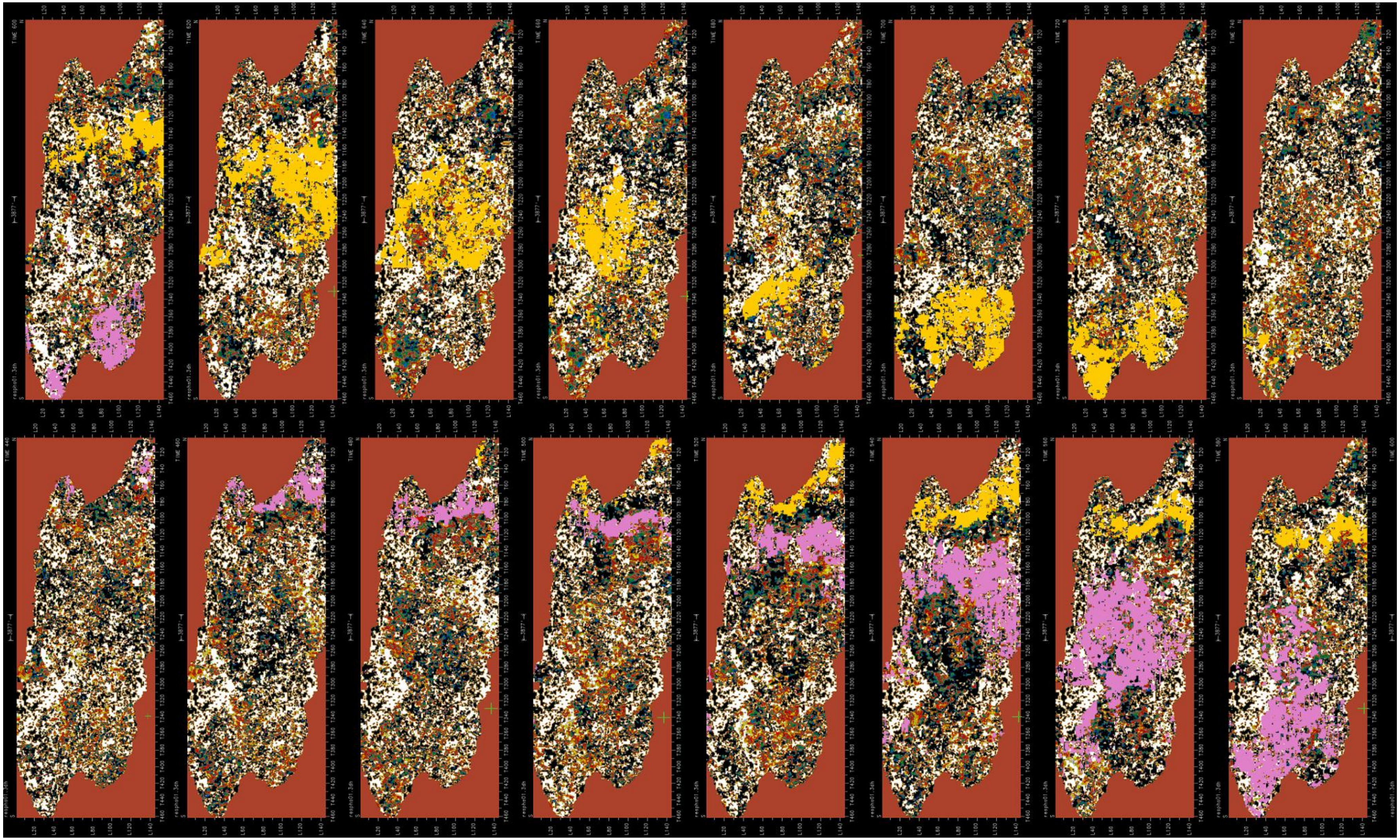
Velocity Sections South Texas



Response Phase South Texas



Response Phase Time-Slices S. Texas



Attributes - Wavelet

Instantaneous attributes computed at the peak of the trace envelope have a direct relation to the Fourier transform of the wavelet in the vicinity of the envelope peak. For example, Instantaneous frequency at the peak of the envelope is equal to the mean frequency of the wavelet amplitude spectrum. Instantaneous phase corresponds to the intercept phase of the wavelet. This attribute is also called the "response attribute".

Tury Taner, **Attributes Revisited**, *www.rocksolidimages.com/pdf/attrib_**revisited**.htm*.

Wavelet Attributes Include

1) Wavelet envelope
2) Time Derivative - Wavelet Env.
3) 2nd Derivative - Wavelet Env.
4) Wavelet Phase
5) Wavelet Frequency
6) Env. Weighted Wavelet Freq.
7) Acceleration of phase
8) Dominate Frequency
9) Wavelet Band Width
10) Wavelet Q factor
11) Apparent polarity - Wavelet

Tury Taner, **Attributes Revisited**, *www.rocksolidimages.com/pdf/attrib_**revisited**.htm*.

Attributes - Geometrical

Geometrical attributes describe the spatial and temporal relationship of all other attributes. Lateral continuity measured by semblance is a good indicator of bedding similarity as well as discontinuity. Bedding dips and curvatures give depositional information. Geometrical attributes were initially thought to help the stratigraphic interpretation. However, further experience has shown that the geometrical attributes defining the event characteristics and their spatial relations, quantify features that directly help in the recognition of depositional patterns, and related lithology.

Geometrical Attributes Include

1) Event Continuity
2) Sand/Shale Ratio
3) Chaotic Reflection
4) Parallel Bedding Indicator
5) Zone of Unconformity
6) Dip of Maximum Similarity
7) Dip Variance (average-local)
8) Similarity
9) Smoothed Similarity
10) Similarity Variance (average-local)
11) Smoothed Dip of Maxi. Similarity
12) Instantaneous Dip
13) Instantaneous Lateral Continuity
14) Dip Azimuth
15) Upper Bed Thickness (msec)
16) Upper Amplitude-Max Bed Thickness
17) Upper Morphology
18) Middle Bed Thickness (msec)
19) Middle Amplitude-Max Bed Thickness
20) Middle Morphology
21) Lower Bed Thickness
22) Lower Amplitude-Max Bed Thickness
23) Lower Morphology

Tury Taner, **Attributes Revisited**, *www.rocksolidimages.com/pdf/attrib_**revisited**.htm*.

Attributes - Reflective

Attributes corresponding to the characteristics of interfaces. All instantaneous and wavelet attributes can be included under this category. Pre-stack attributes such as AVO are also reflective attributes, since AVO studies the angle dependent reflection response of an interface.

Tury Taner, **Attributes Revisited**, *www.rocksolidimages.com/pdf/attrib_**revisited**.htm*.

Attributes – Curvature

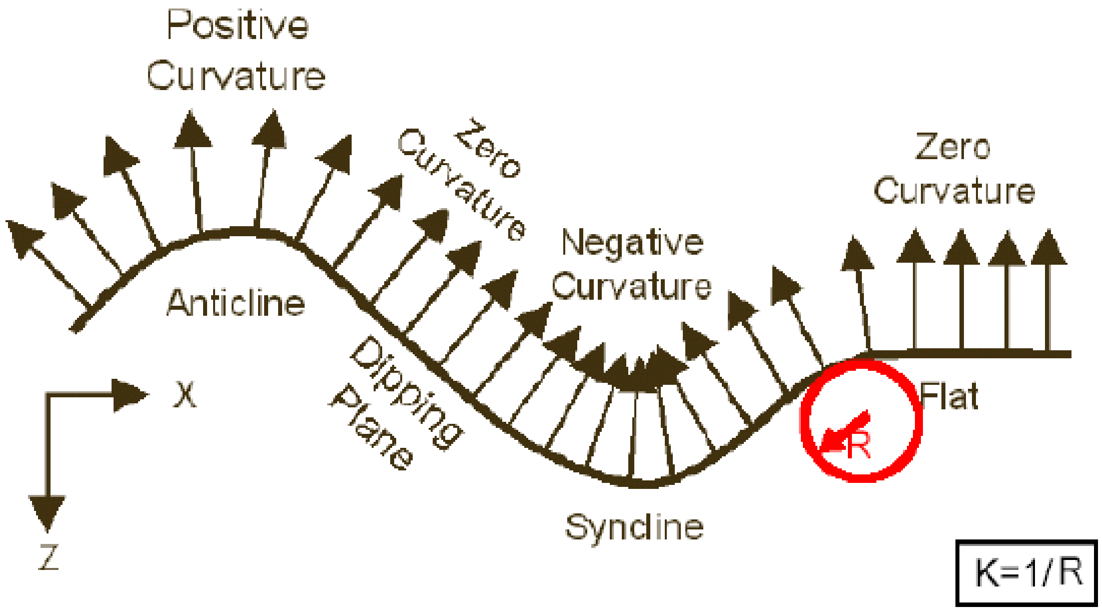


Figure 6. Curvature in two dimensions. Curvature (K) is defined as the inverse of the radius of a circle that is tangent to the surface at any point; positive curvature is concave downward and negative curvature is concave upwards. The curvature algorithms used in this study operate on the entire 3-D seismic volume, and do not require pre-interpretation of horizons. This is particularly helpful in karst areas with irregular surfaces. (After Roberts, 2001.)

Susan E. Nissen, Kansas Geological Survey and E. Charlotte Sullivan, Allied Geophysical Laboratories, Univ. of Houston in **DOE Report**, April 2005 .

Attributes – Curvature

PRIMARY OUTPUTS
1) Principal Component Filter
2) Maximum Curvature(.25)
3) Azimuth Min. Curvature(.25)
4) Minimum Curvature(.25)
5) Most Negative Curvature(.25)
6) Most Positive Curvature(.25)

FILTERED VOLUMES
1) Structure Oriented Mean Filter
2) Structure Oriented Median Filter
3) Principal Component Filter

SHAPES
1) Bowl Attribute
2) Dome Attribute
3) Ridge Attribute
4) Shape Index Calculation
5) Saddle Attribute
6) Valley Attribute

LONG WAVE (.25)
1) Curvedness Calculation
2) Dip Curvature
3) Gaussian Curvature
4) Lineament Delineation
5) Strike Curvature

SEMBLANCE
1) Measure of Confidence of Dip
2) Cross Correlation of Real vs Imaginary
3) Derivative of Total Energy
4) Test Vector vs Covariance Matrix

Energy
1) Coherent Energy
2) Total Energy in Centered Window
3) Coherent to Total Energy Ratio

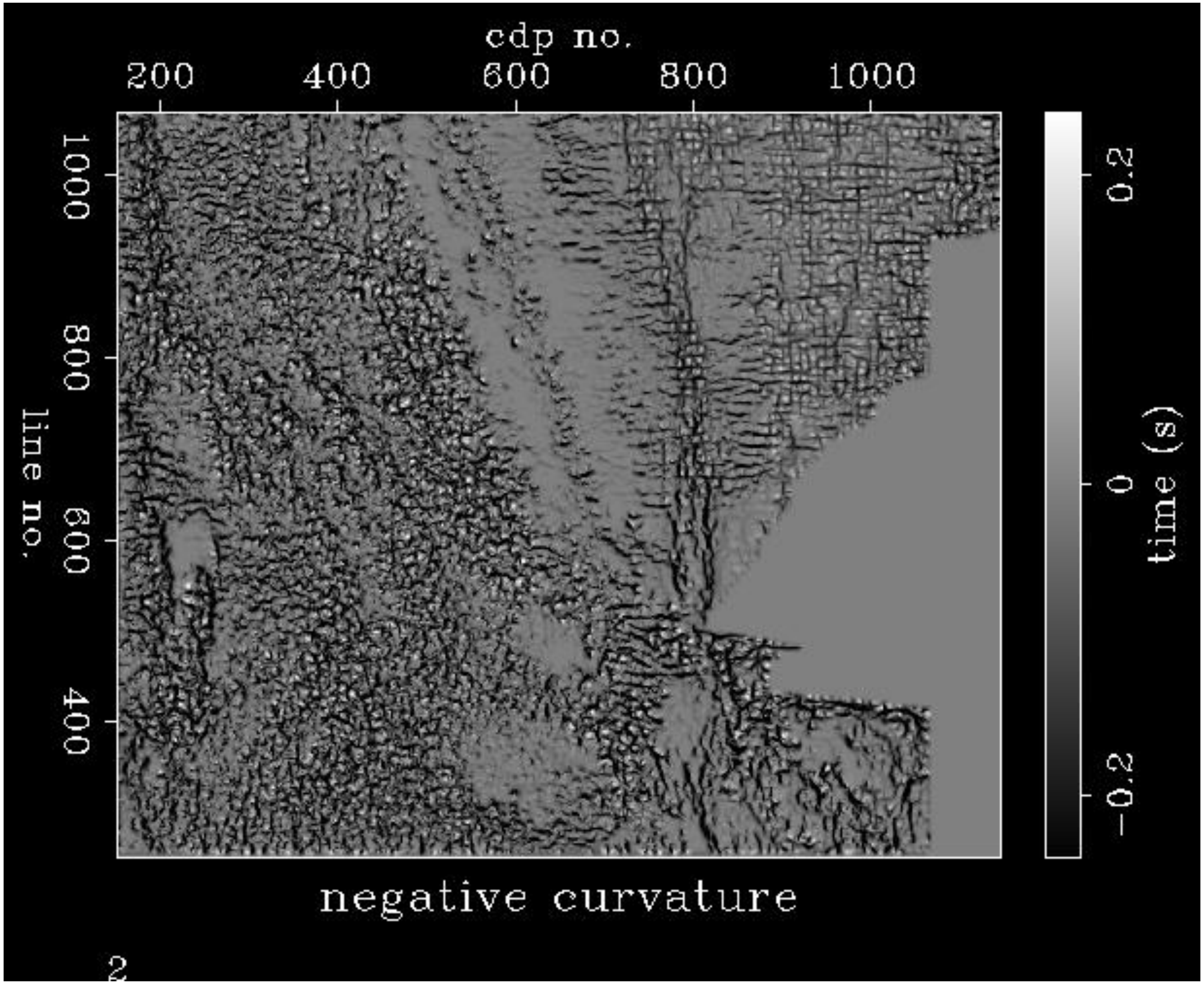
HIGH RESOLUTION (.75)
1) Curvedness Calculation
2) Dip Curvature
3) Gaussian Curvature
4) Lineament Delineation
5) Maximum Curvature
6) Azimuth of Minimum Curvature
7) Minimum Curvature
8) Most Negative Curvature
9) Most Positive Curvature

GEOMETRIC
1) Dip Azimuth
2) Xline Apparent Dip
3) Inline Apparent Dip
4) Dip Magnitude
5) Xline Energy Weighted Amplitude
6) Inline Energy Weighted Amplitude

GRADIENTS
1) Curvedness Calculation
2) Gaussian Curvature
3) Maximum Curvature
4) Minimum Curvature
5) Azimuth of Minimum Curvature
6) Most Negative Curvature
7) Most Positive Curvature

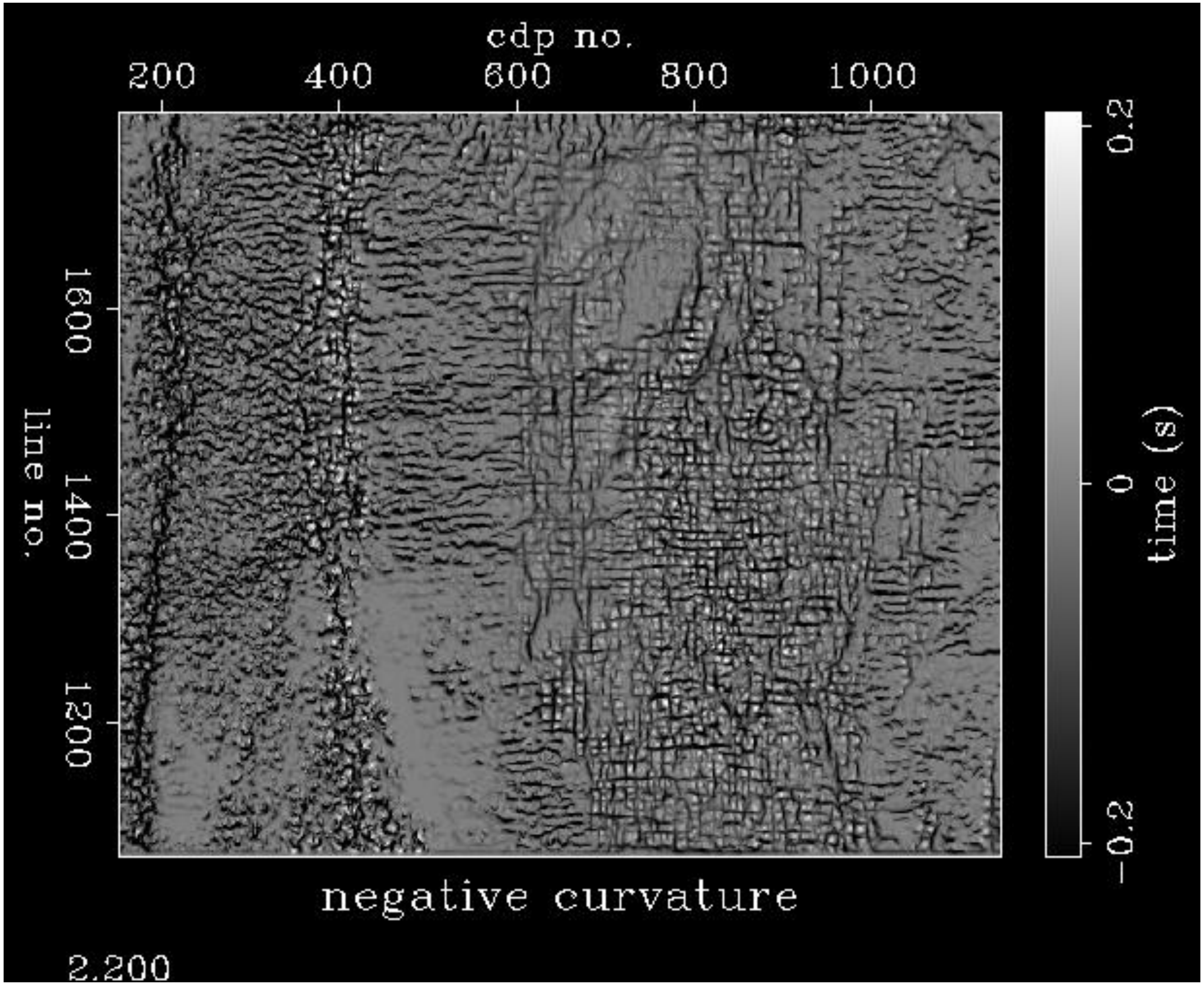
Susan E. Nissen, Kansas Geological Survey and E. Charlotte Sullivan, Allied Geophysical Laboratories, Univ. of Houston in **DOE Report**, April 2005 .

Negative Curvature at 2.0 seconds



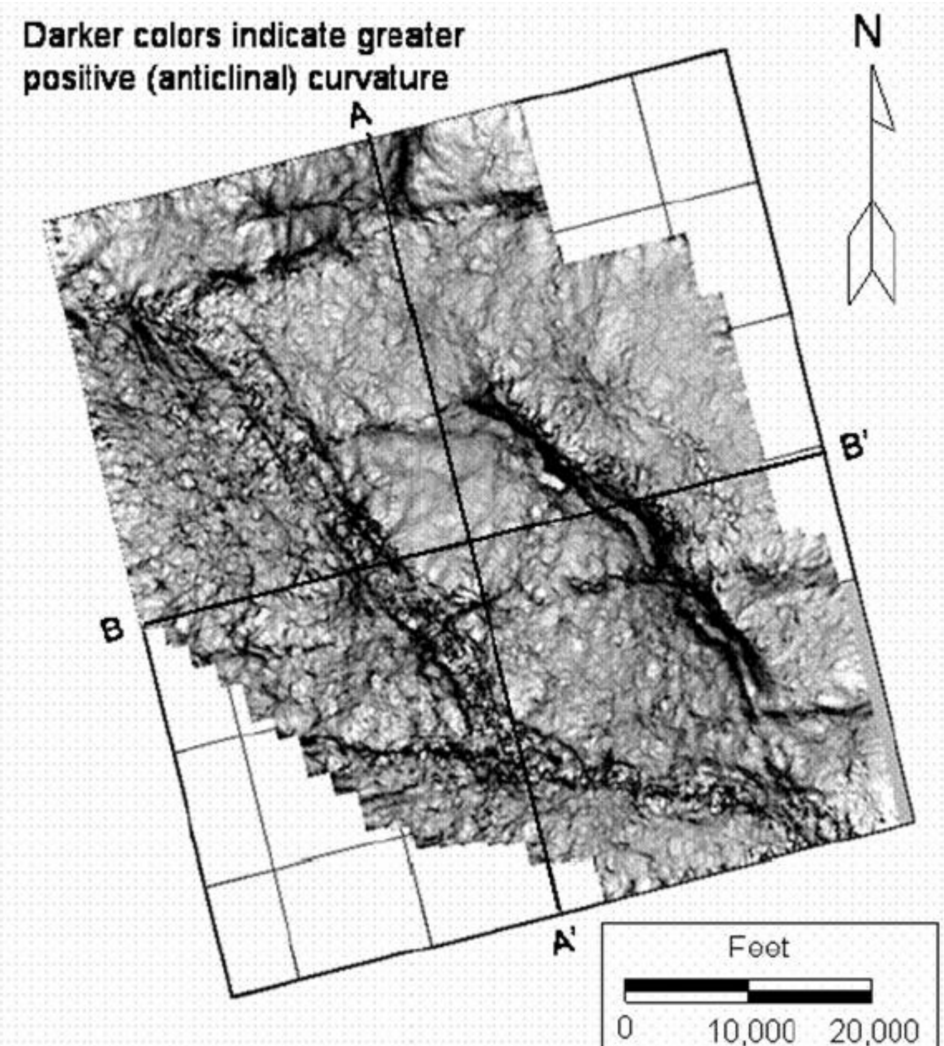
Data courteous L. Viertel.

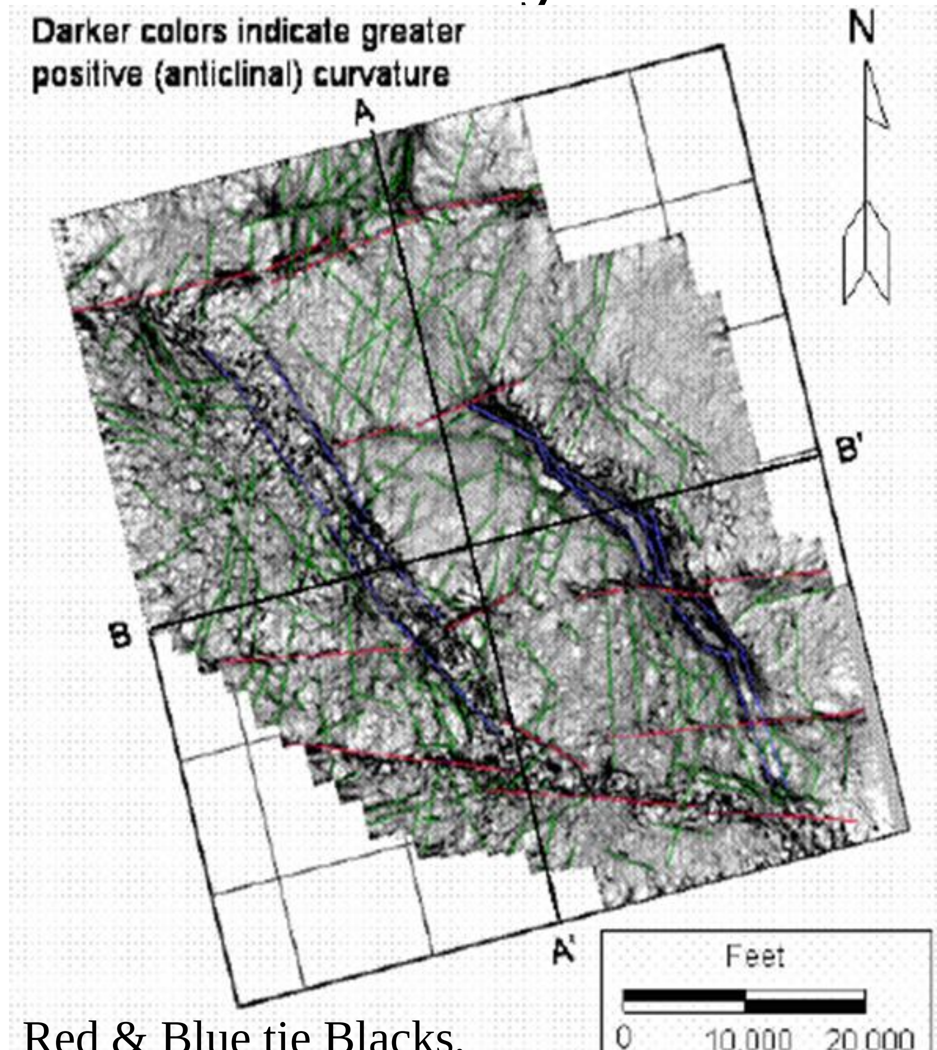
Negative Curvature at 2.2 seconds



Data courteous L. Viertel.

Volumetric Curvature Analysis

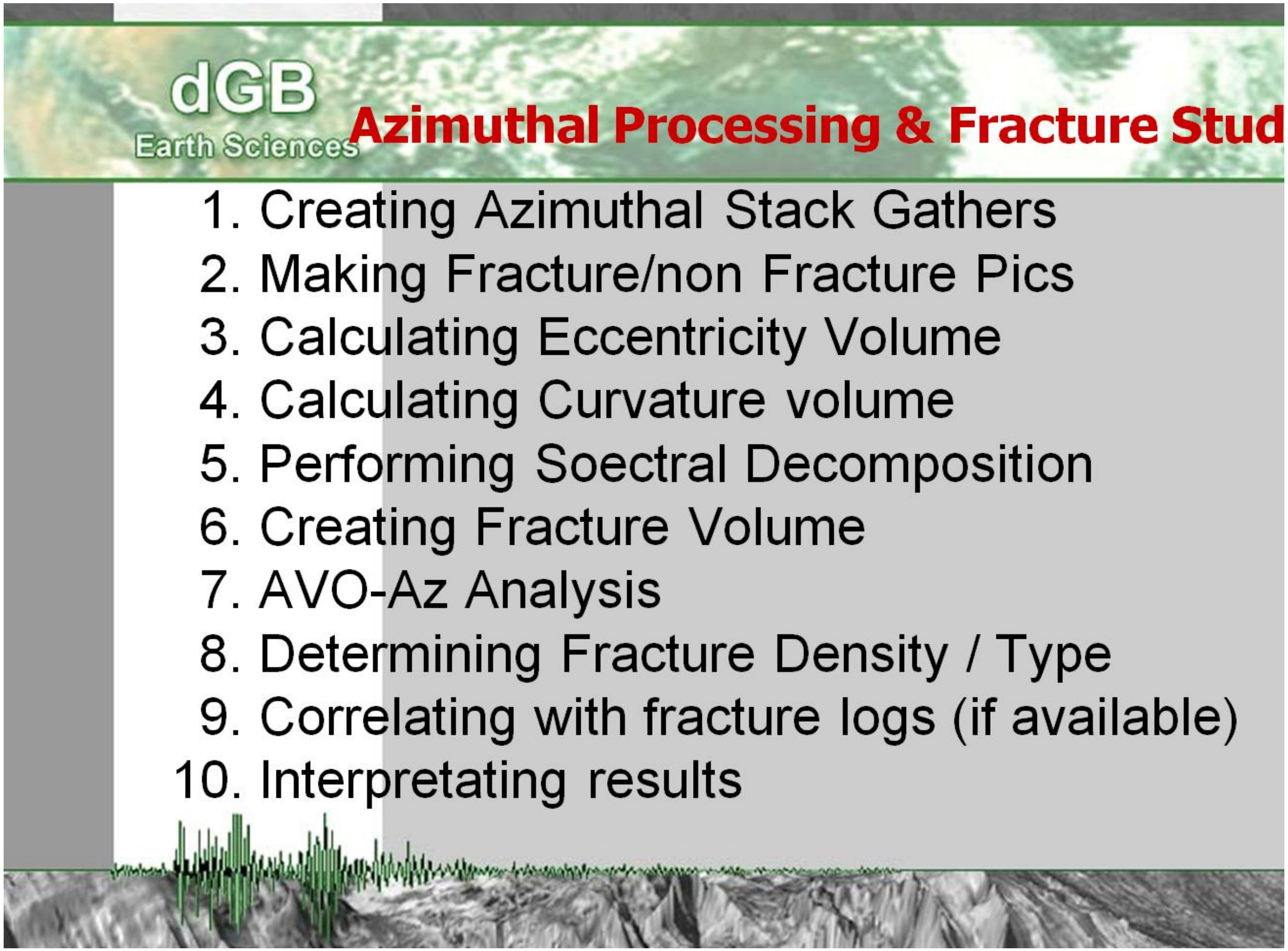




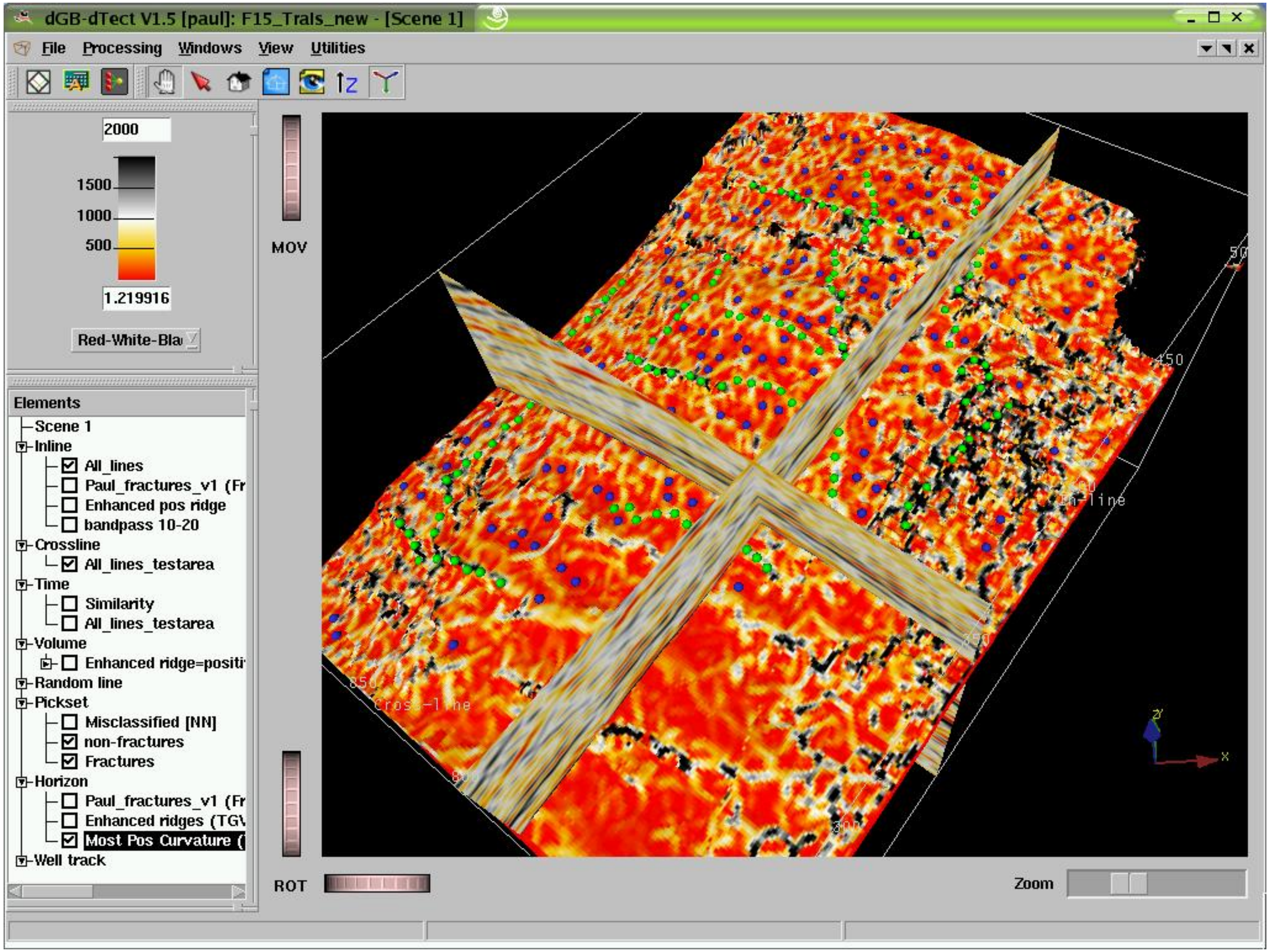
Blacks represent coherency lineaments.
Data courteous L. Viertel.

Red & Blue tie Blacks,
while Greens only after volumetric curvature.

An Example of Using Curvature

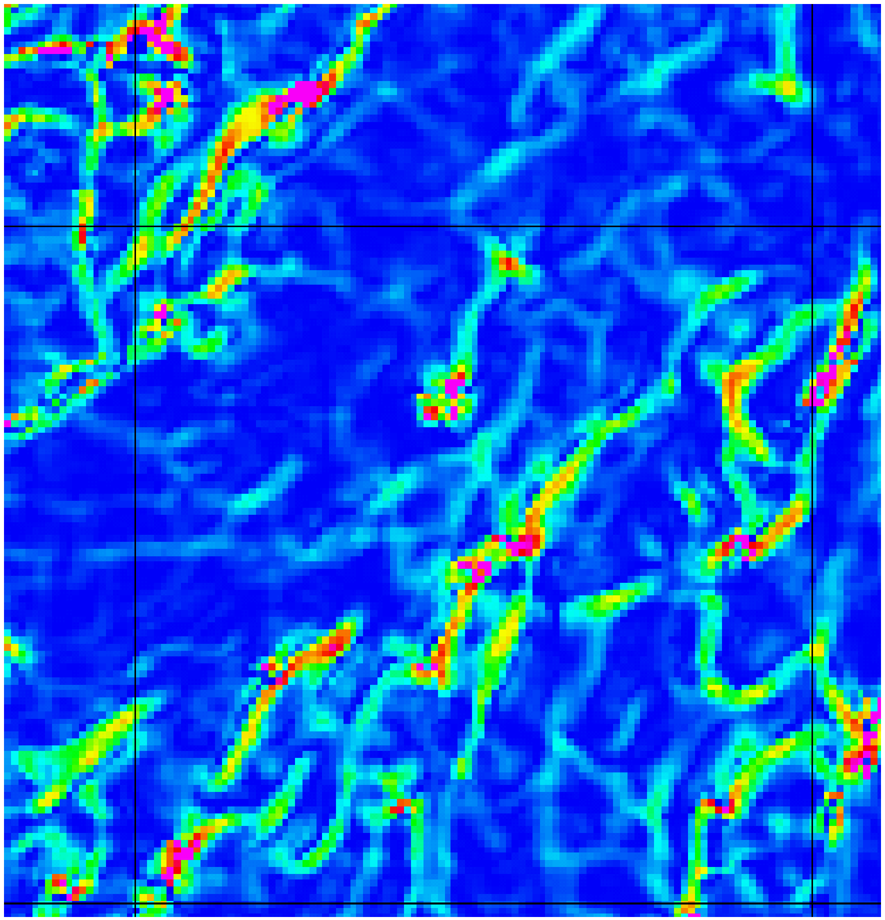


Picked Fractures and Non-Fractures
An Example of Using Curvature

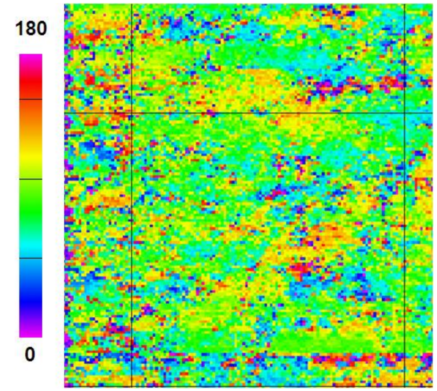


Seismic + Ridge Enhanced Fractures

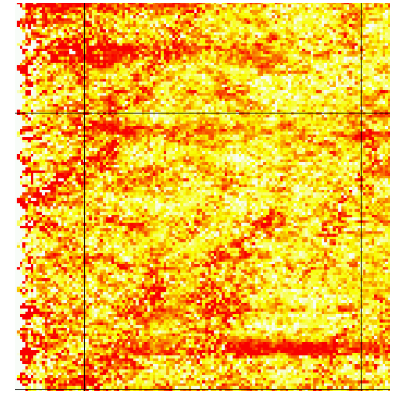
An Example Using Curvature



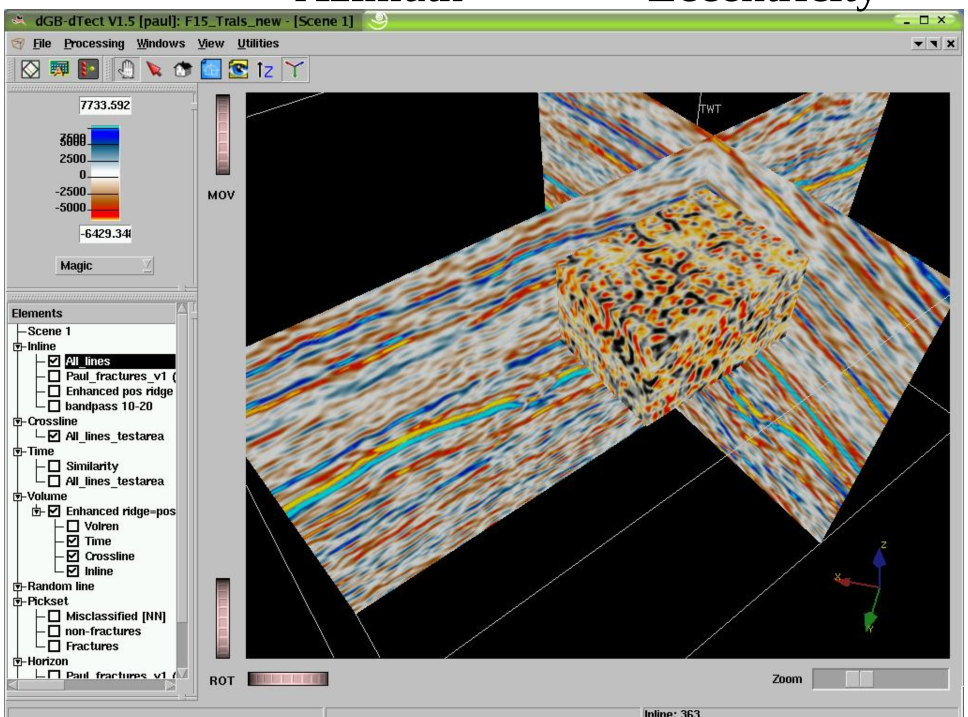
Curvature Post-Stack Attribute Slice



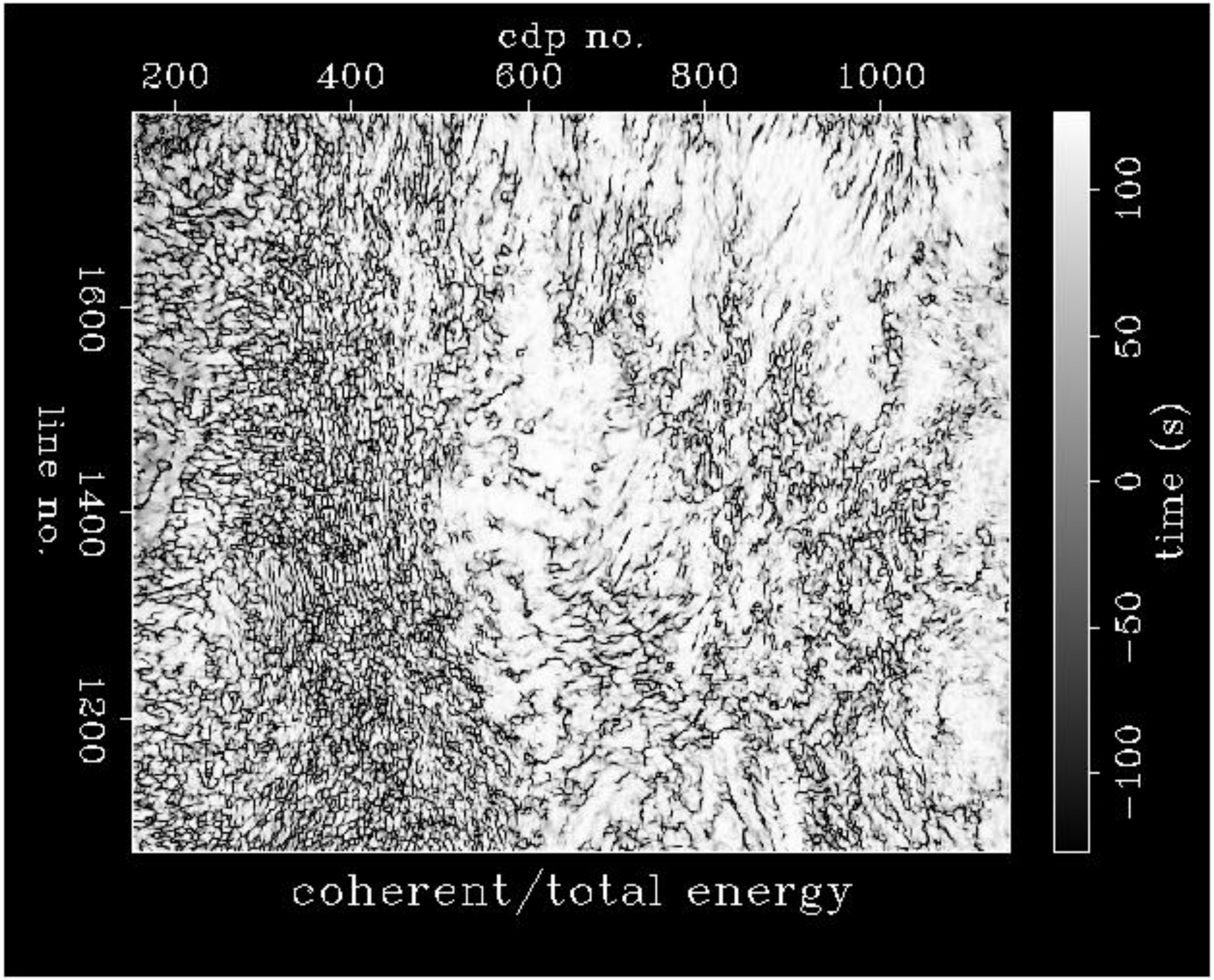
Azimuth



Eccentricity

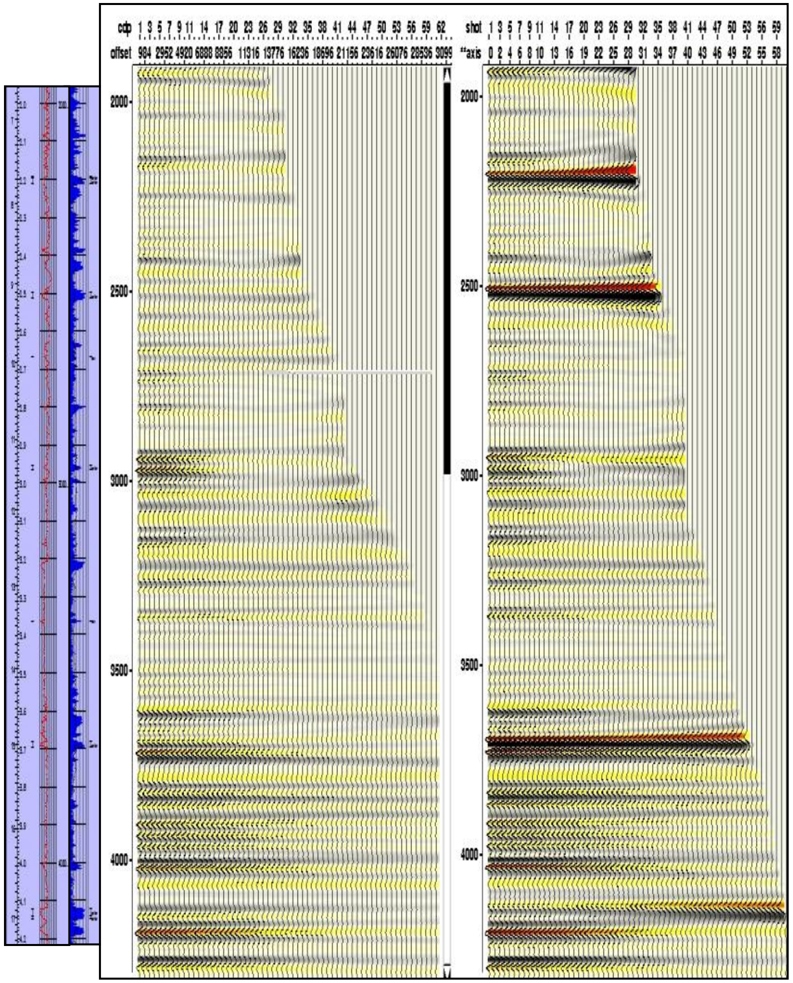


Attributes - Coherence



Predicting AVO Proves a Prospect

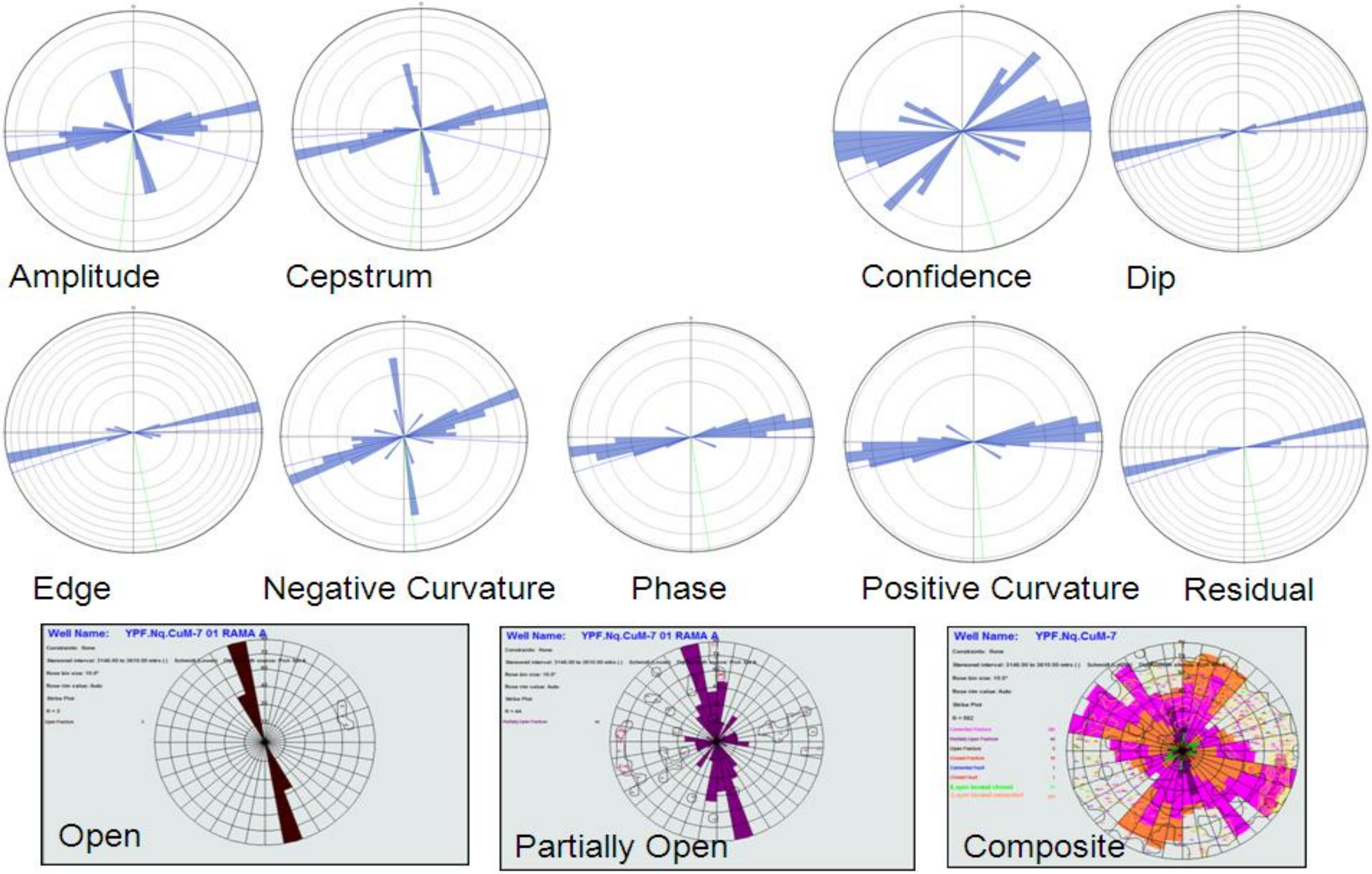
- Regional Trends
- Rock Property Data
- Individual LAS Well Data
- Fluid substitution models
- Trend Curves from Individual Well Studies
- Displayable in Commercial Visualization Environments and Navigated like a Game



In-situ Wet Sands | *Substituted Gas Sands*

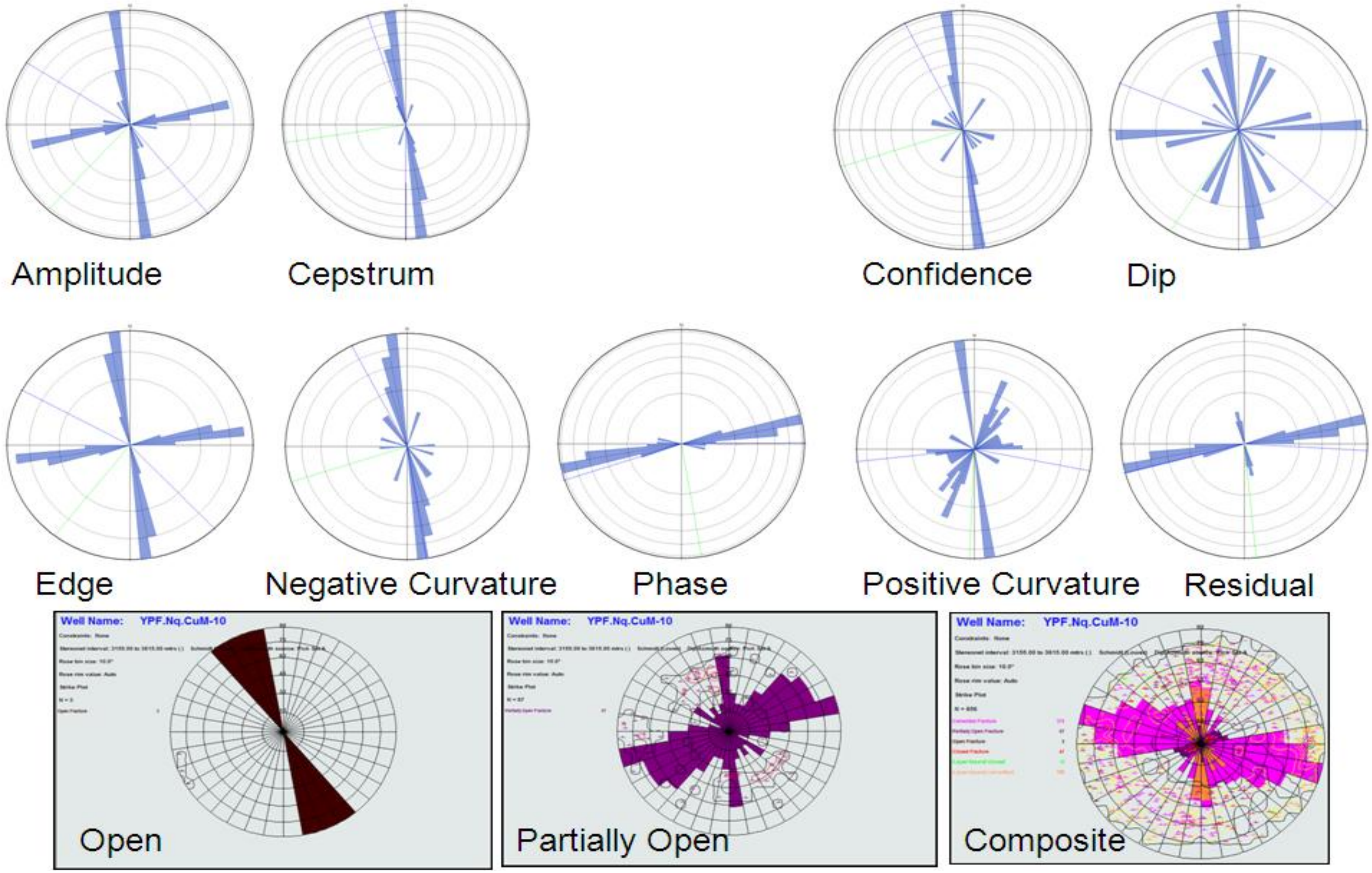
Data from **Geokinetics**, from HRN papers.

#1 Image Logs Compared to Lineaments from Seismic Attributes



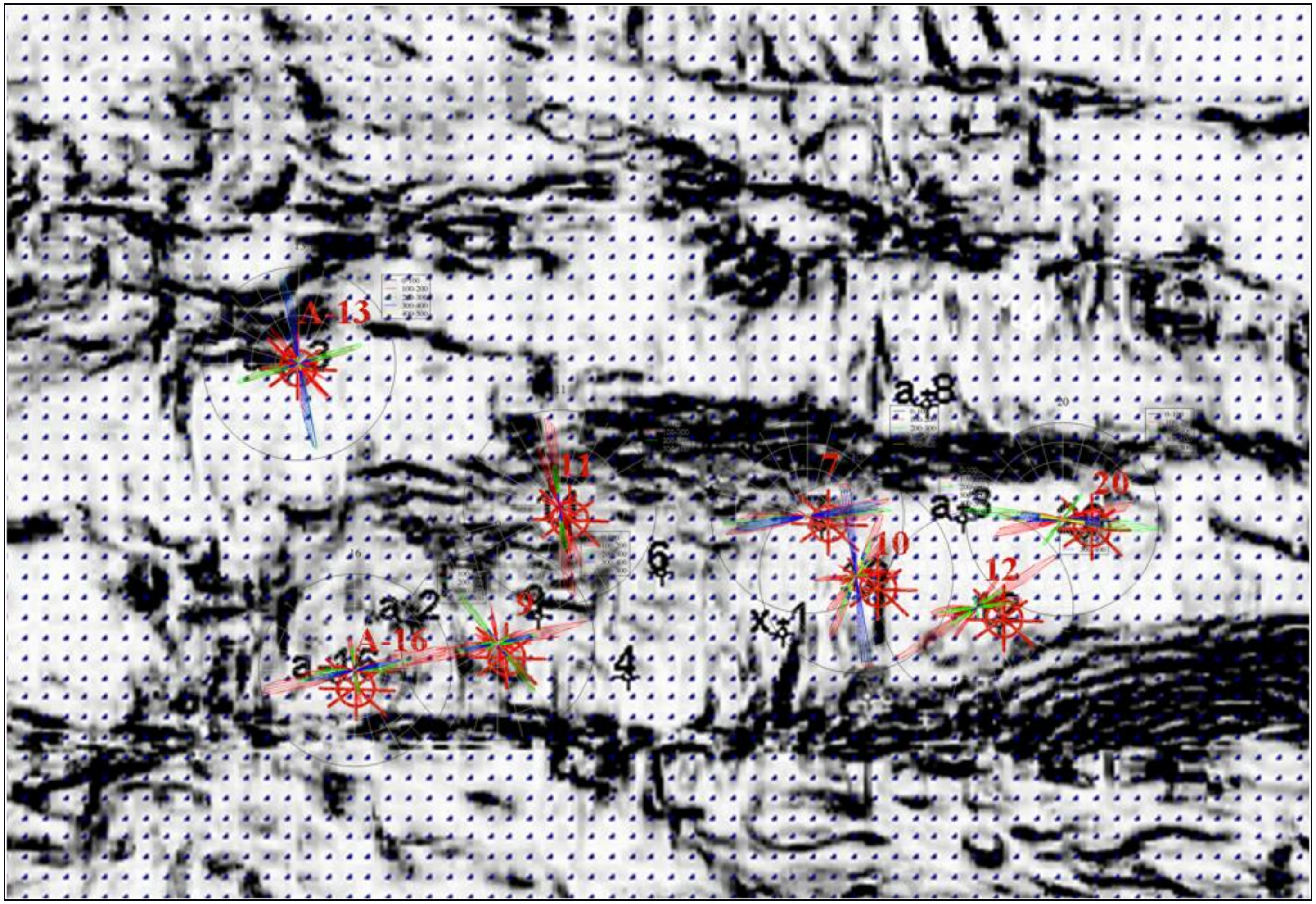
Les Denham, **II&T**, Personal Communication.

#2 Image Logs Compared to Lineaments from Seismic Attributes



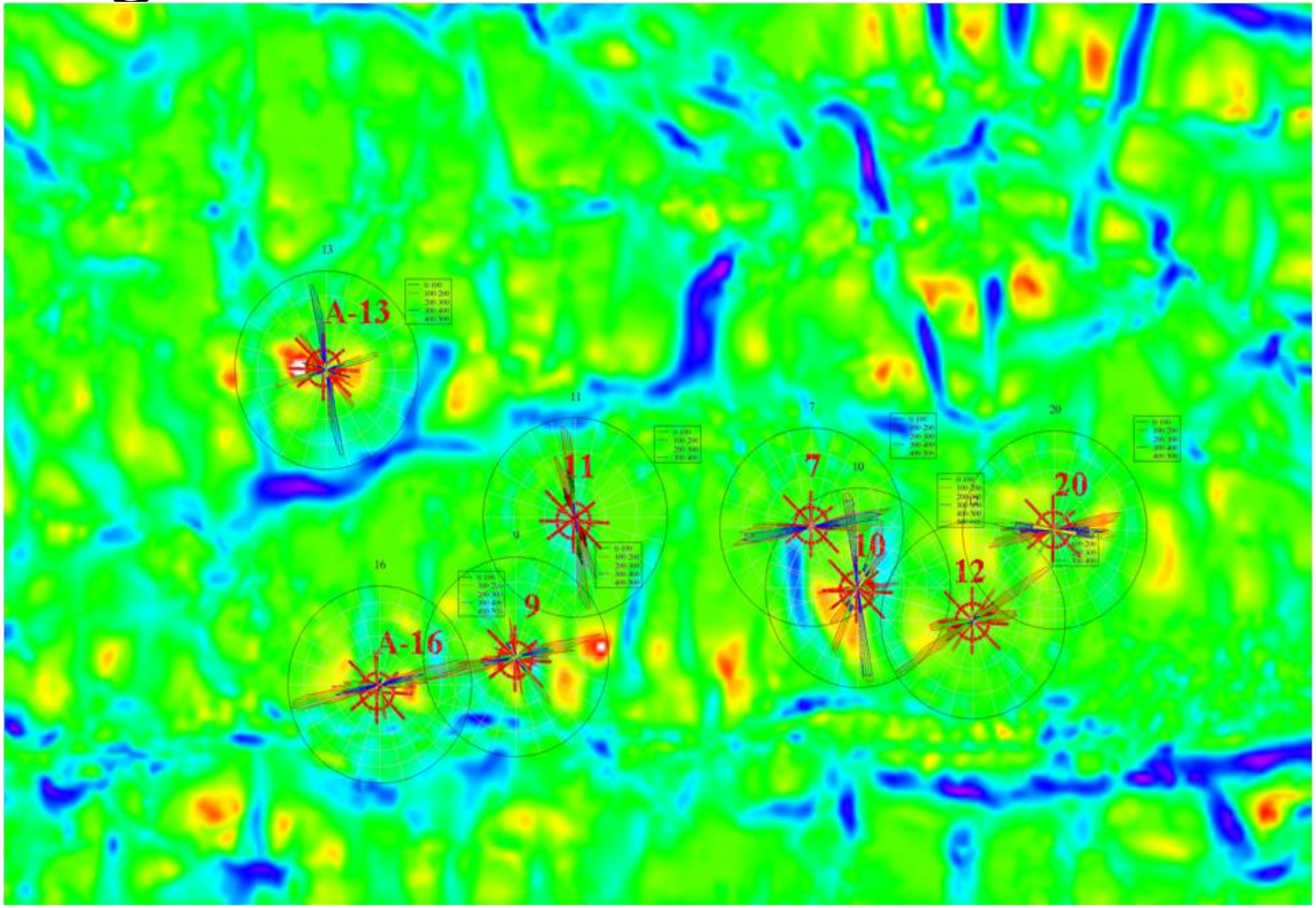
Les Denham, **II&T**, Personal Communication.

Rose Diagrams from Positive Curvature on Semblanced Seismic Attribute



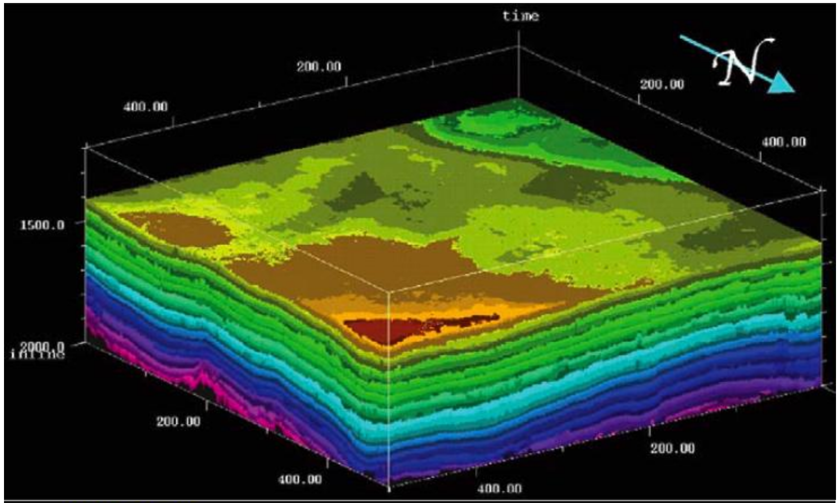
Les Denham, **II&T**, Personal Communication.

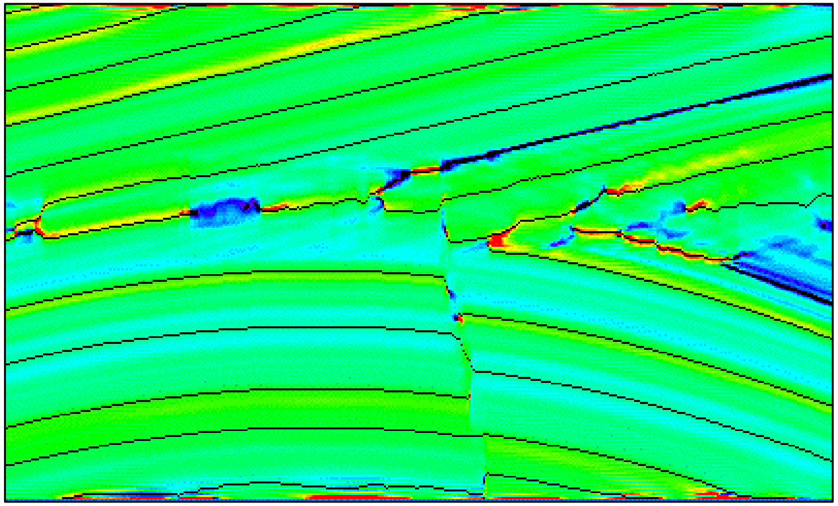
Rose Diagrams from Positive Curvature on Negative Curvature Horizon-Slice

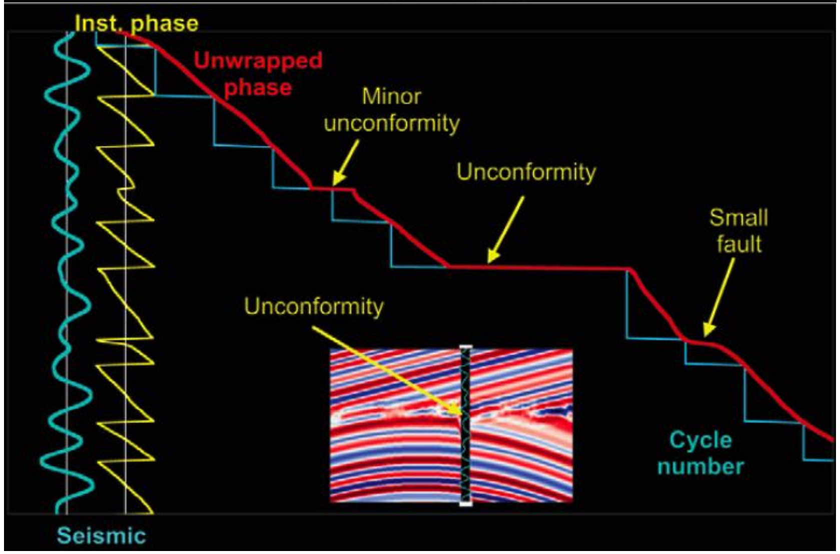


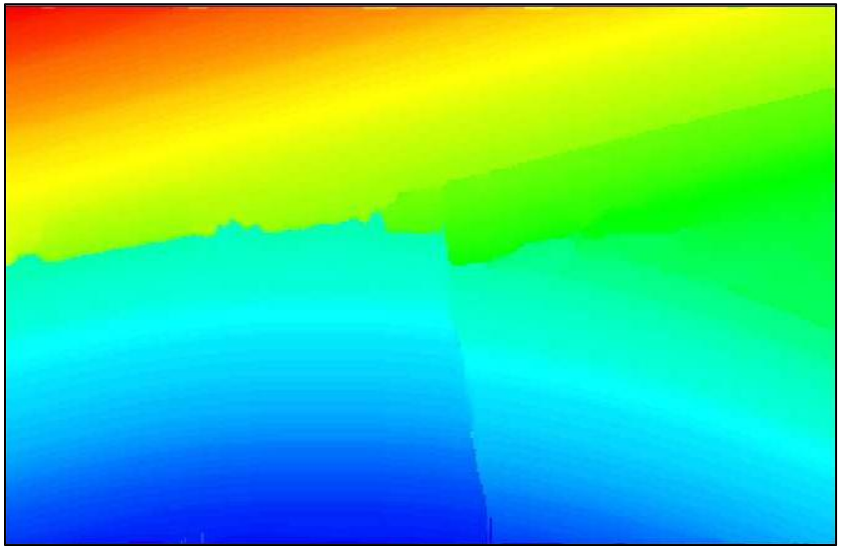
Les Denham, **II&T**, Personal Communication.

Unwrapping Phase to Reconstruct Time



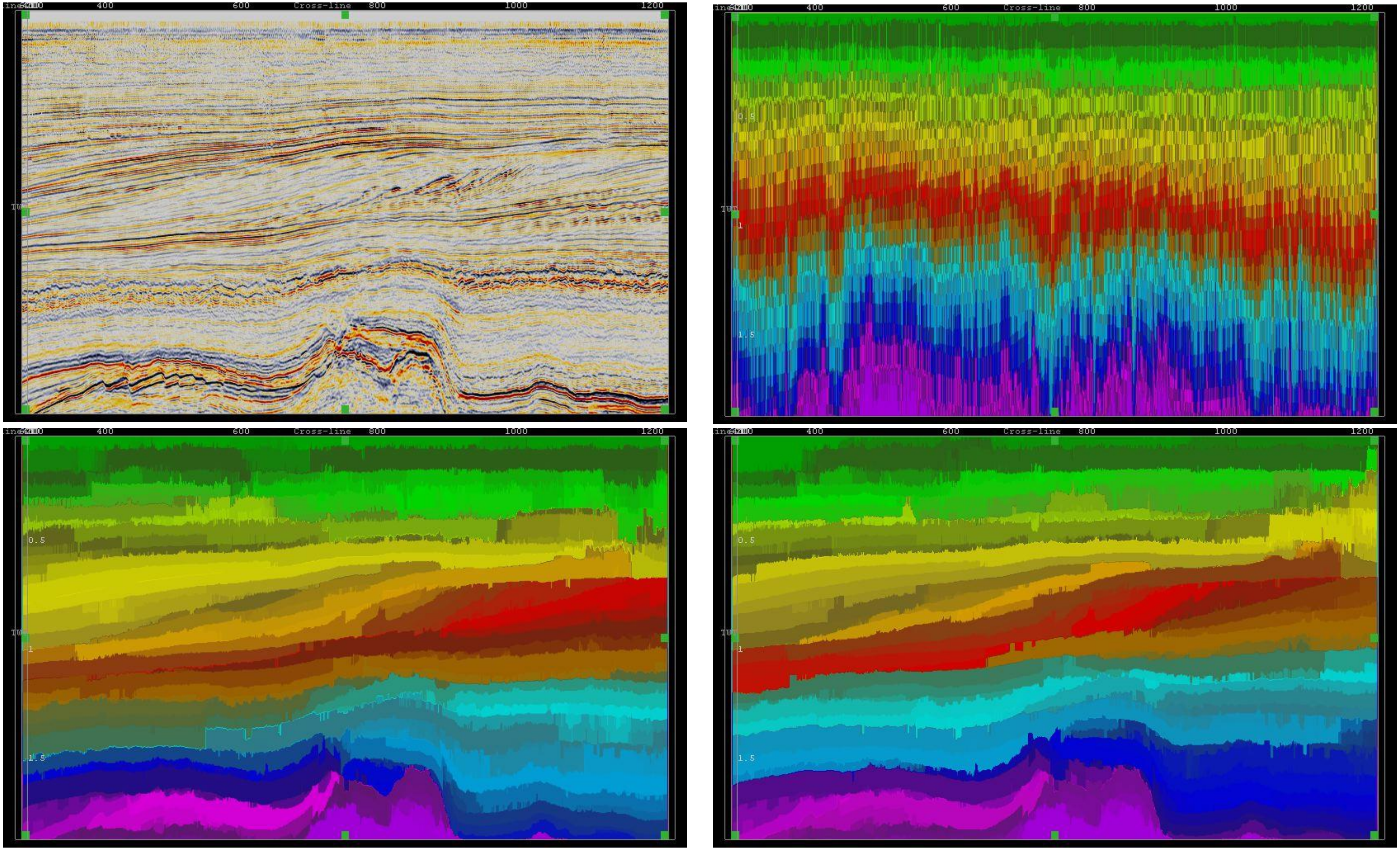






Tracy Stark, **Stark Research**, Personal Communication

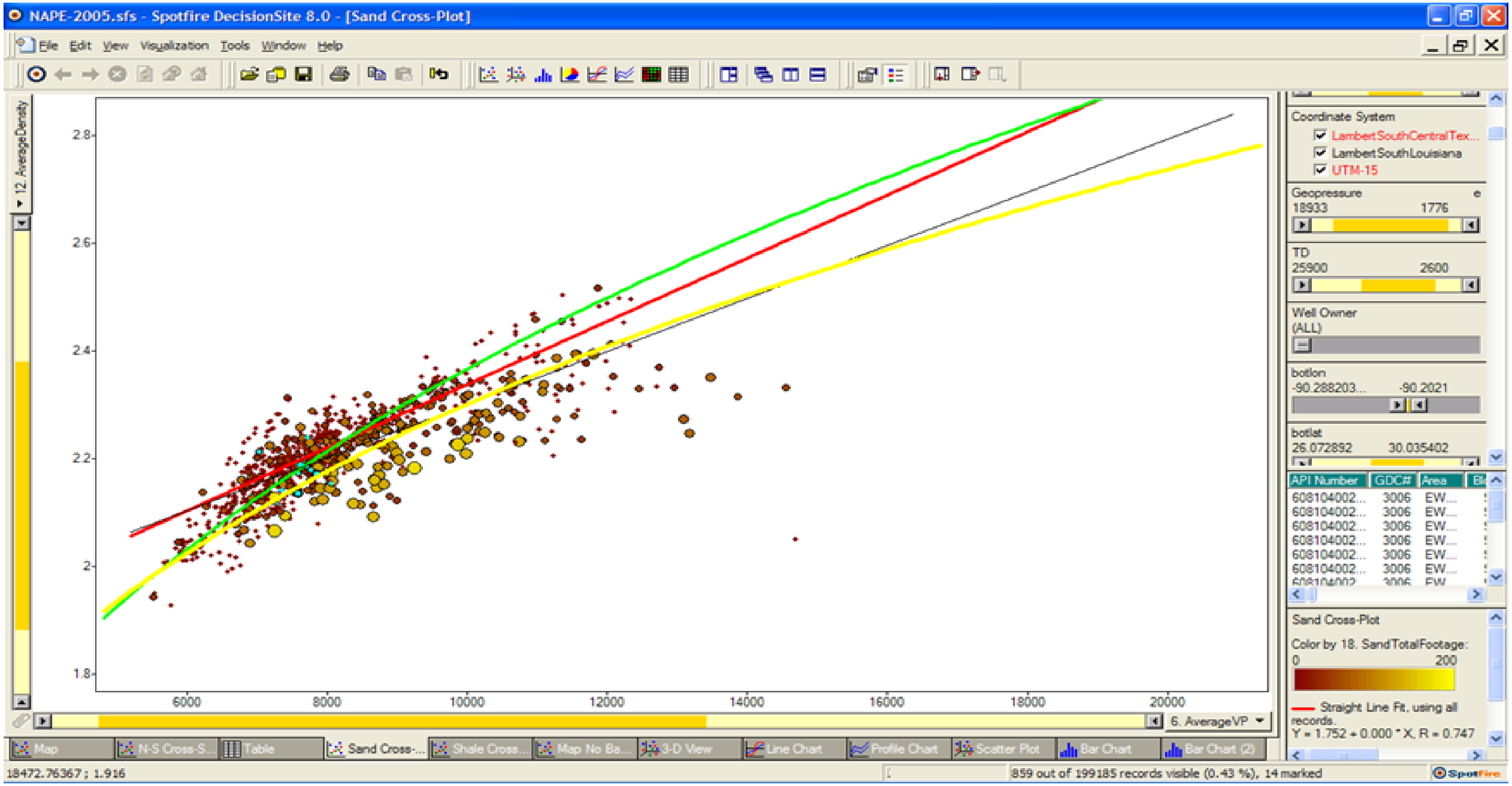
Unwrapping Phase to Reconstruct Time



Tracy Stark, **Stark Research**, Personal Communication

Rock Density vs. Average Vp

South Timbalier Area

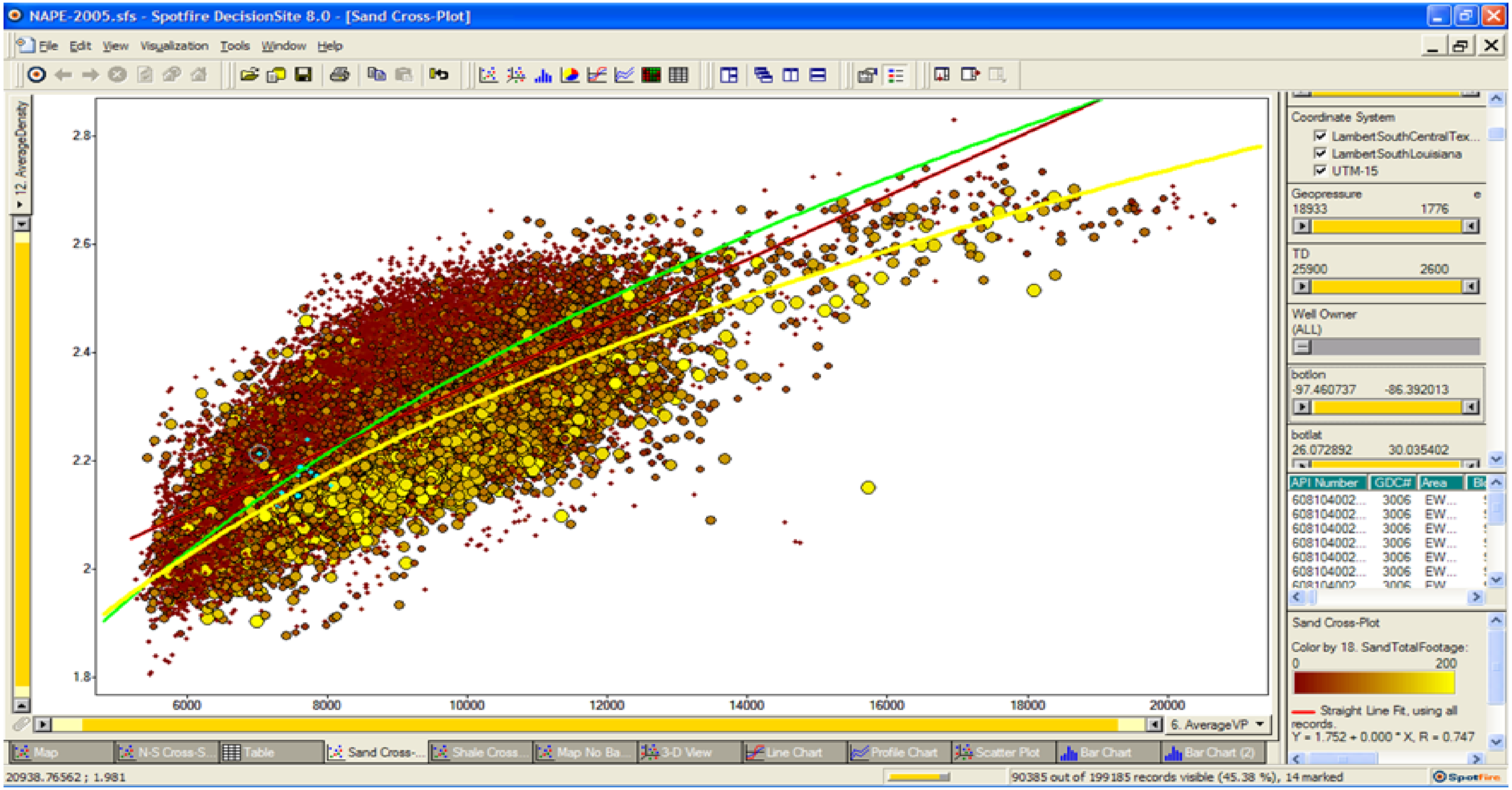


Average Density vs Average Vp follows Gardners (yellow) and BP (green) compaction curve.

Samuel Mentemeier, et. al., **Classification of Rock Properties Trends in the Gulf of Mexico using GDC data in DecisionSite**, 2004.

Rock Density vs. Average Vp

Entire Gulf of Mexico Shelf

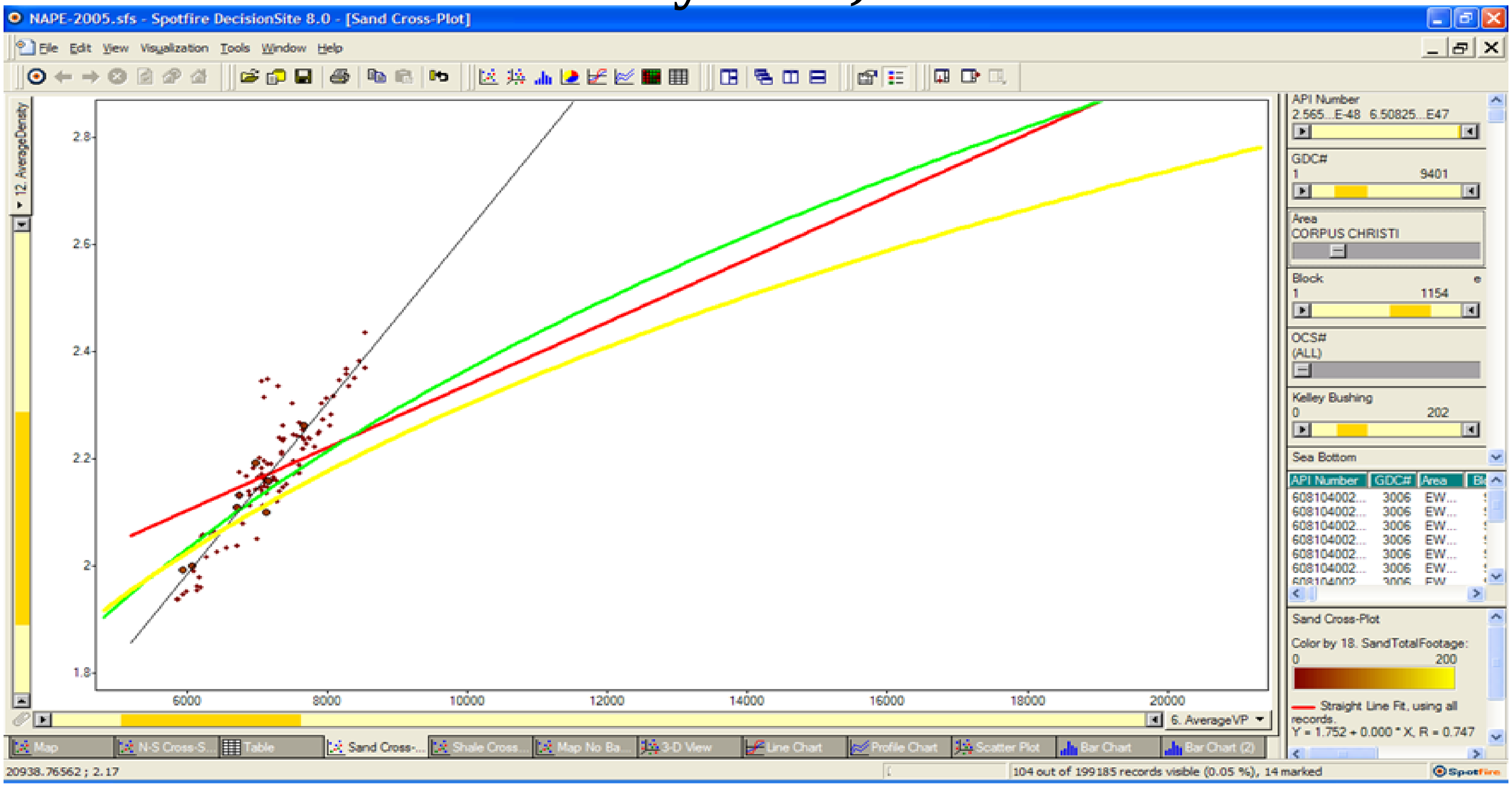


Average Density vs Average Vp follows Gardners (yellow) and BP (green) compaction curve.

Samuel Mentemeier, et. al., **Classification of Rock Properties Trends in the Gulf of Mexico using GDC data in DecisionSite**, 2004.

Rock Density vs. Average Vp

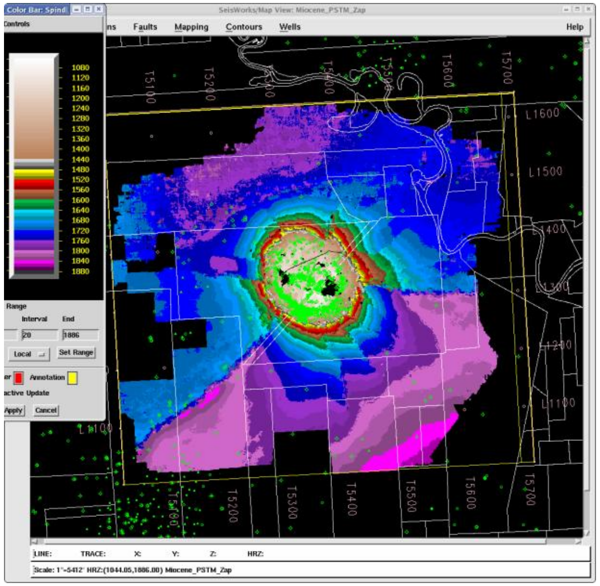
Rio Grand Embayment, South Texas Shelf



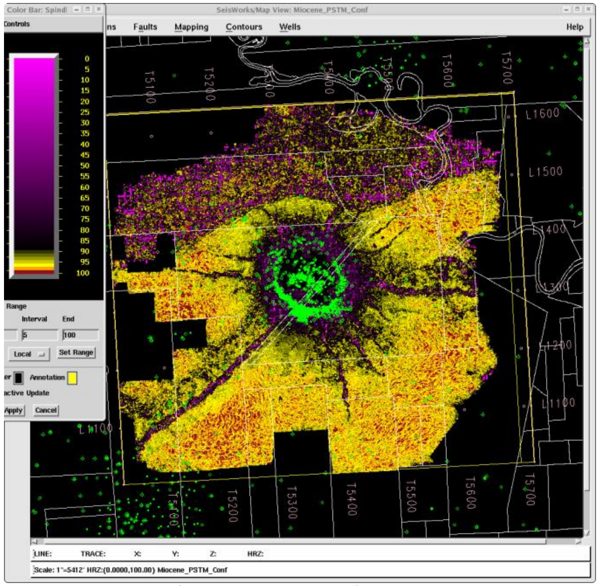
Average Density vs Average Vp does not follow normal compaction curves.

Samuel Mentemeier, et. al., **Classification of Rock Properties Trends in the Gulf of Mexico using GDC data in DecisionSite**, 2004.

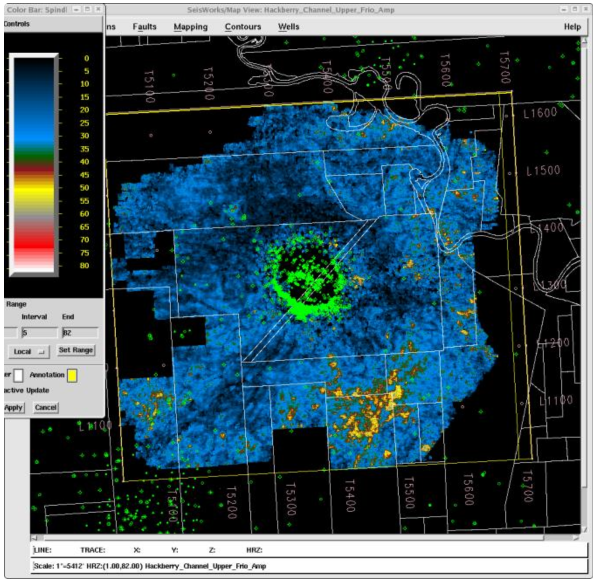
Map Attributes South Texas



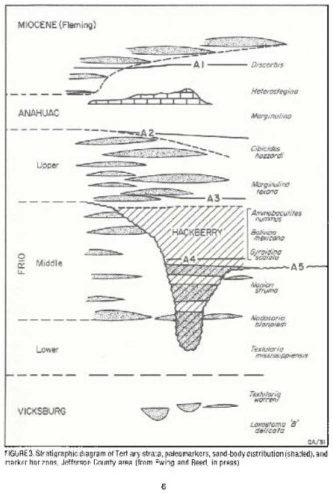
ZAP: Automatic Picking

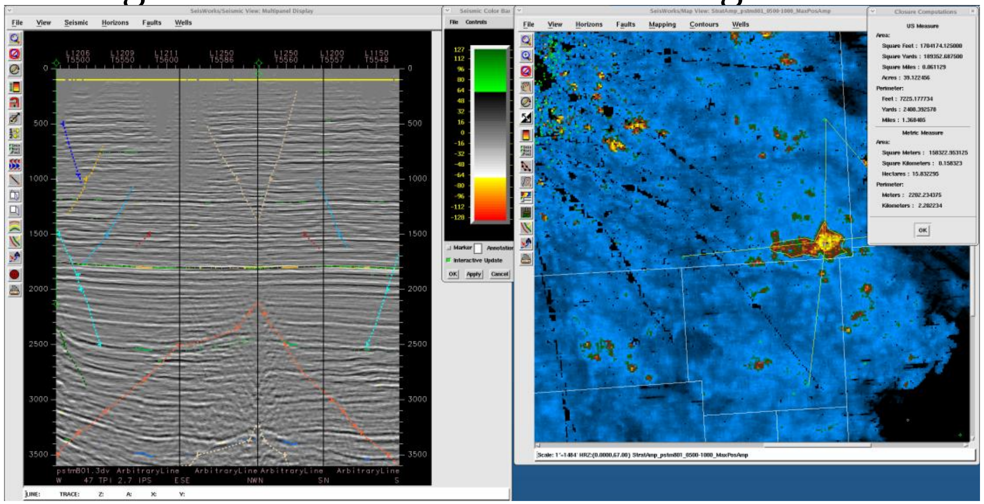


Confidence of Picking



PSTM Amplitudes

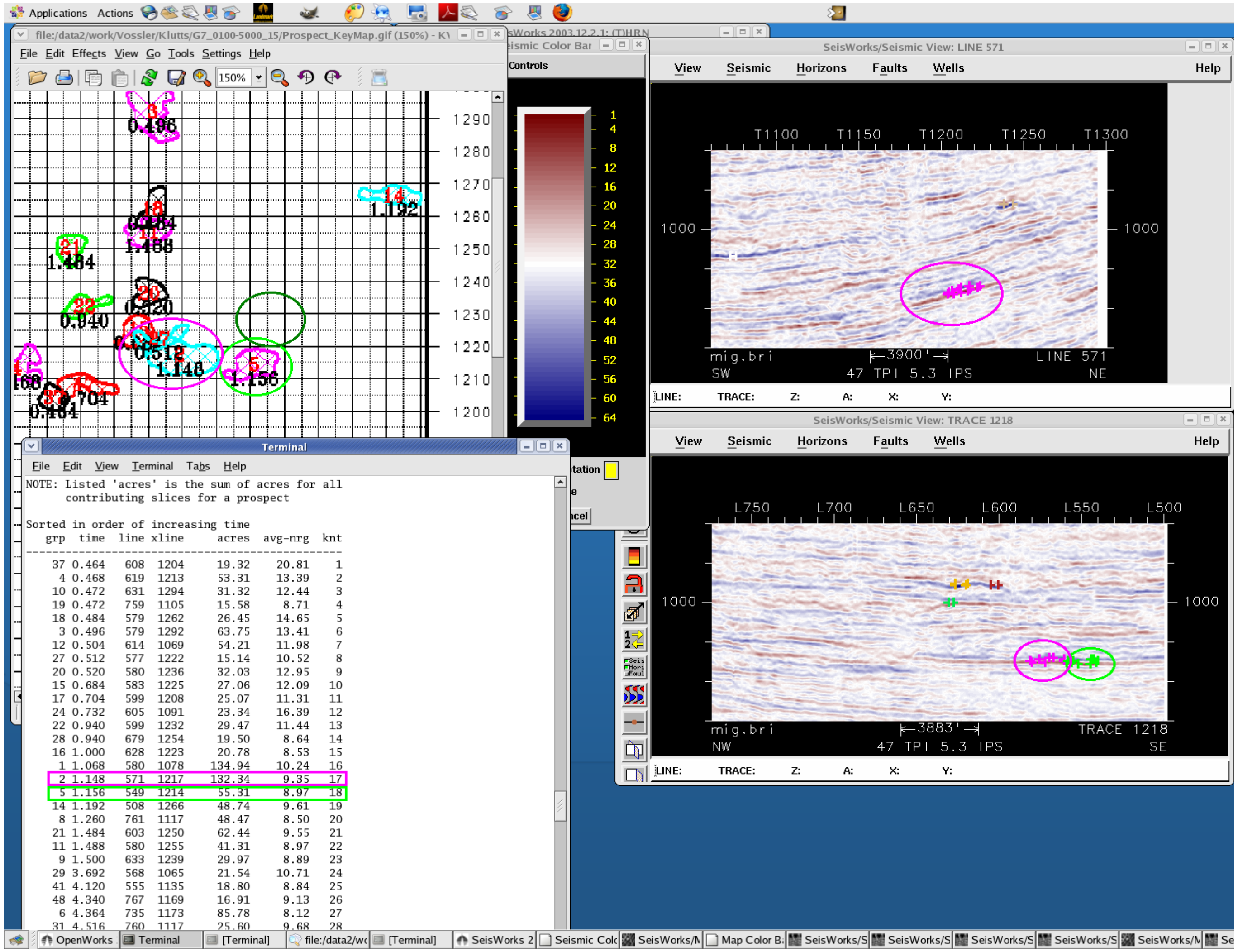




39 acre structure.
~0.936 BCF gas.
Based on:
acres*20 ft gas *
1.2 MCF/acre ft /
1000 MCF/BCF.
At $4/MCF = $3.7 MM,
For a $1.2MM well.

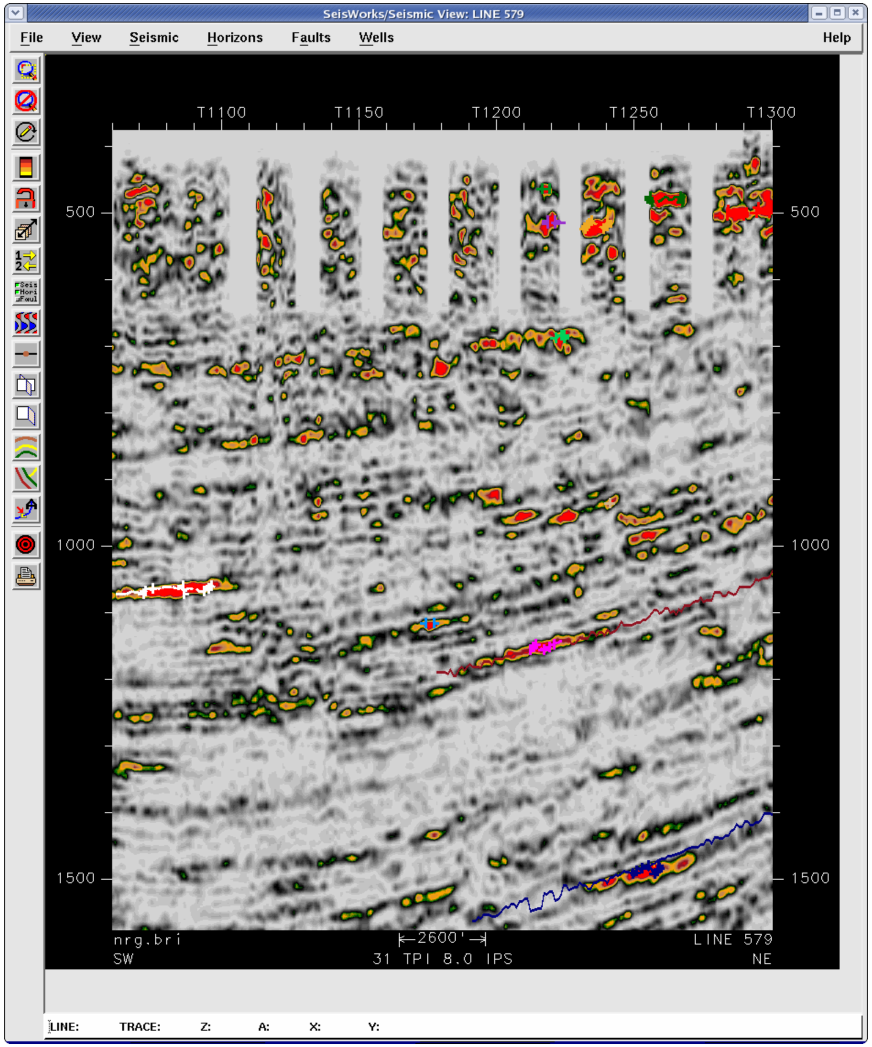
Attribute Automatic Ranking of Leads

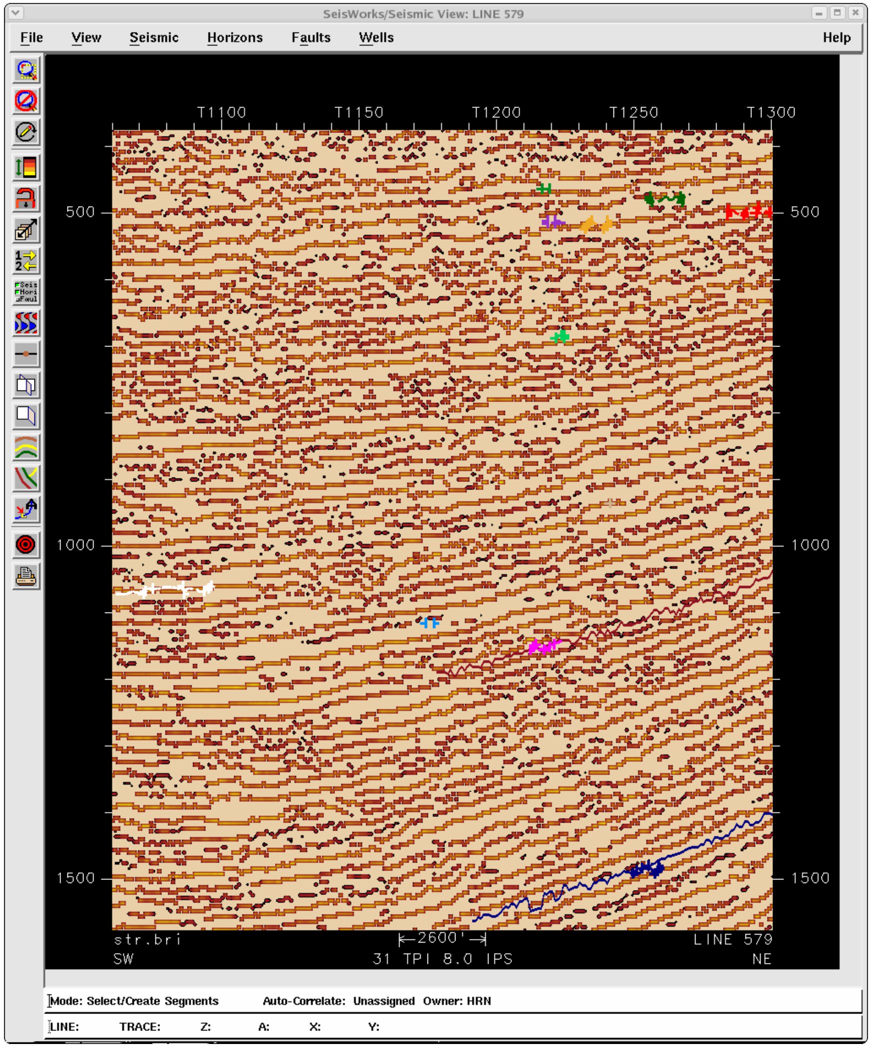
South Louisiana



NGR and STR for Automatic Ranking

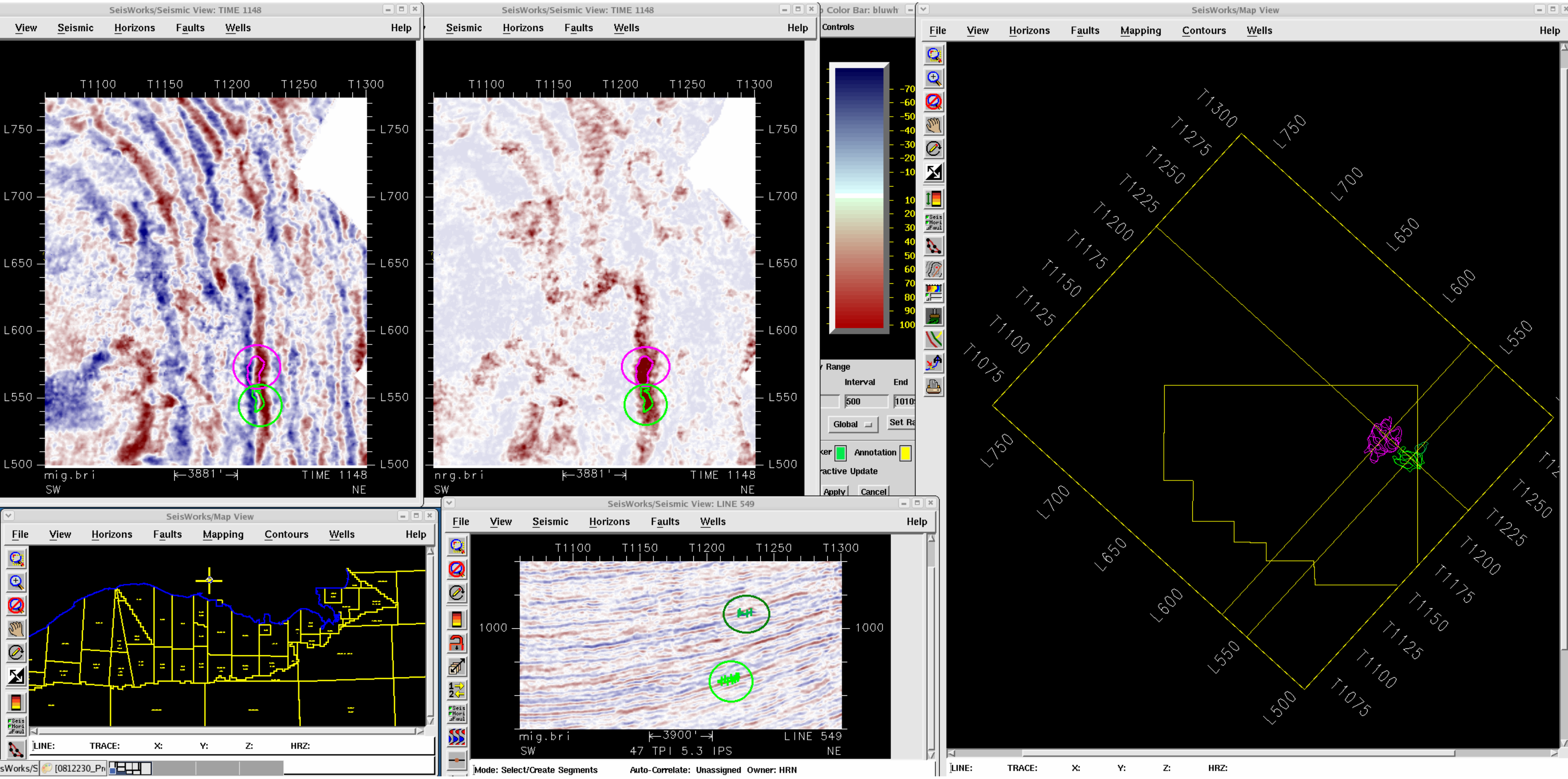
South Louisiana



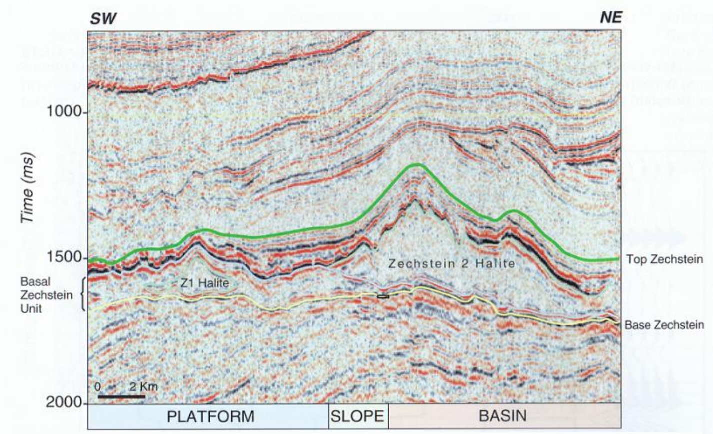


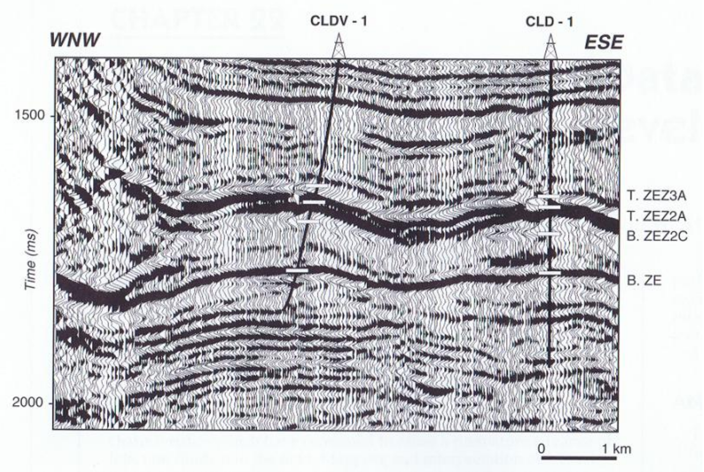
Attribute Automatic Ranking of Leads

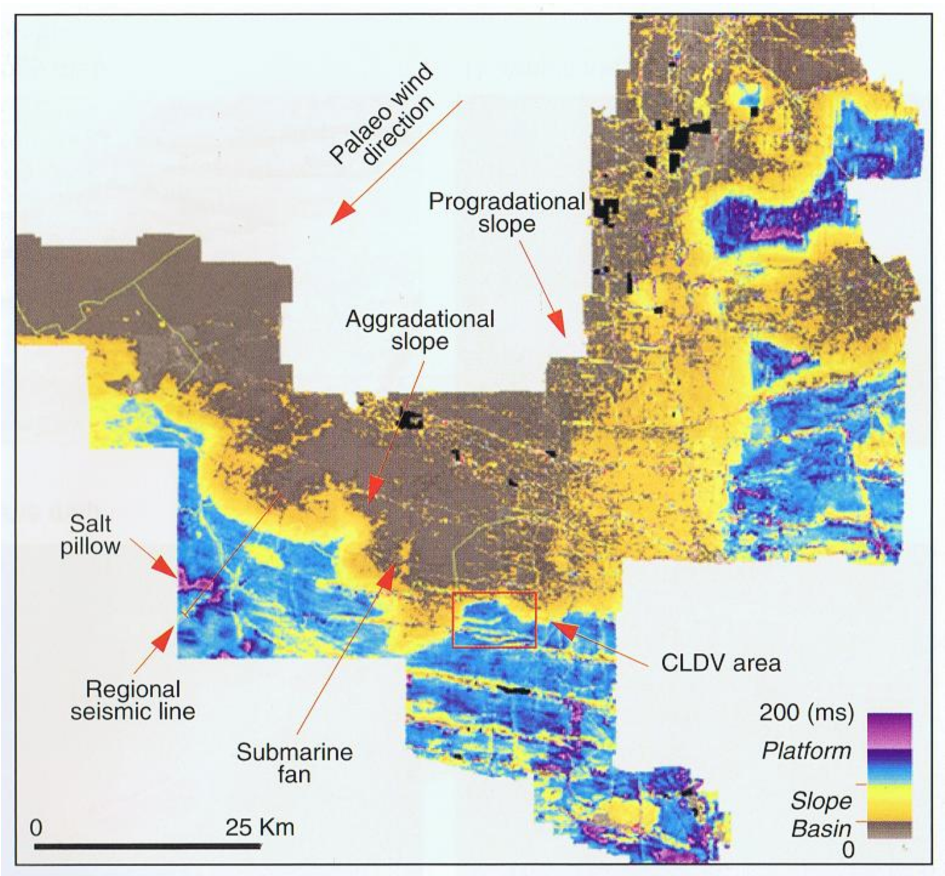
South Louisiana



Predicting Reservoir Parameters
Zechstein 2 Carbonate Play, NE Netherlands



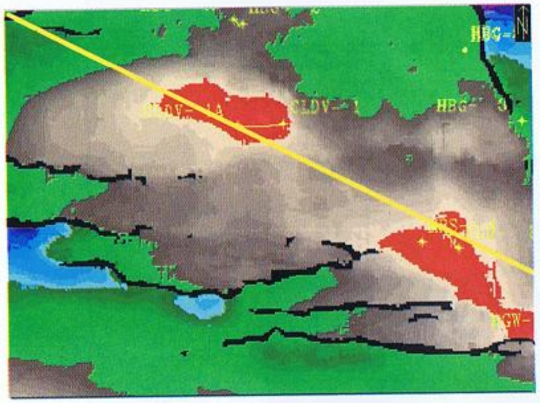




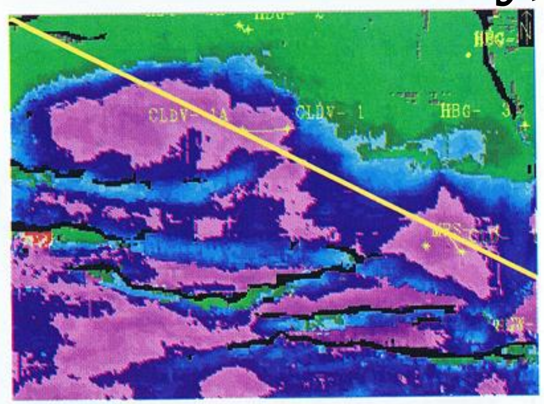
Jan M.M. van de Sande in **Application of 3-D Seismic Data to Exploration and Production**, pages 201-203, data from Shell (SIPM) and Exxon (ECI) in NE Netherlands.

Predicting Reservoir Parameters

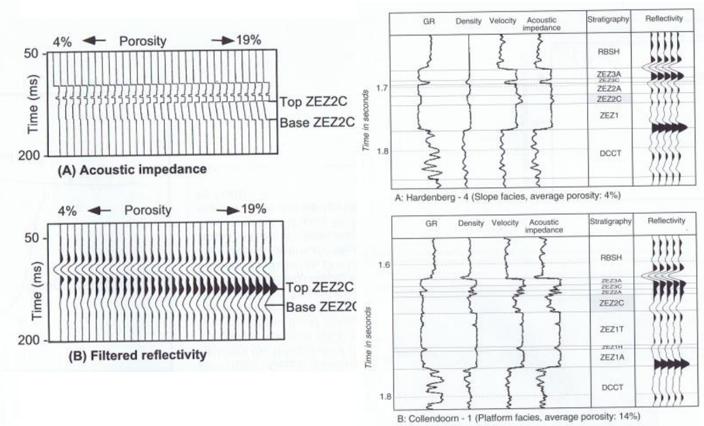
Zechstein 2 Carbonate Play, NE Netherlands

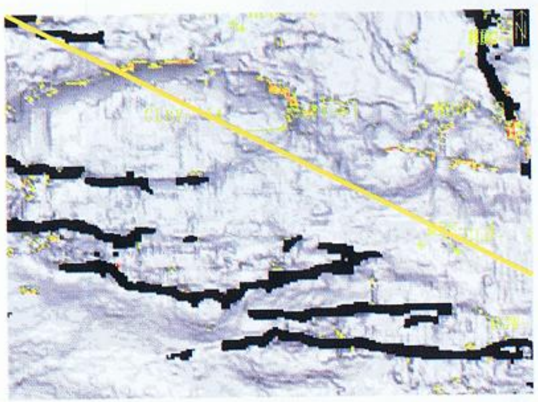


A: Time map

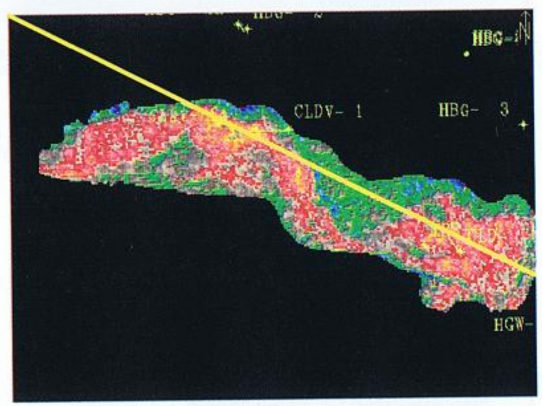


B: Time isochore map

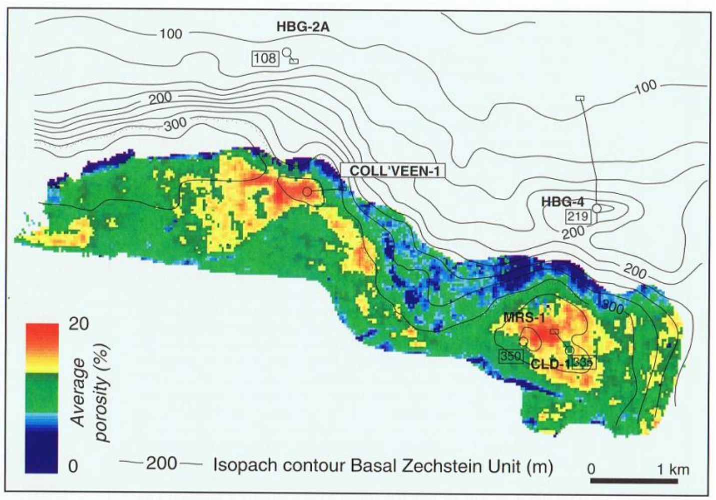




C: Edge map



D: Amplitude map



Jan M.M. van de Sande in **Application of 3-D Seismic Data to Exploration and Production**, pages 201-203, data from Shell (SIPM) and Exxon (ECI) in NE Netherlands.

Pre-Program Questionnaire

- What are the basic seismic attributes and how do they help seismic interpretation?
  - Wavelet attributes?
  - Curvature attributes?
  - AVO (Amplitude vs. Offset) analysis?
  - AVA (Amplitude vs. Angle) analysis?