[AV]The Marcellus Shale Revealed with Full Azimuth 3D Multi-Component Seismic Data*

Tony Rebec[1], Jim Gaiser[1], Alvaro Chaveste[1], and Richard Vern[1]

Search and Discovery Article #110160 (2011)
Posted June 20, 2011

*Adapted from oral presentation at Session: Seismic Reservoir Characterization, at AAPG Annual Convention and Exhibition, Houston, Texas, USA, April 10-13, 2011

[1]Geokinetics, Houston (Tony.Rebec@geokinetics.com)

Summary

- 3D seismic data *will* contribute significantly to the understanding of the Marcellus.

- Geophysical analysis/evaluation, although in the early stages, looks very *promising* for optimizing well locations.

References

Engelder T., 2008, Structural geology of the Marcellus and other Devonian gas shales: Geological conundrums involving joints, layer-parallel shortening strain, and the contemporary tectonic stress field: Field Guidebook for Pittsburgh Association of Petroleum Geologists Field Trip, September 12-13, 2008, and AAPG Eastern Section Meeting Field Trip, October 11-12, 2008, 91 p.

Piotrowski, R.G., and J.A. Harper, 1979, Black shale and sandstone facies of the Devonian "Catskill" clastic wedge in the subsurface of western Pennsylvania: US Department of Energy, Eastern Gas Shales Project, Morgantown Energy Technology Center, Morgantown, West Virginia, EGSP Series 13, 40 p.

The Marcellus Shale Revealed with Full Azimuth 3D Multi-Component Seismic Data.

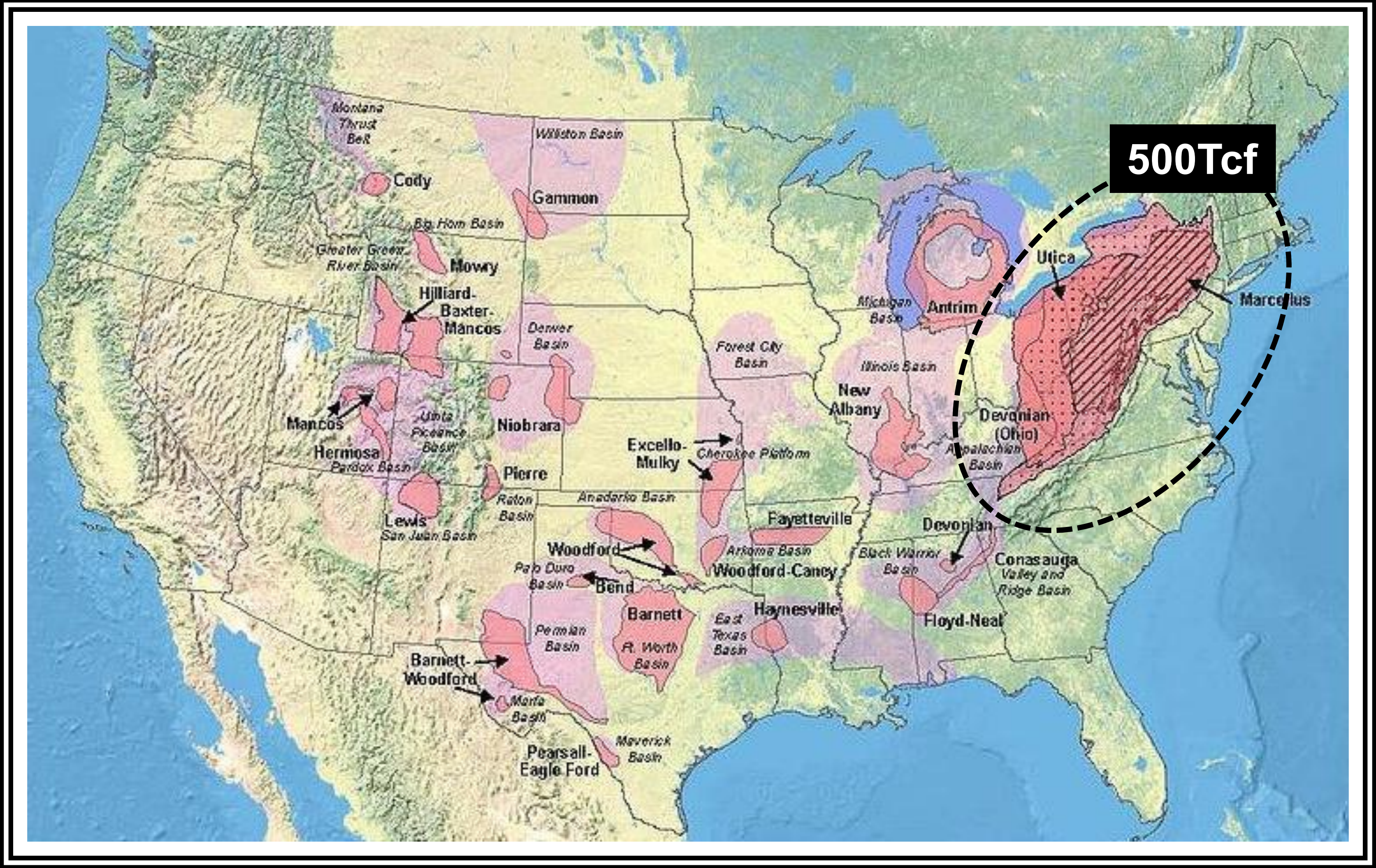
By

Tony Rebec, Jim Gaiser, Alvaro Chaveste and Richard Vern,
Geokinetics, Houston.

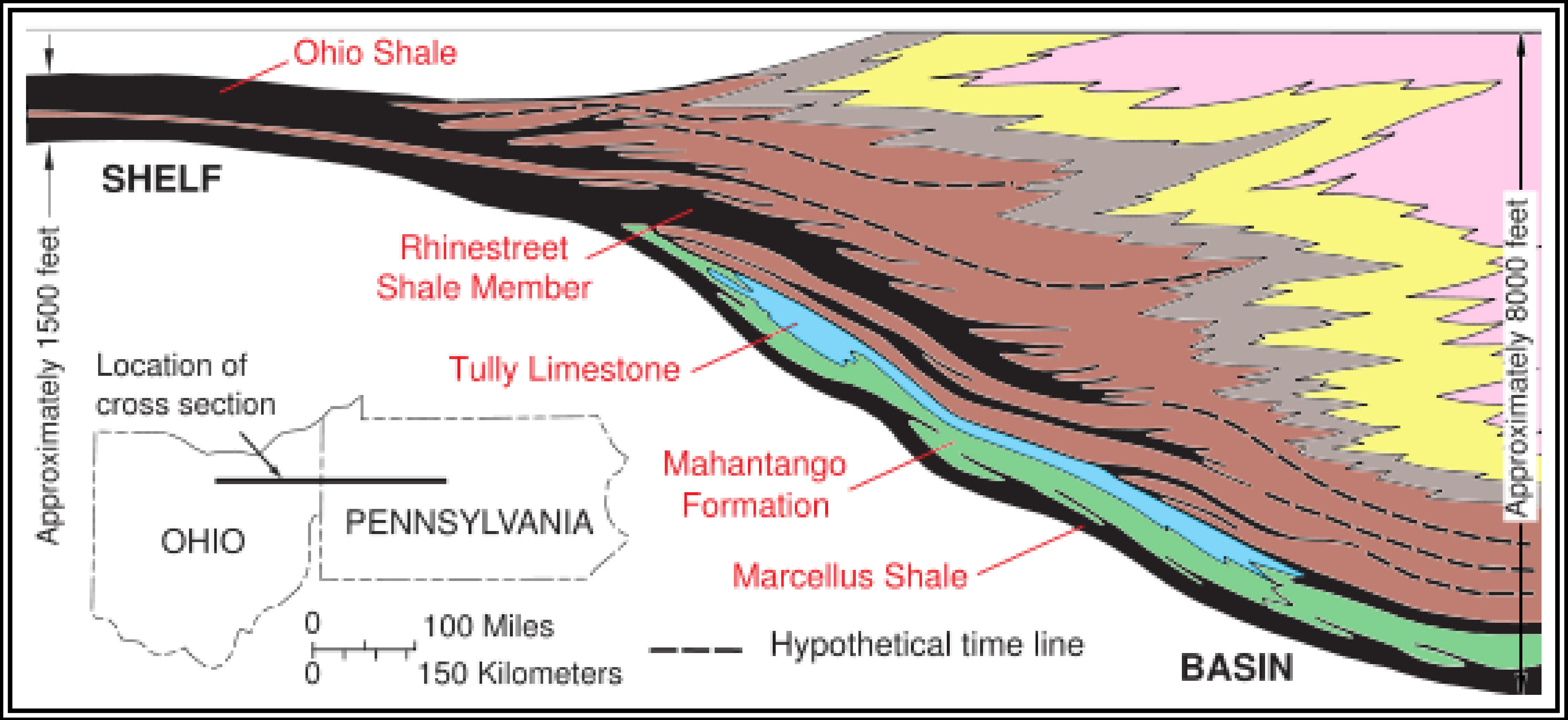
The Marcellus Shale Revealed with Full Azimuth 3D Multi-Component Seismic Data.

- *Introduction to the Marcellus Shale/data*
- *Vertical Calibration & Resolution*
- *Spatial Resolution & Geometric Attributes*
- *Anisotropic/Rock Property Attributes*
- *Conclusions*

United States Shale Gas Plays

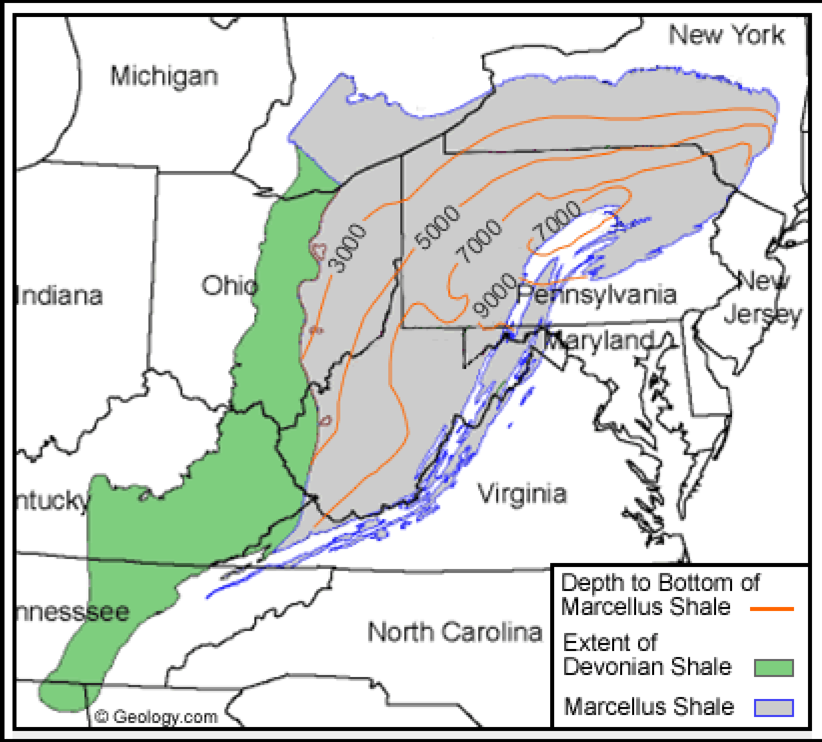


Generalized Geologic Cross-Section of Catskill Delta Magna Facies

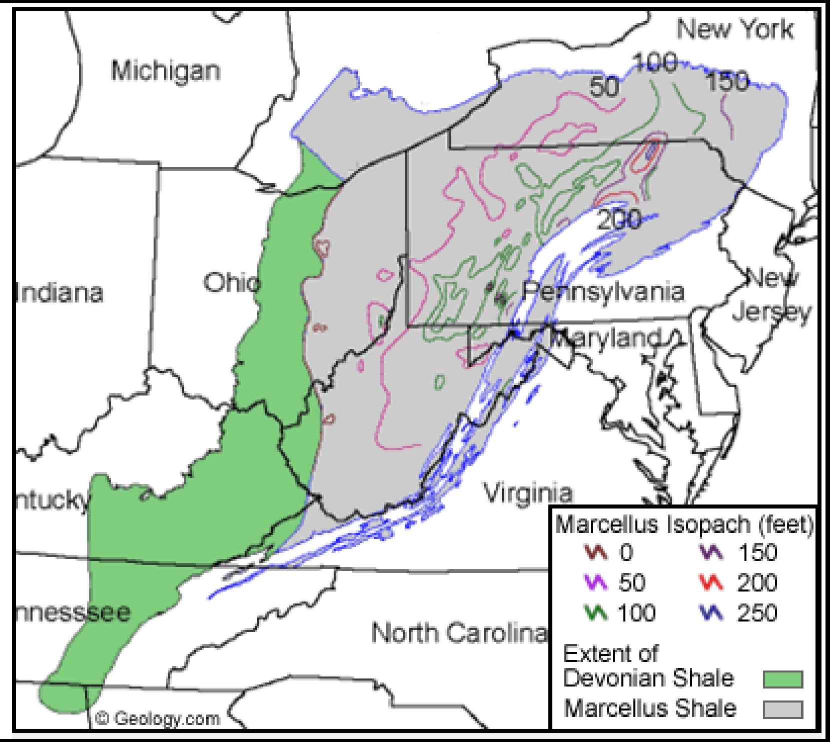


Marcellus Shale – Depth & Isopach Maps

Depth

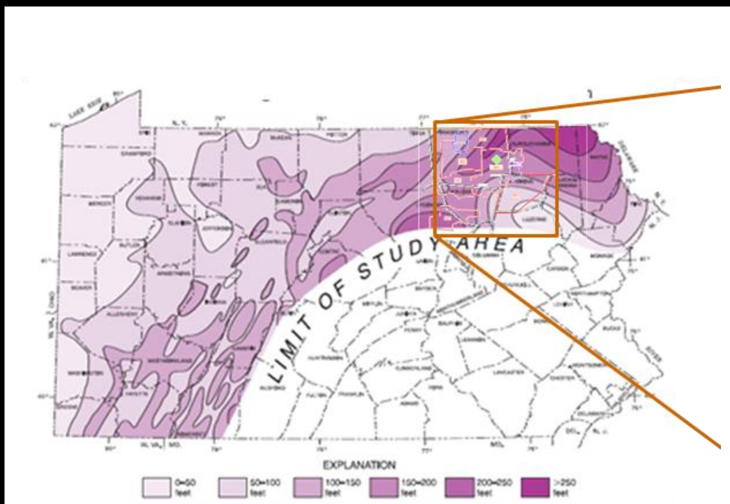


Isopach



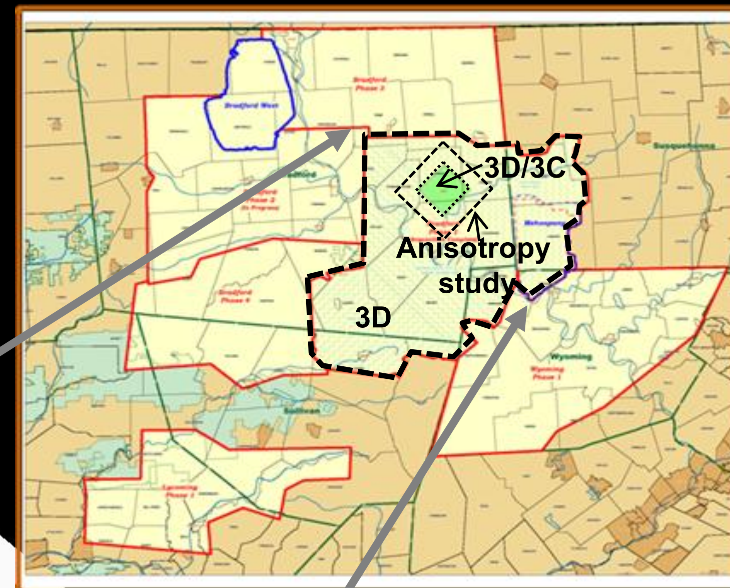
Bradford-Mehoopany 3D
Pennsylvania

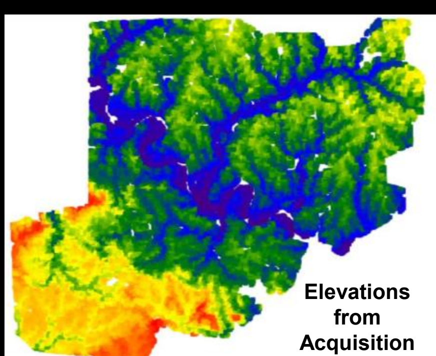
Net Feet of Organic Rich Shale in the Marcellus Formation, Pennsylvania

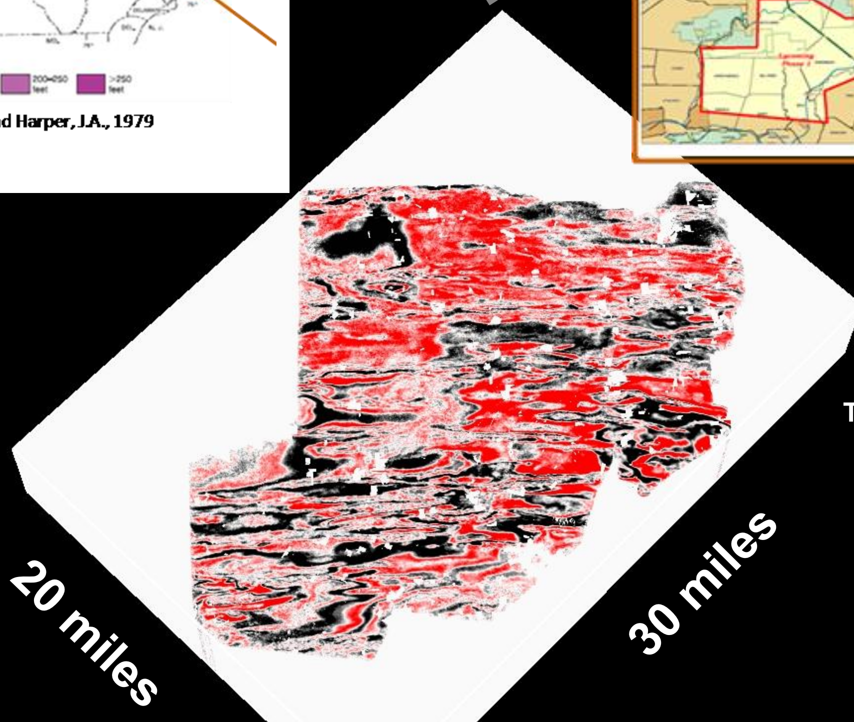


Map from Geology.com, after Piotrowski, R.G. and Harper, J.A., 1979

Bradford County

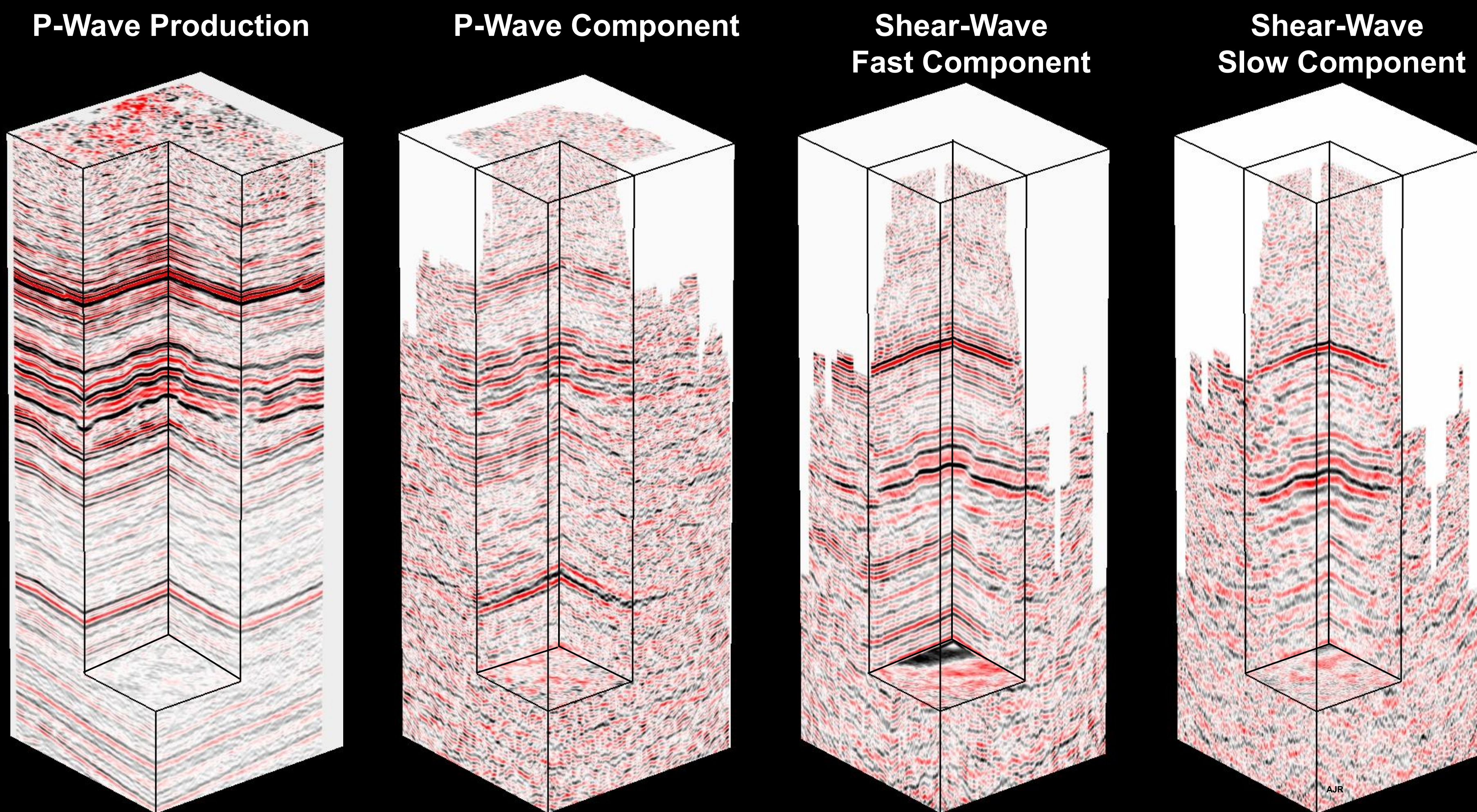






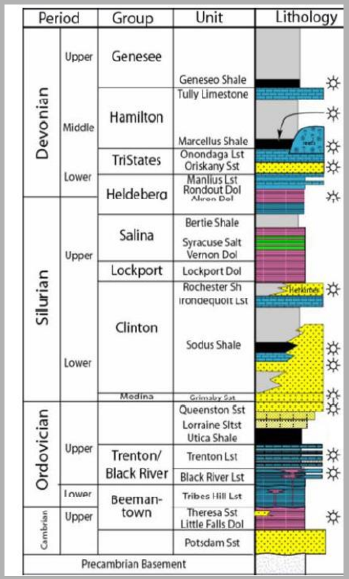
Time Slice from Bradford 3D Phase I & Mehoopany Seismic Survey

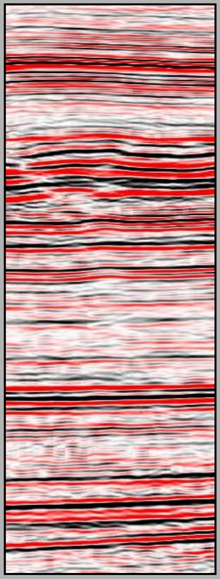
3D Data Sets



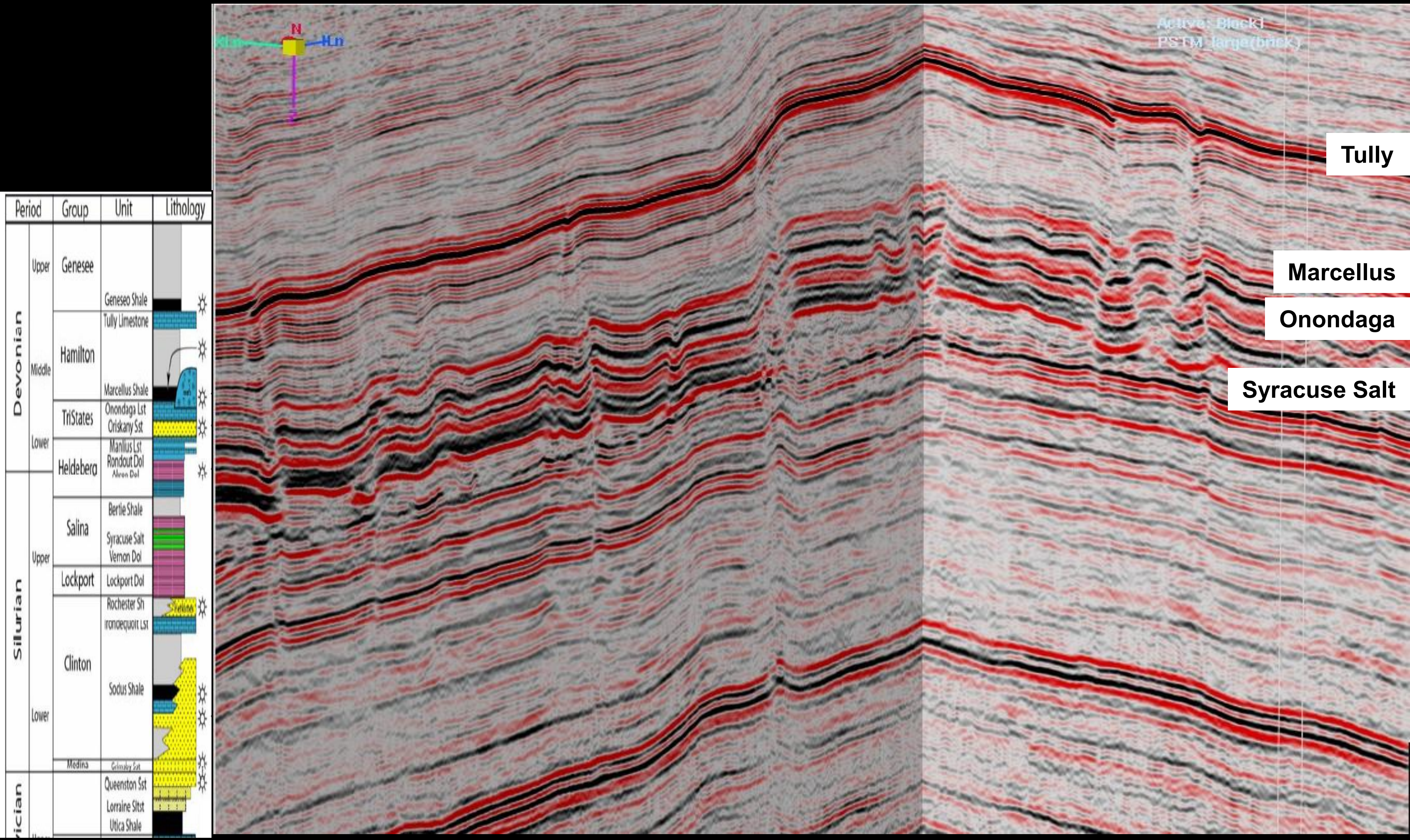
Zeroing in on the Marcellus Shale Play in Pennsylvania with High Fidelity 3D Full Azimuth Surface Seismic Data Including Simultaneous Multi-Component 3D data for Calibration and Identification of Fracture Sweet Spots. (Data not vertically corrected for velocity differentials)

Vertical Calibration/Resolution

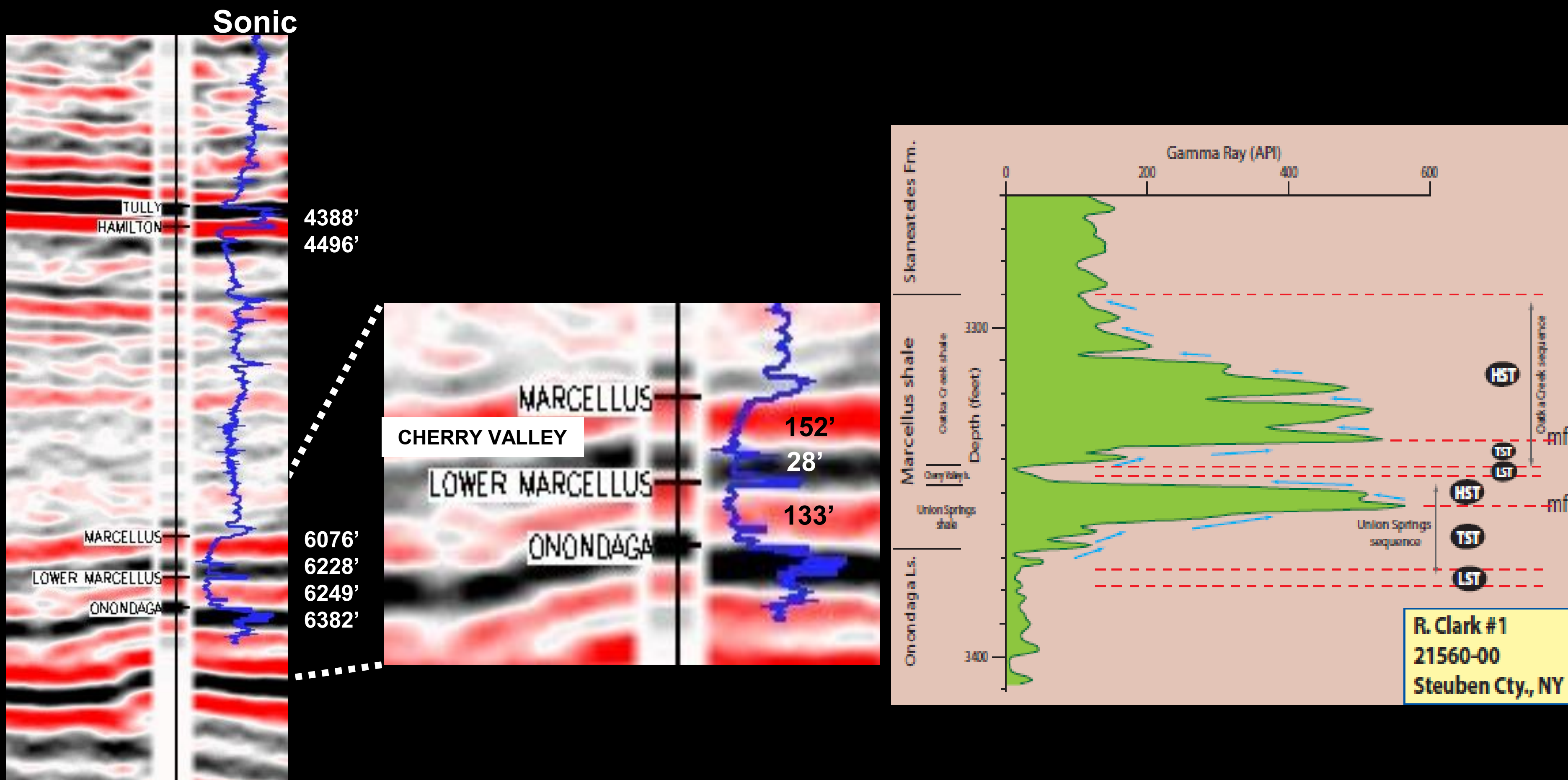




Inline & Crossline

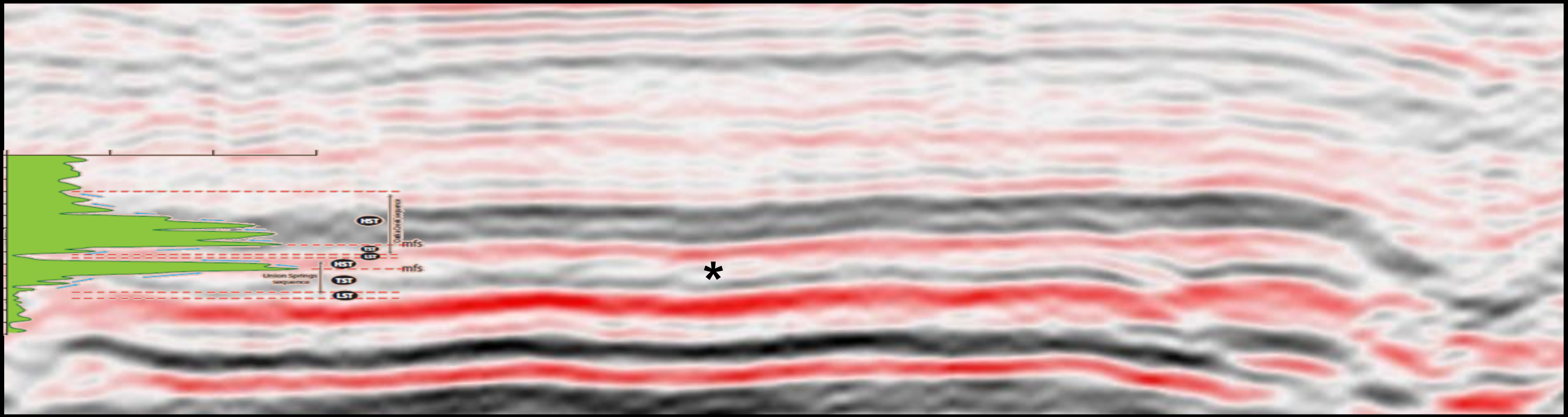


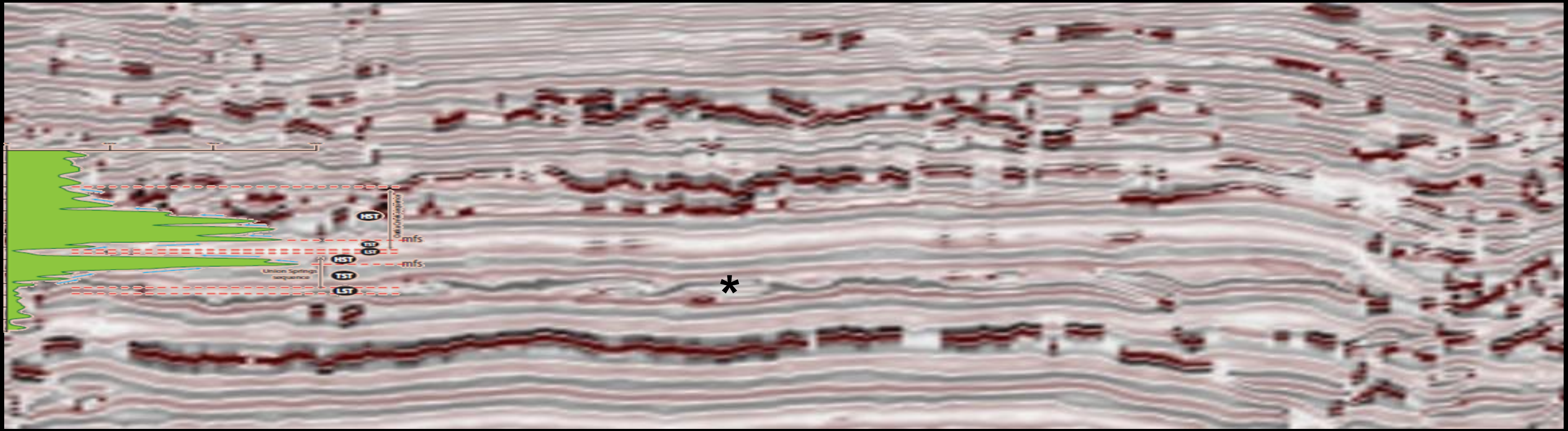
Marcellus Shale Vertical Resolution



Vertical Resolution

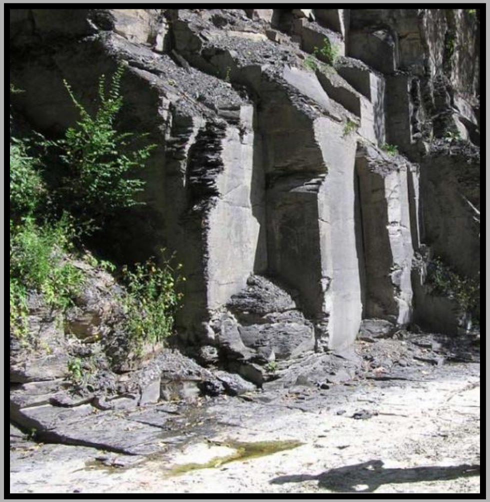
Seismic

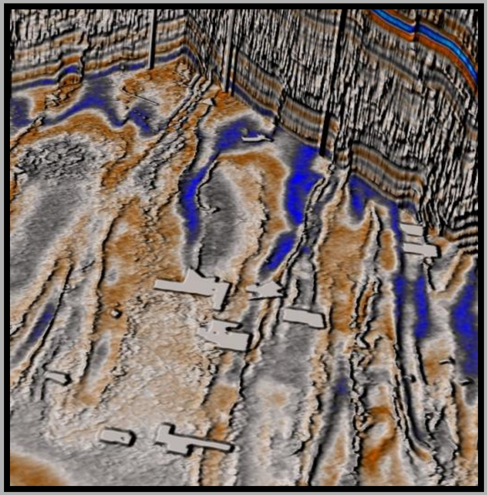




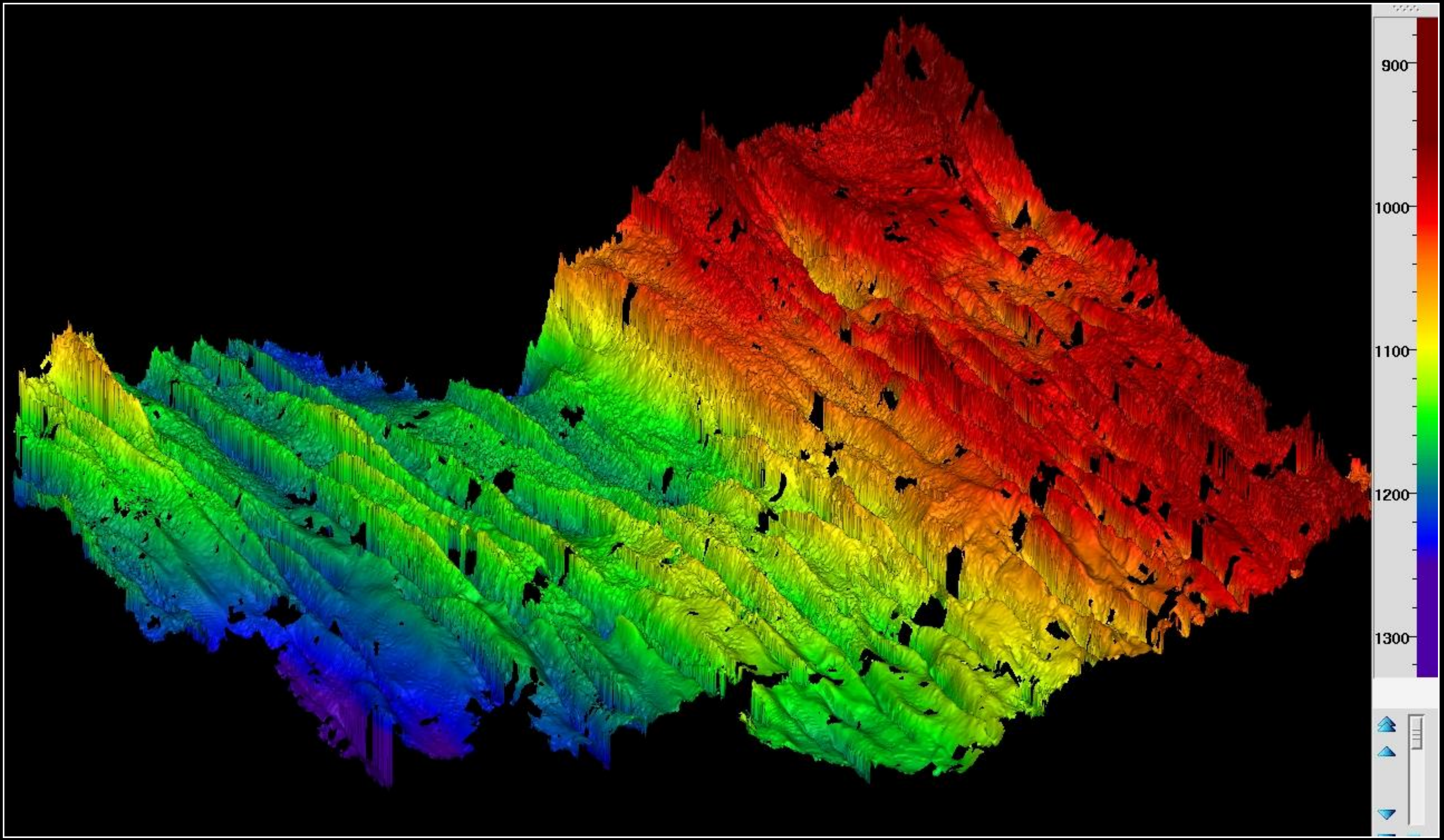
Thin-Bed Reflectivity re Tanner

Spatial Resolution/Geometric Attributes

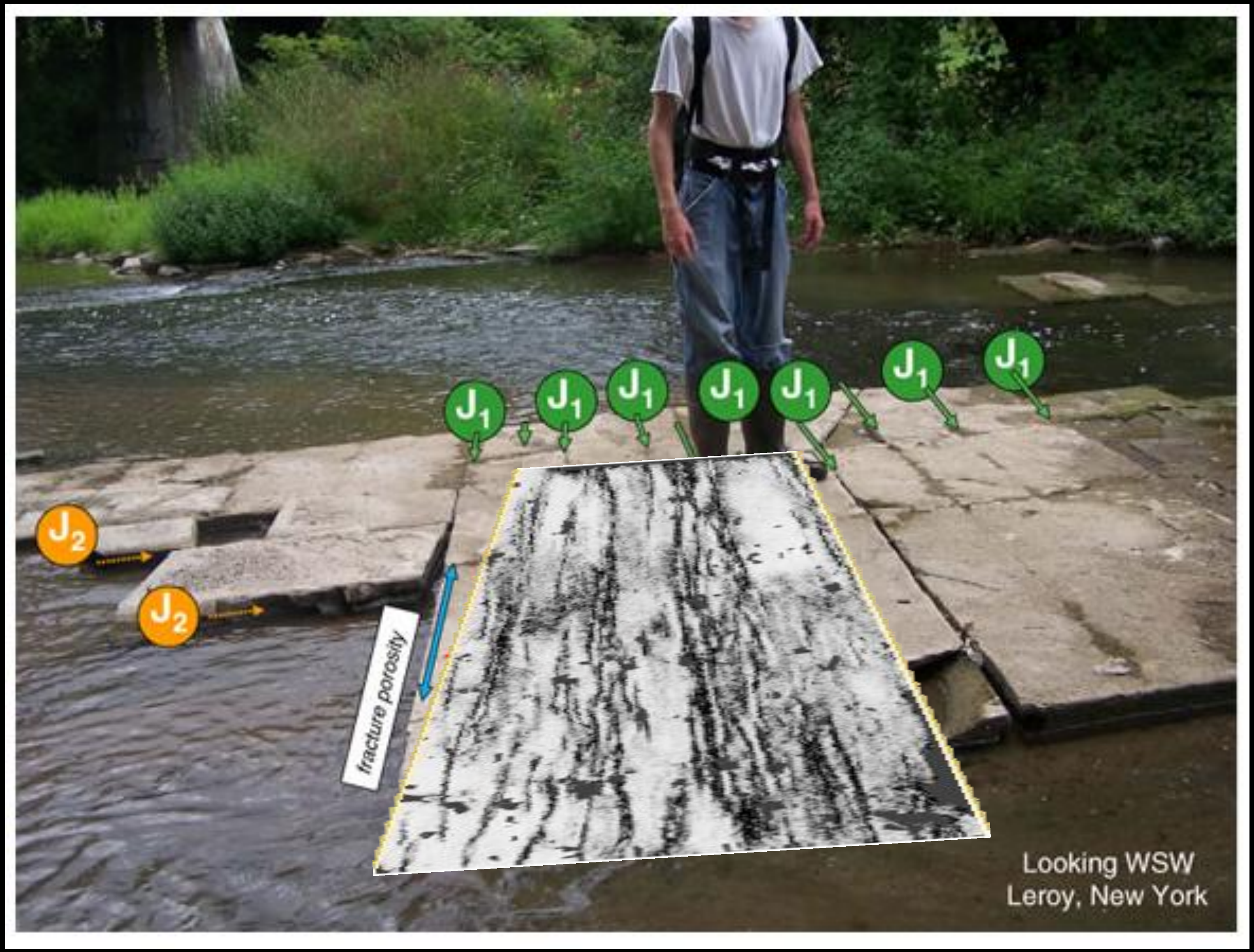




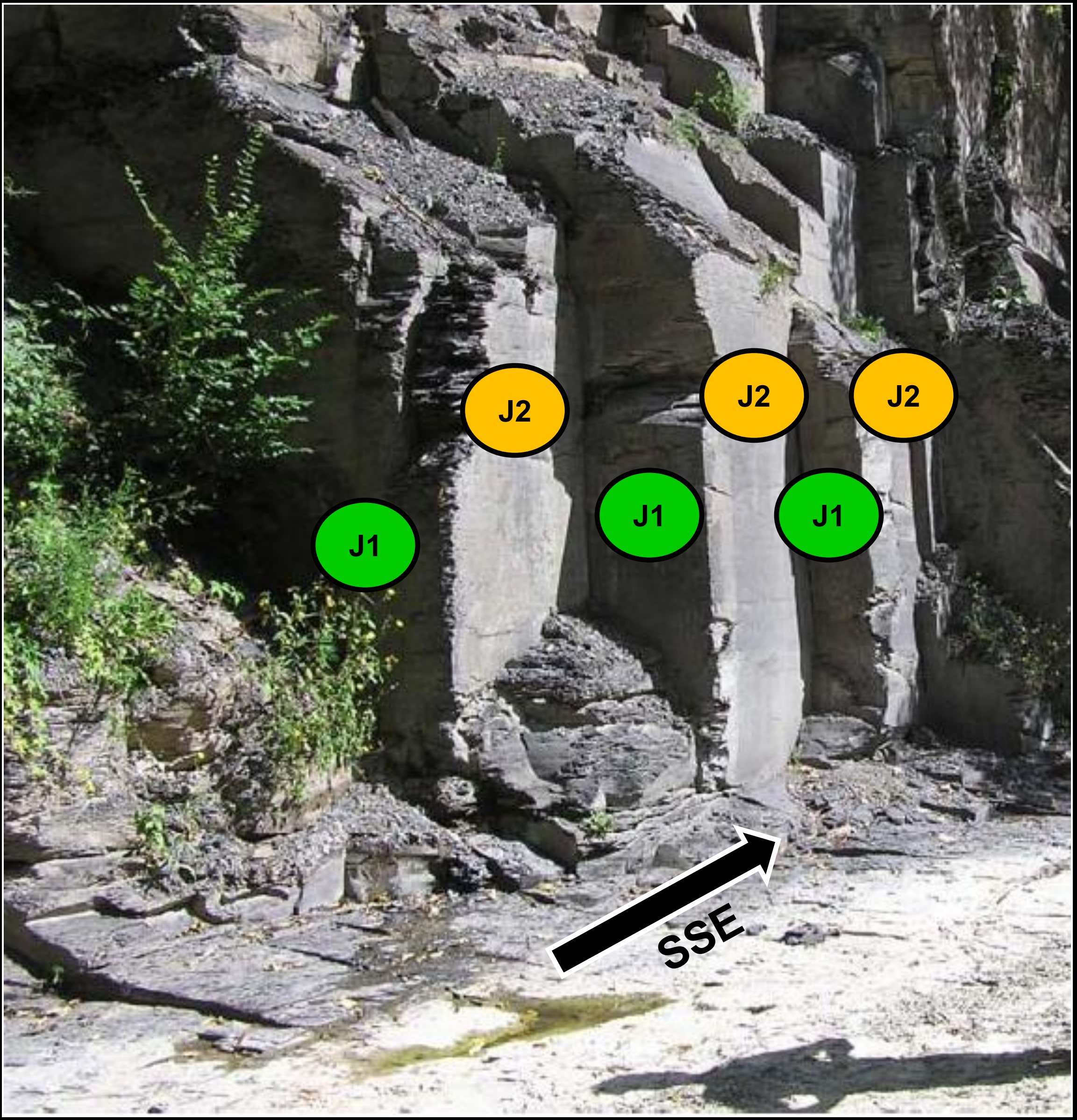
Base Marcellus Shale - twt



J1 & J2 Fracture Sets in Marcellus

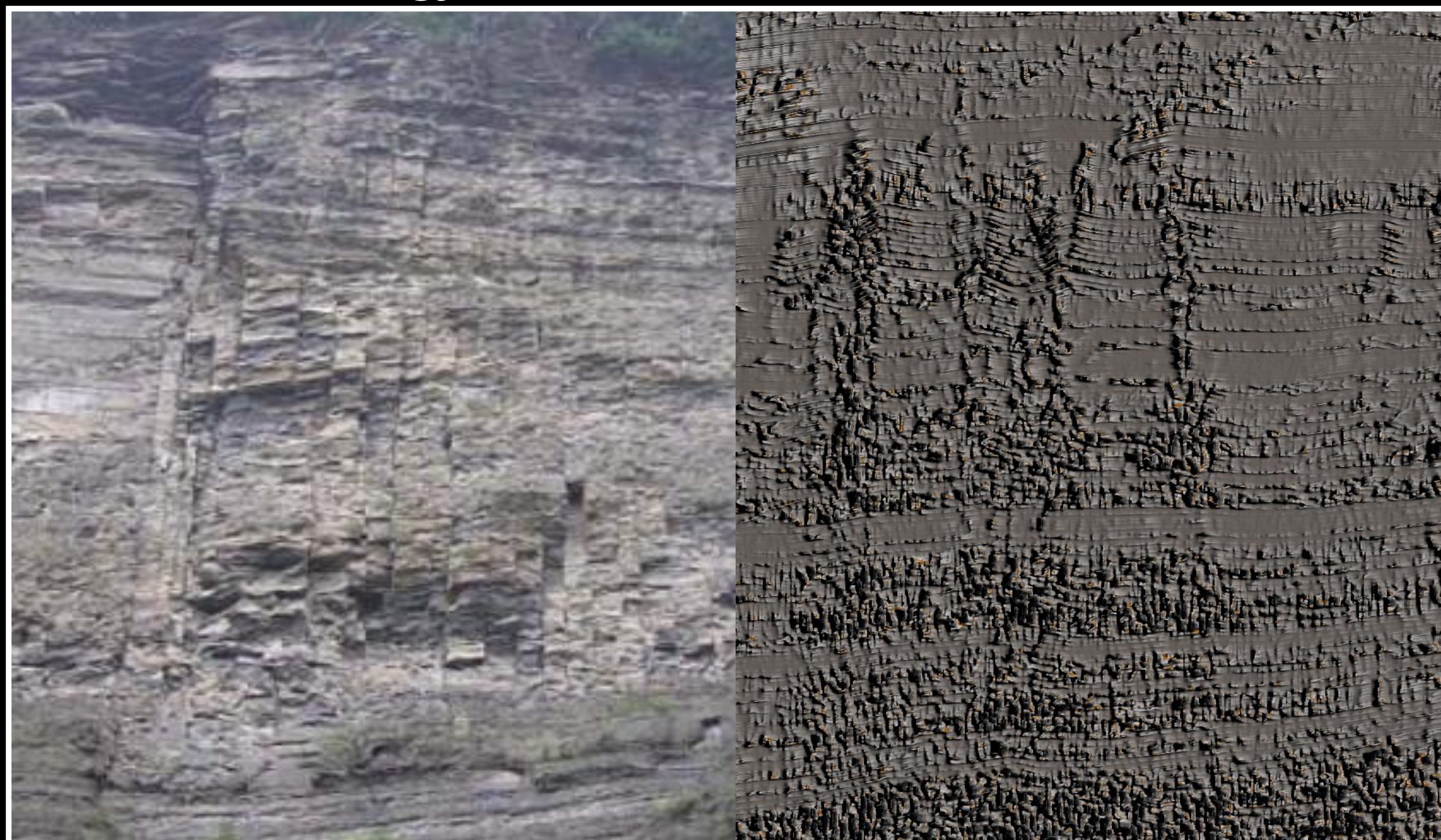


J1 & J2 Fracture Sets in Marcellus

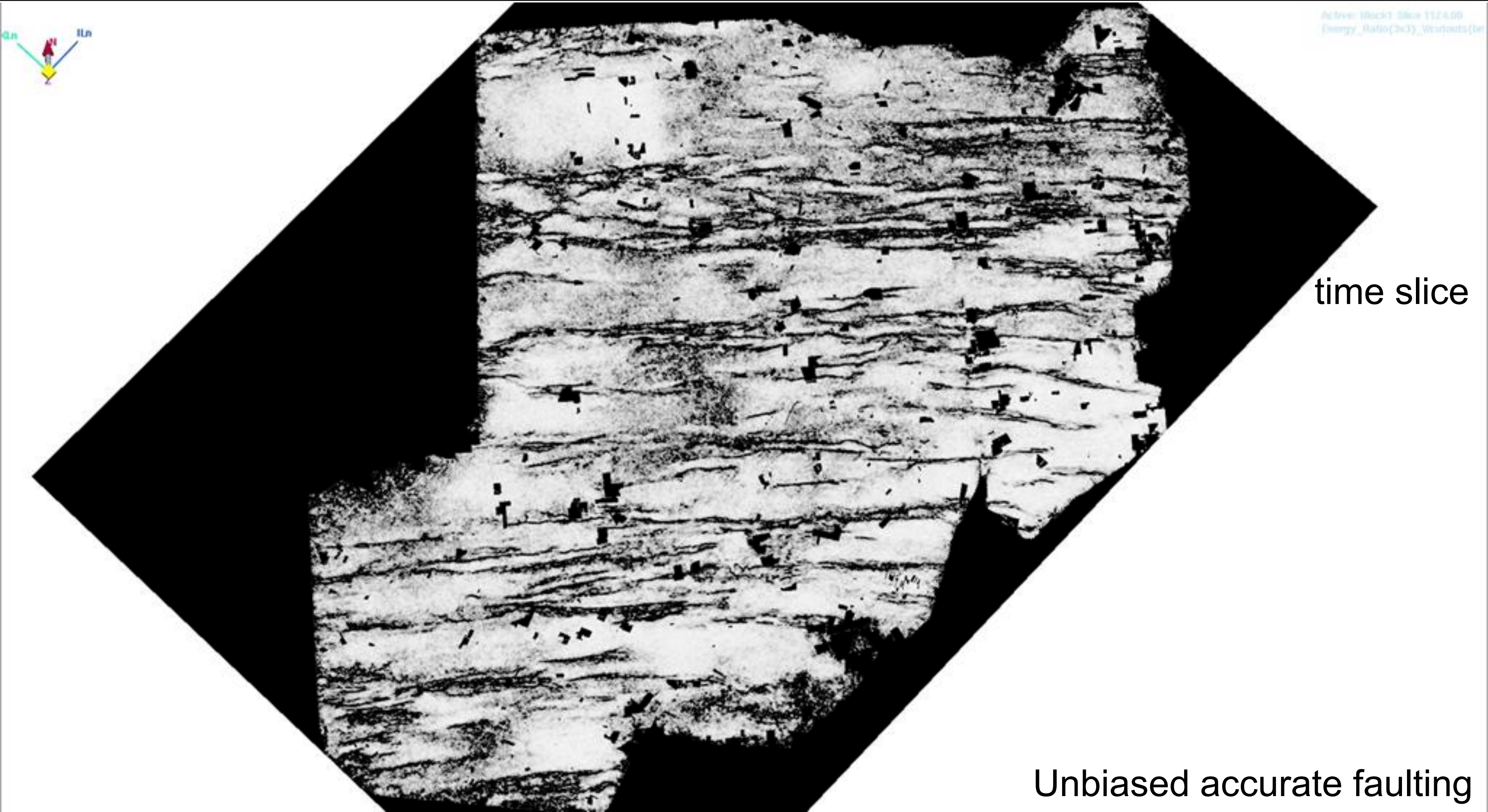


Natural gas chimneys in black shale showing cross fold J_2 joints

Geology **Seismic**

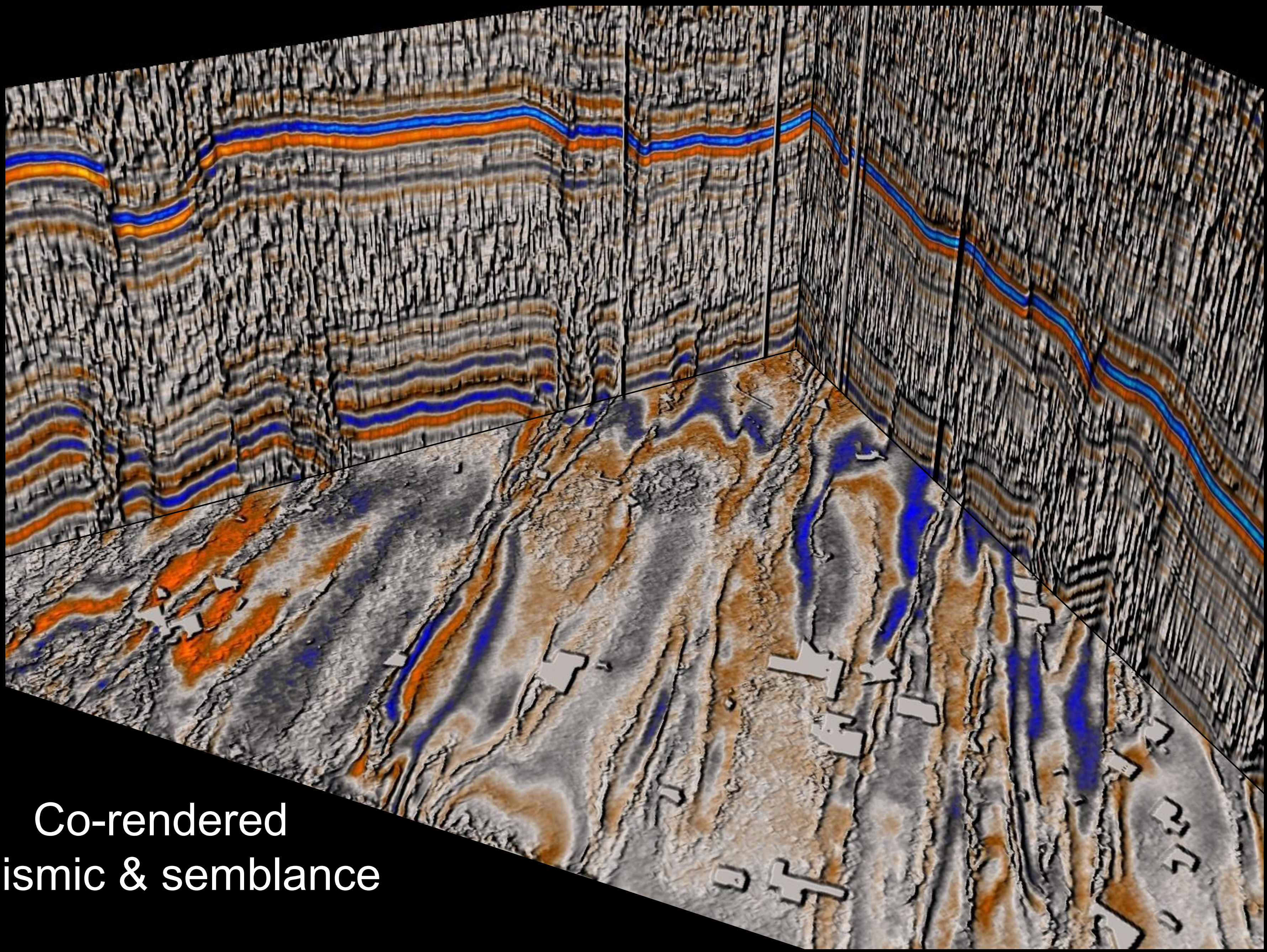


Energy Ratio



time slice

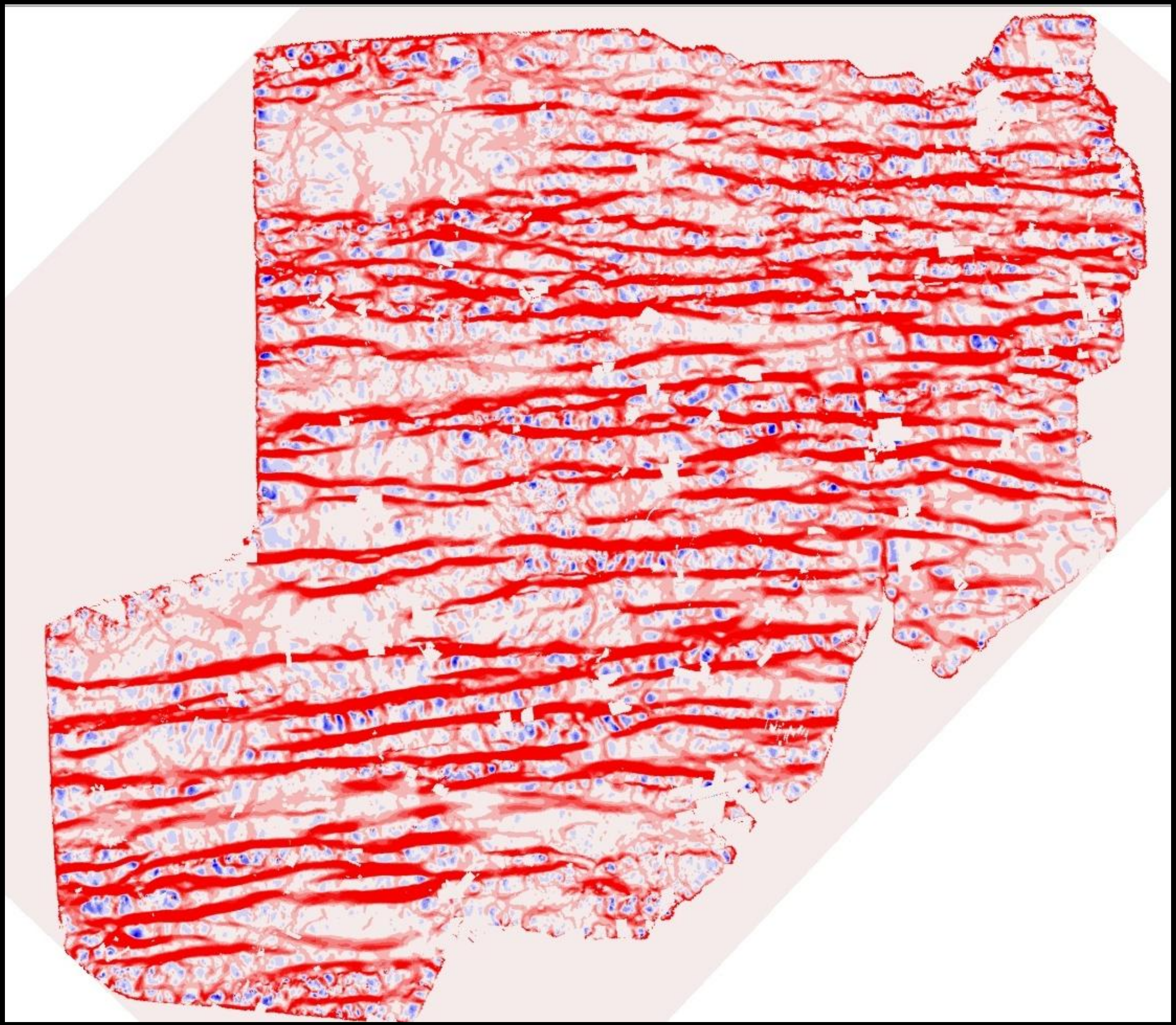
Unbiased accurate faulting

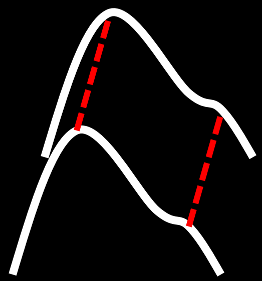


Co-rendered
seismic & semblance

Landmark GeoProbe

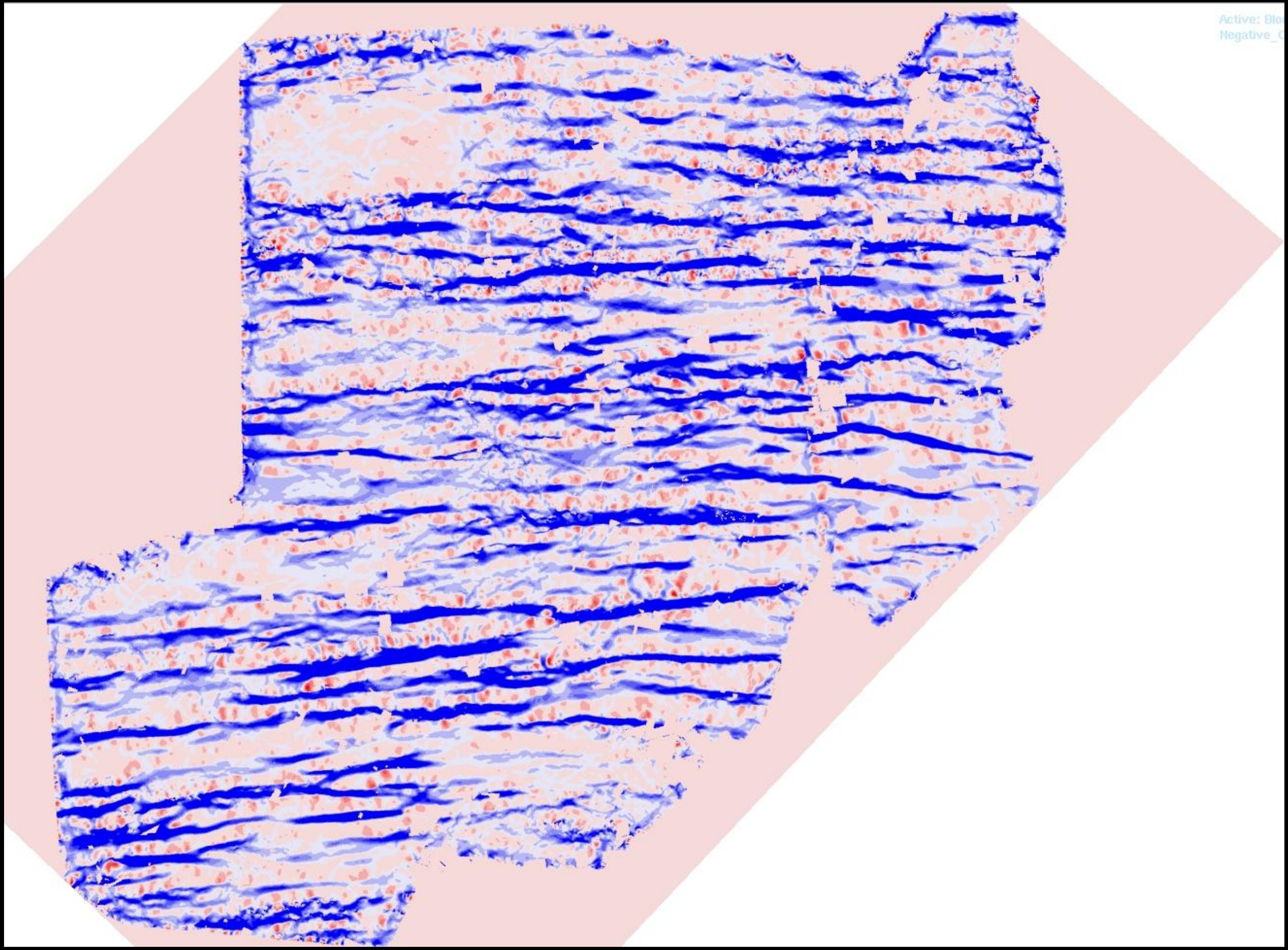
Positive Curvature – time slice

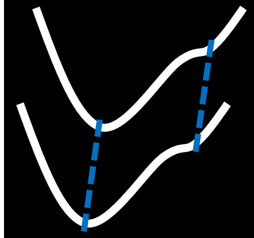




Unbiased accurate structural deformation – positive flexures (highs)

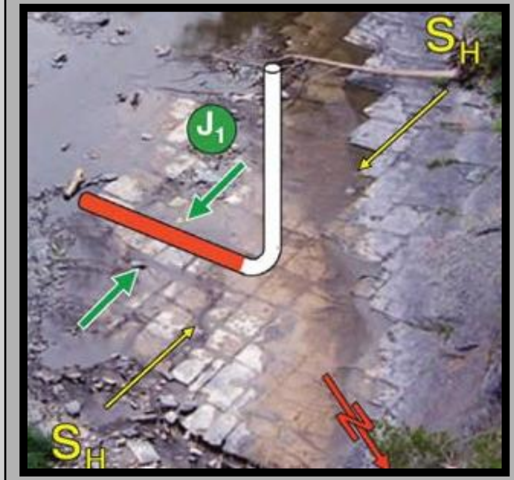
Negative Curvature – time slice

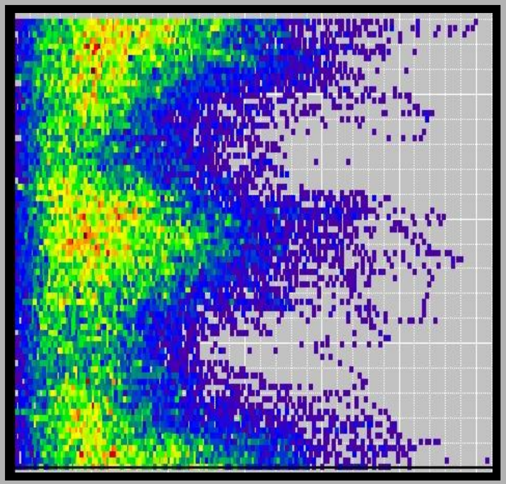




Unbiased accurate structural deformation – negative flexures (lows)

Anisotropic Attributes





Anisotropic/Rock Property Attributes

Anisotropy

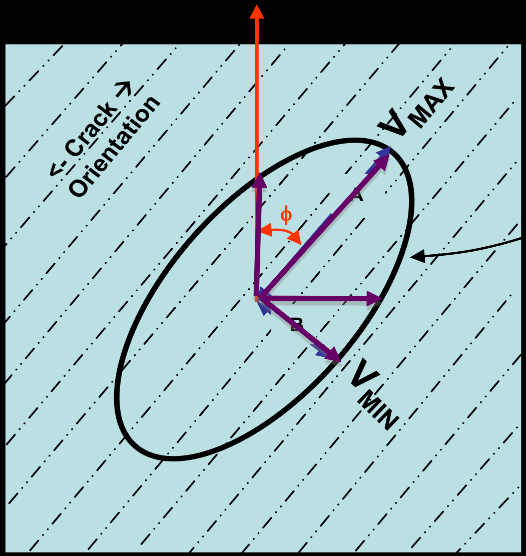
1. Elliptical Inversion using P-wave Interval Velocities

2. Time differentials from Shear waves (3 comp)

Rock Properties

1. Lambda*Rho Mu *Rho

Density and Orientation of Micro-fractures
Physical Basis



ϕ - Azimuth

V_{MAX}

V_{MIN}

$(V_{MAX}-V_{MIN})/V_{MAX}$

ε - Error

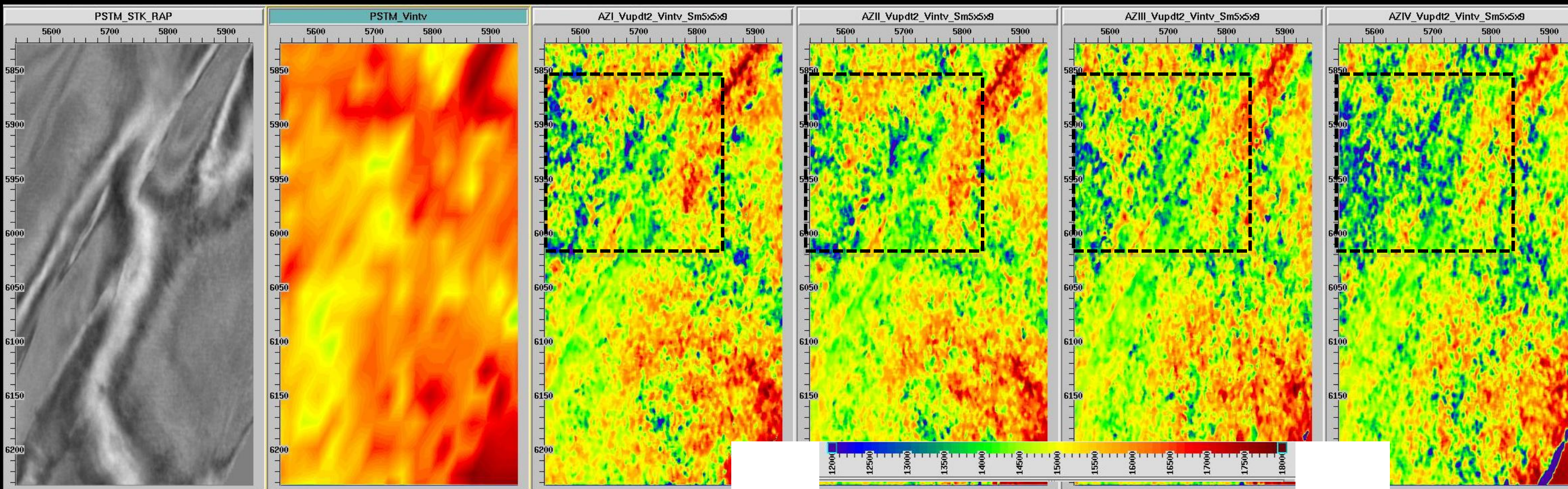
Velocities dependence on fractures' direction.

Difference between fast and slow velocities (anisotropy) is a measure of fracture density

Elliptical Inversion (EI) to estimate anisotropy

Automatic Velocity Picking

Time Slice: 680 ms



pstm stk

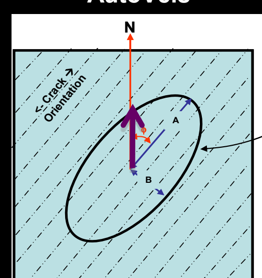
Interval Velocities
All Azimuths
Hand-Picked

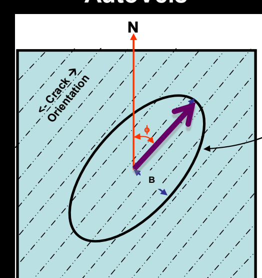
Interval Velocities
Azimuth 1
AutoVels

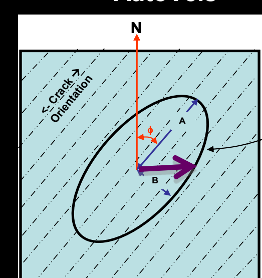
Interval Velocities
Azimuth 2
AutoVels

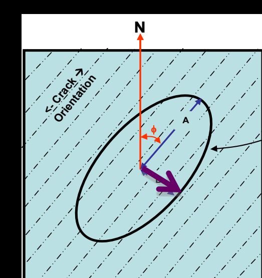
Interval Velocities
Azimuth 3
AutoVels

Interval Velocities
Azimuth 4
AutoVels









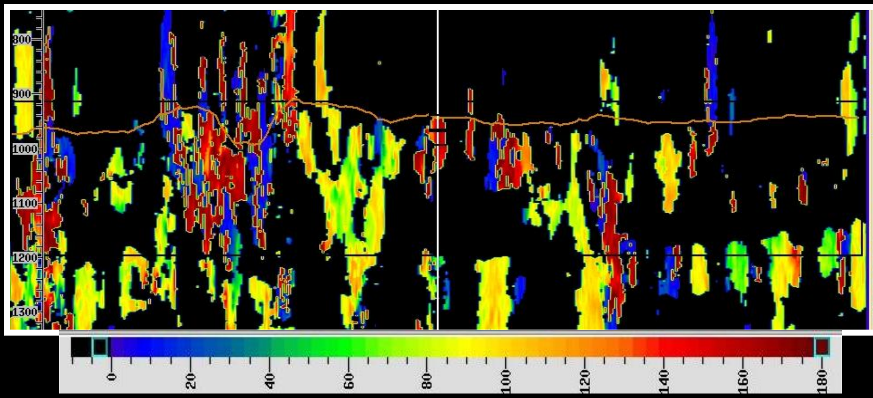
Better resolution velocity field

Velocity field for azimuthal NMO correction

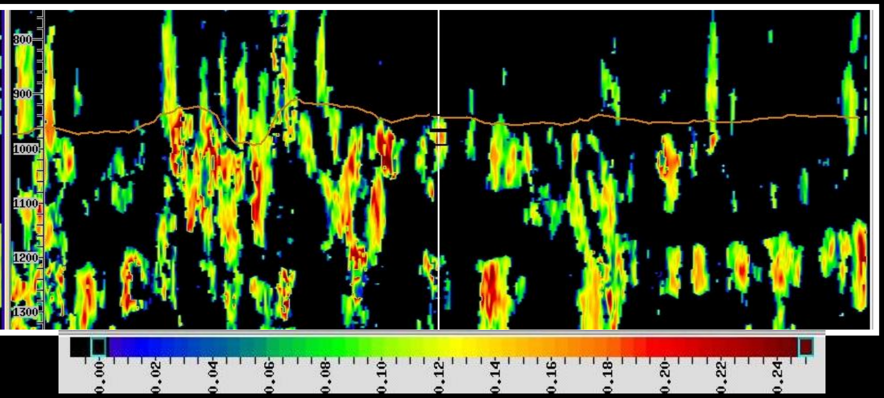
Elliptical Inversion

Inline

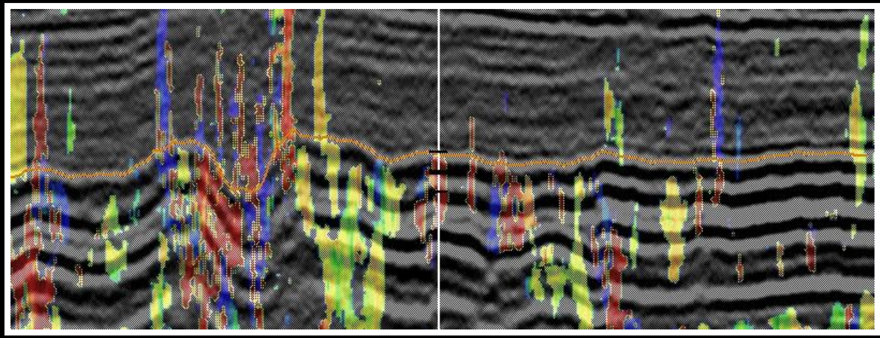
Azimuth (degrees)



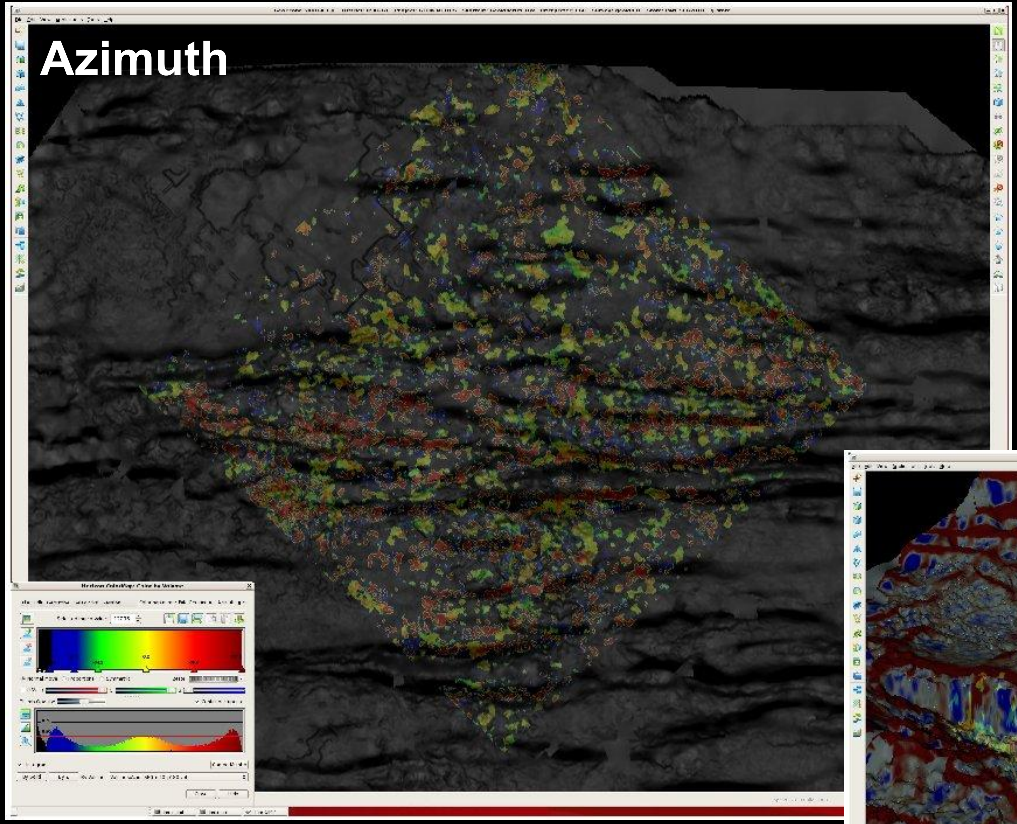
Anisotropy



Azimuth co-rendered with Stack



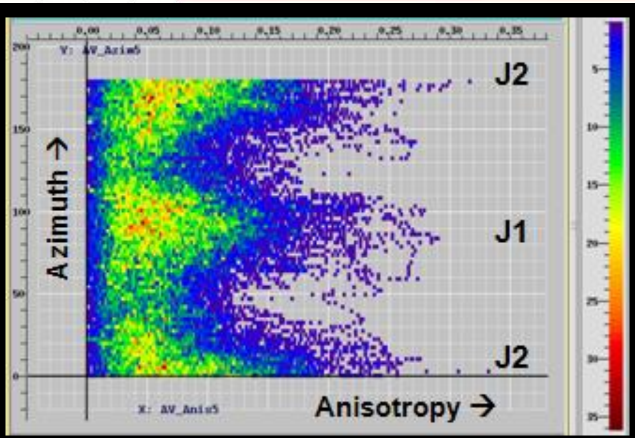
Co-rendered Azimuth/Anisotropy - Positive Curvature

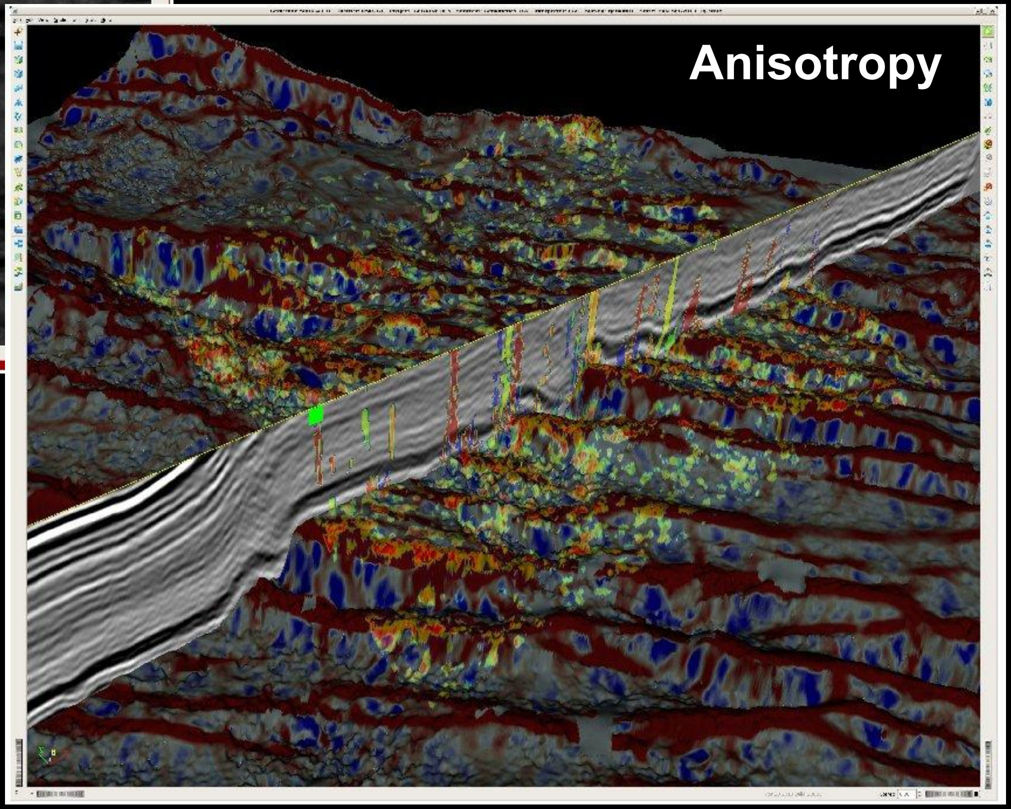


J1 – “Maintains ENE orientation regardless of location relative to the oroclinal bends”

J2 - “In the Valley and Ridge, J2 is found normal to fold axes…”

Engelder, T. “Structural geology of the Marcellus and other Devonian gas shales”





Anisotropic/Rock Property Attributes

Anisotropy

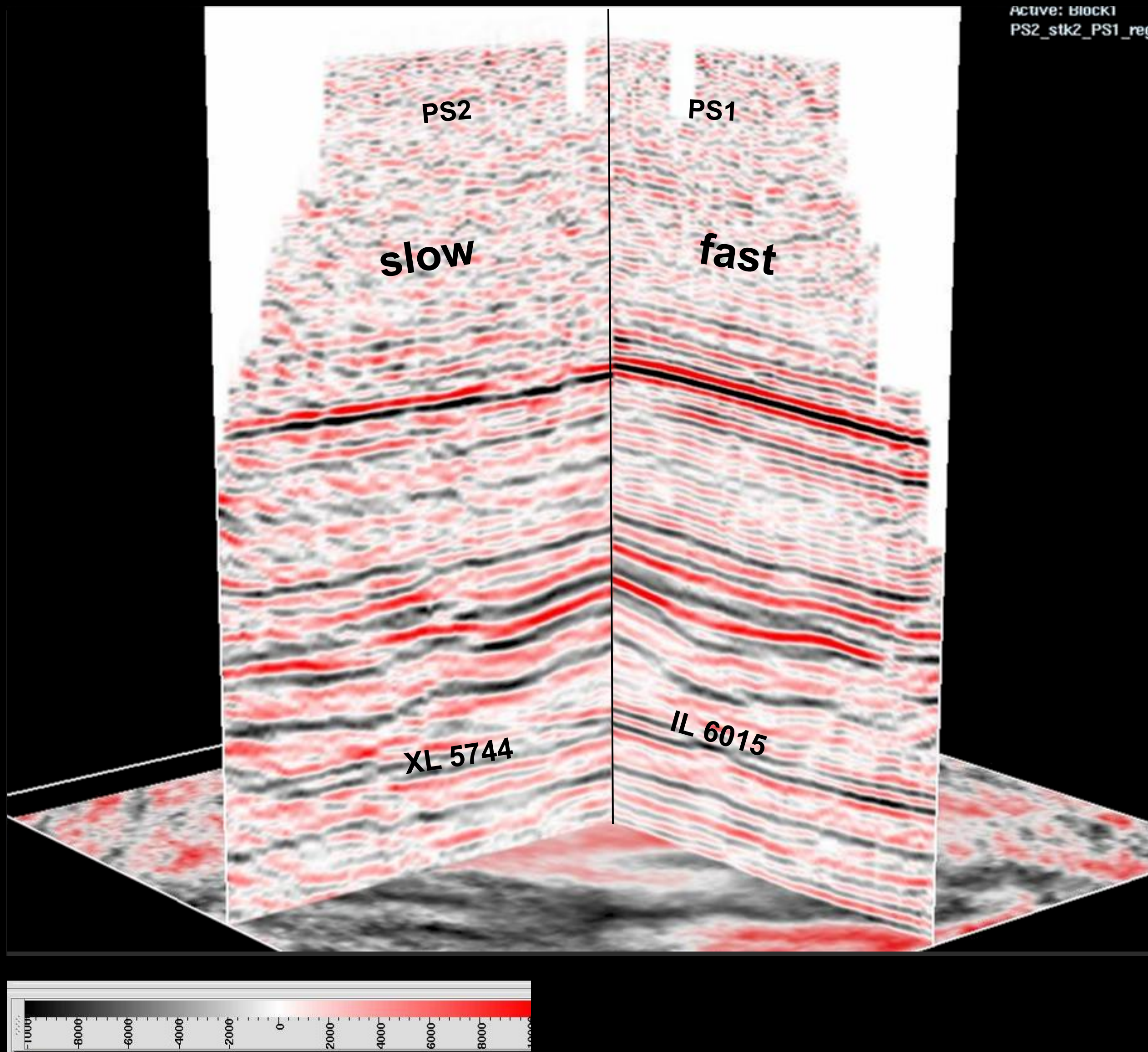
1. Elliptical Inversion using P-wave Interval Velocities

2. Time differentials from Shear waves (3 comp)

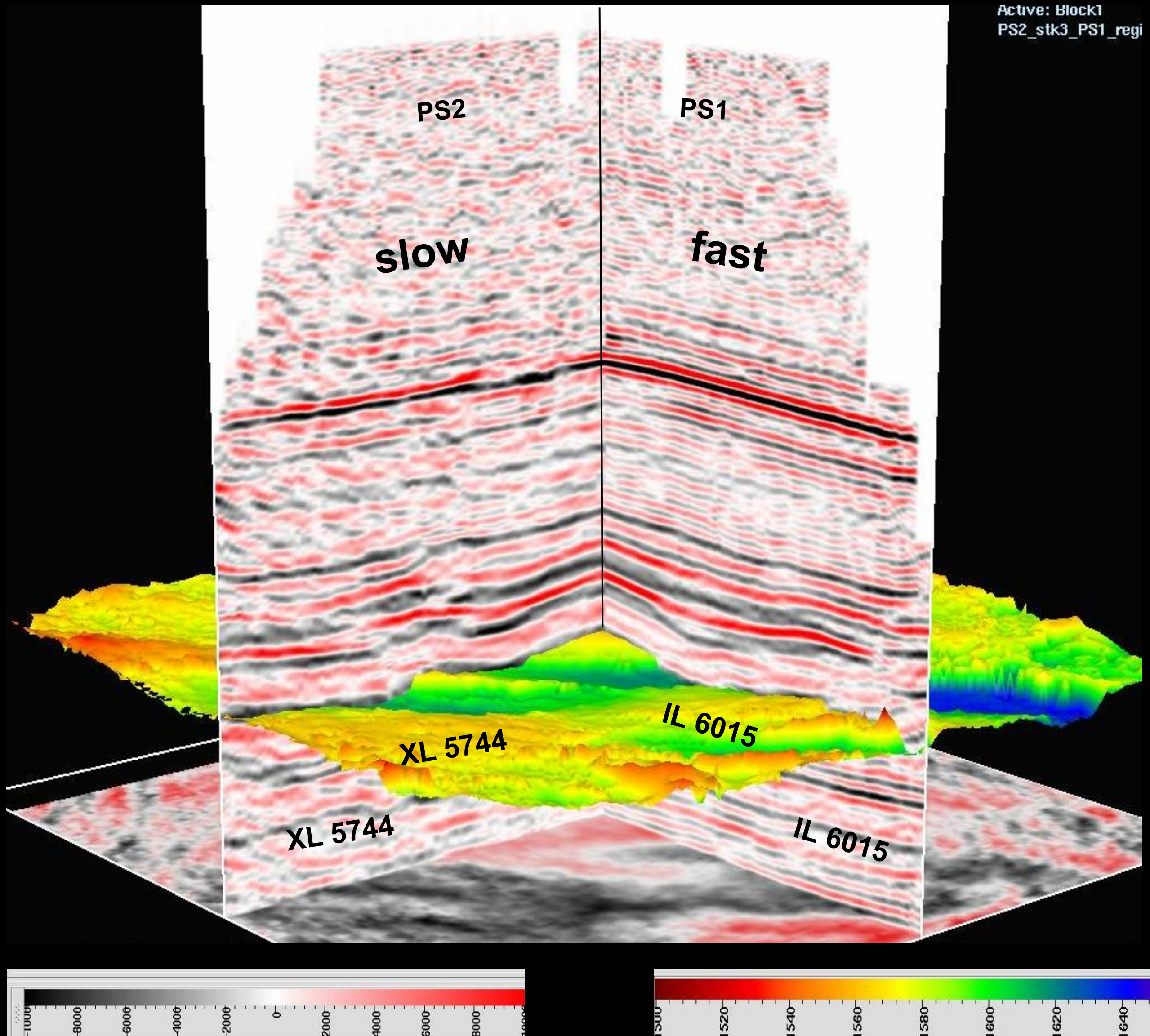
Rock Properties

1. Lambda*Rho Mu *Rho

PS2 to PS1 Registration



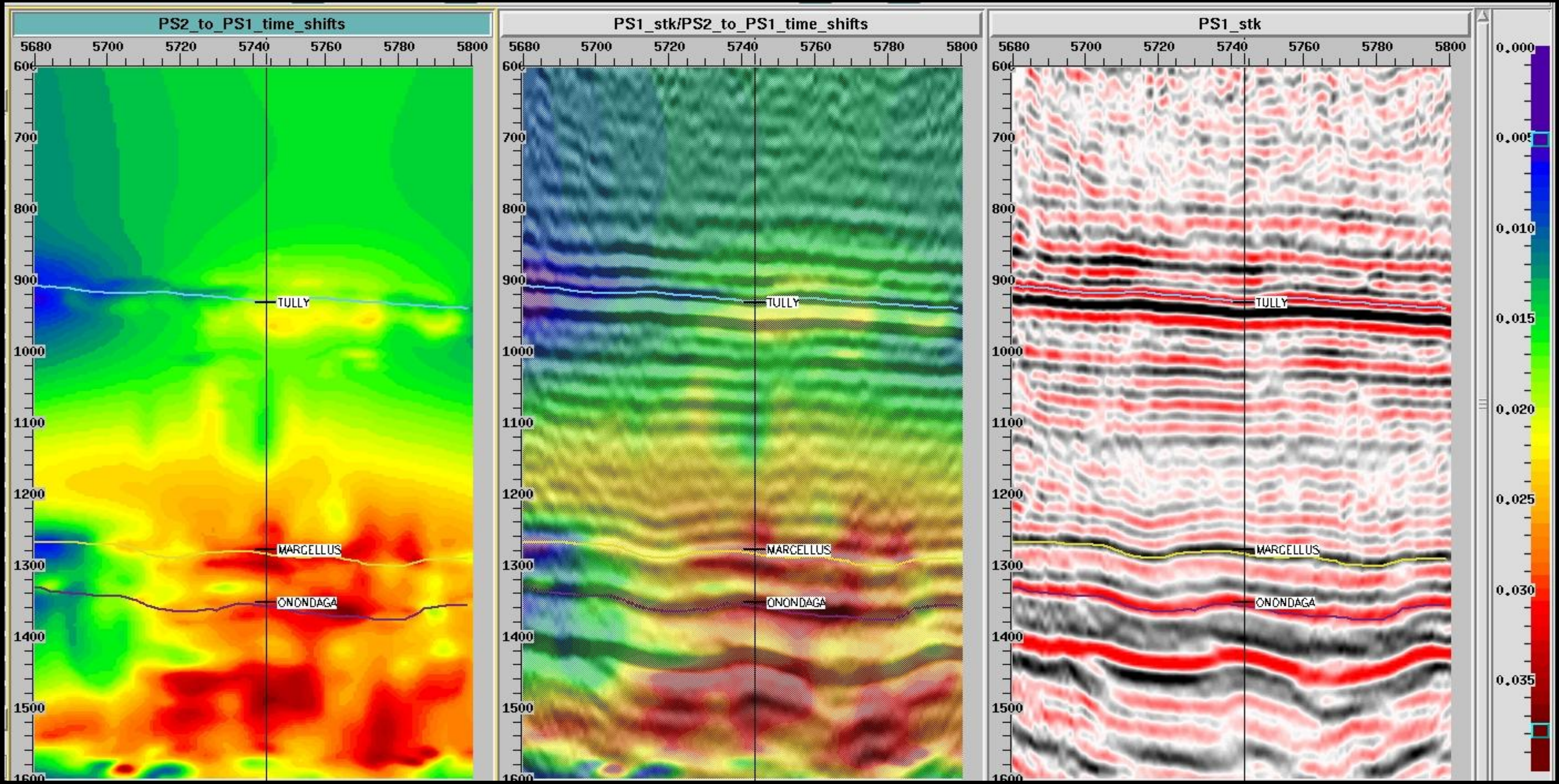
PS2 to PS1 Registration



Time to Top Salt

PS2 to PS1 Registration

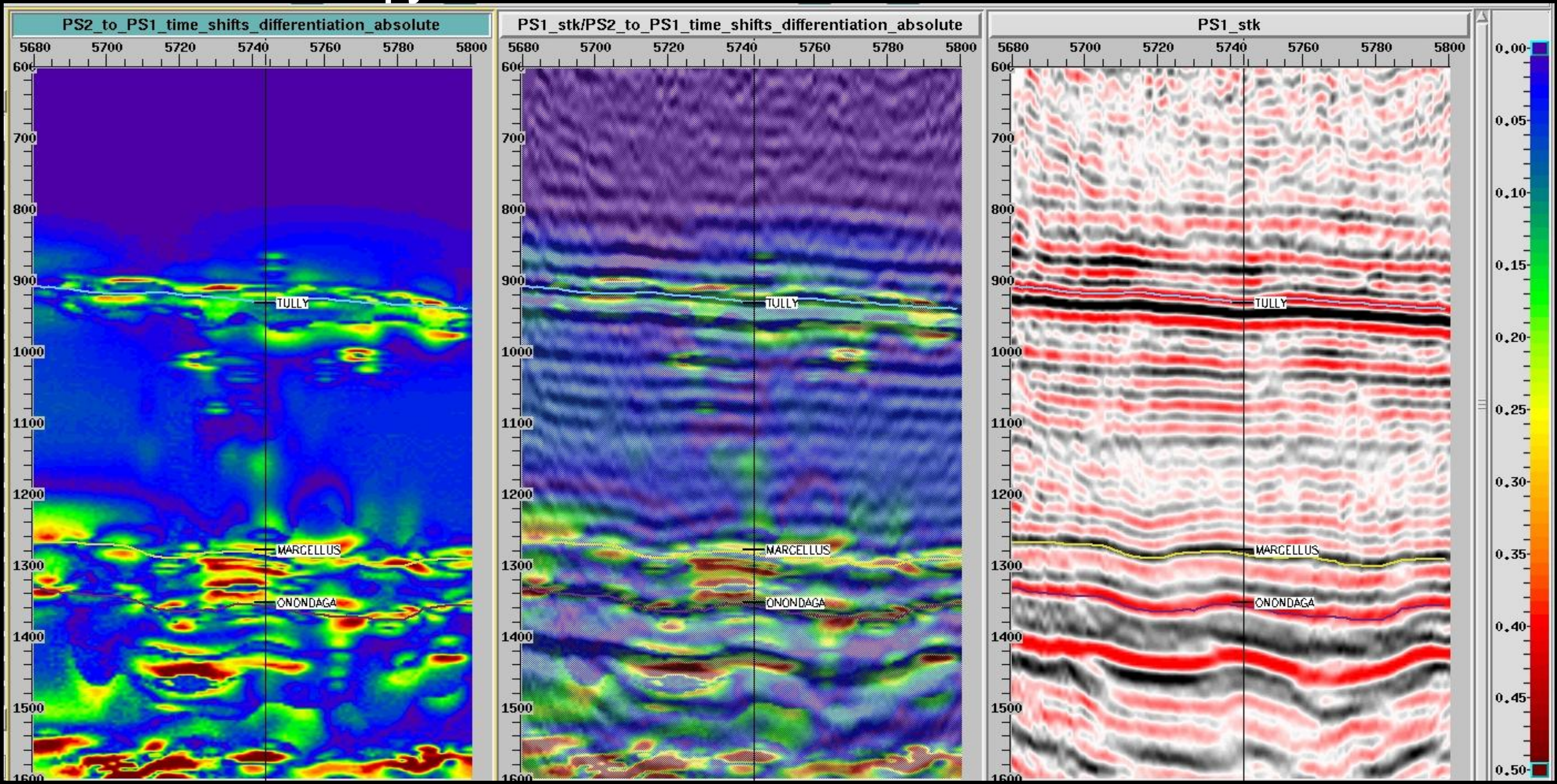
Cumulative Time Differences **PS1 Stack**



PS2 to PS1 Registration

Absolute Interval Anisotropy

PS1 Stack



Anisotropic/Rock Property Attributes

Anisotropy

1. Elliptical Inversion using P-wave Interval Velocities

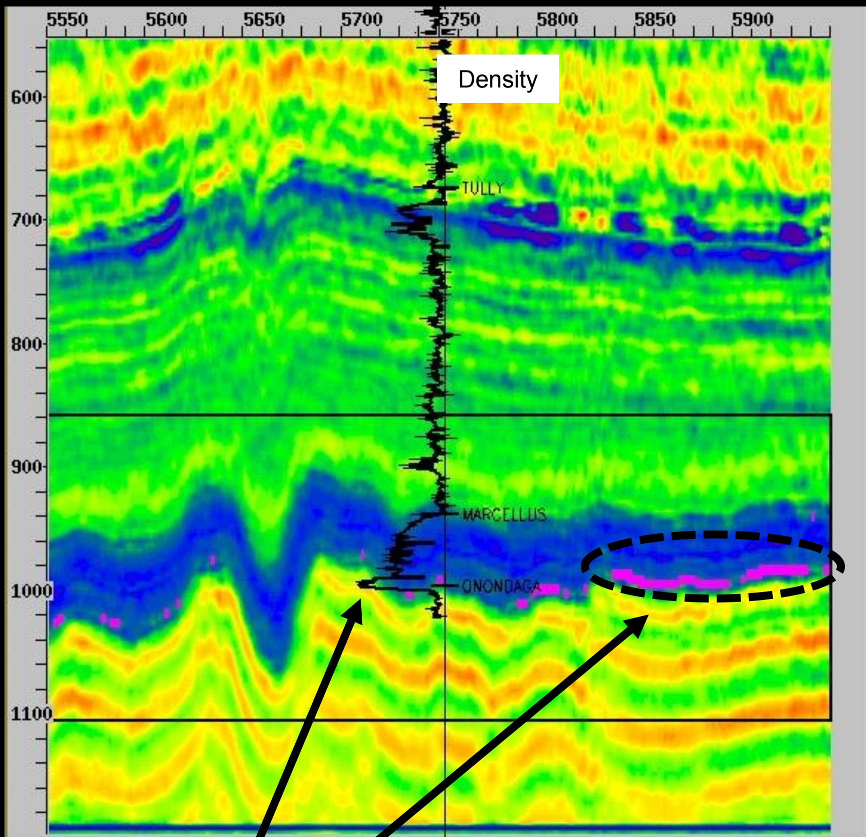
2. Time differentials from Shear waves (3 comp)

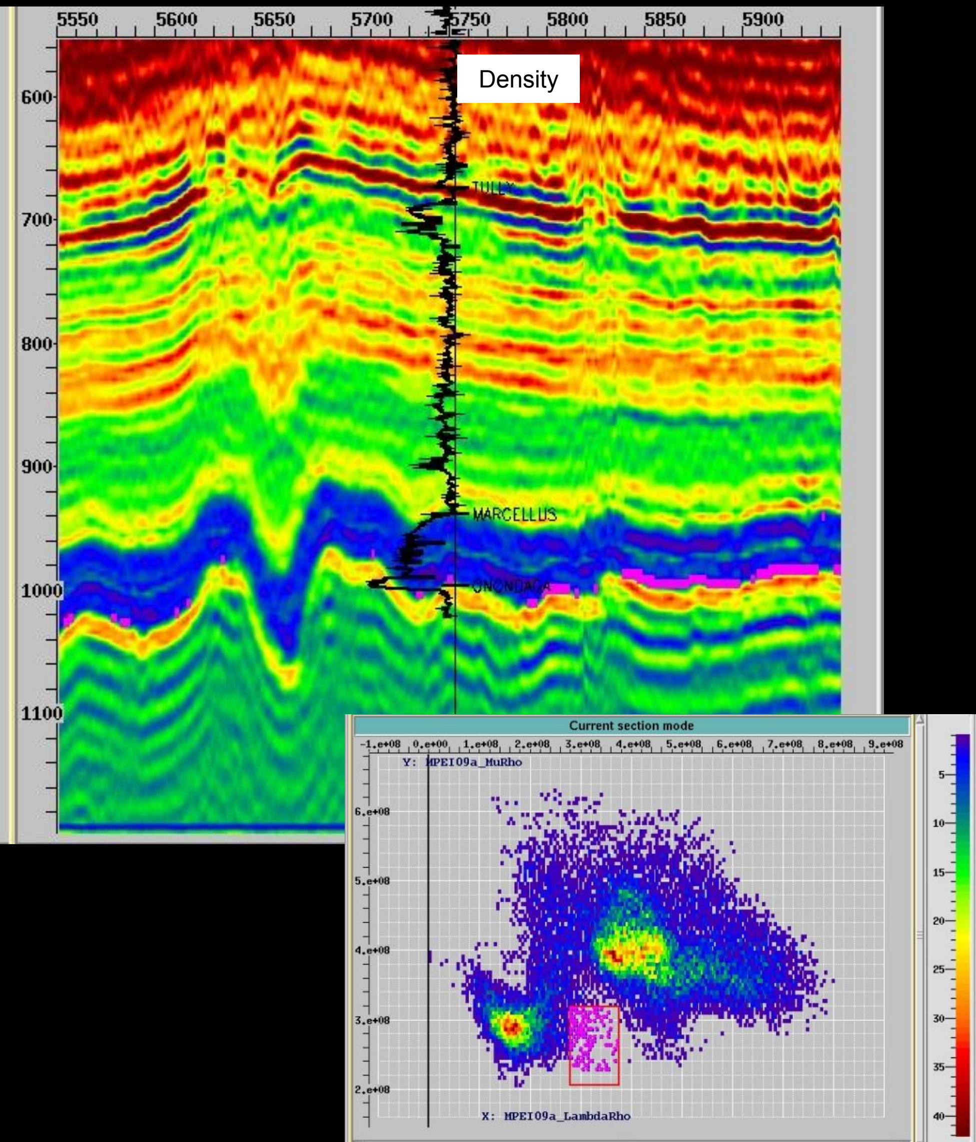
Rock Properties

1. Lambda*Rho Mu *Rho

Cross-plot from Seismic

Lambda*Rho (λρ) **Mu*Rho (μρ)**





Low density ~ high TOC

Conclusions

3D seismic data *will* contribute significantly to the understanding of the Marcellus

Geophysical analysis/evaluation, although in the early stages, looks very *promising* for optimizing well locations

The Marcellus Shale Revealed with Full Azimuth 3D Multi-Component Seismic Data

Acknowledgements

AAPG

THANK YOU

Geokinetics

GEOPHYSICAL PURSUIT, INC.

Jim Gaiser

Alvaro Chaveste

Richard Vern

Martin Stupel