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


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

500Tcf
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

Bradford County

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

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

Elevations from Acquisition

20 miles

30 miles

Anisotropy study

3D/3C
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

![Diagram of stratigraphic columns and rock units](image)
Inline & Crossline

- Tully
- Marcellus
- Onondaga
- Syracuse Salt
Marcellus Shale Vertical Resolution

- Sonic
- CHERRY VALLEY
- Marcellus shale
  - 4388'
  - 4496'
  - 6076'
  - 6228'
  - 6249'
  - 6382'

- Lower Marcellus
- Onondaga
- 152'
- 28'
- 133'

Graph showing gamma ray data with depth and formation layers.
Vertical Resolution

Seismic

Thin-Bed Reflectivity re Tanner
Spatial Resolution/Geometric Attributes
J1 & J2 Fracture Sets in Marcellus
Natural gas chimneys in black shale showing cross fold $J_2$ joints
Energy Ratio

Unbiased accurate faulting

time slice
Co-rendered seismic & semblance
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

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

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. $\lambda \cdot \rho \quad \mu \cdot \rho$
PS2 to PS1 Registration
PS2 to PS1 Registration

Cumulative Time Differences

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. \( \lambda \times \rho \) \( \mu \times \rho \)
Cross-plot from Seismic

\[ \lambda \rho \] and \[ \mu \rho \]

Low density $\sim$ 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
Acknowledgements

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Alvaro Chaveste
Richard Vern

THANK YOU