Seismic attributes of the Barnett and Bakken shales

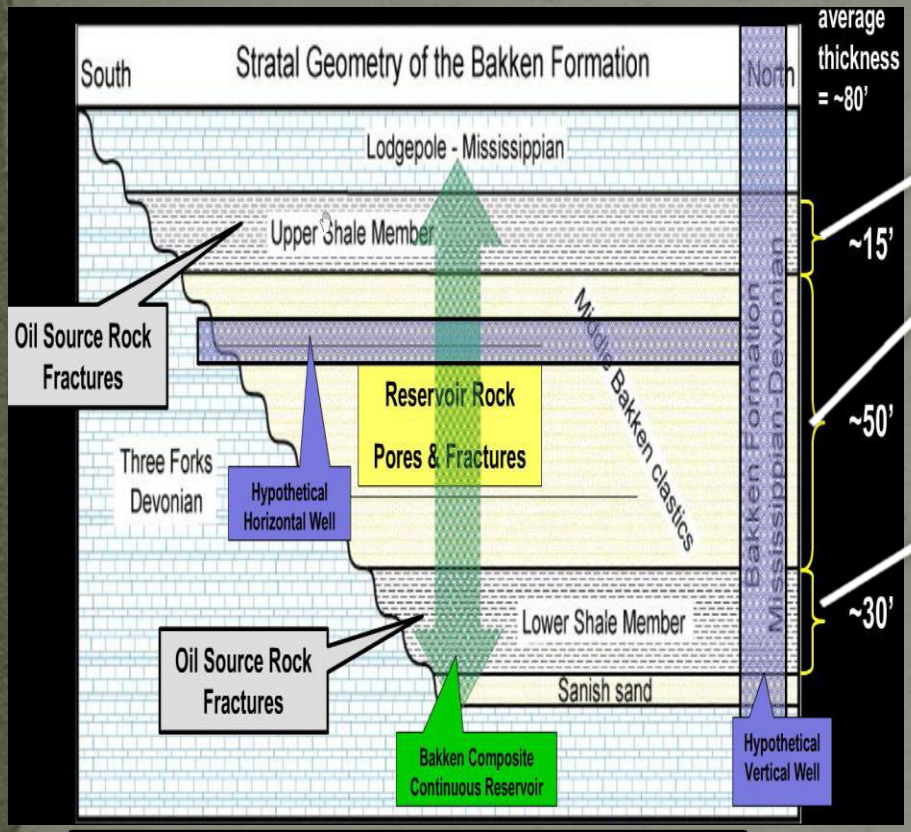
Bode Omoboya

16th May, 2013

- Introduction
- Bakken Shale Case Study
- Barnett Shale Case Study
- Other Forward Modeling Projects

Allied Geophysical Laboratories
UNIVERSITY of HOUSTON

Bakken Shale Quick Facts

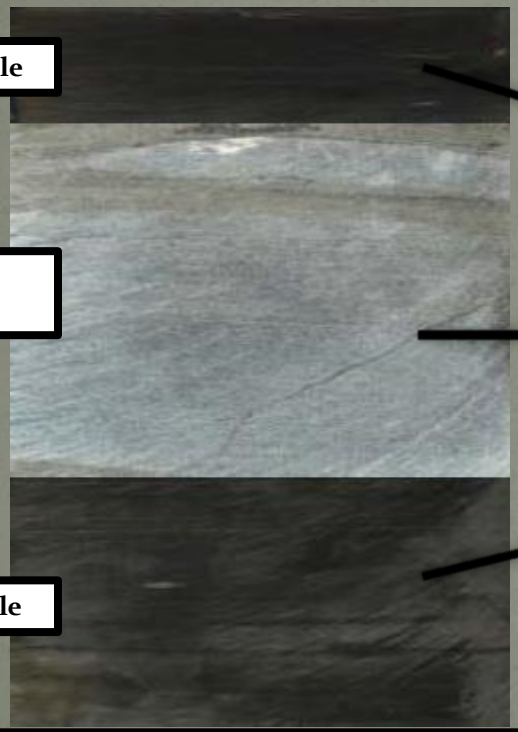


Geologic Age	Upper Devonian /Lower Miss
Lithology (Middle Member)	Sandstone /Siltstone /Dolomite
Total Area (sq mi)	200000
Total Gas (tcf)	945
Producable Gas (tcf)	20
Depth (feet)	10000
Thickness (feet)	150
Pressure (psi)	5600
Porosity (%)	5
Matrix Permeability (nD)	10000
Pressure Gradient (psi/ft)	0.5
Clay Content (Middle Member %)	5
Average Horz Well Cost ($M)	5.5

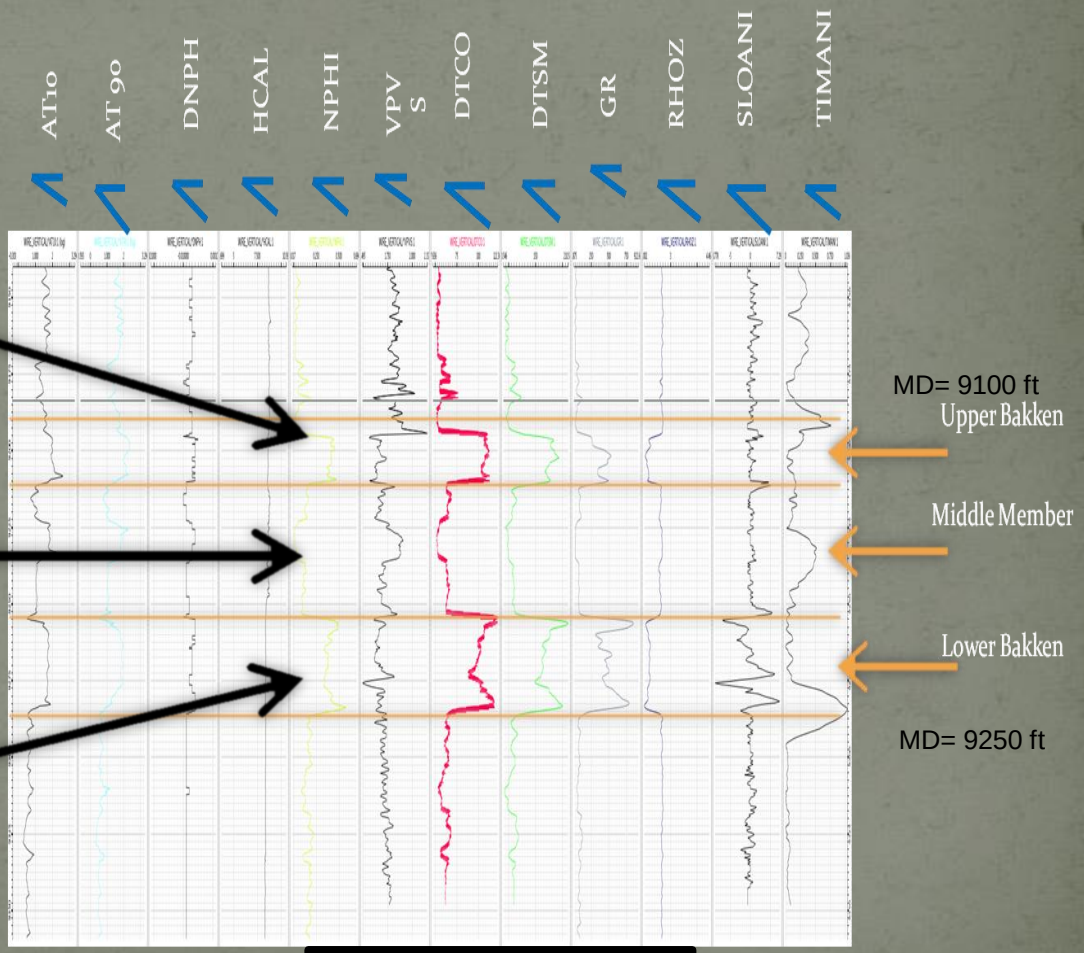
Most oil in the Bakken petroleum system resides in open fractures in the Middle Member (Pitman et al, 2001).

Source: USGS

Bakken Shale – Core Samples and Well Logs



Core Image from NDIC

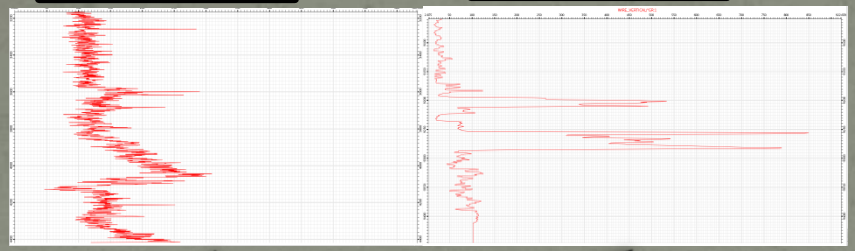


Well: NELSON

Bakken Shale – Shale Volume

1000 ft. Interval
40% – 60% Vsh

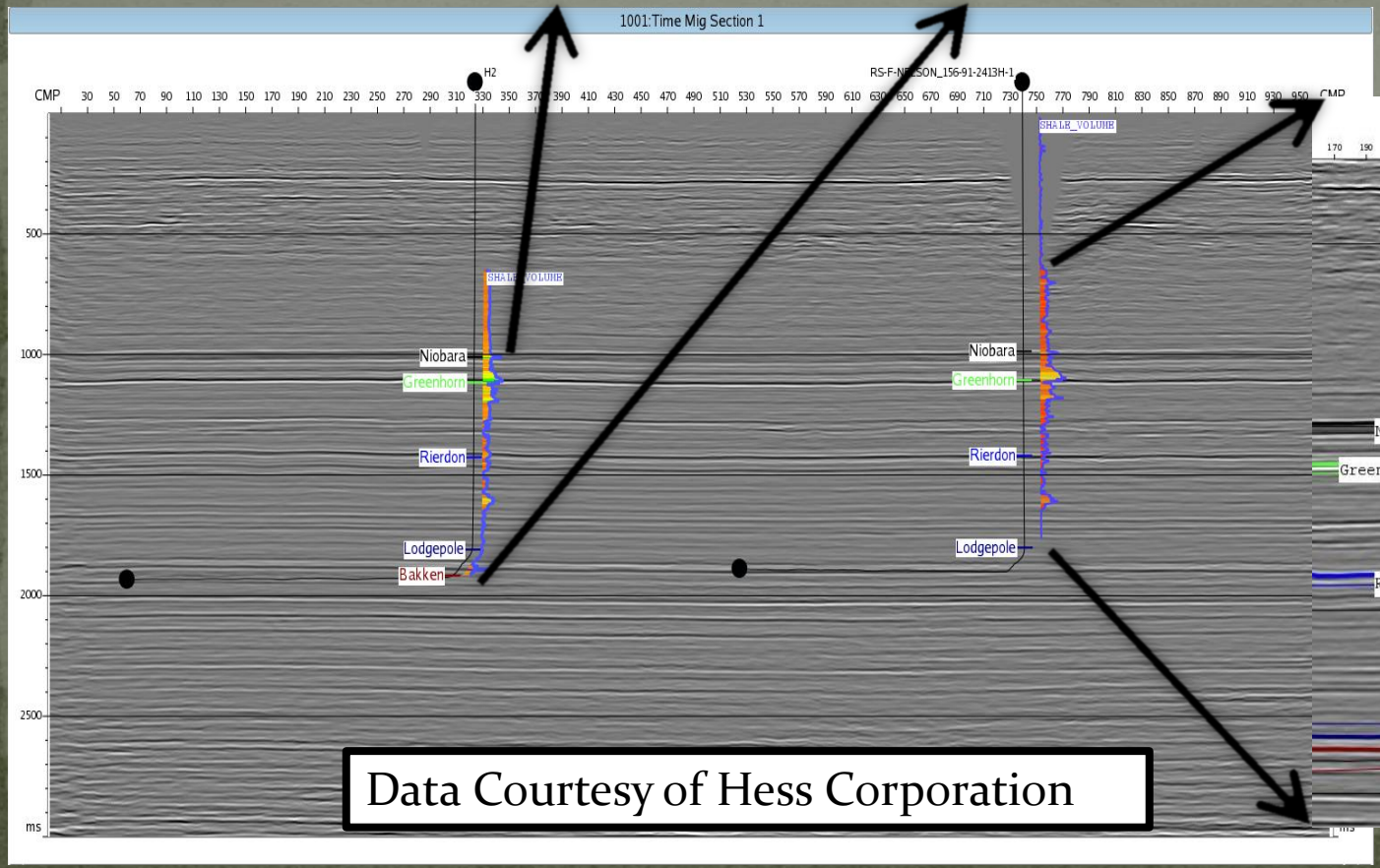
200 ft. Interval
80% Vsh

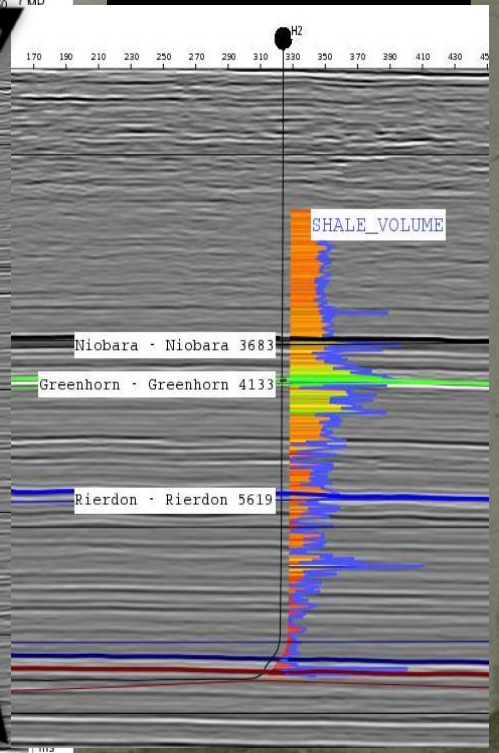


$$I_{GR} = \frac{GR_{log} - GR_{min}}{GR_{max} - GR_{min}}$$

Steiber, 1970

$$V_{sh} = \frac{I_{GR}}{3 - 2I_{GR}}$$

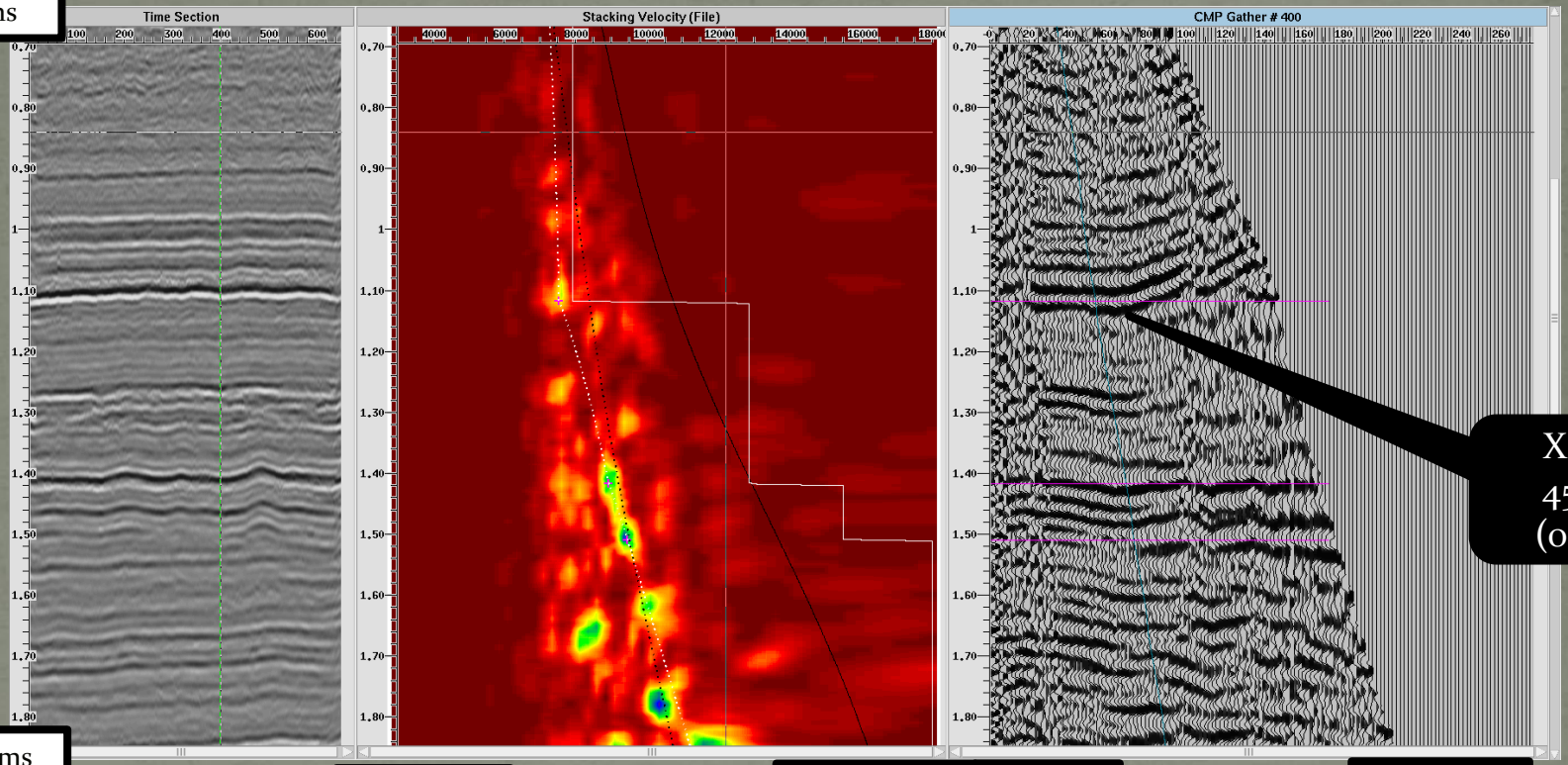




Data Courtesy of Hess Corporation

Bakken Shale – Non-Hyperbolic Moveout

t=700 ms



t=1800 ms

V=3000ft/s

V=16000ft/s

X= 0 ft

X= 15000 ft

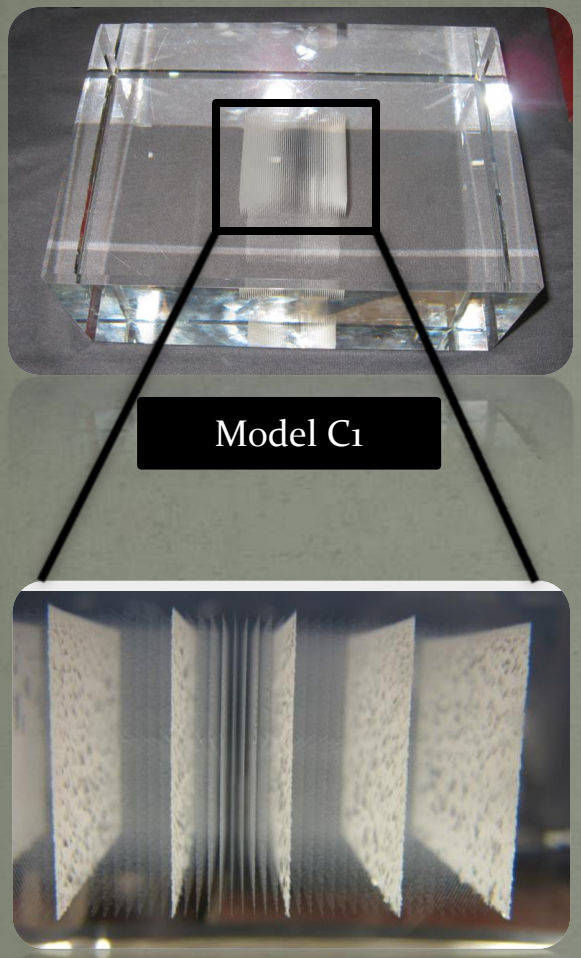
C_{11}	C_{33}	C_{44}	C_{66}	C_{13}	ε	γ	δ
343	227	54	106	107	0.255	0.481	-0.051

η from Core = 0.341

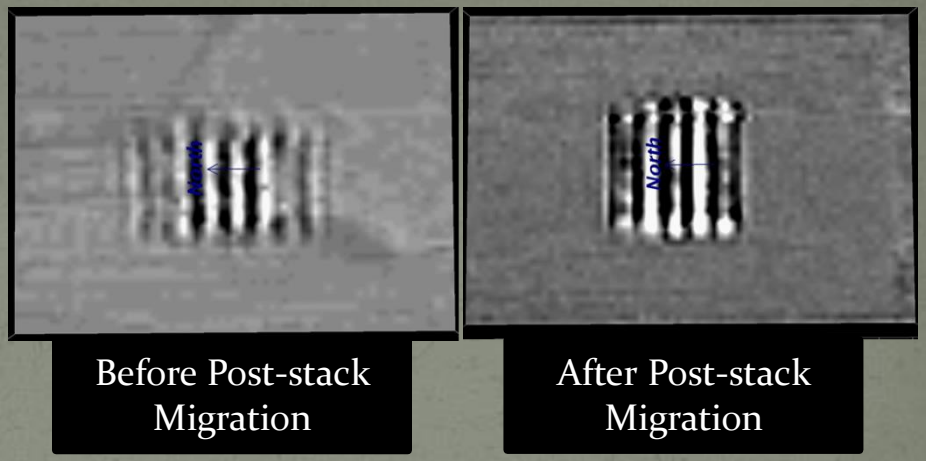
η from Seismic ≈ 0.32

Jones and Wang, 1981

Bakken Shale – Forward Modeling Project



Model C1



Before Post-stack Migration

After Post-stack Migration

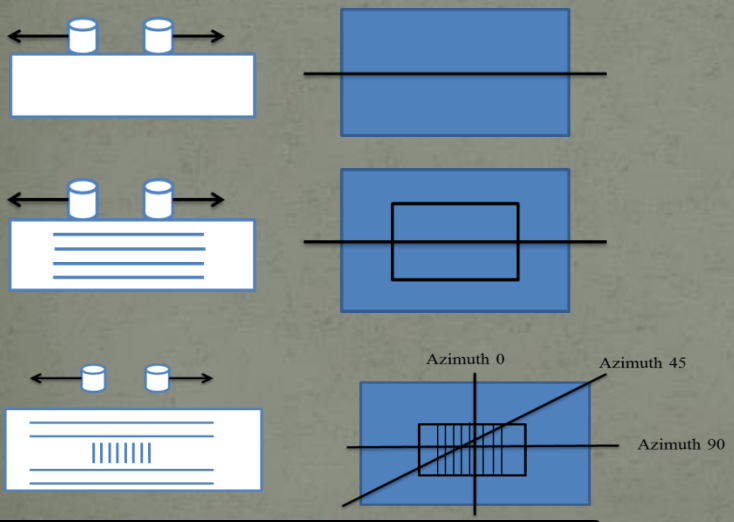
Physical modeling of anisotropic domains: Ultrasonic imaging of laser-etched fractures in glass

(Geophysics, 2013)

Robert. R. Stewart
Nikolay Dyaur
Bode Omoboya
J.J.S de Figueiredo
Mark Willis
Samik Sil

Bakken Shale – Forward Modeling Project

Minimum Offset	400m
Maximum Offset	2000m
CMP Interval	20m
Depth of Model	800m (TWT to end of model = 350ms)
Average Velocity of Model	5800m/s
Dominant Frequency/ Wavelength	120 Hz / 50m



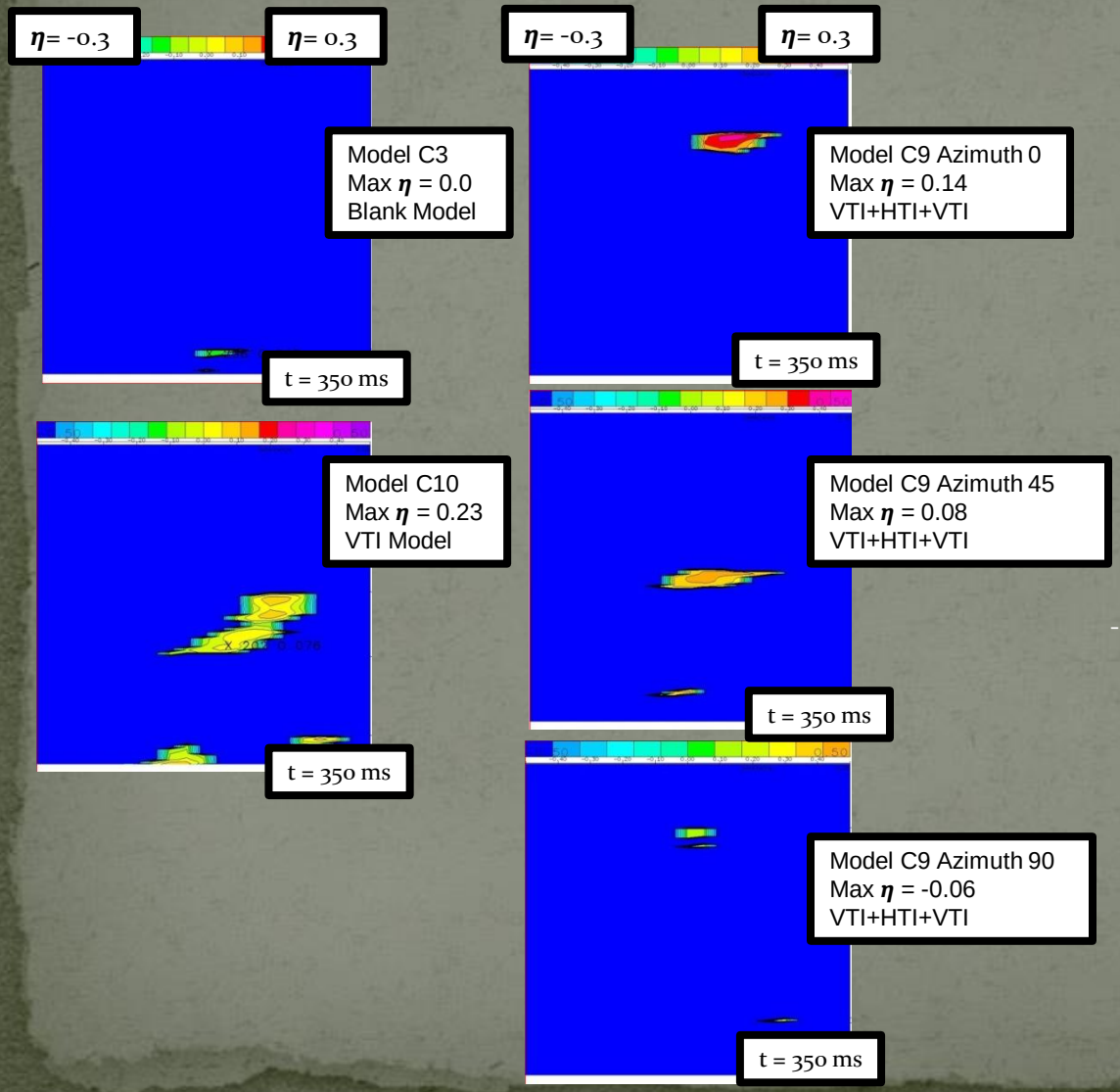
Schematic of NMO eta scan experiments on glass models

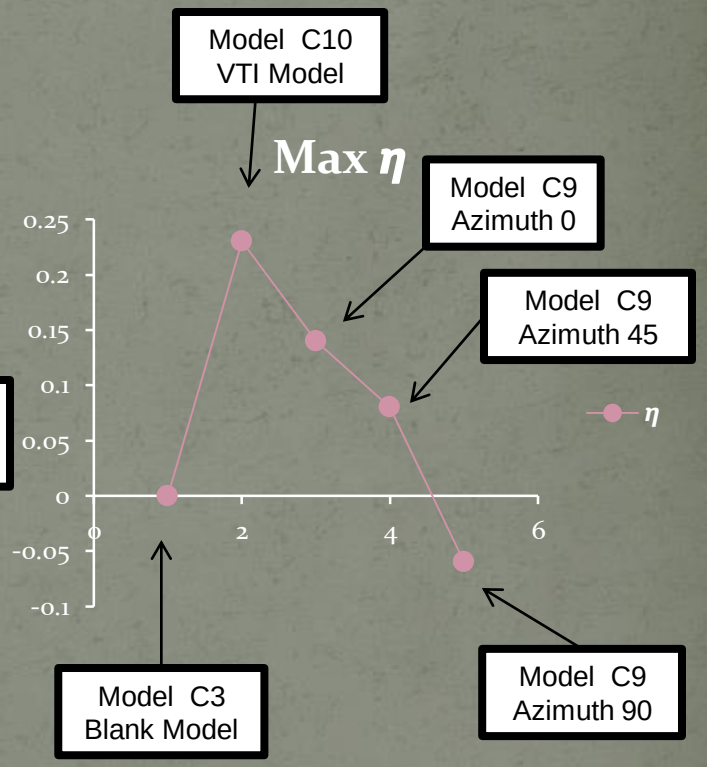
Model C3

Model C10

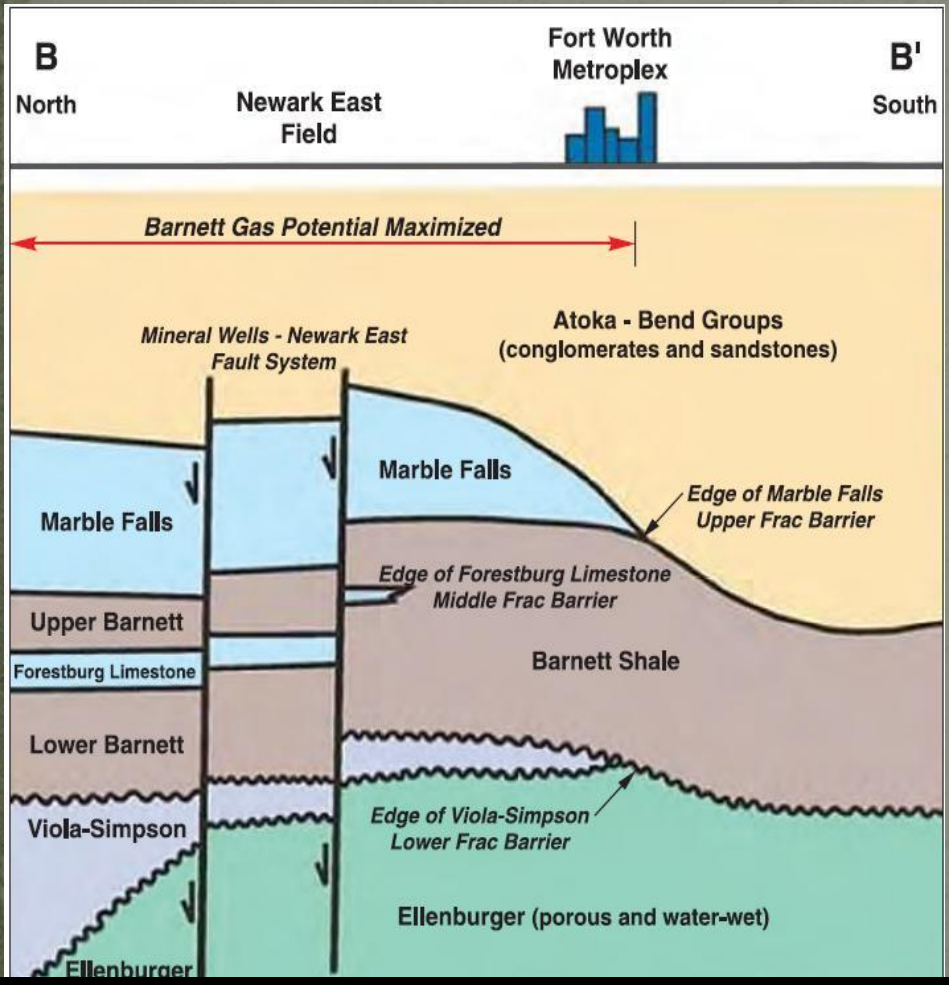
Model C9
“BAKKEN MODEL”

Bakken Shale – Forward Modeling Project





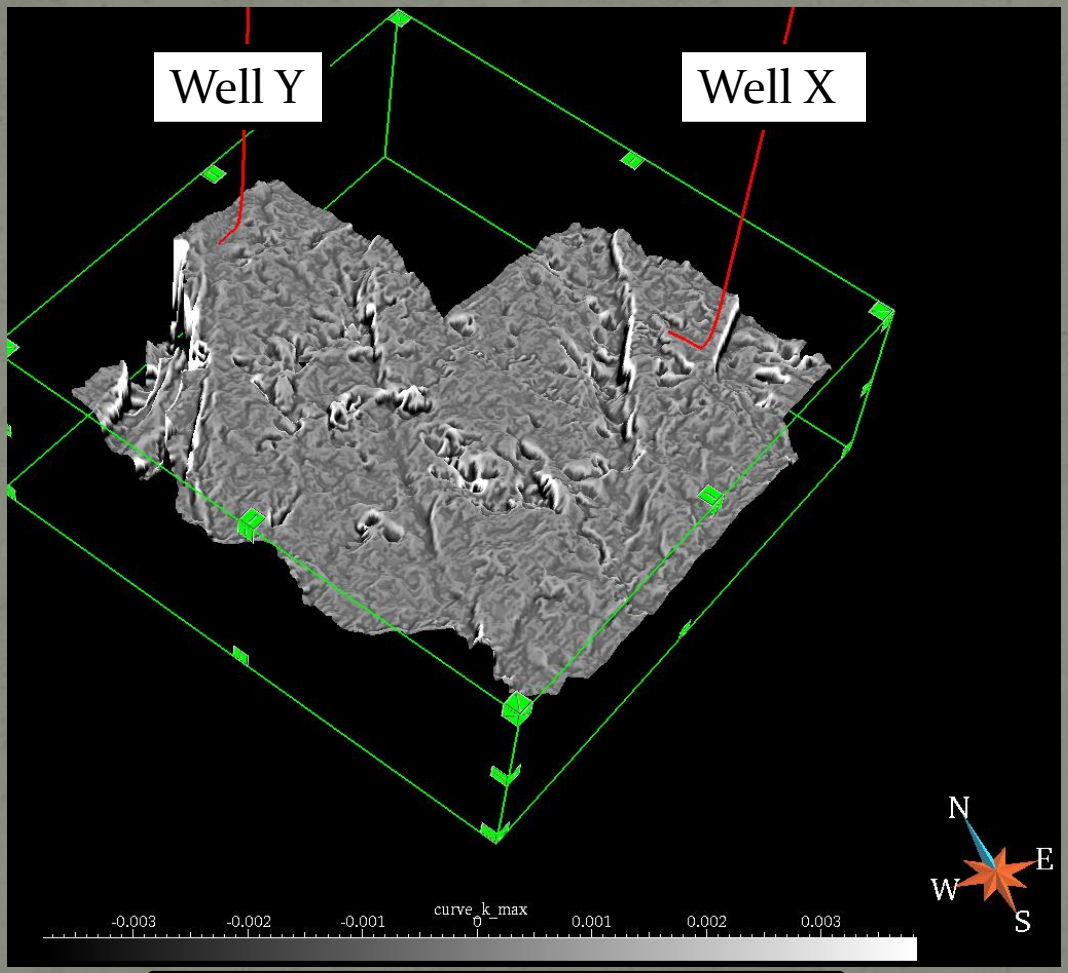
Barnett Shale Quick Facts



Geologic Age	Mississipian
Lithology	Dense Organic rich shale
Water Saturation (clay-bound)	20-30%
Gas Saturation	70-80%
Depth (feet)	4000 - 5000
Thickness (feet)	5-1000 ft
Pressure (psi)	5600
Porosity (%)	5
Natural fractures	100 to 120 deg
Natural fractures	More common in limestone interbeds
Artificial fractures	Oriented in the direction of minimal stress

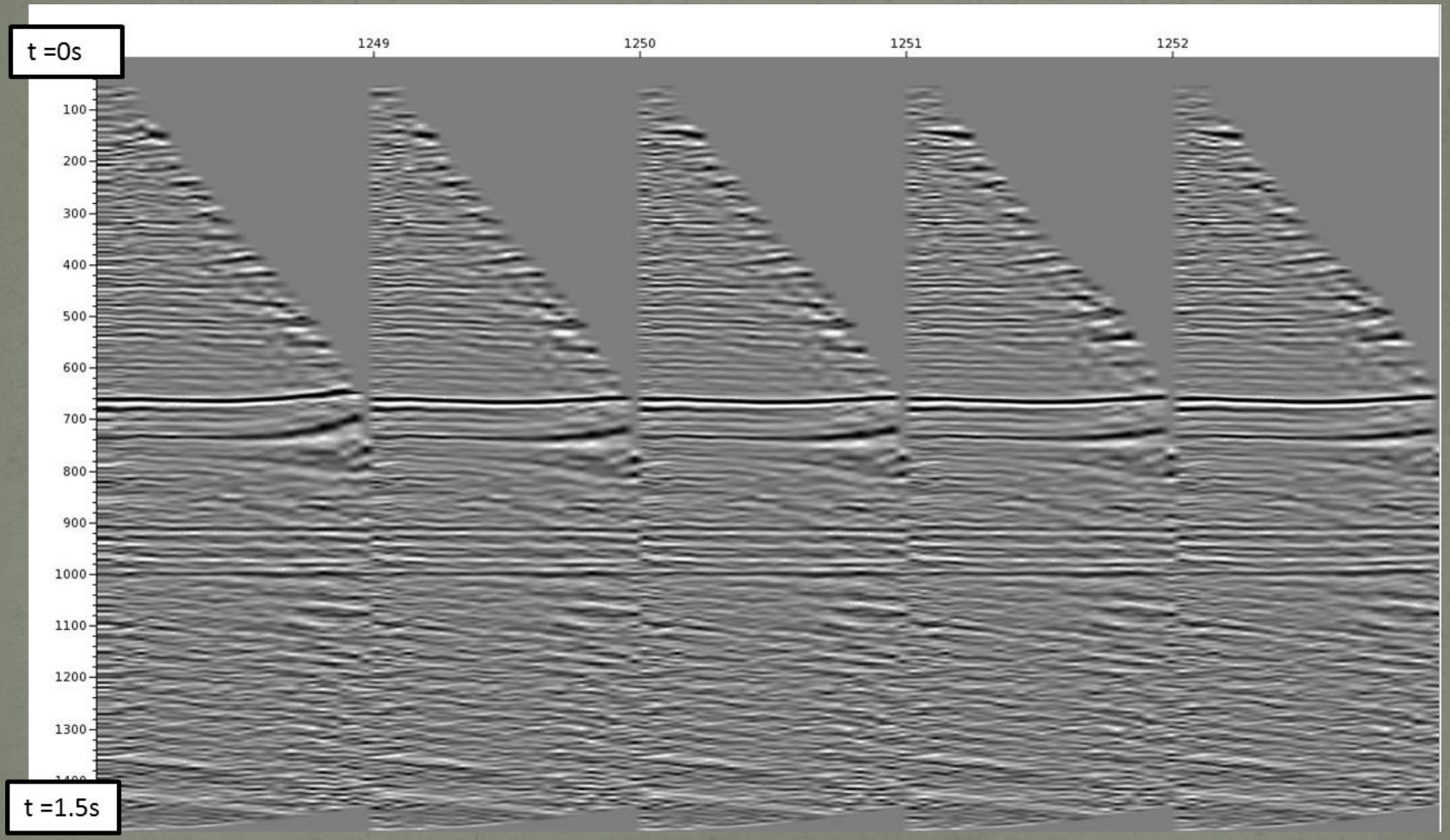
N-S structural cross section through the Newark Field in the Fort Worth Basin. Modified after Burna and Smosna, 2011

Barnett Shale – Top Ellenberger – Maximum Curvature Attribute

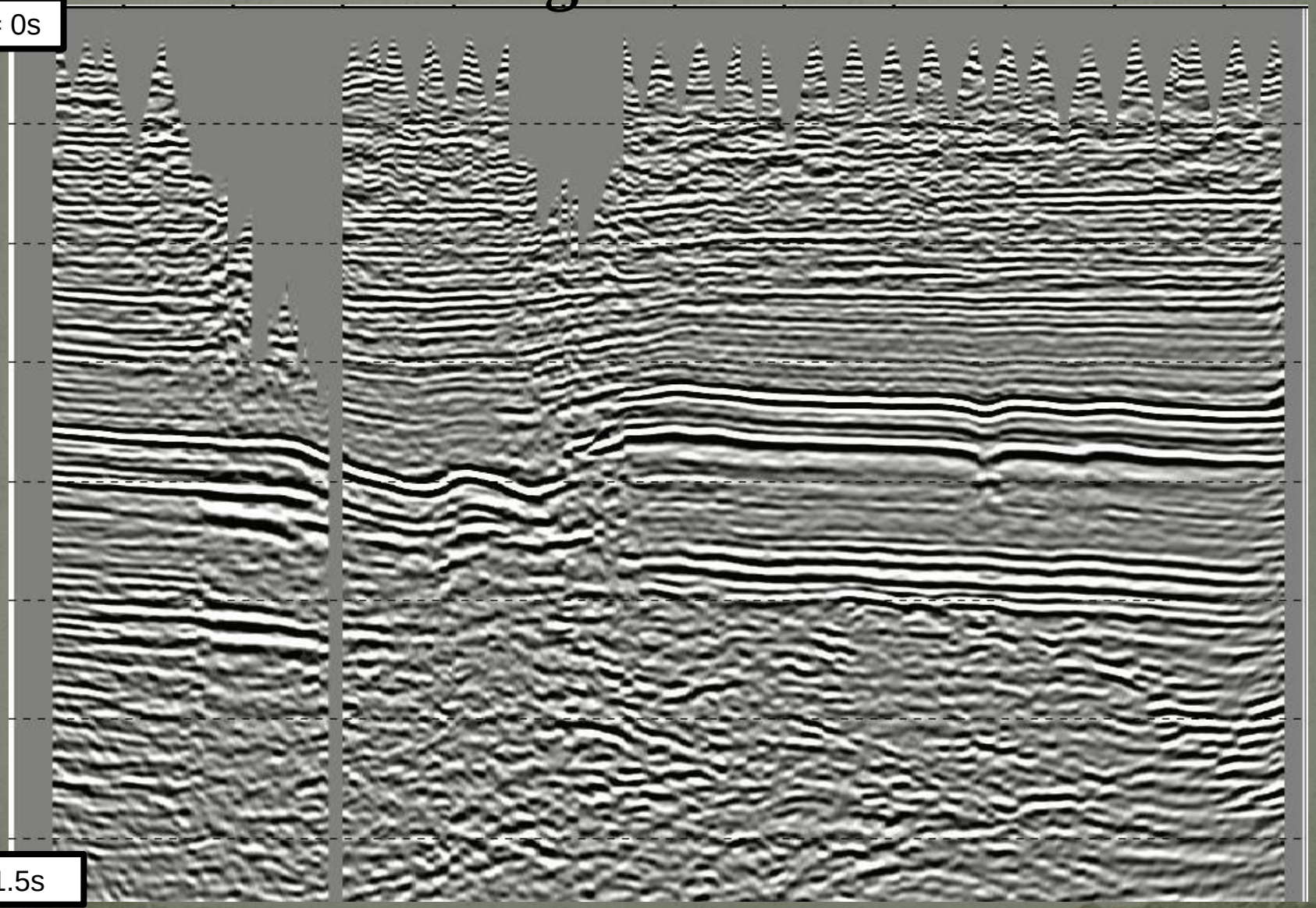


Data Courtesy of Marathon Oil

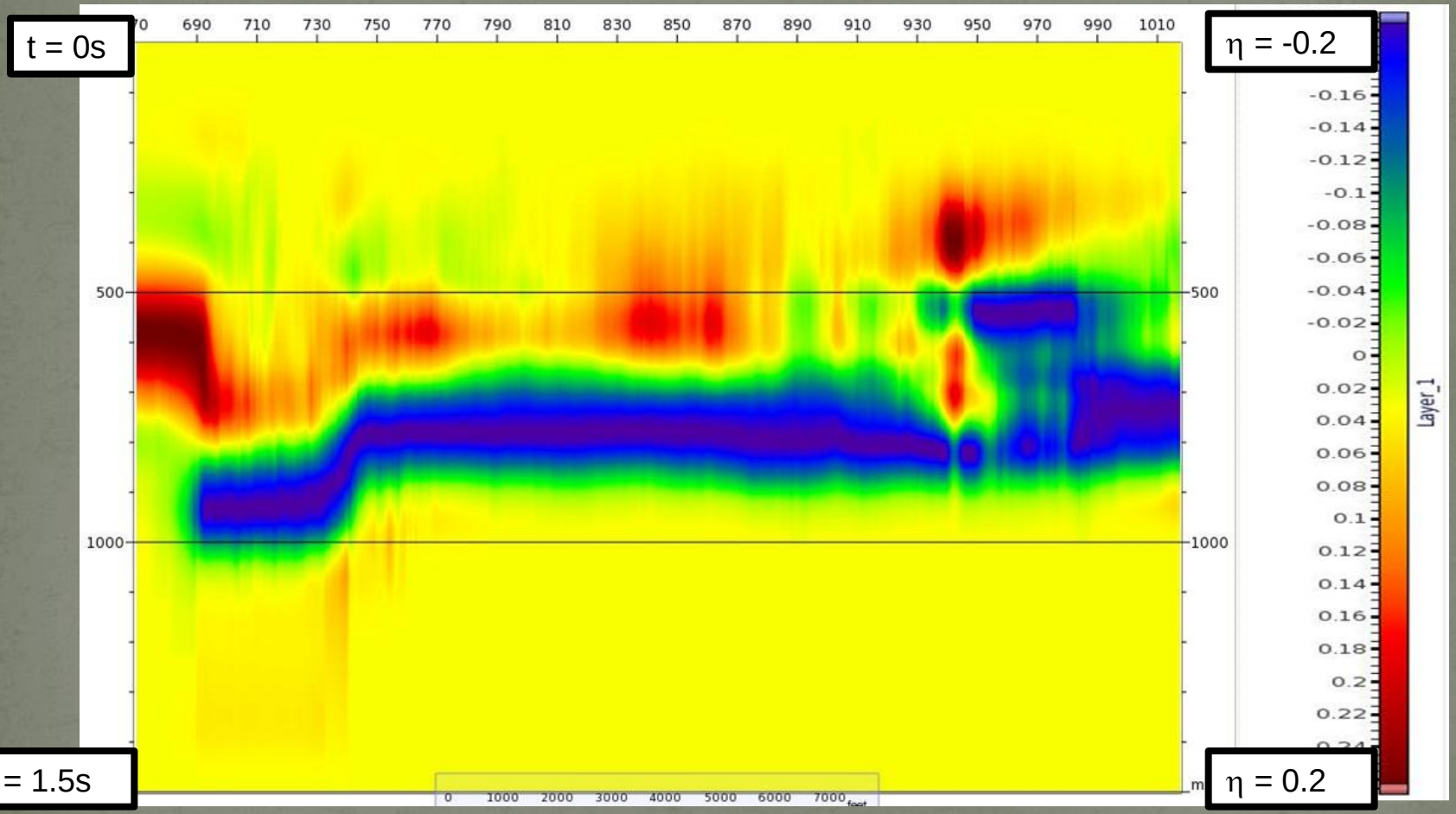
Barnett Shale – CDP Gathers after Time Processing and Migration



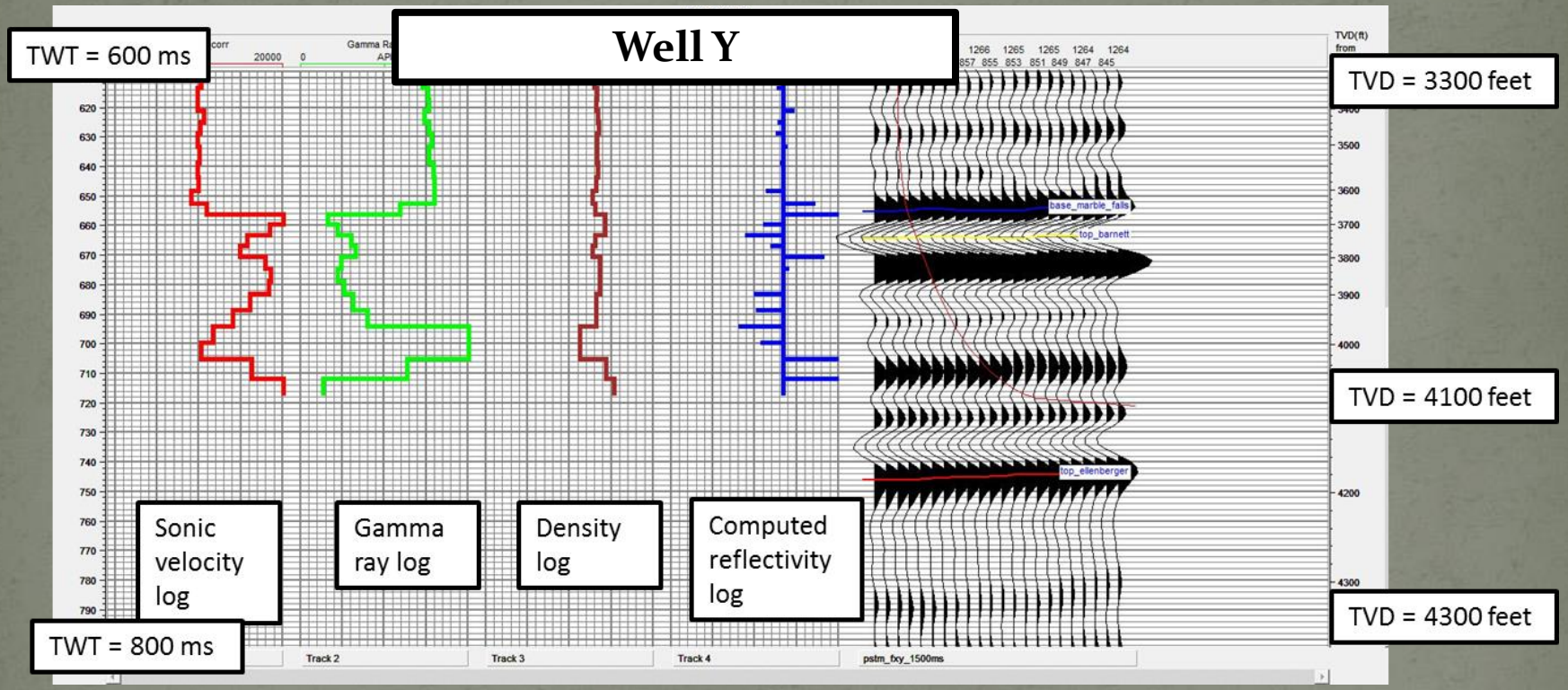
Barnett Shale – Migrated Stack + FXY Decon



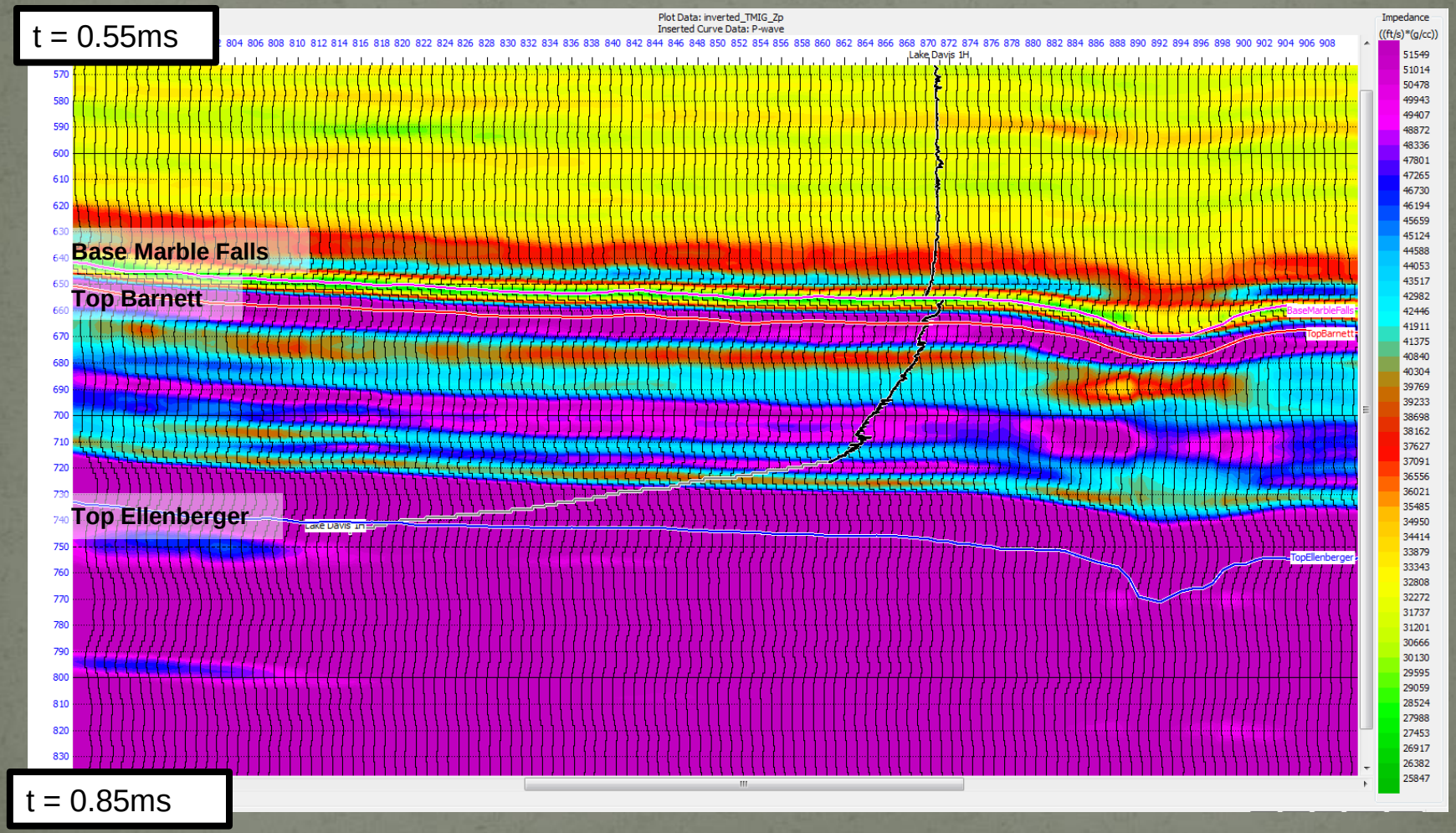
Barnett Shale – Residual eta (η) Volume



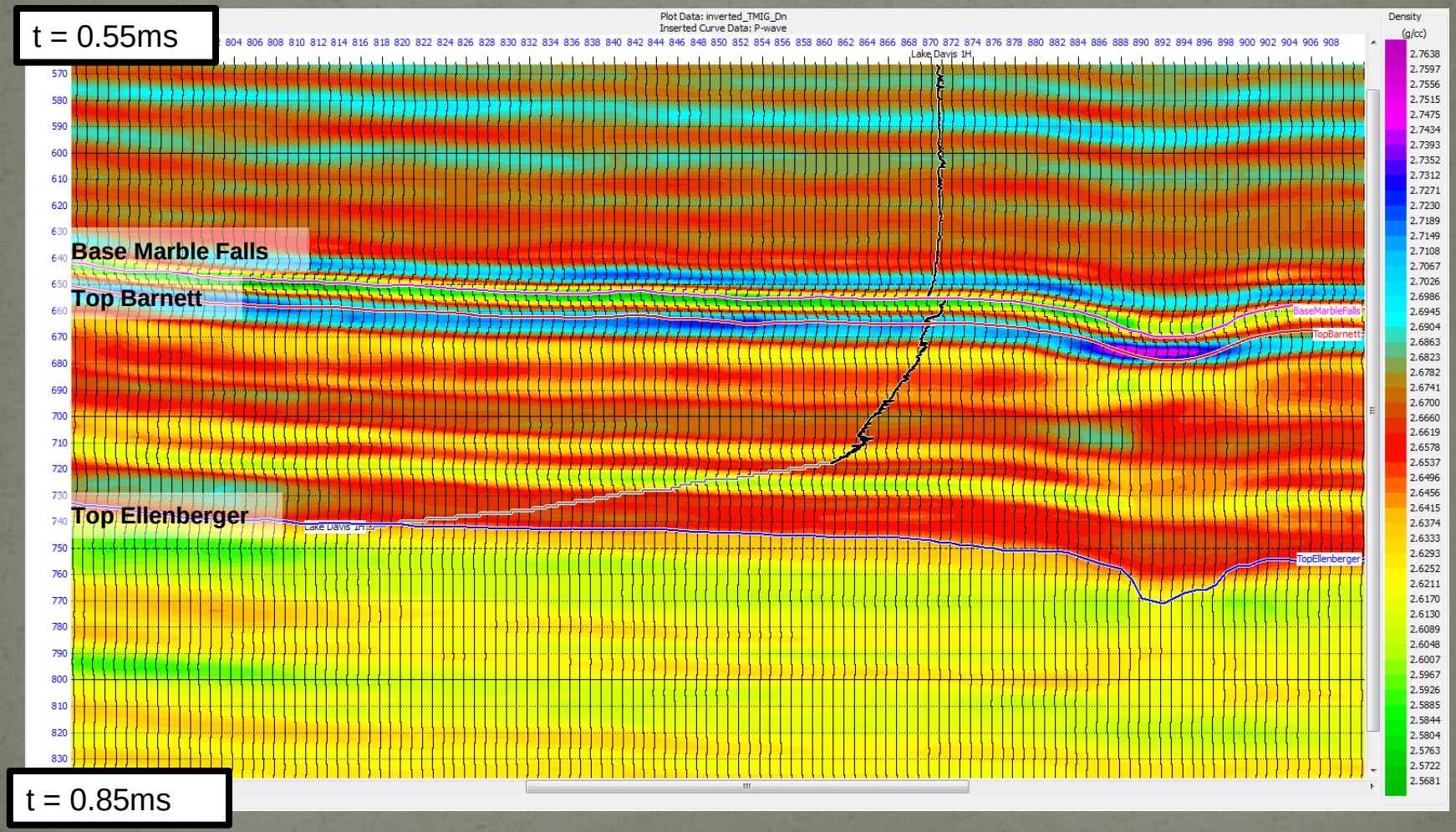
Barnett Shale – Seismic to well tie



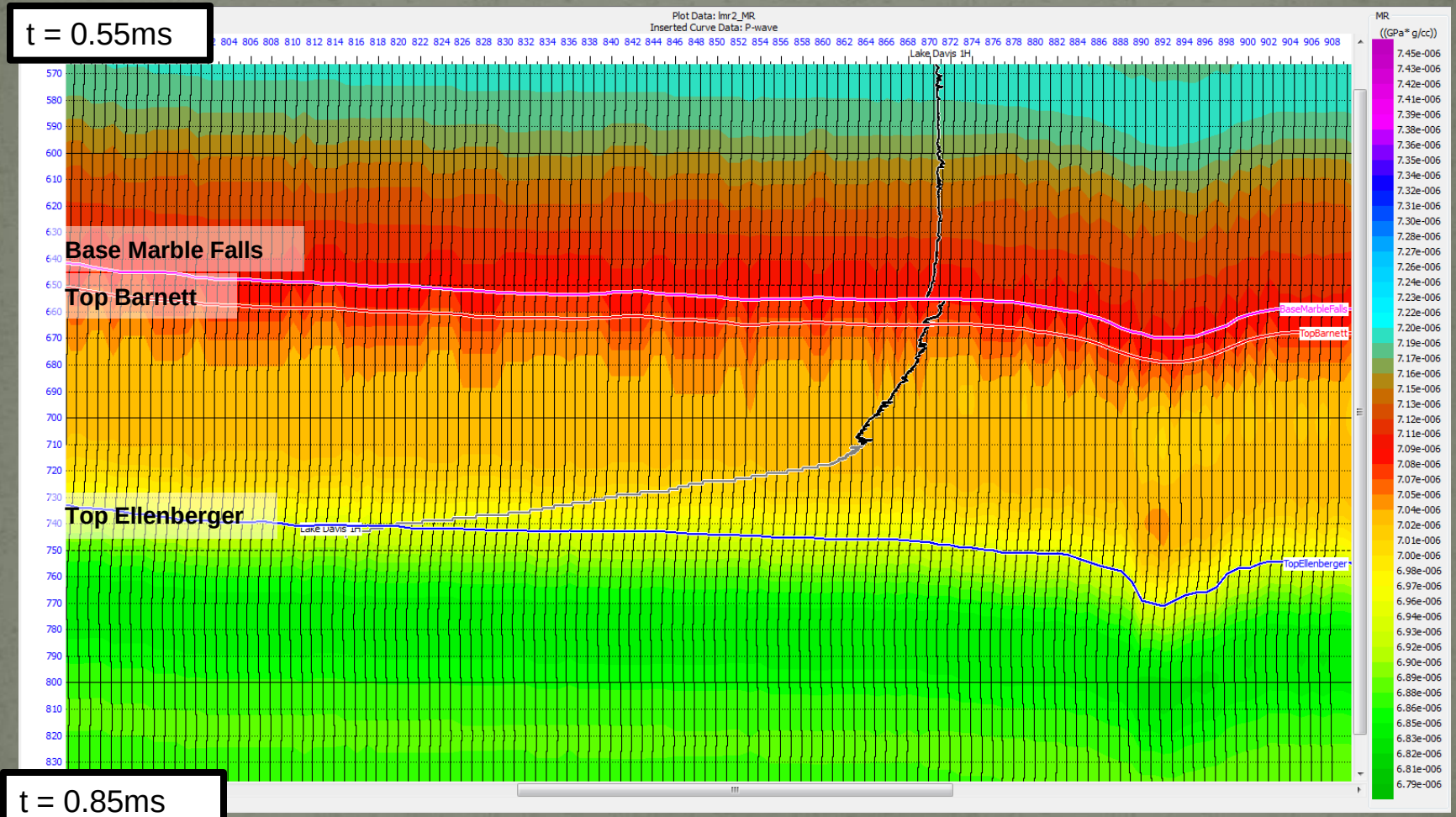
P-Impedance Volume



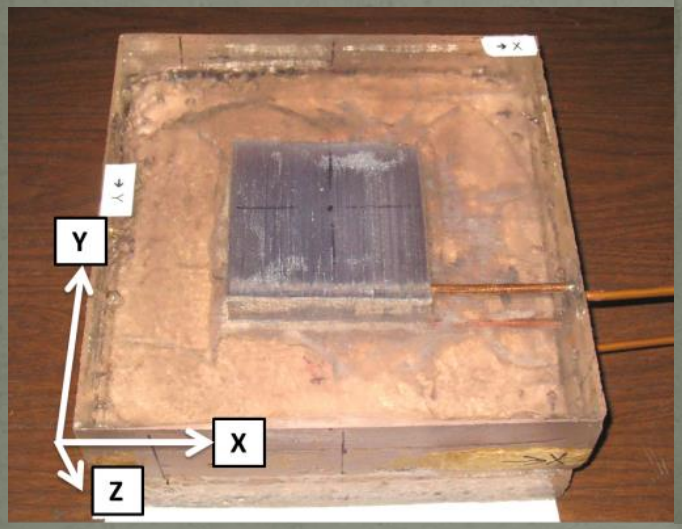
Density Volume

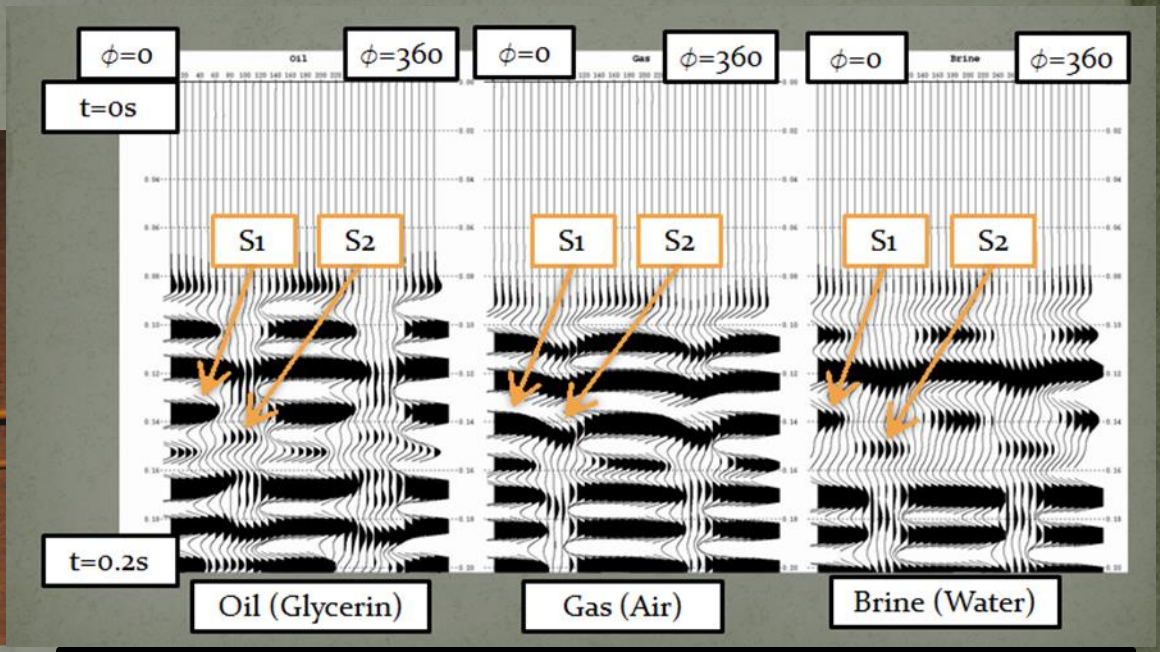


Mu-Rho Volume



Barnett Shale – Forward Modeling Project



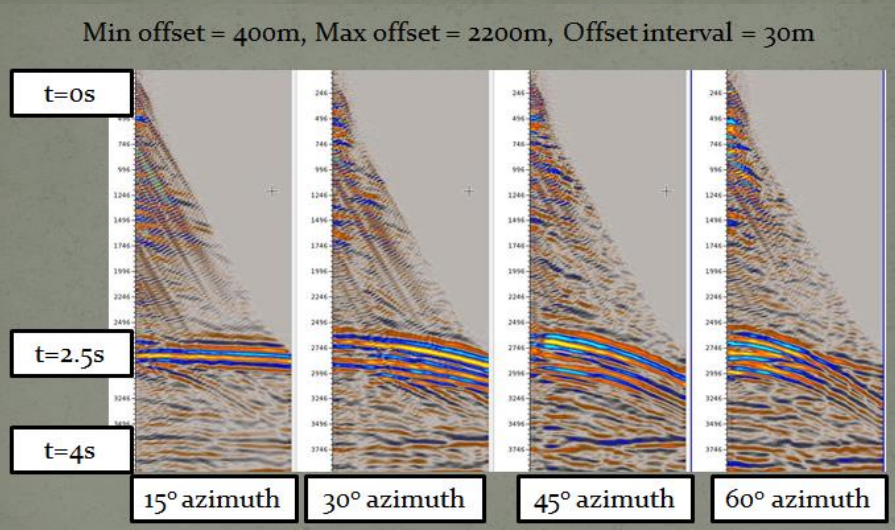


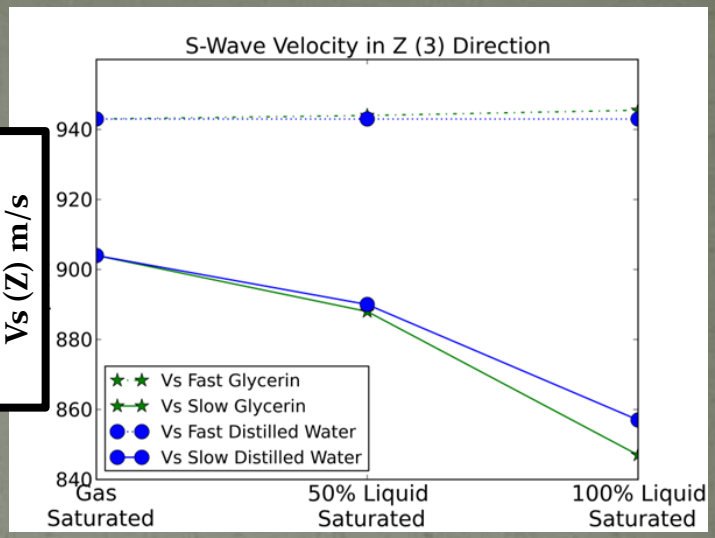
Constituent Materials:

- Resin
- Plexiglass (polycarbonate)
- Copper tubes

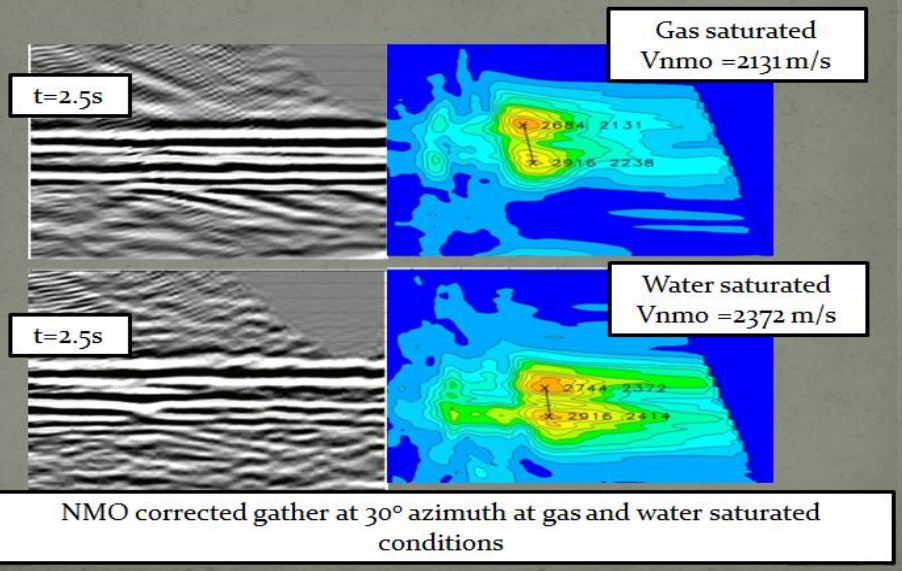
Experimental study of the influence of fluids on seismic azimuthal anisotropy.
(Geophysical Prospecting, 2013, submitted, under review)
Bode Omoboya
Emrah Pacal
J.J.S de Figueiredo
Nikolay Dyaur
Robert. R. Stewart

Barnett Shale – Forward Modeling Project

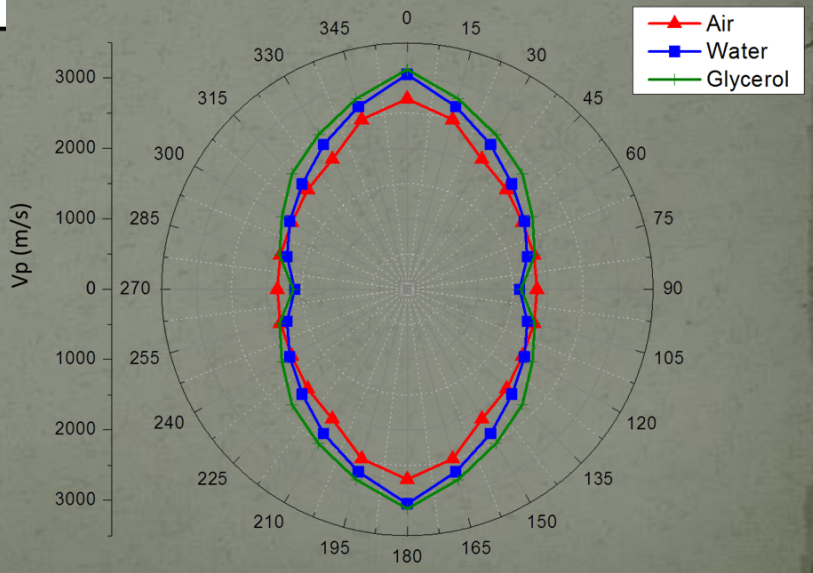




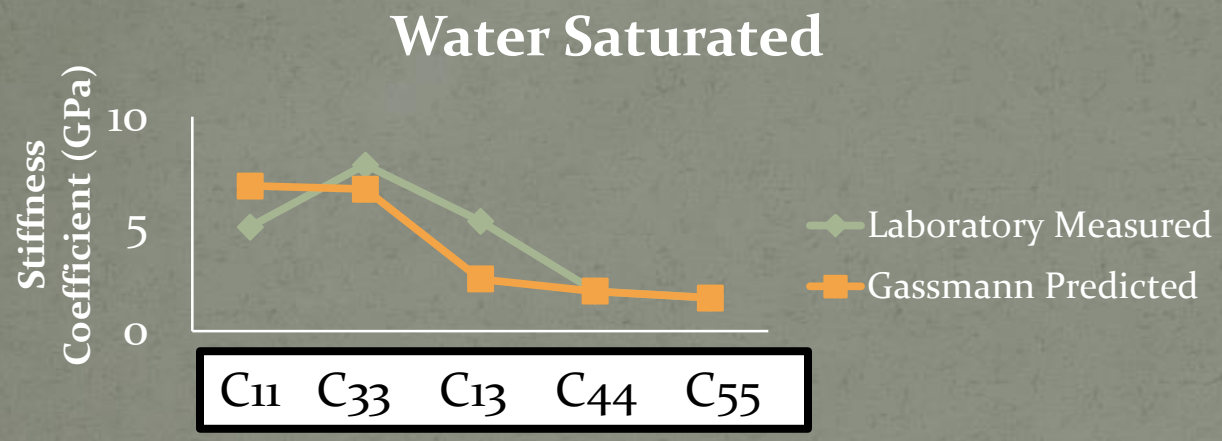
All travel time and distance/offset measurements are scaled by a factor of 10,000

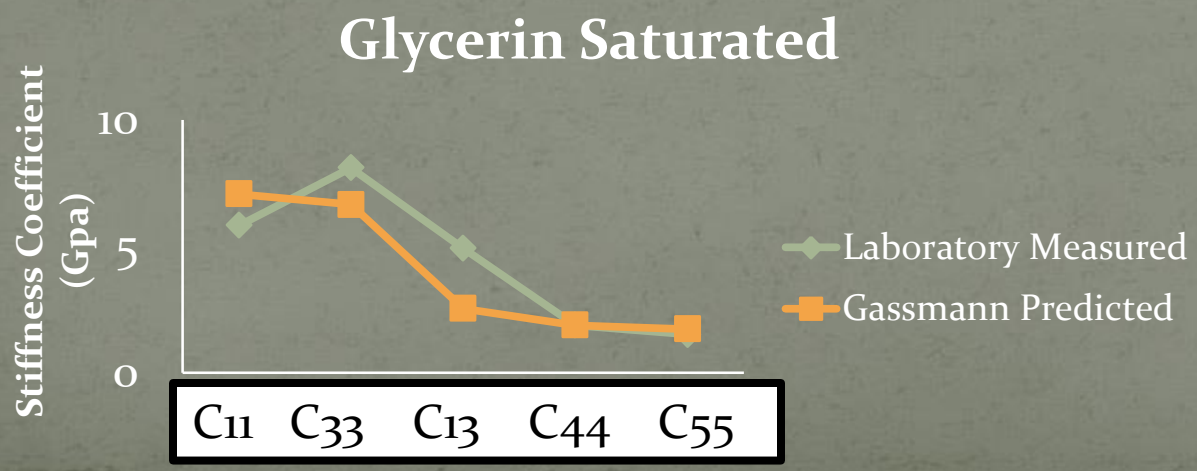


NMO corrected gather at 30° azimuth at gas and water saturated conditions



Barnett Shale – Forward Modeling Project





Forward Modeling Examples: Source Frequency VS Anisotropy

$$\varepsilon = \frac{N\pi r^2 h}{V}$$

Hudson, 1981

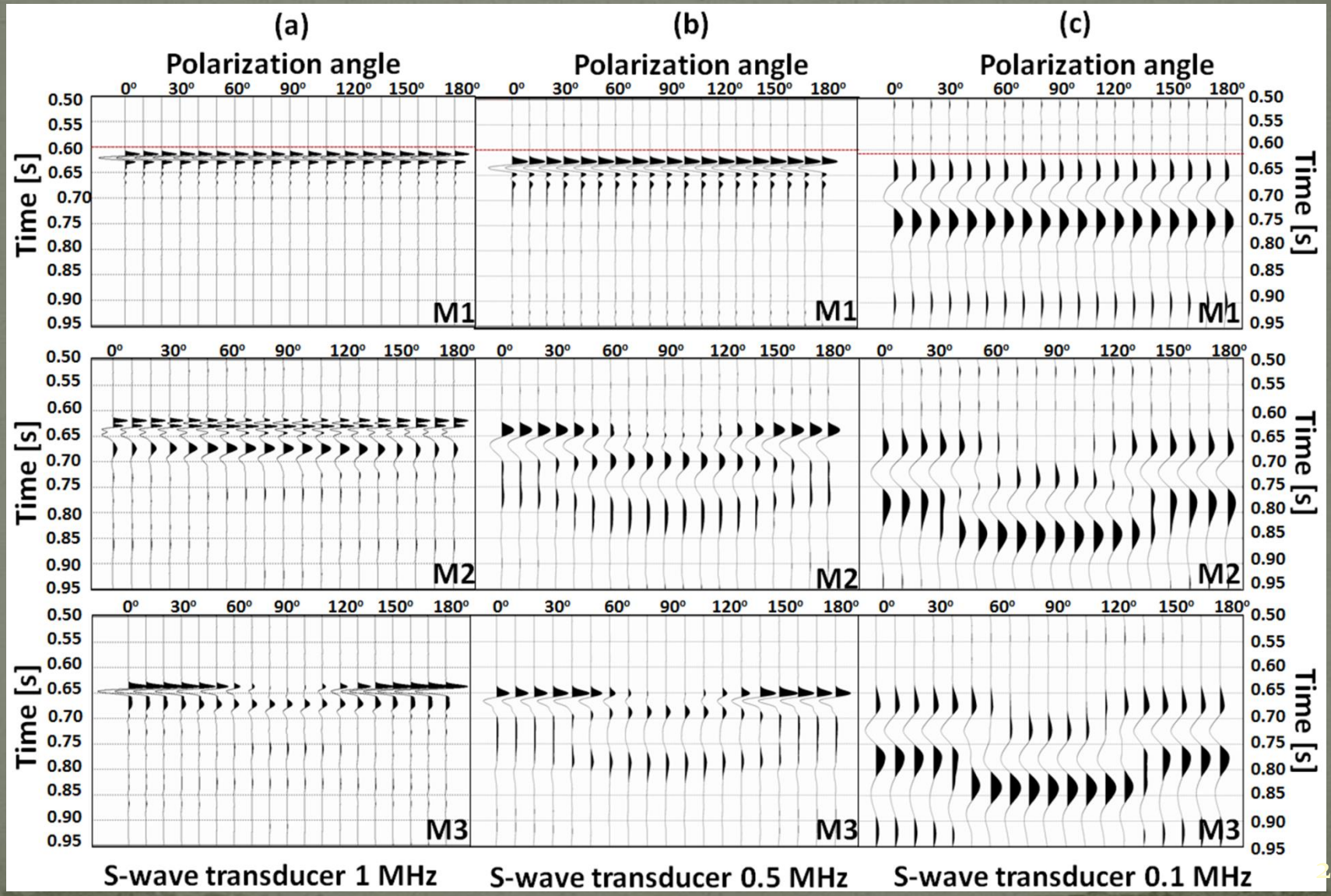
Model M1
Reference Model

Model M2
Crack Density = 4.5 %

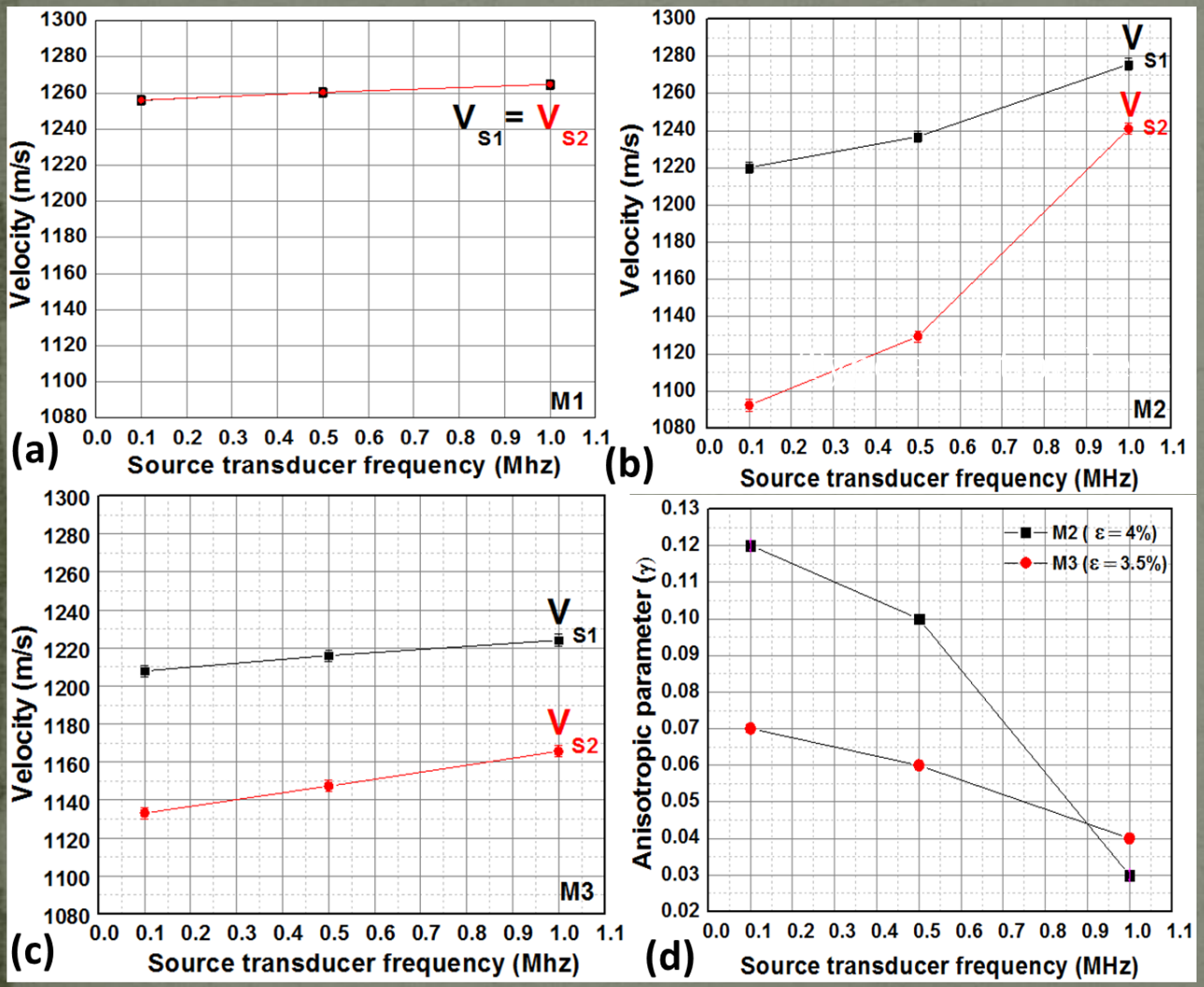
Model M3
Crack Density = 4.0 %

Shear wave anisotropy from aligned inclusions: ultrasonic frequency dependence of velocity and attenuation
(Geophysical Journal International, 2013)
J.J.S de Figueiredo
Nikolay Dyaur
Bode Omoboya
Robert. R. Stewart

Forward Modeling Examples: Source Frequency VS Anisotropy



Forward Modeling Examples: Source Frequency VS Anisotropy



$$\Upsilon = \frac{1}{2}\left(\frac{V_{s1}^2}{V_{s2}^2} - 1\right)$$

Thomsen, 1986

Acknowledgement

- Dr. Steve Peterson – Marathon Oil
- Michelle Simon – Hess Corporation
- Dr. Edip Baysal – Paradigm
- Schlumberger (For VISTA Processing Software)