

The Shear Difference: Insightful Perspectives and a Proposal

Robert Windels
Michael O'Brien



RCPMeeting
Colorado School of Mines – April 2010

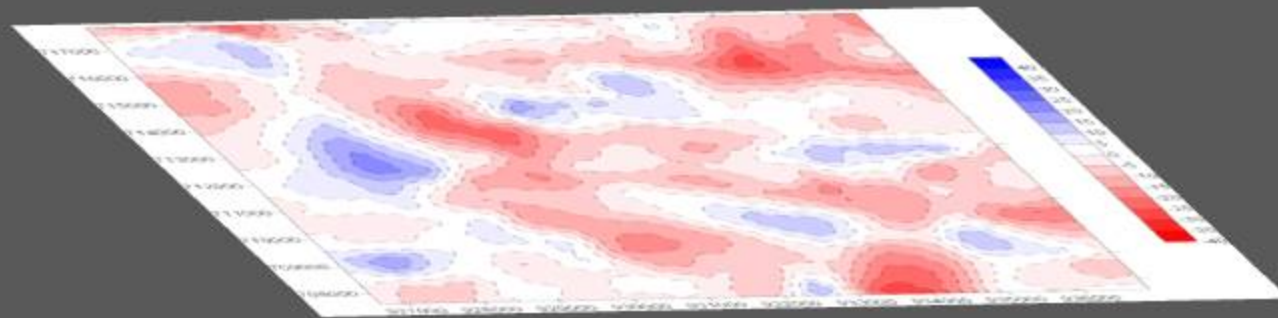


Proposal

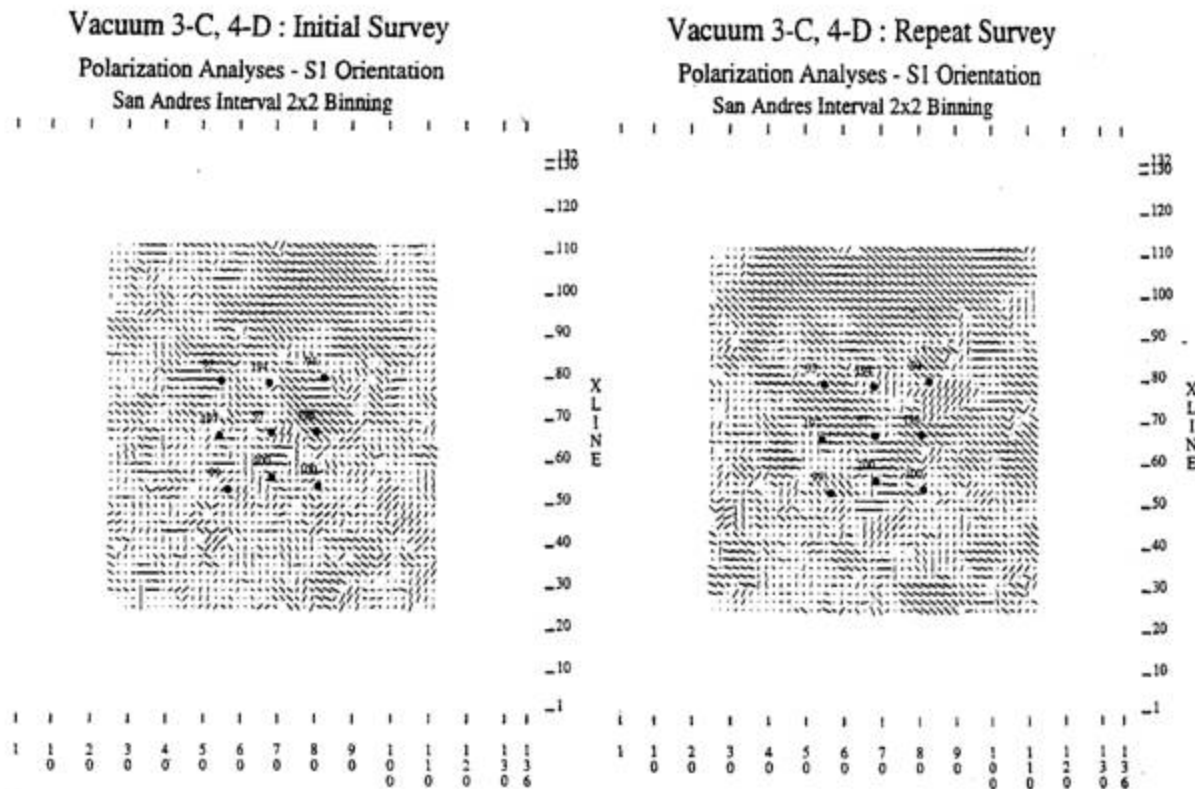
To engage RCP sponsors in a collaborative calculation of synthetic shear data.



CSM Phase XII: Baseline / Time Lapse 1 Surveys

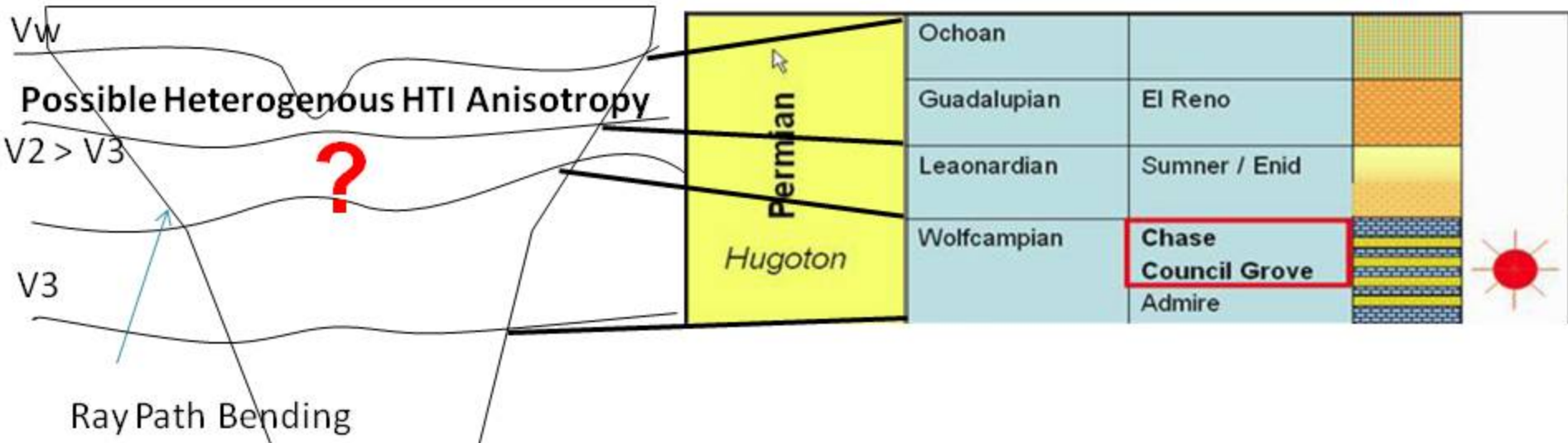


**Direct Mode Shear Wave Shallow
Birefringence and Time lapse
Measurements
Robert Windels**



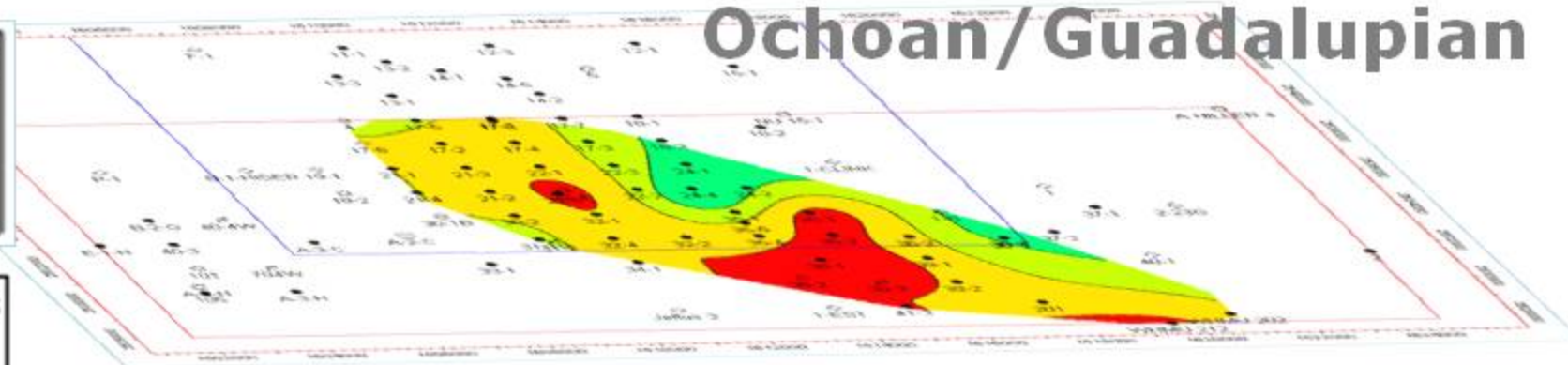
Figures 2 and 3. Polarization analysis over the reservoir zone, initial and repeat surveys
 Benson, Davis, Roche (1997)

Changes in Polarization appear associated with changes in reservoir pressure. An increase in pore pressure opens fractures, micro-fractures, and low aspect ratio structure which all affect the shear wave polarization.

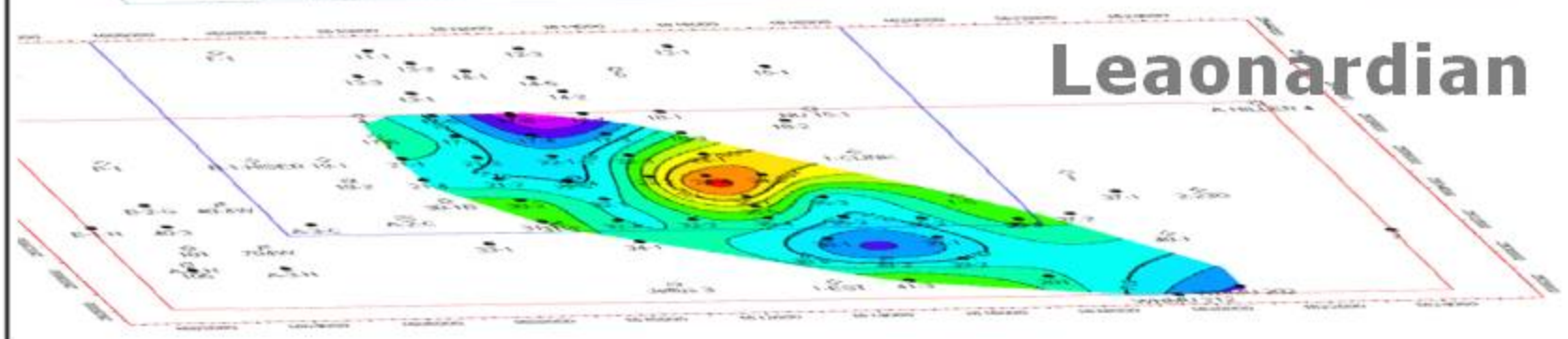
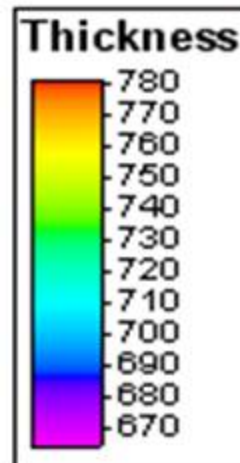


Pennsylvanian Morrow
Mississippian

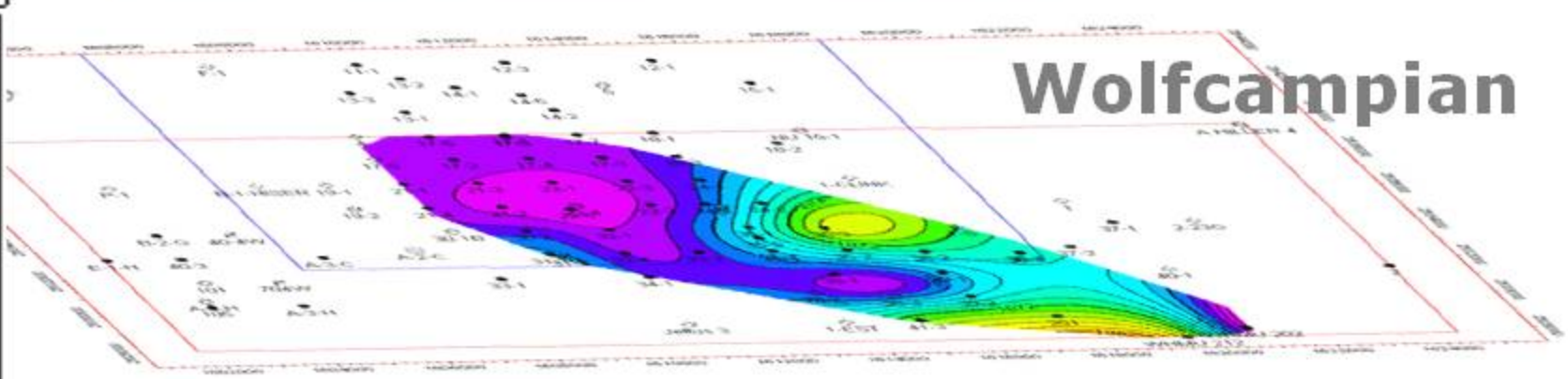
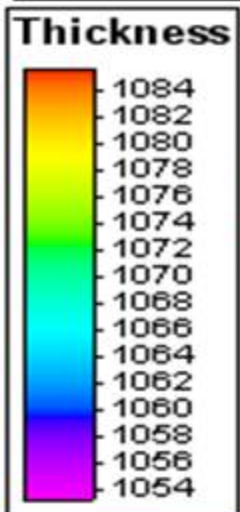
Ochoan/Guadalupian



Leonardian



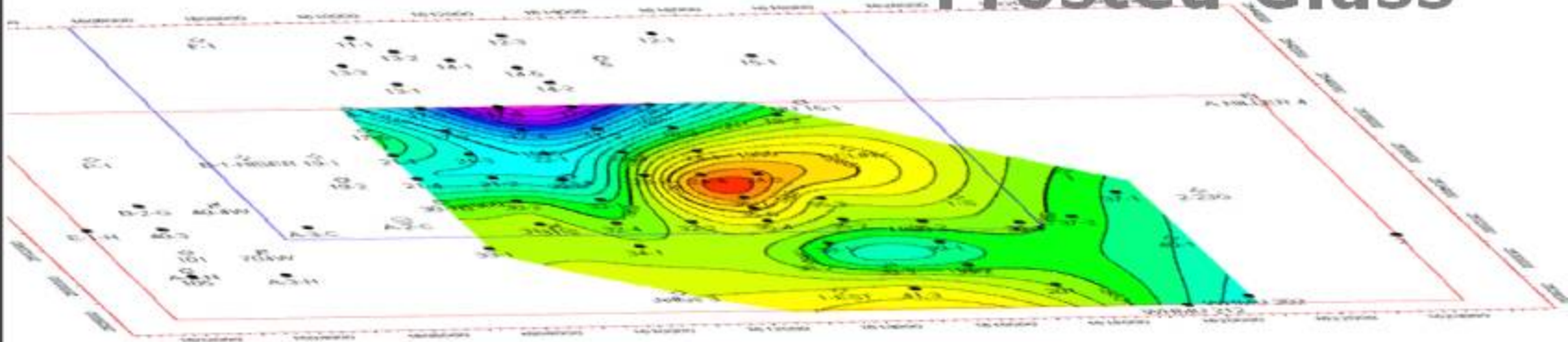
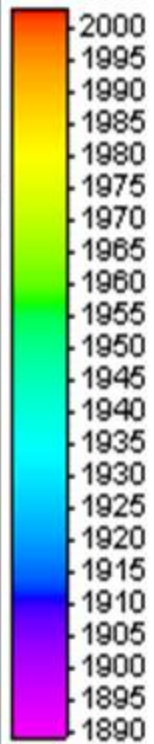
Wolfcampian



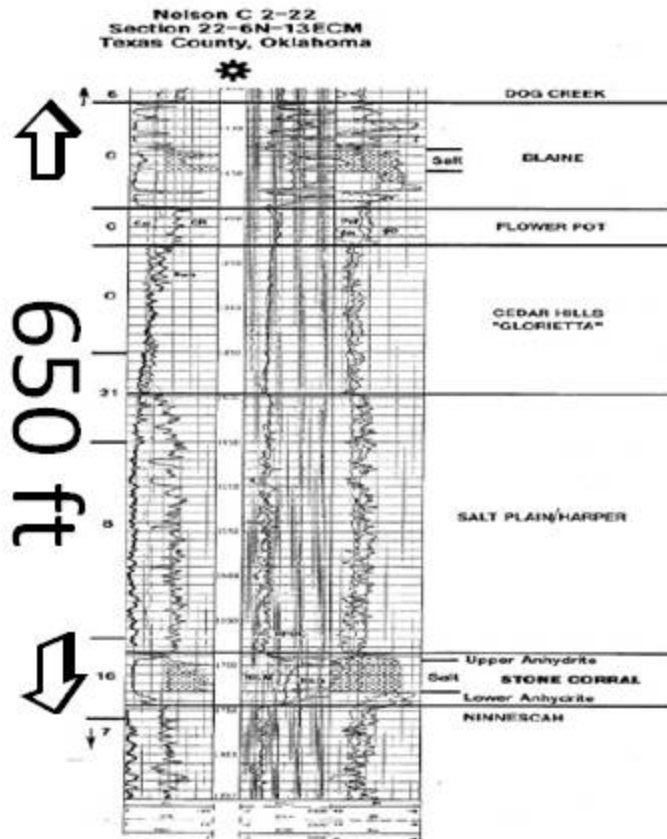
Mark Wiley (2009)

Permian "Frosted Glass"

Thickness



Leonardian



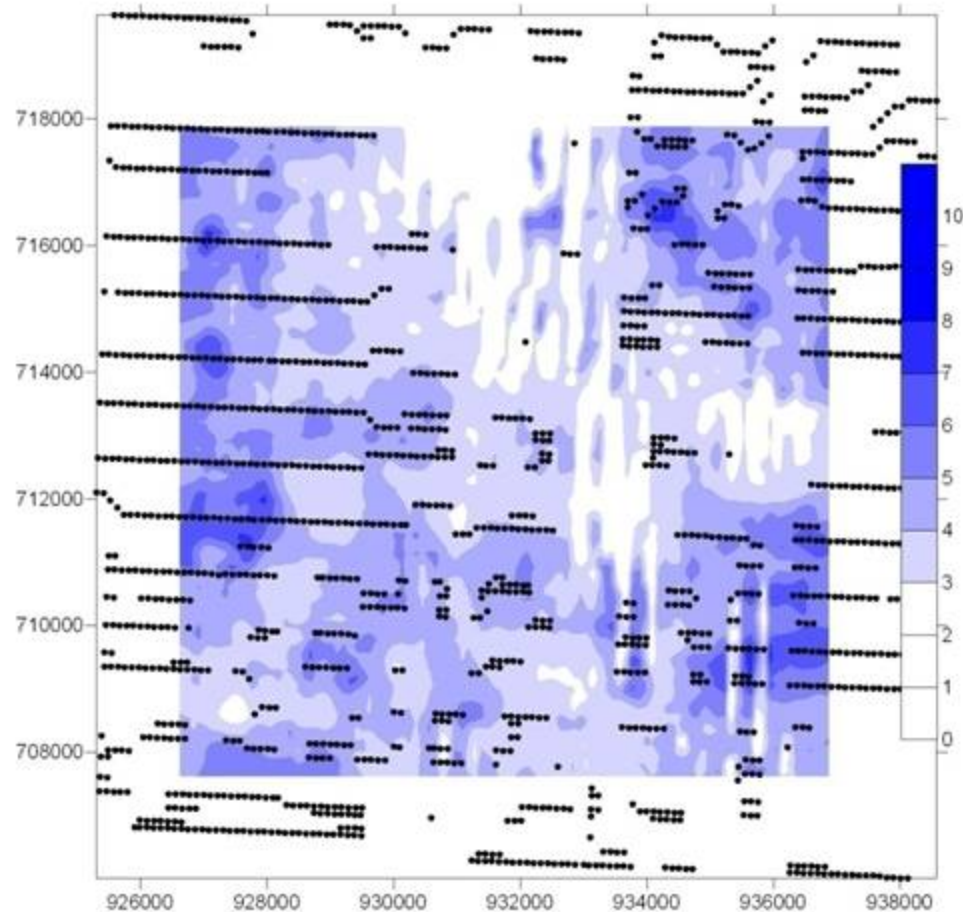
Material	Density g/cc	P Velocity (ft/sec)
Dolomite	2.83-2.87	23000 – 24,000
Limestone	2.7	21,000-23,000
Anhydrite	2.98	20,000
Salt	2.03	15,000
Gypsum	2.31	9,500

From Sorrensen, 1996

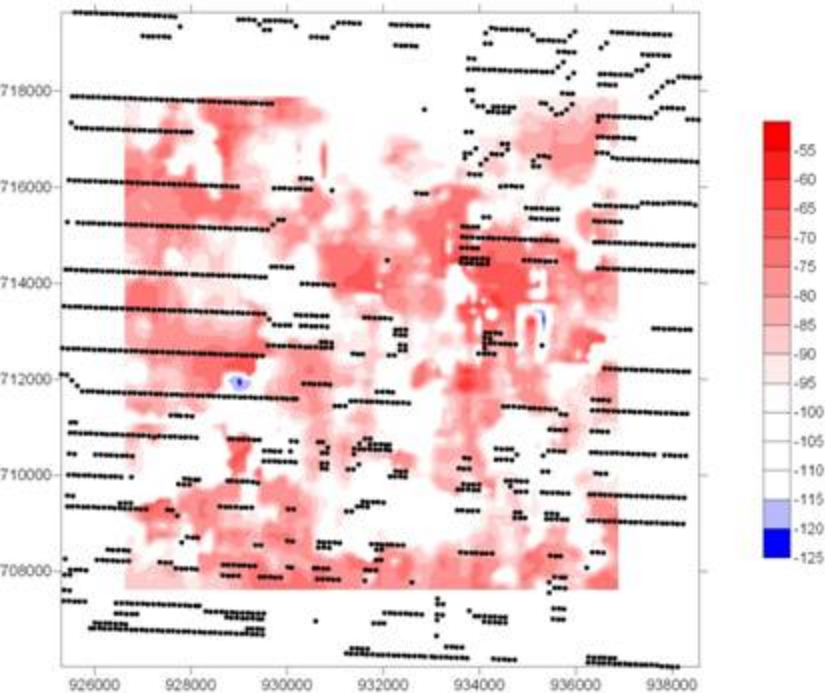
Direct Mode Shear Wave Experiment

- Measure Shear Wave Polarization at the Permian Level.
 - 4C Rotate to maximize energy ratio
 - (Principle Component Energy/Off Diagonal Energy)
 - Measure amount of splitting
 - arrival time difference on the Principles (S1,S2)

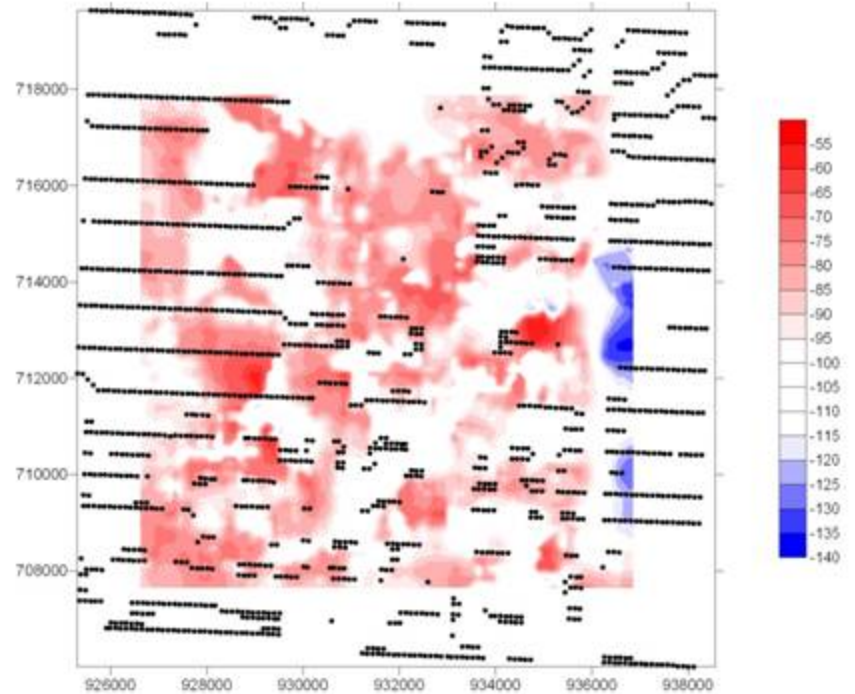
Baseline Survey – Ratio – principle energy/off diagonal energy



Baseline and Time Lapse Survey – Polarization Analysis

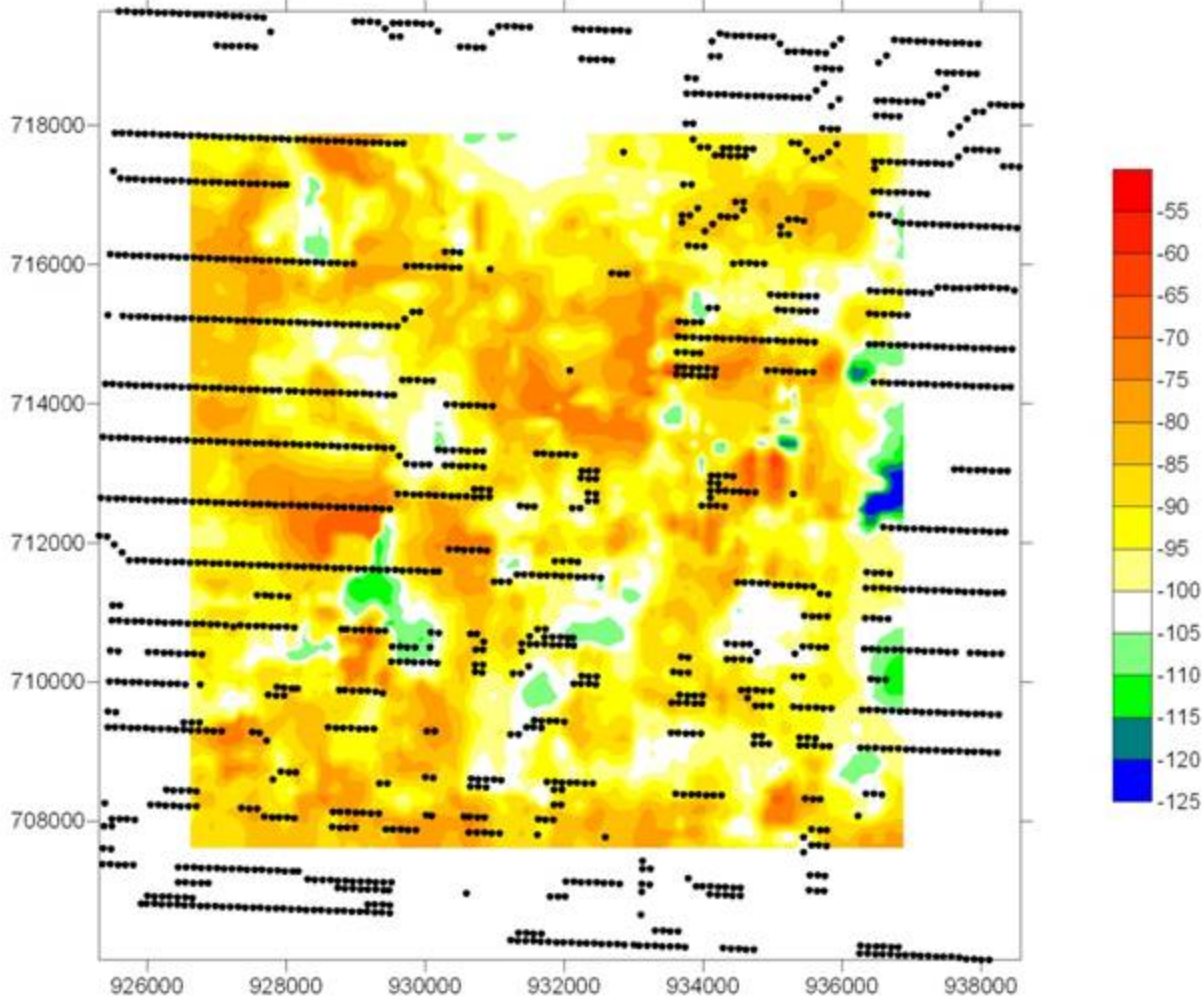


Base Line Survey

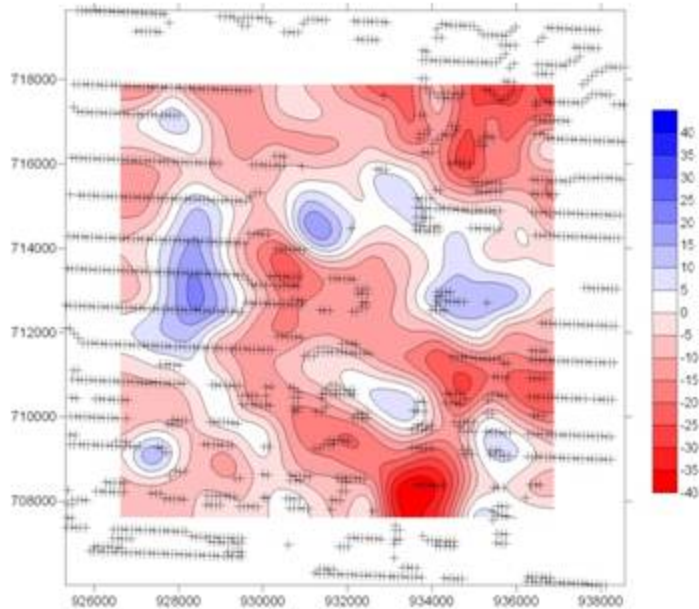


Time Lapse Survey

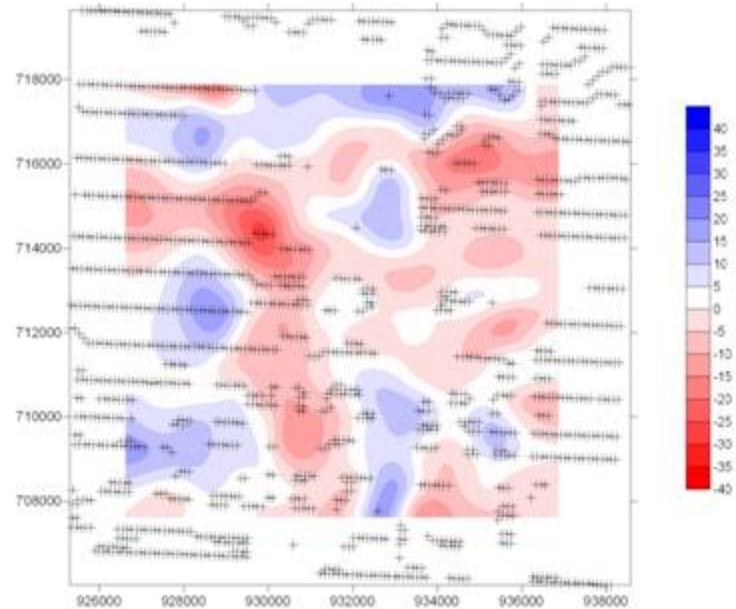
Baseline and Time Lapse Survey – Average – Polarization direction



Baseline and Time Lapse Survey – Splitting S1 – S2

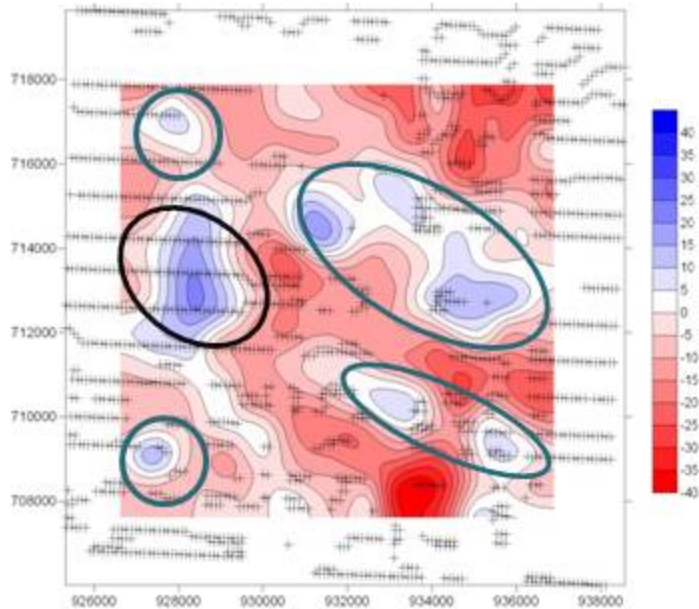


Base Line Survey

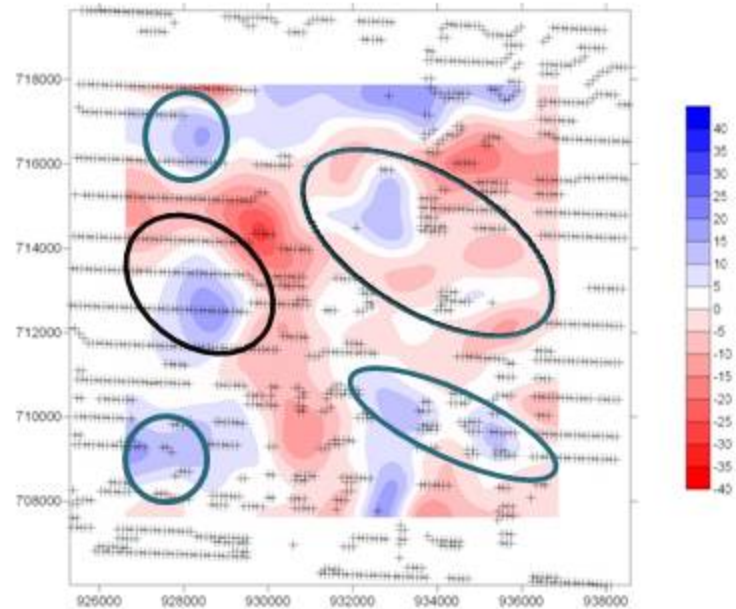


Time Lapse Survey

Baseline and Time Lapse Survey – Splitting S1 – S2



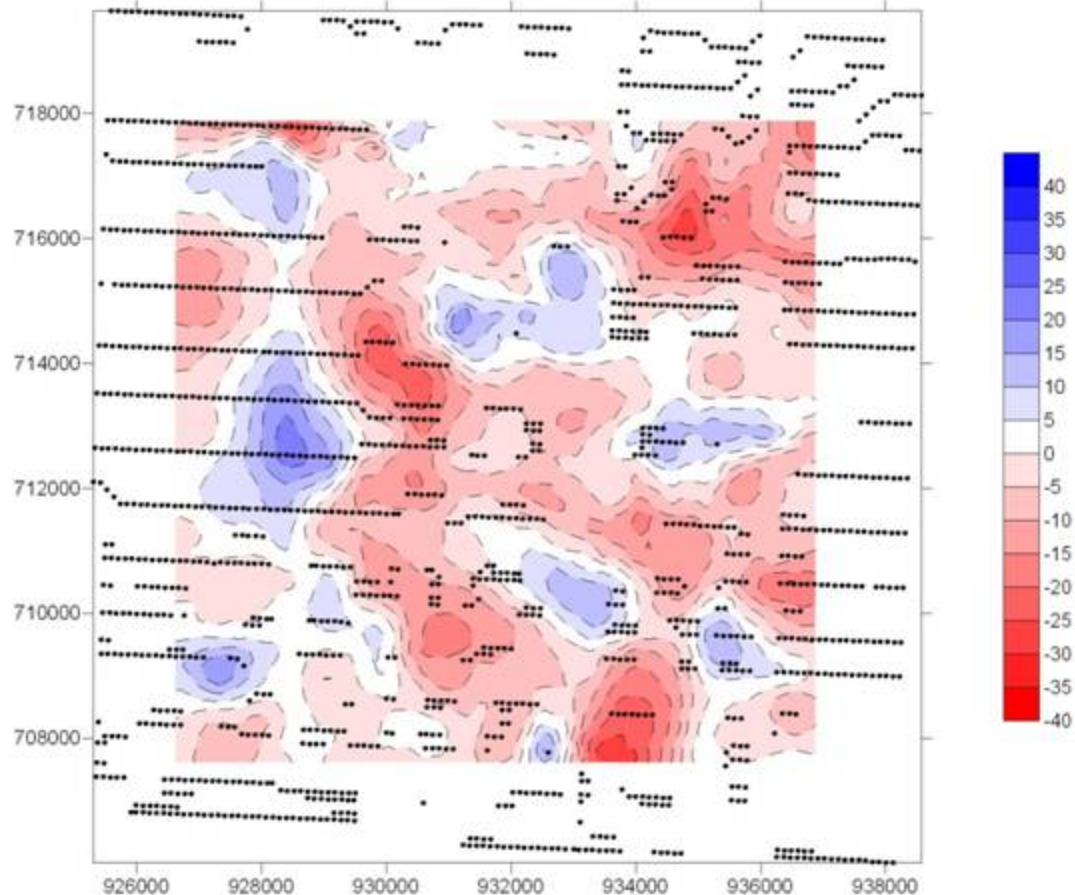
Base Line Survey



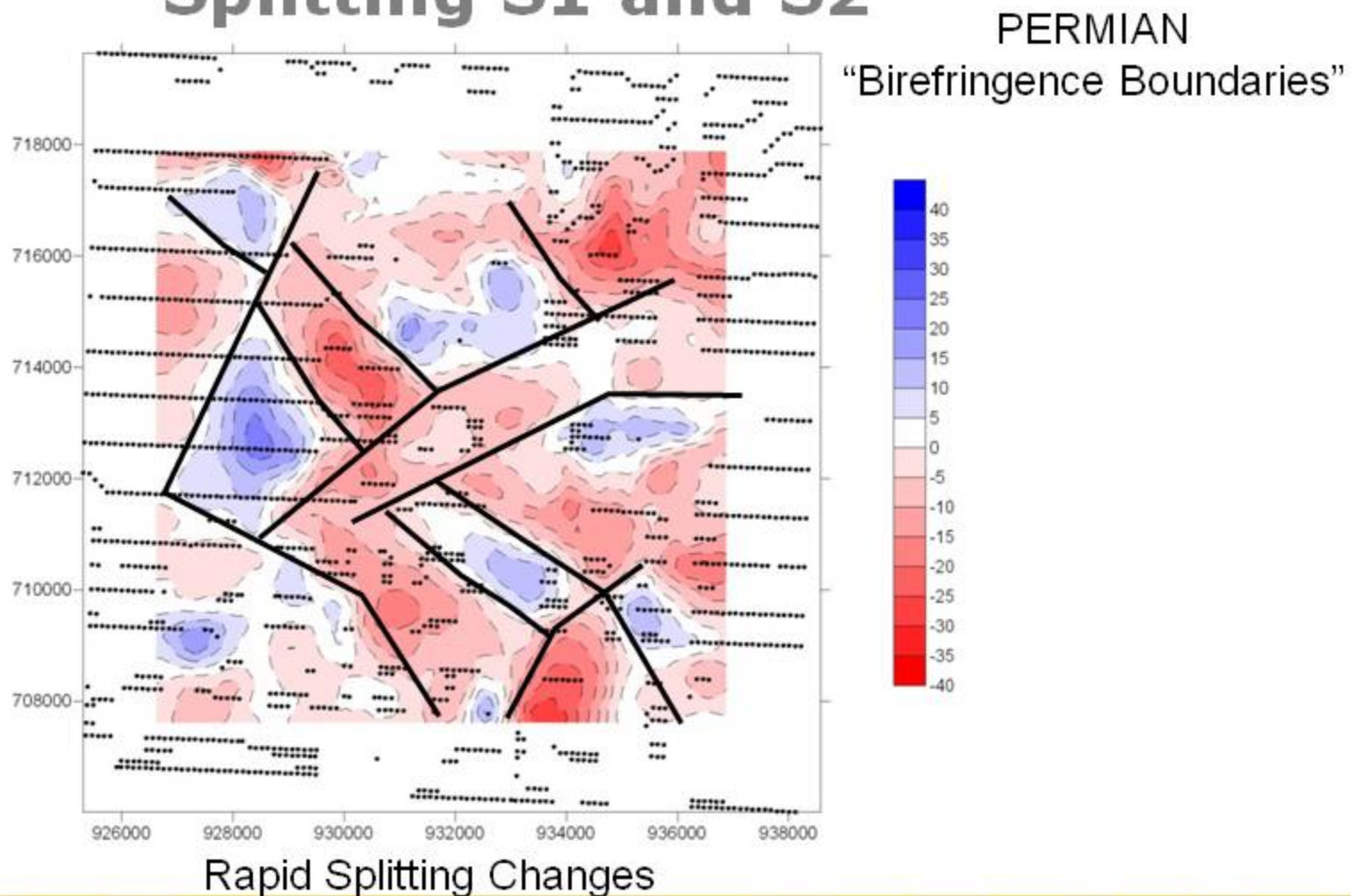
Time Lapse Survey

Splitting Reversals

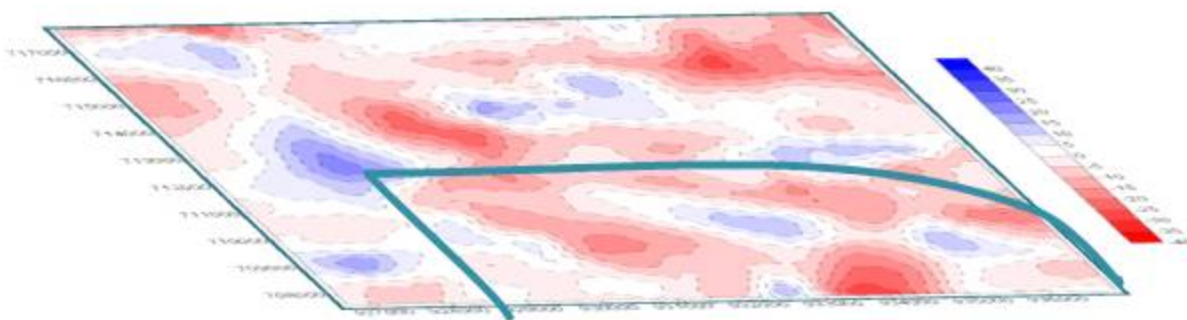
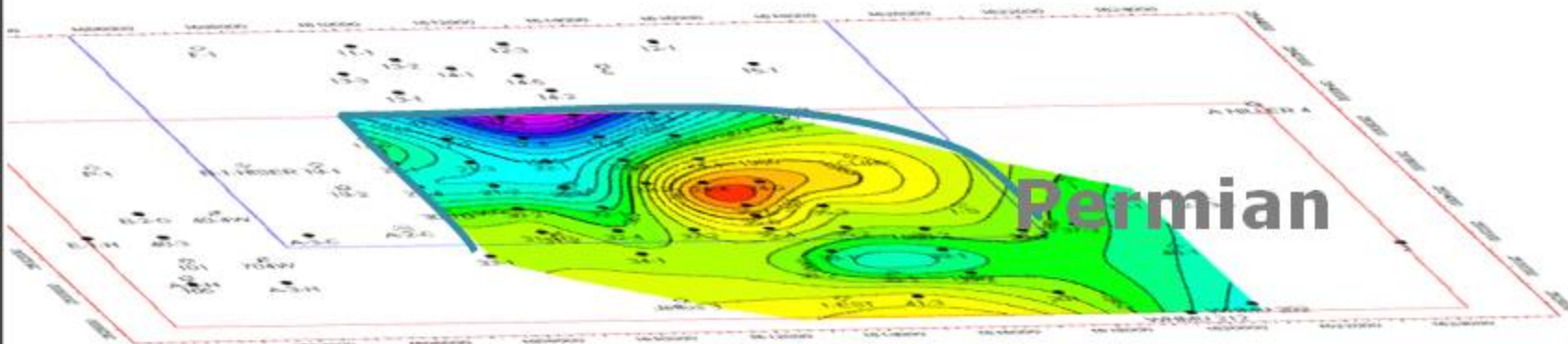
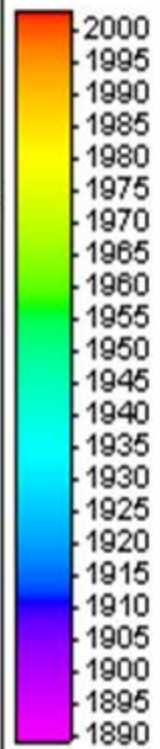
Baseline and Time Lapse Survey – Average surveys Splitting S1 and S2



Baseline and Time Lapse Survey – Average both surveys Splitting S1 and S2



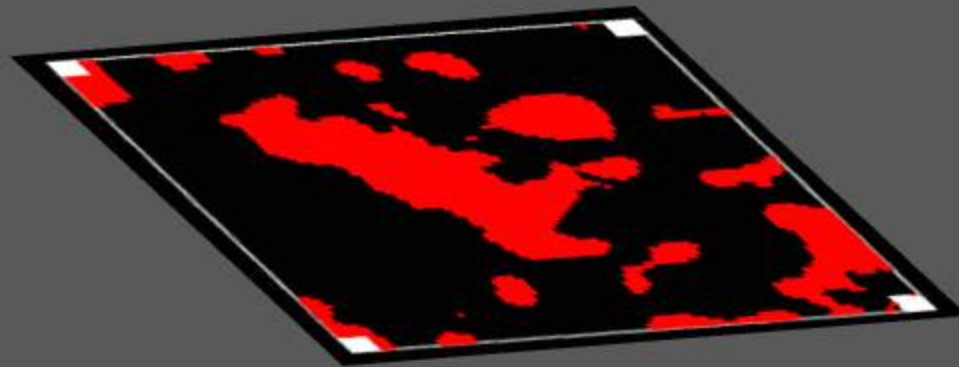
Thickness



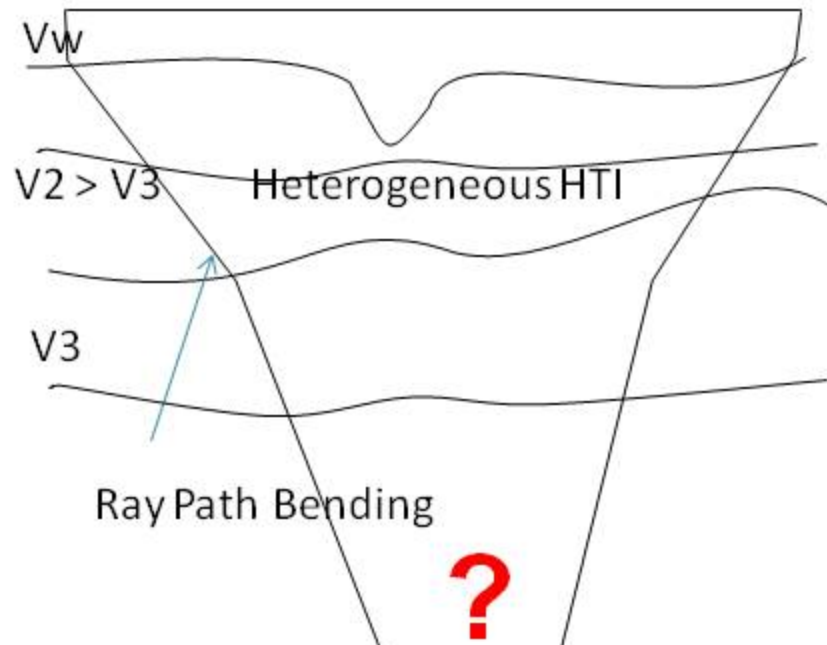
Permian Splitting
CSM RCP Data (S1/S2 Splitting)

Polarization of shear wave data provides information related to the velocity anisotropy of the bulk rock properties.

CSM Phase XII: Baseline / Time Lapse 1 Surveys

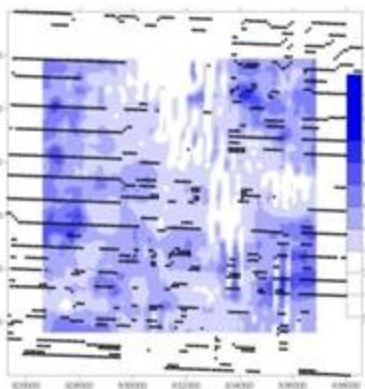


**Direct Mode Shear Wave
Pennsylvanian Time Lapse
Measurements**

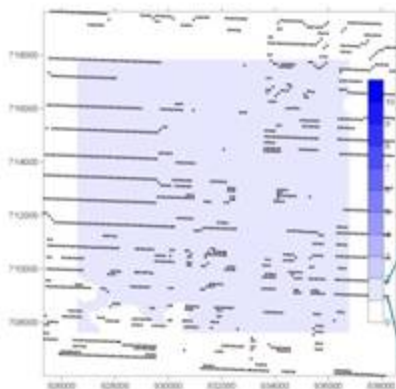


Pennsylvanian Morrow Mississippian

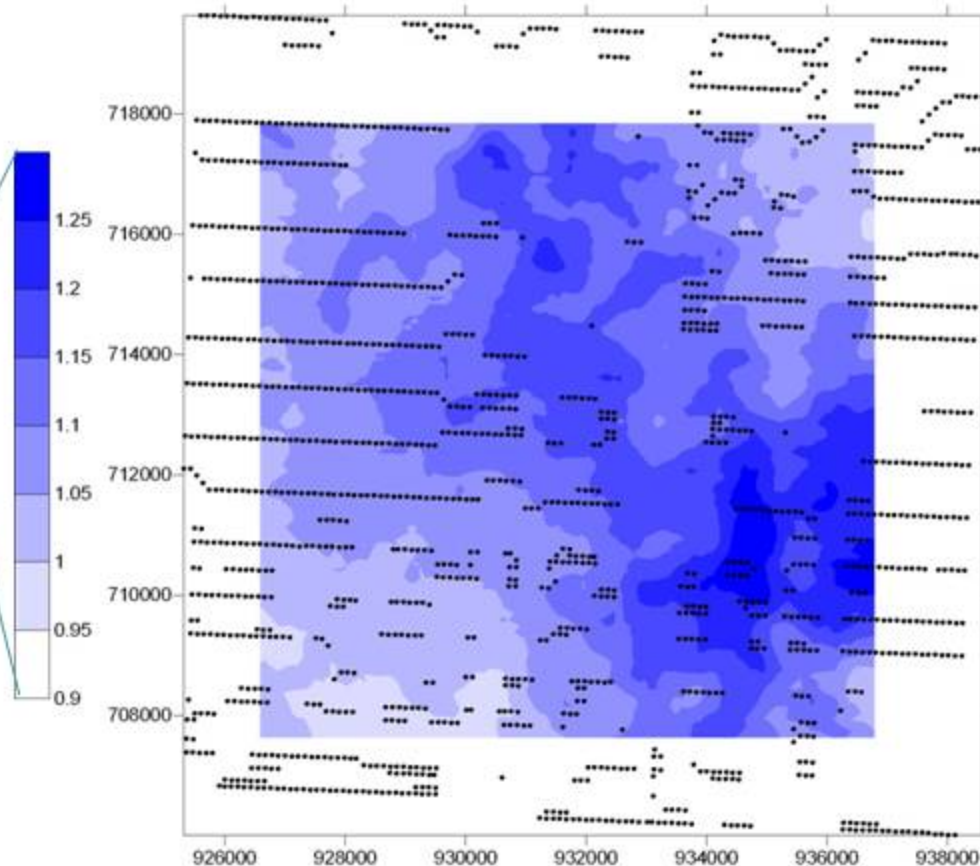
Baseline Survey – Energy Ratio – principle energy/off diagonal energy



Permian
Gate

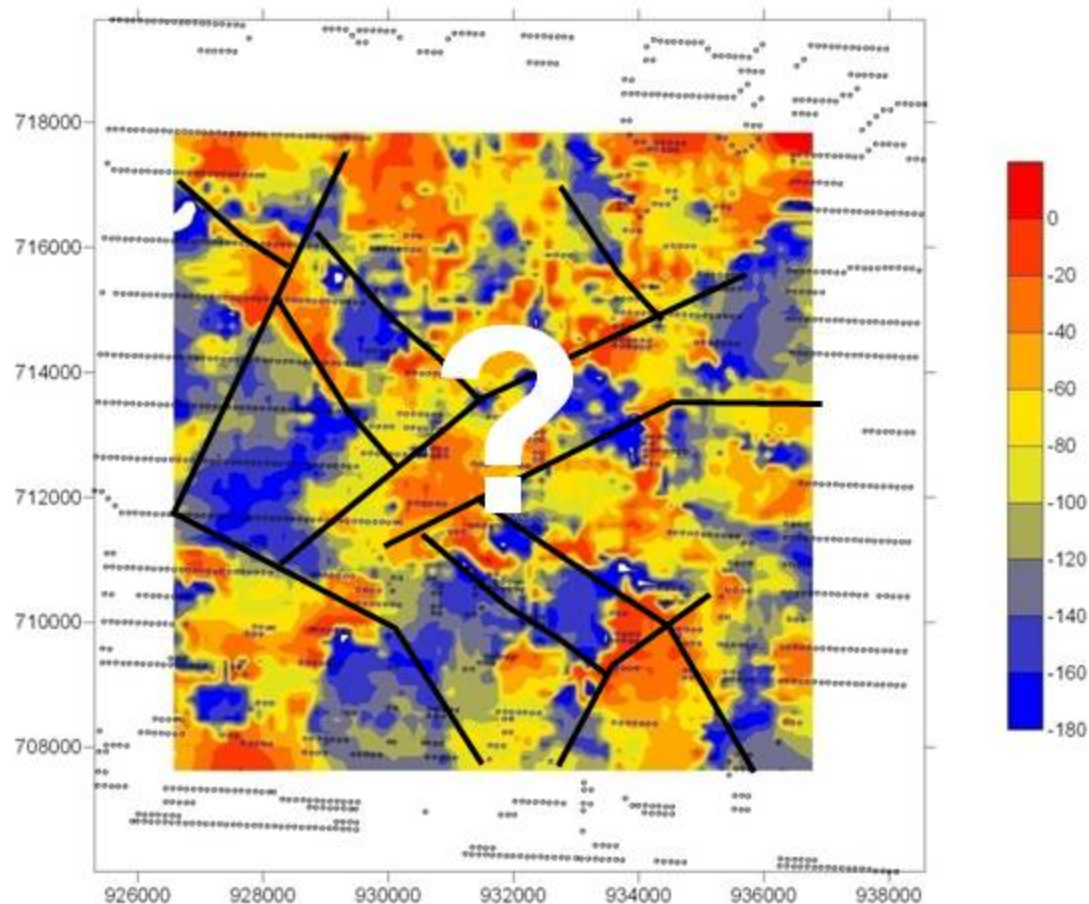


Pennsylvanian
Gate

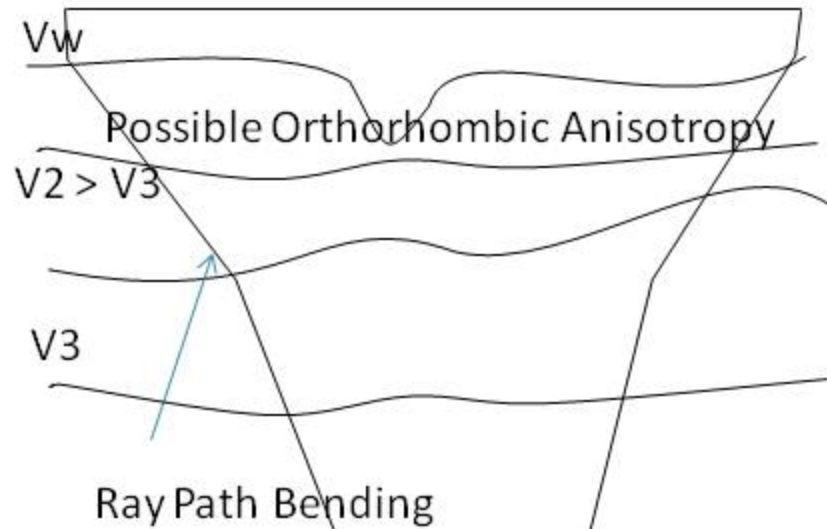


Pennsylvanian
Gate

Average Baseline and Time Lapse Pennsylvanian gate - measured Direction



Large Splitting Changes

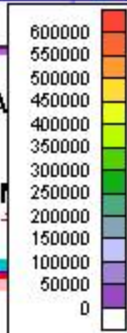


Pennsylvanian ? Morrow

What birefringence measurements can we make at the Morrow Level to make recommendations for the EOR?

Reservoir Barrels Removed

RCP Phase XII 3D Survey

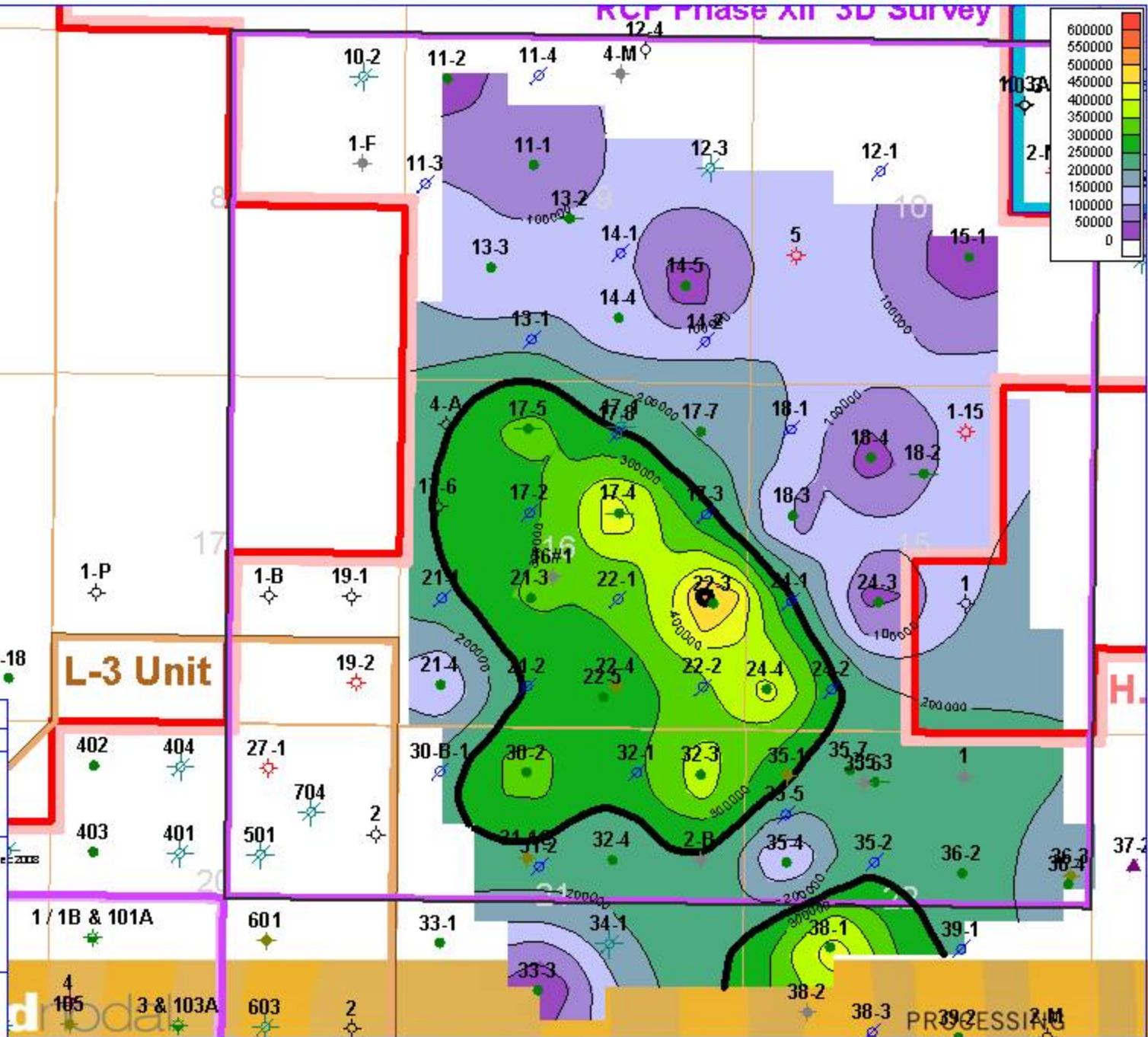


Postle Field - RCP Phase XII Area

Barrels Produced

CONTOURS
 2005 - TOT_PROD (D FM) - Total Vol Removed March to Dec 2005
 RCP_2005TOT_PROD (D FM) RD
 Contour Interval = 50000

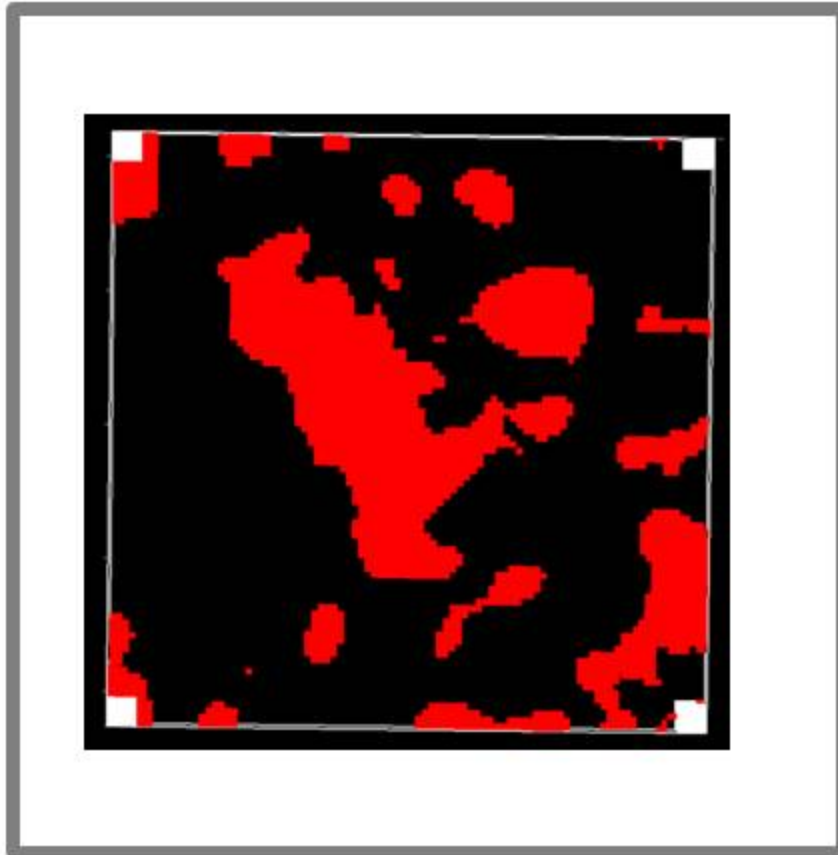
REMARKS
 Total Reservoir Barrels of Fluid
 Extracted between March 1, 2005
 and December 31, 2005



S2 Time Delay Map

Morrow Interval

increasing time delays between Baseline and Time lapse 1

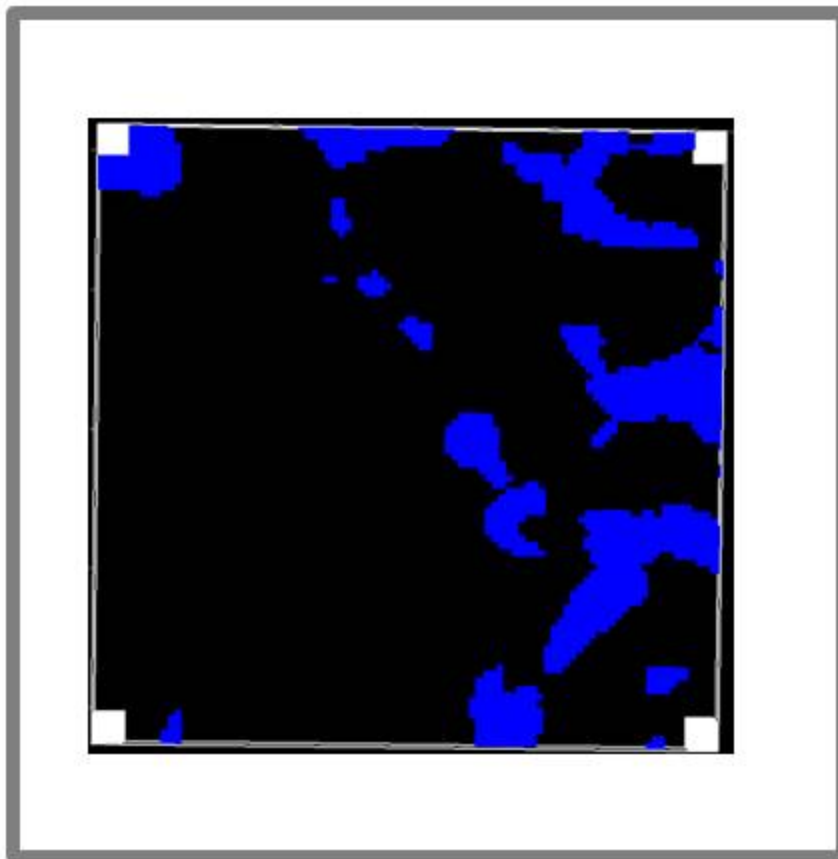


The S2 data is sensitive to the pressure increases, the cracks are opening up orthogonal to the S2 polarization direction.

S1 Time Delay Map

Morrow Interval

increasing time delays between Baseline and Time lapse 1



'anisotropic' processes tested

- **Layer stripping.**
 - Observe birefringence at permian level, remove it, to improve image below.
- **Surface consistent elliptical statics.**
 - Observe azimuthally dependent surface consistent statics, fit to an ellipse, remove to improve image.
- **CDP consistent elliptical statics.**
 - Observe azimuthally dependent CDP statics, fit to an ellipse , remove to improve image.

RECOMMENDATIONS:

- **Model Heterogeneous HTI**
 - With Heterogeneities and with out
- **Develop tools to image data sensitive to HTI.**
 - Compressional Waves are not as sensitive to HTI as Shear Waves
 - Shear Wave Data Processing require HTI processes.
- **Processing tools can be improved with a known model as input.**

Timing

Summer 2010

Allied Geo prepares models and executables for distribution to sponsor computing centers.

Fall 2010 through 2011

Sponsors perform calculation in 'white space' and return data to RCP.

2011 and beyond

Data are used to advance understanding of S-wave data quality issues.



Models to Calculate

Heterogeneous HTI without near-surface complexity (elastic)

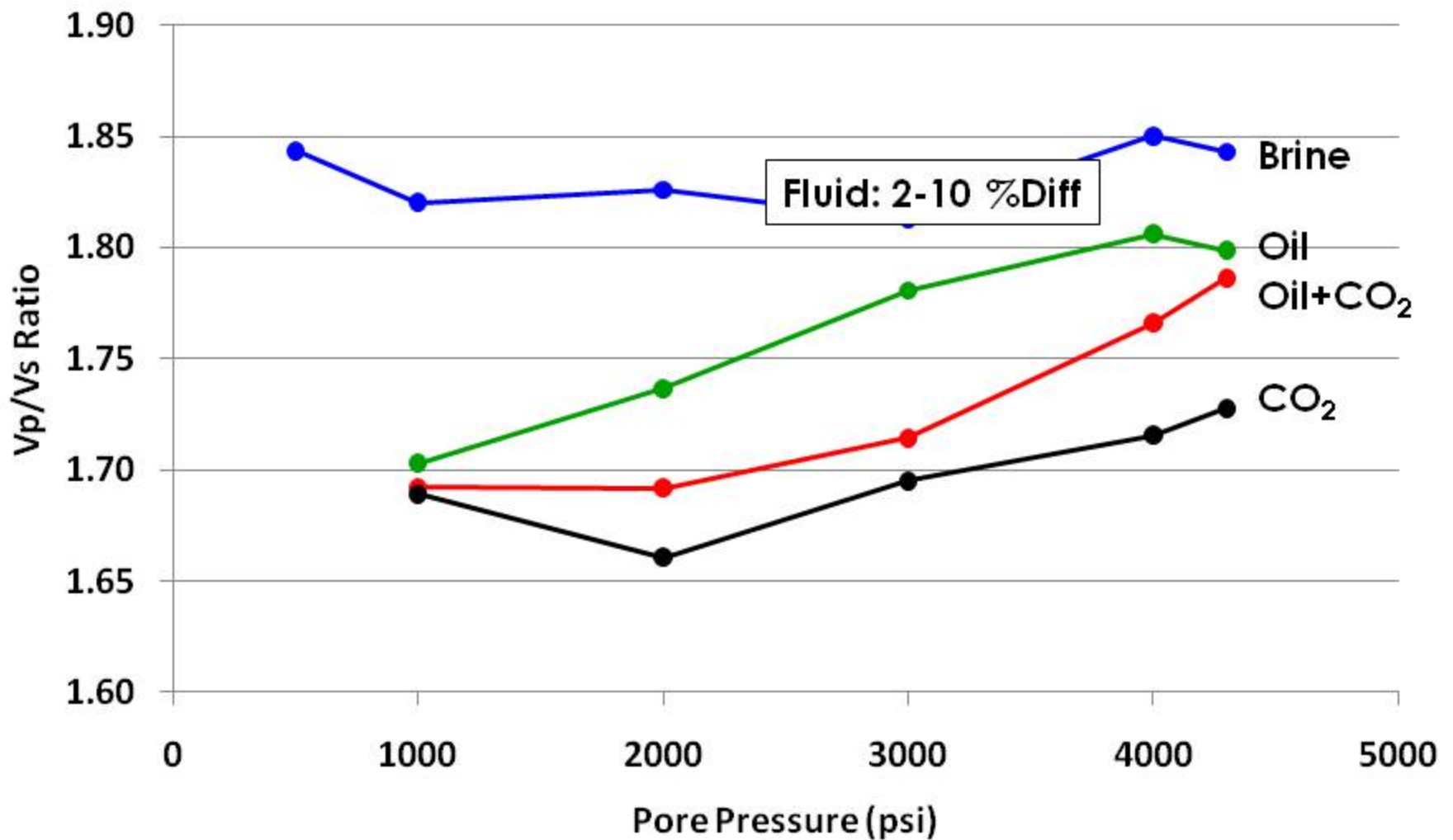
Introduce near-surface complexity (elastic)

Introduce time-lapse component (elastic)

Introduce attenuation (anelastic)



Sample 6164 ft: $P_c=6500$ psi, V_p/V_s



(RCP 2010)

The reservoir is overpressure below injection wells 13-1, 17-8 and 17-3.

