Attribute Expression of the Mississippi Lime

Kurt J. Marfurt (The University of Oklahoma)

Attribute expression of the Mississippi Lime

- Lithology ← Impedance
- Fractures
  - Strain ← Curvature
  - Thickness ← Spectral components
  - Lithology ← Impedance

Diagenesis ← Textures

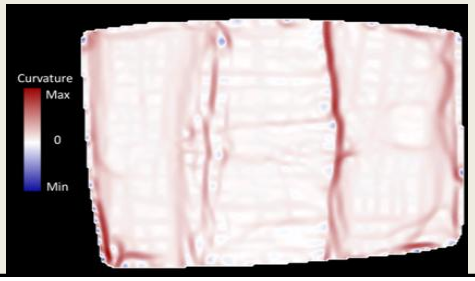
Outline

- Correlation of fractures to curvature
  - Clay models
  - Outcrop analogues
  - Hunton Limestone – seismic with image logs

  A proposed workflow using post-stack data
  - Kansas fractured carbonate
- Attribute images of Osage County surveys
- Recommendations for future seismic acquisition

Clay model experiments

k_{pos} from scanned surface



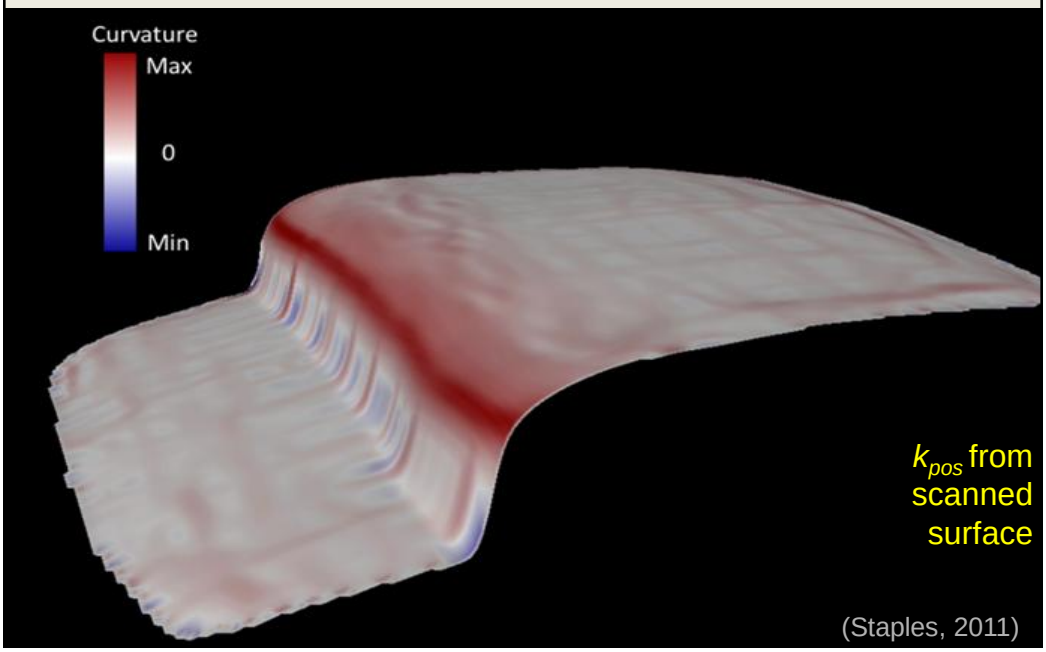
(Staples, 2011)

Clay model experiments

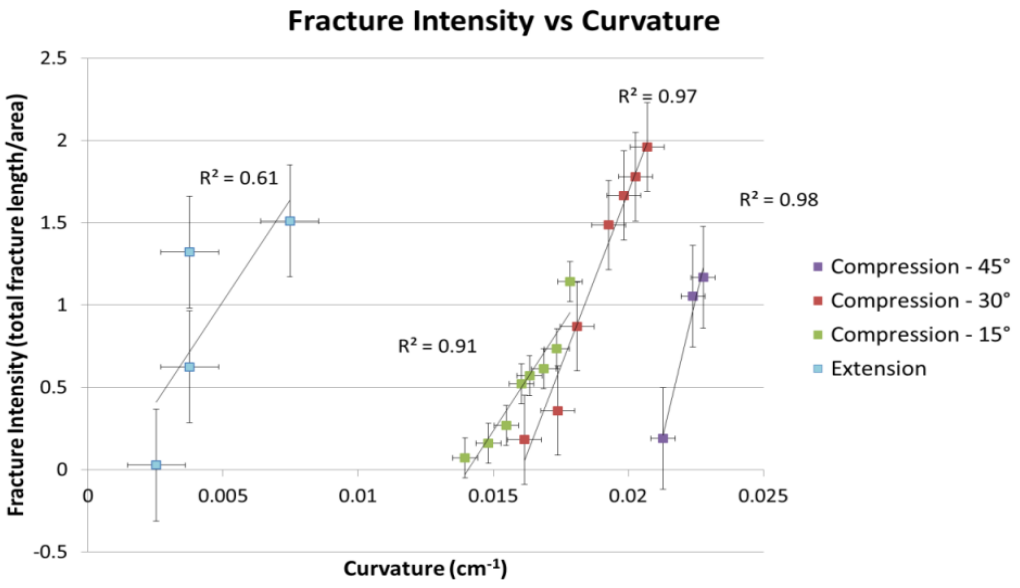
photo

(Staples, 2011)

Clay model experiments



Clay model experiments



(Staples, 2011)

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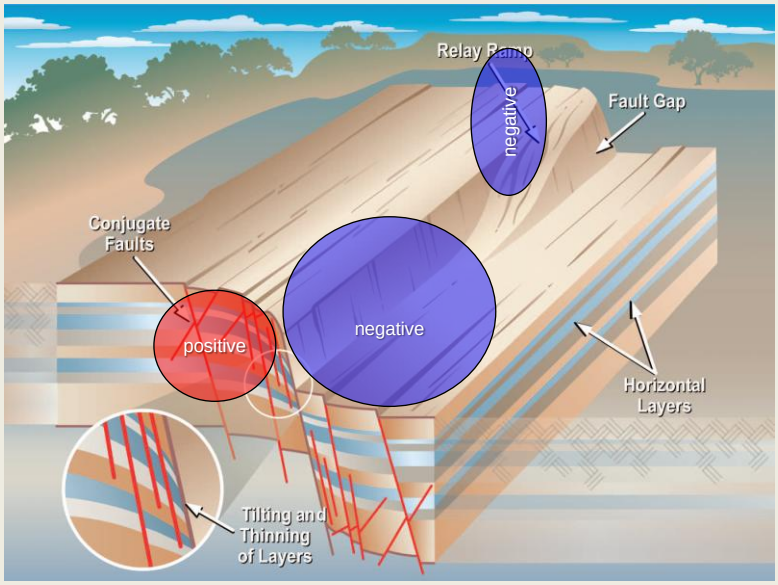
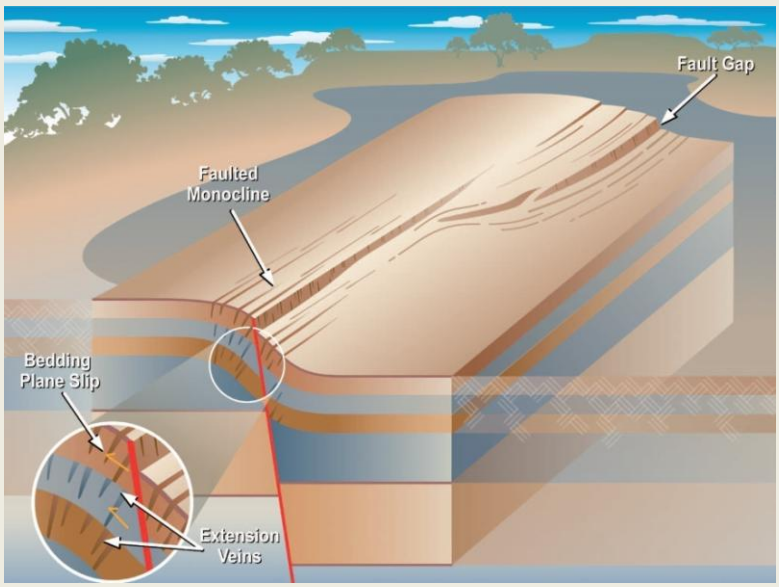
Deformation of mixed competency rocks (Glen Rose fm)



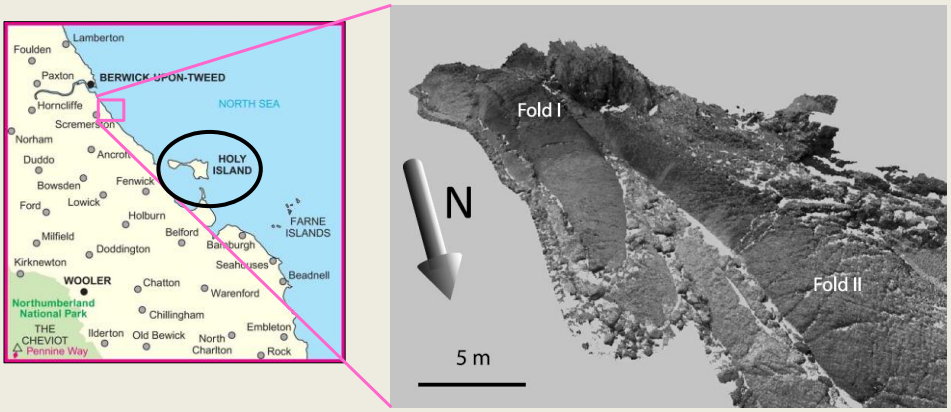
(Ferrill and Morris, 2008)

Deformation of less competent rocks (e.g. Eagleford fm)



(Ferrill and Morris, 2008)

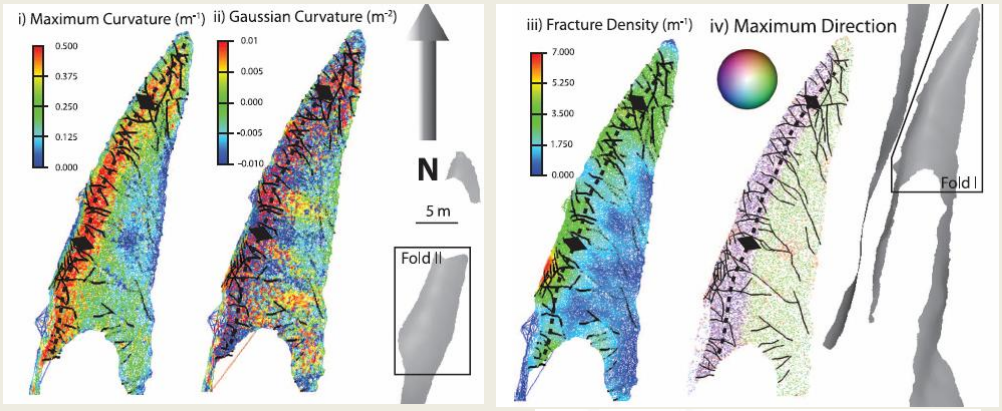
Lidar correlation of fractures on outcrops to curvature (UK)

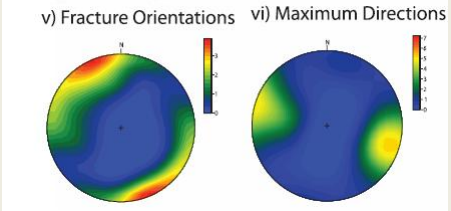


Carboniferous Eelwell limestone

(Pearce et al., 2011)

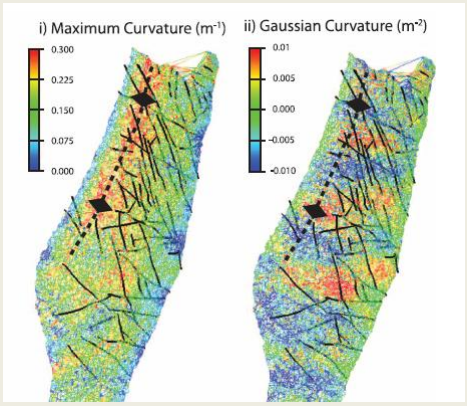
Lidar correlation of fractures on outcrops to curvature (UK)

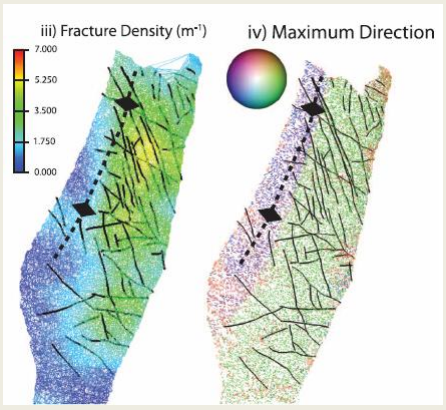




(Pearce et al., 2011)

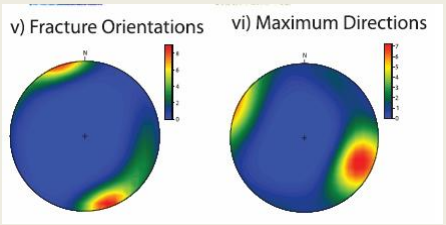
Lidar correlation of fractures on outcrops to curvature (UK)





"I endorse this correlation."
(Saint Aiden)

(Pearce et al., 2011)



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  - **Hunton Limestone – seismic with image logs**

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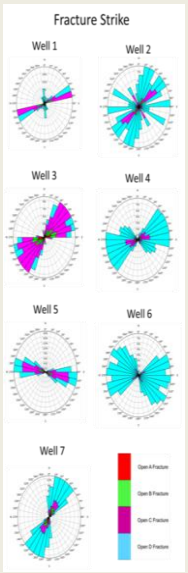
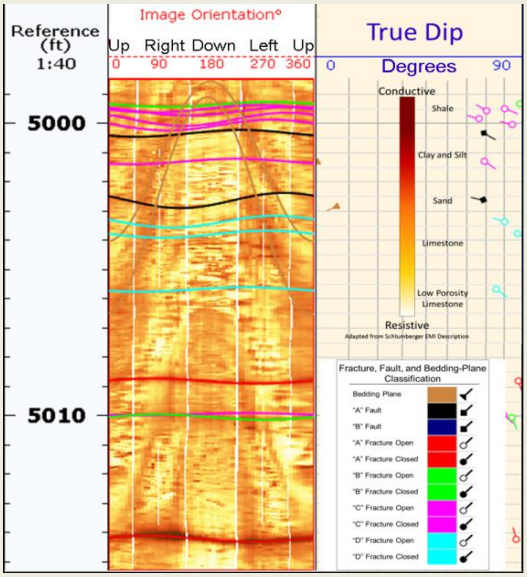
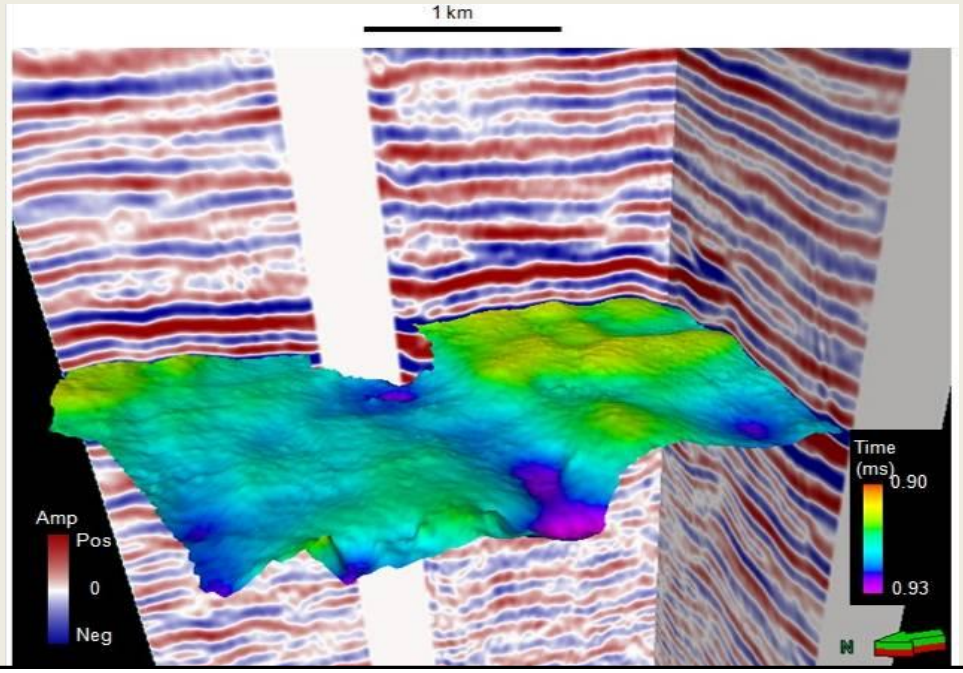
Hunton Limestone, Central OK



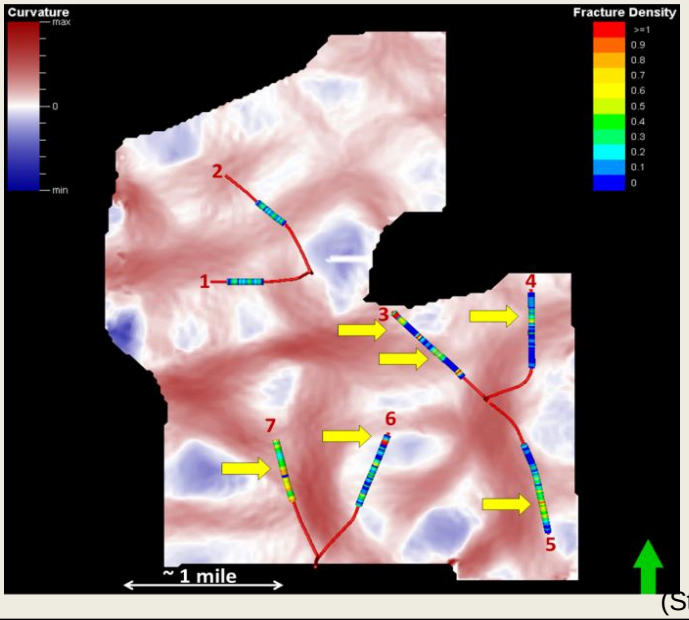


(Staples, 2011)

Hunton Limestone, Central OK

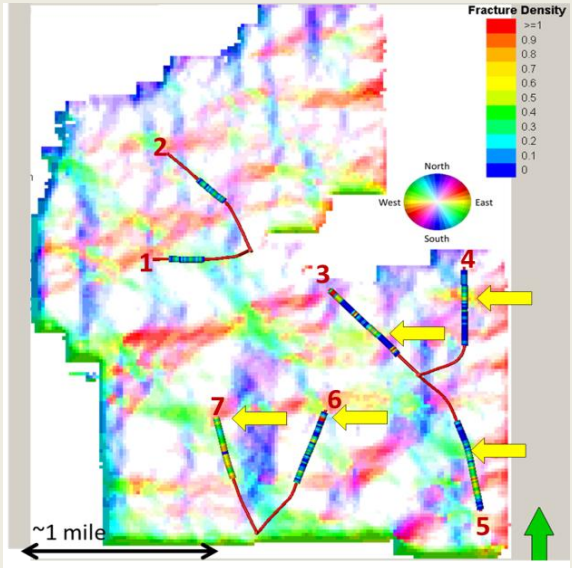


Most-positive principal curvature, k_1,
co-rendered with image log fracture density



(Staples, 2011)

Strike of most-positive principal curvature, k_1,
co-rendered with image log fracture density



(Staples, 2011)

Correlation of fractures with curvature

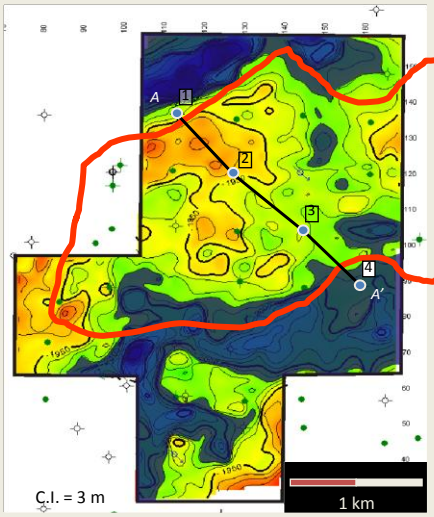
Azimuthal Intensity Correlations to Fracture Density			
Well Number	Azimuth	Azimuthal Intensity vs. Fracture Density Correlation (r)	Measured Length Along Wellbore (ft)
1	---	No correlation	---
2	45	**0.69**	5800 - 6290
3	75	**0.77**	5400-6230
3	45	**0.88**	7275-7605
4	75	**0.80**	7120-7560
5	45	**0.70**	7890-8495
5	-75	**0.57**	6405-6955
6	-75	**0.66**	7065-7505
7	-75	**0.69**	5800-6185

(Staples, 2011)

Correlation of Geometric Attributes to Production

The problem

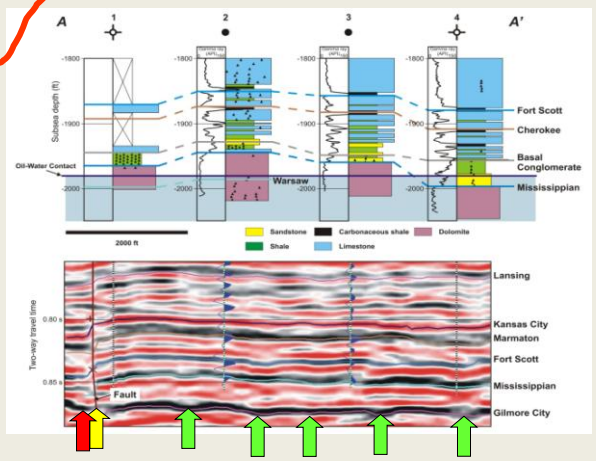
- Geometric attributes are an indirect measure of the paleo rather than the present-day stress regime
- Since the time of fracture initiation
  - the direction of S_{hmax} has probably rotated
  - fractures may have been diagenetically altered (cemented, filled, or enlarged)



Seismic Depth Map of Top Mississippian

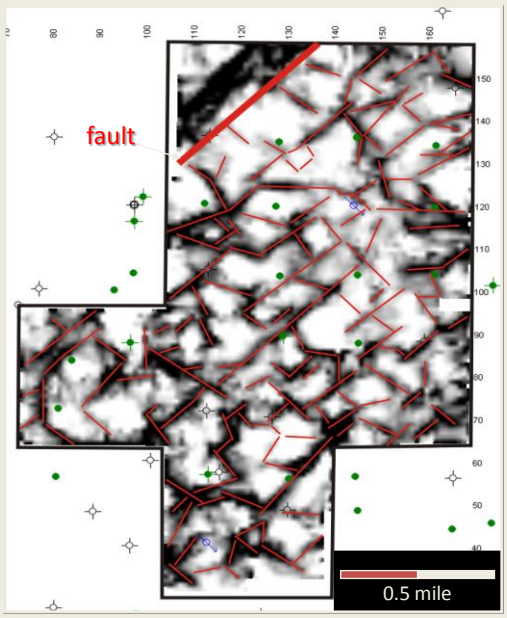
Dickman Field (Kansas, USA)

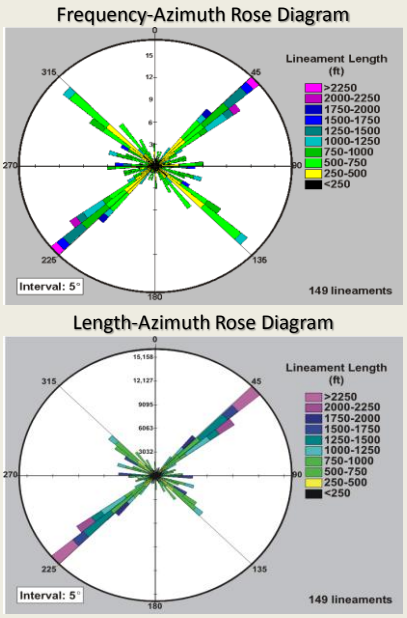
- Discovered in 1962
- Cumulative production >1.7 million bbl oil
- High water cut (>94%)



(Nissen et al., 2005)

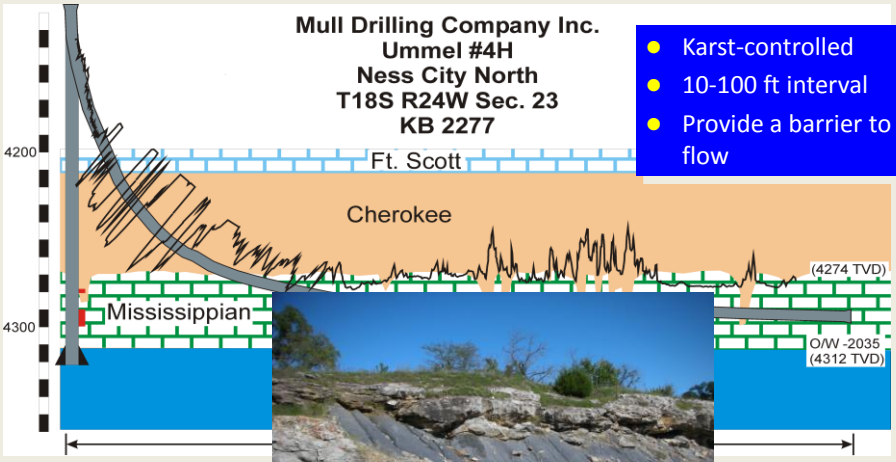
Volumetric Curvature – Gilmore City Horizon





(Nissen et al., 2005)

Shale-filled fractures intersected by horizontal well (Kansas, USA)

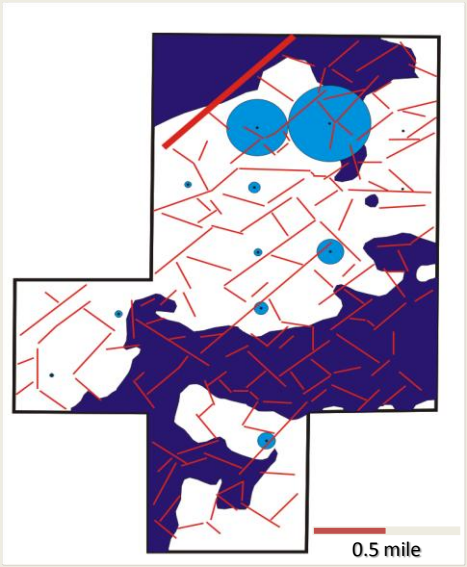


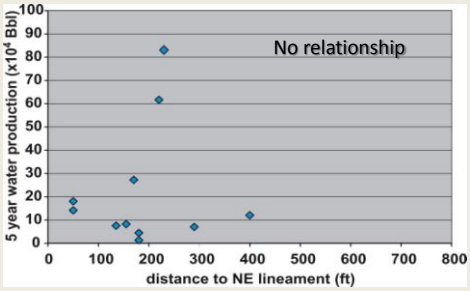
- Karst-controlled
- 10-100 ft interval
- Provide a barrier to fluid flow

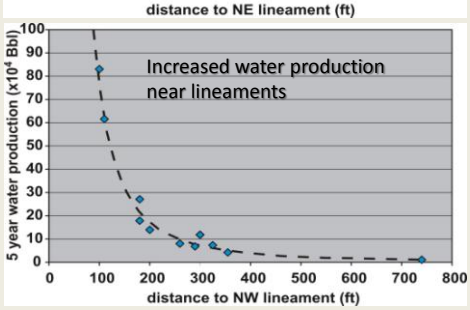
Miissippian cave filled with Pennsylvanian shale, SW Missouri

(Nissen et al., 2005)

Water production versus distance to nearest NW and NE lineaments

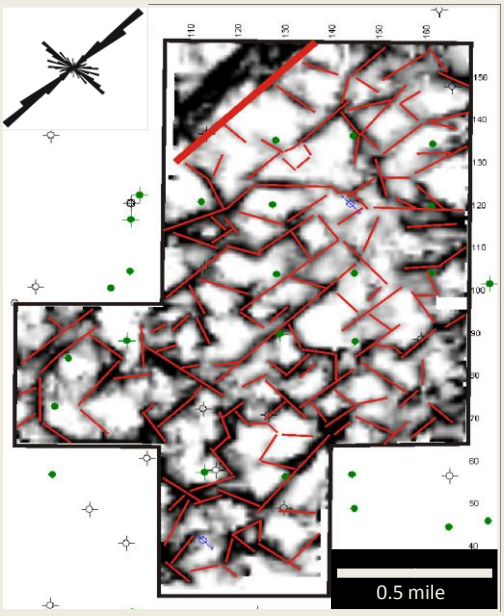




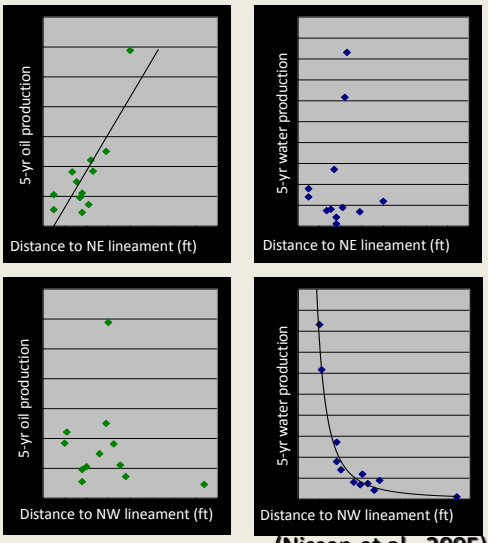


(Nissen et al., 2005)

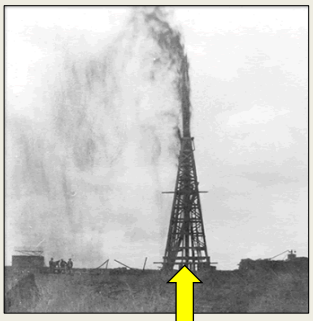
Oriented lineaments -- Kansas Mississippian



Lineament trend vs. production

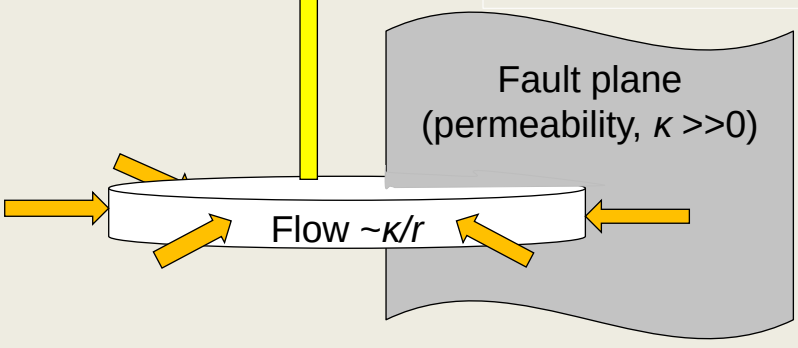


(Nissen et al., 2005)



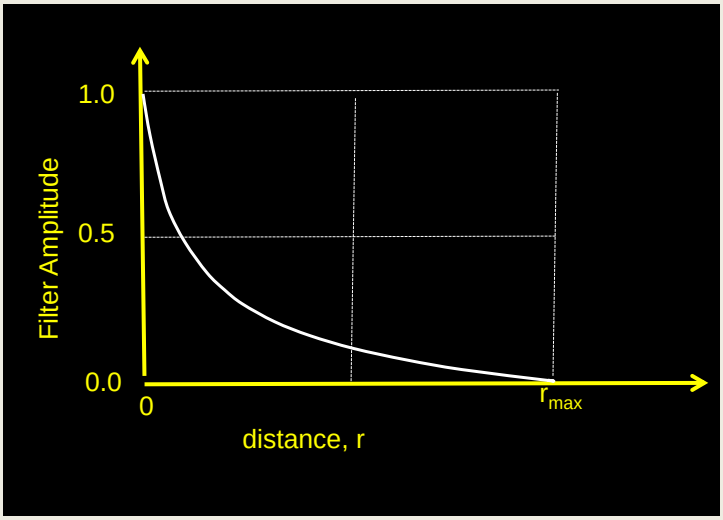
Methodology

- Hypothesize that an anomaly at a given azimuth corresponds to an open fracture
- Assume flow goes as κ/r
- Correlate flow to production to test the hypothesis



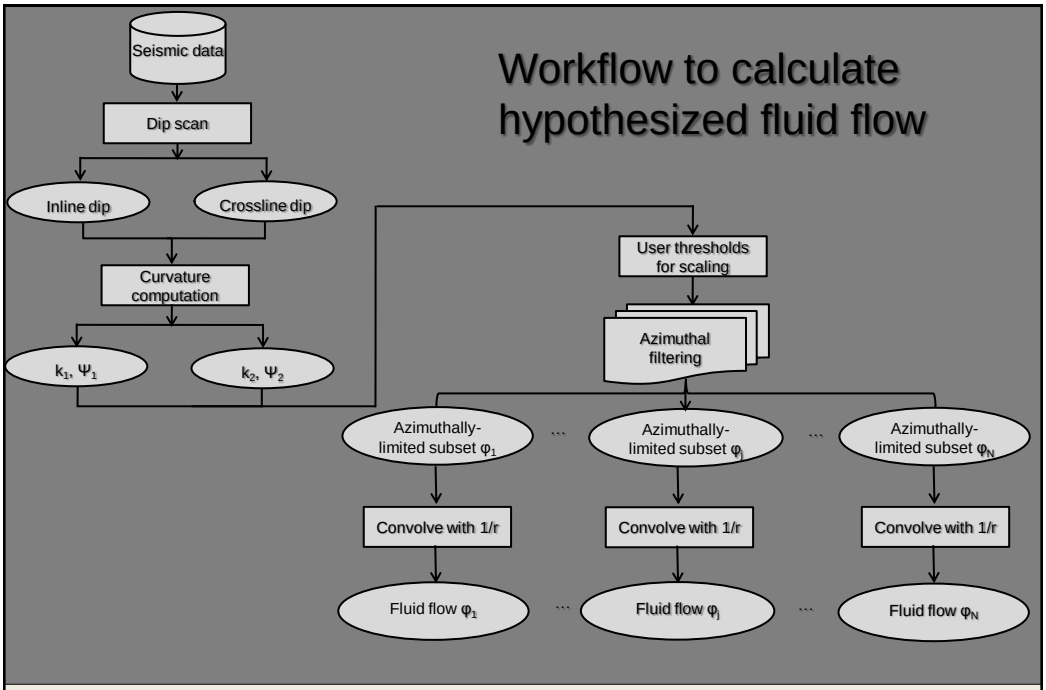
(Guo et al., 2011)

Flow as a function of distance, *r*, from a natural point "injector"



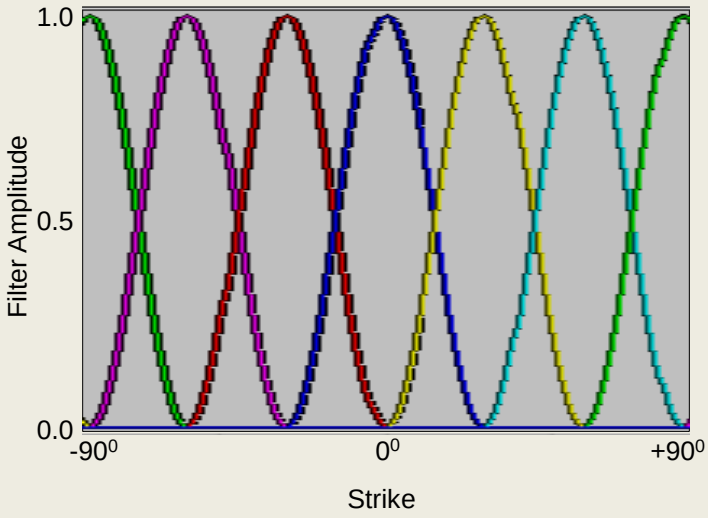
(Guo et al., 2011)

Workflow to calculate hypothesized fluid flow

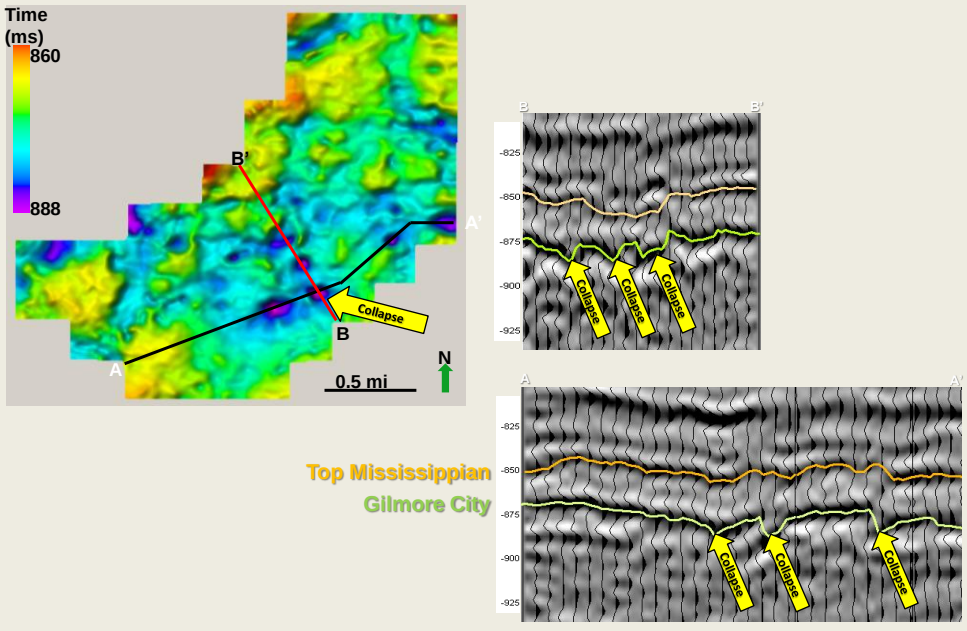


(Guo et al., 2011)

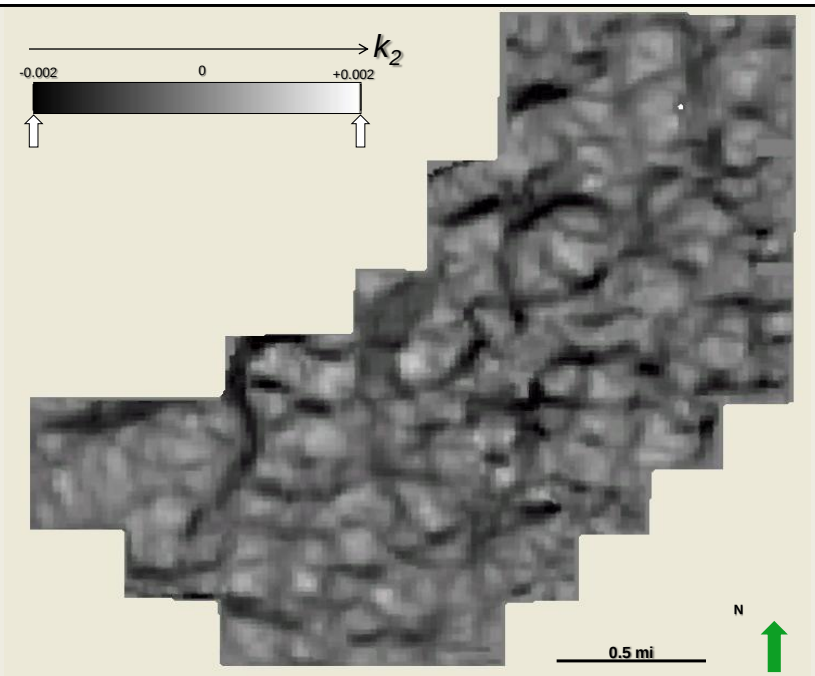
Computing azimuthally-limited curvature volumes



(Guo et al., 2011)

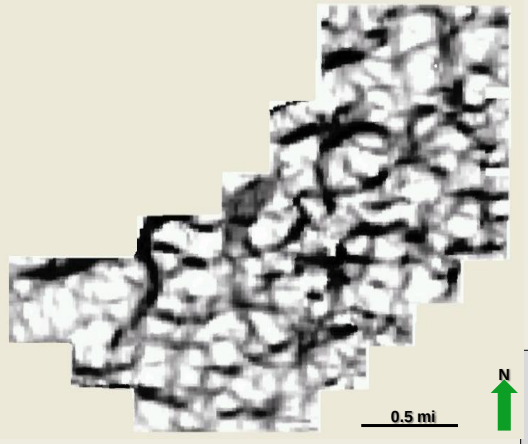


Time-structure map of Gilmore City horizon and two seismic lines (Guo et al., 2011)

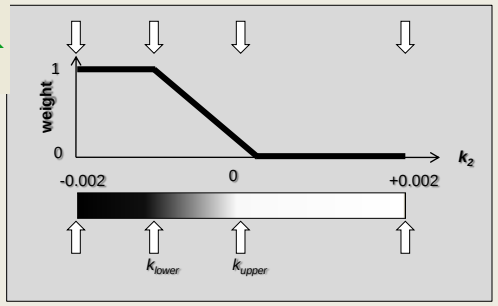


Most negative structural curvature, k_2, through the Gilmore City

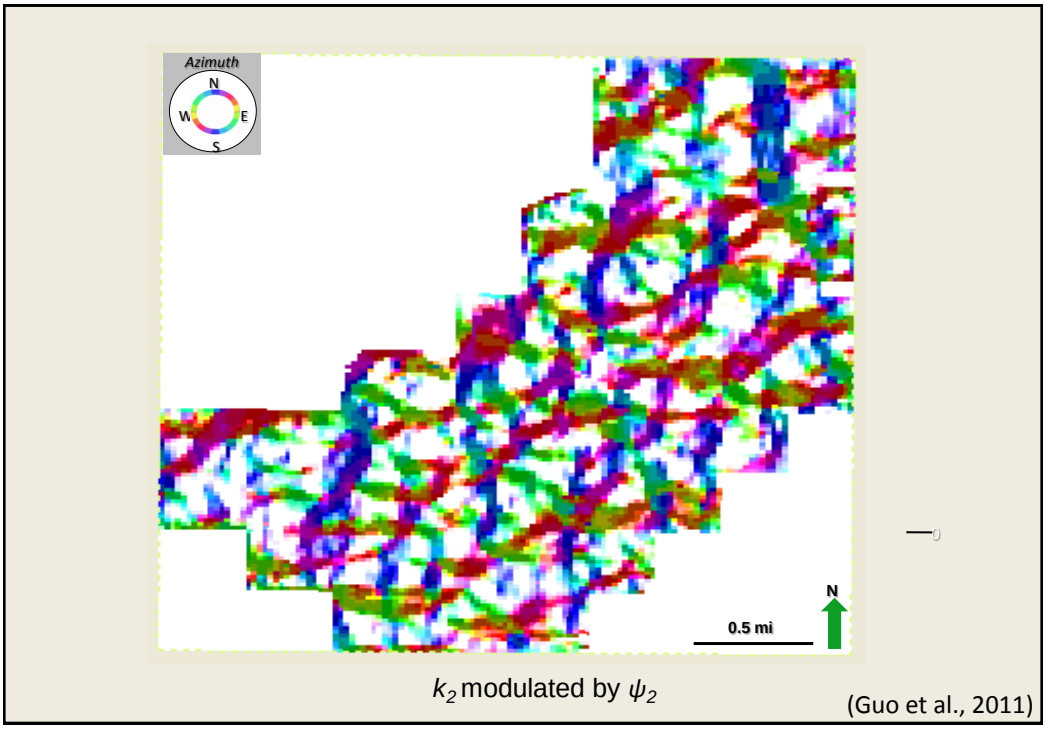
(Guo et al., 2011)



"Skeletonized" image obtained by interactively adjusting the color bar

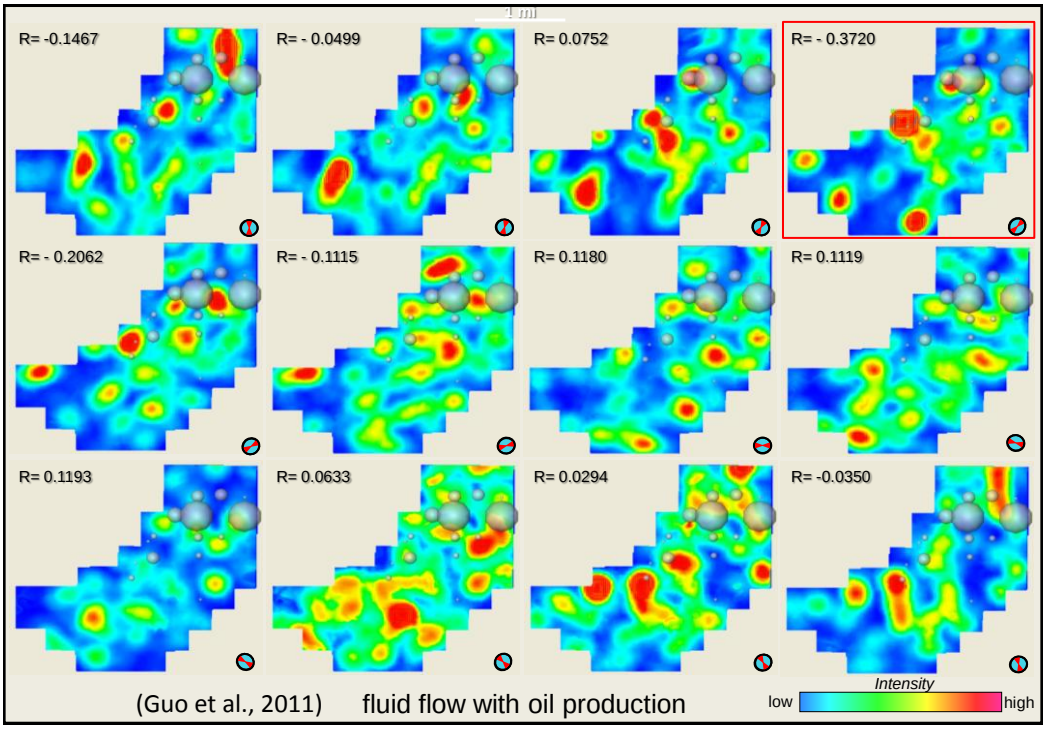


(Guo et al., 2011)

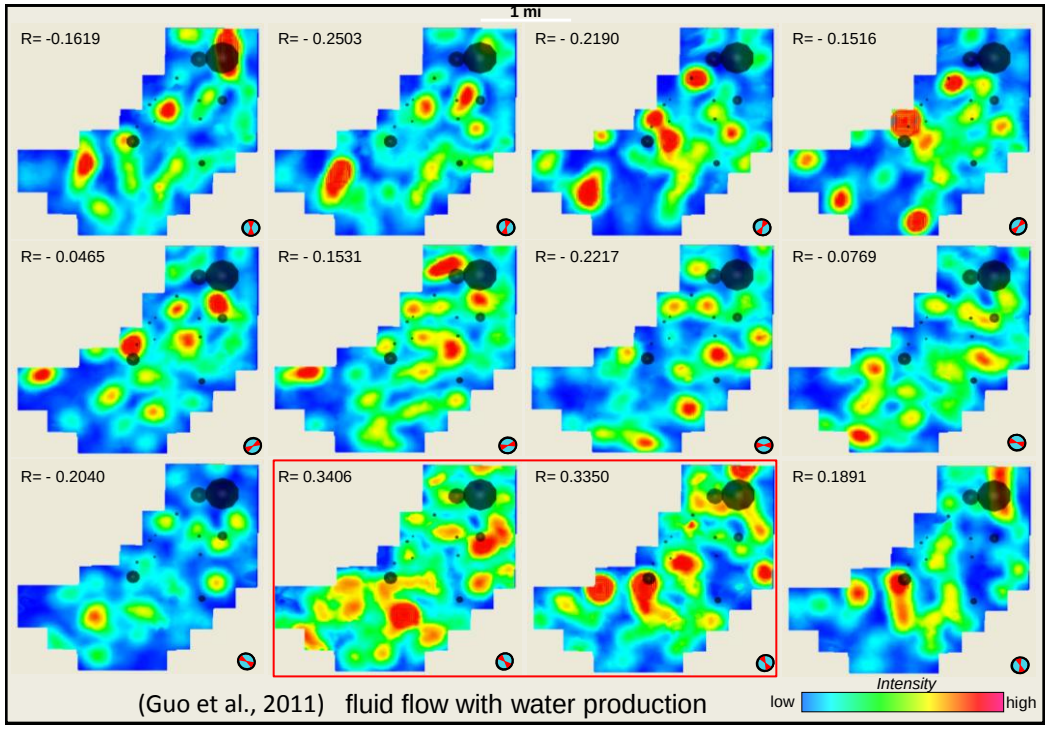


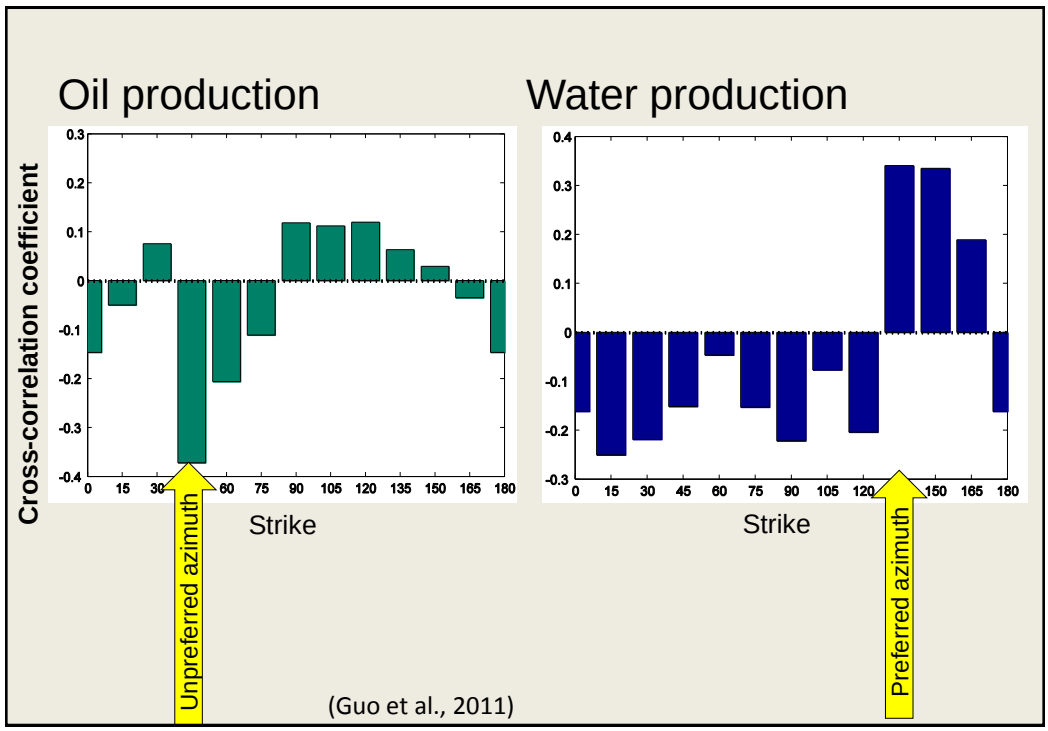
k_2 modulated by ψ_2

(Guo et al., 2011)



(Guo et al., 2011) fluid flow with oil production


1 mi
R= -0.1619
R= - 0.2503
R= - 0.2190
R= - 0.1516
R= - 0.0465
R= - 0.1531
R= - 0.2217
R= - 0.0769
R= - 0.2040
R= 0.3406
R= 0.3350
R= 0.1891
Intensity
low
high
(Guo et al., 2011) fluid flow with water production


Oil production
Water production
Cross-correlation coefficient
Strike
Strike
Unpreferred azimuth
Preferred azimuth
(Guo et al., 2011)

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  - Strain ← Curvature
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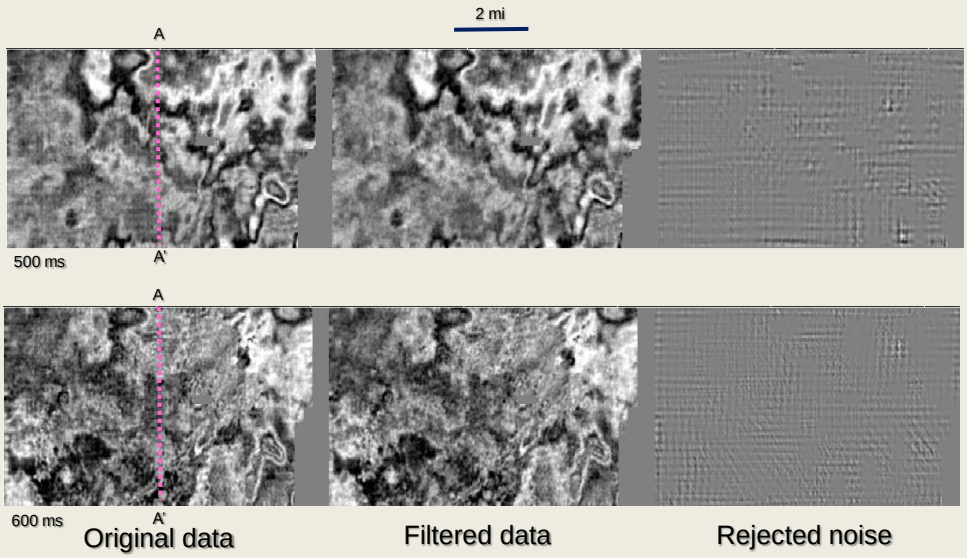
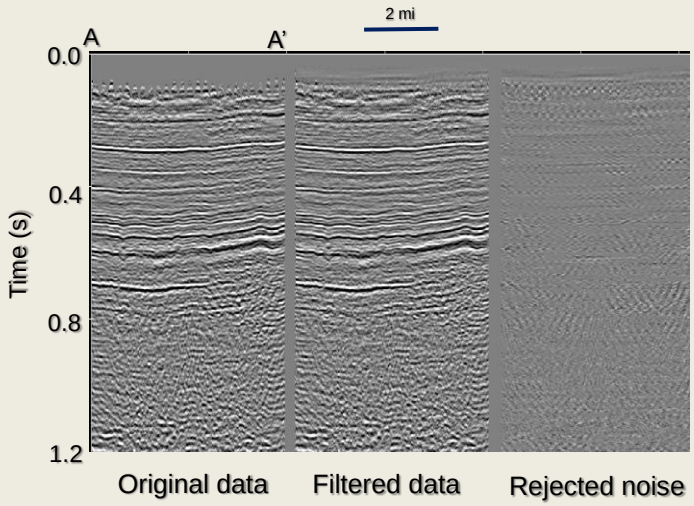
  - Lithology ← Impedance

  Diagenesis ← Textures

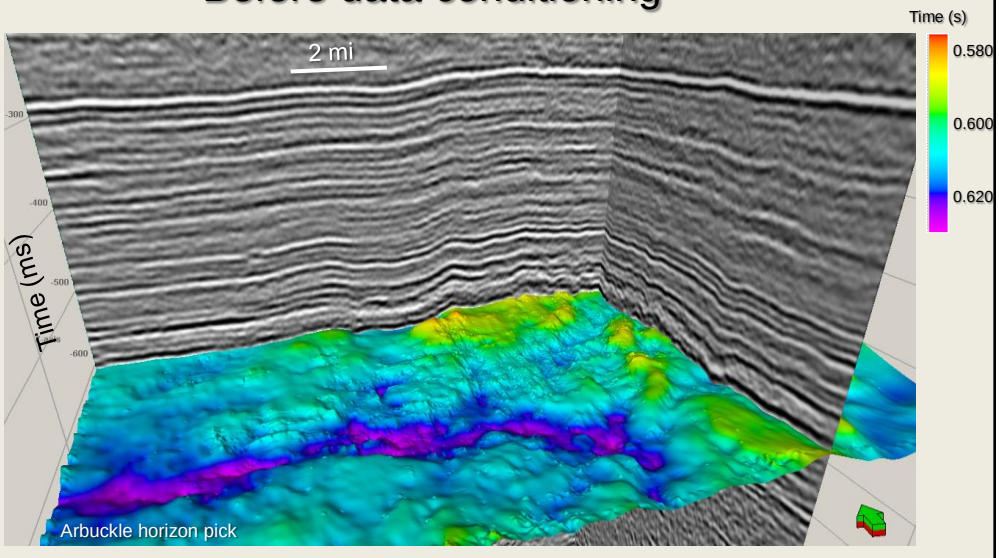
Rejecting periodic components of seismic noise



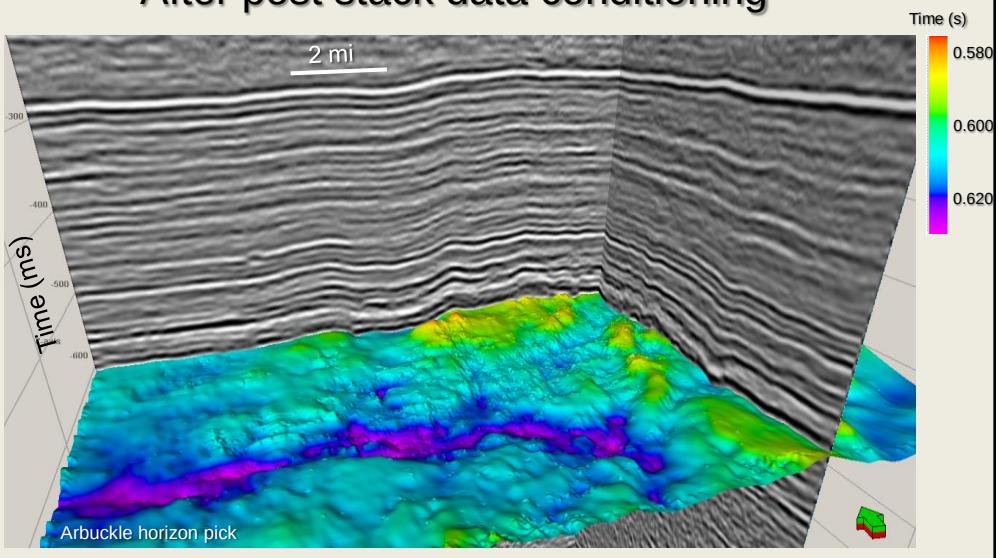
Rejecting periodic components of seismic noise



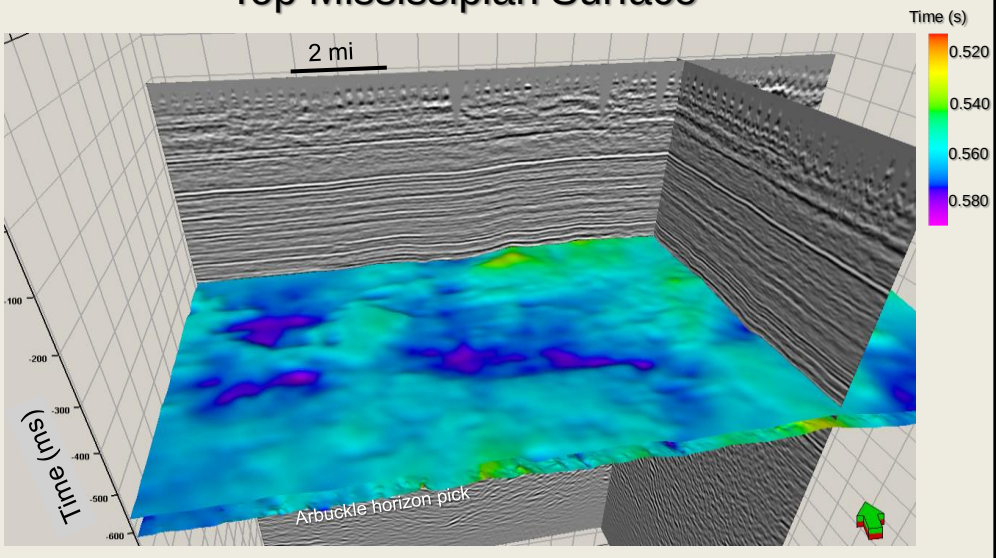
Before data conditioning



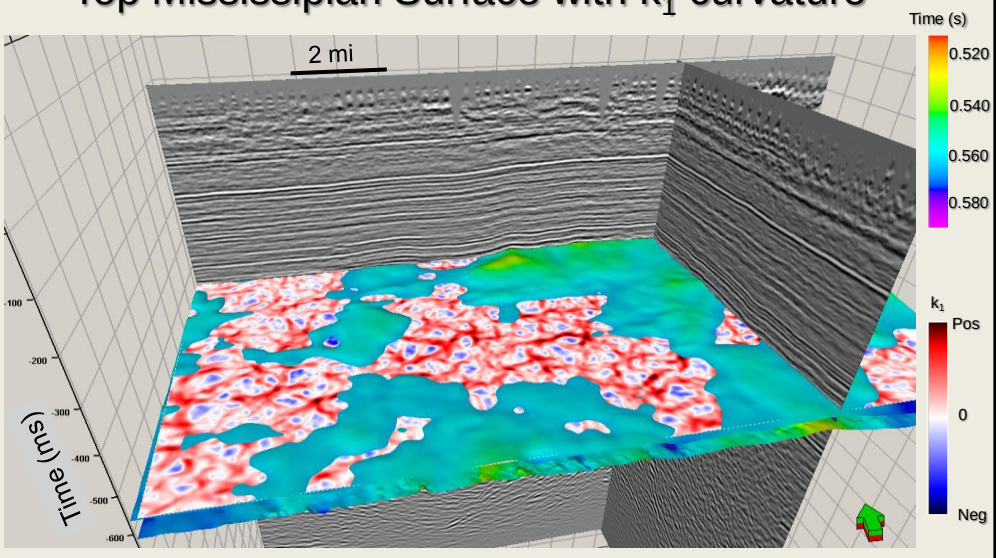
After post stack data conditioning



Top Mississipian Surface

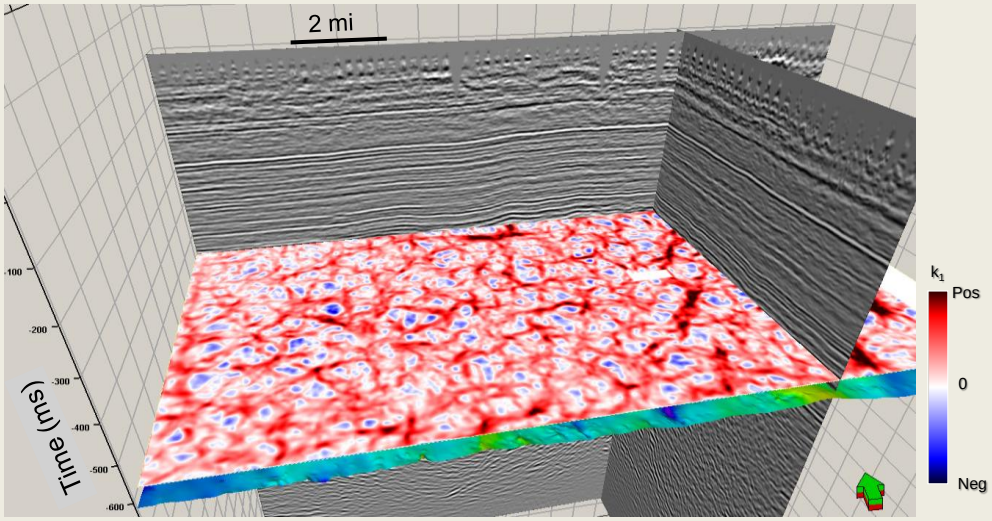


Top Mississipian Surface with k_1 curvature



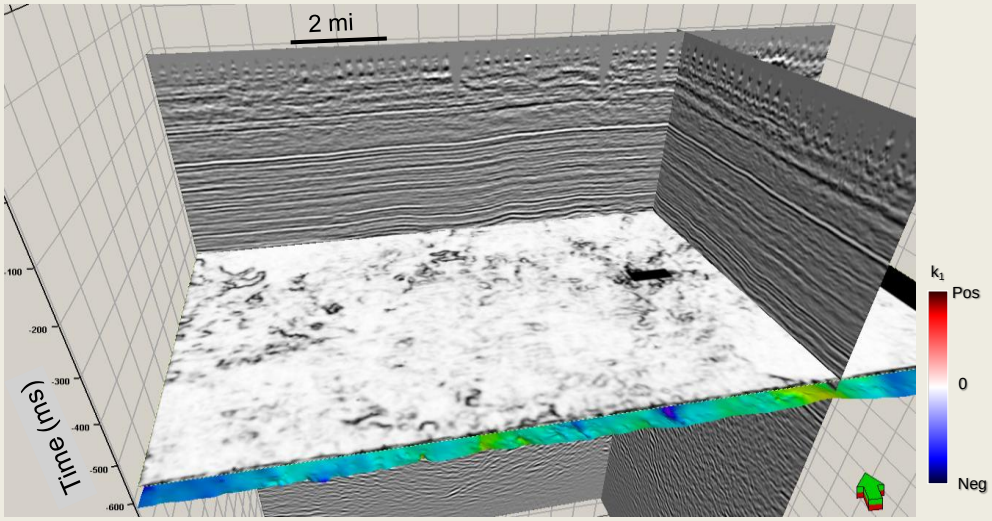
Time slice at 0.6 s

k_1 curvature



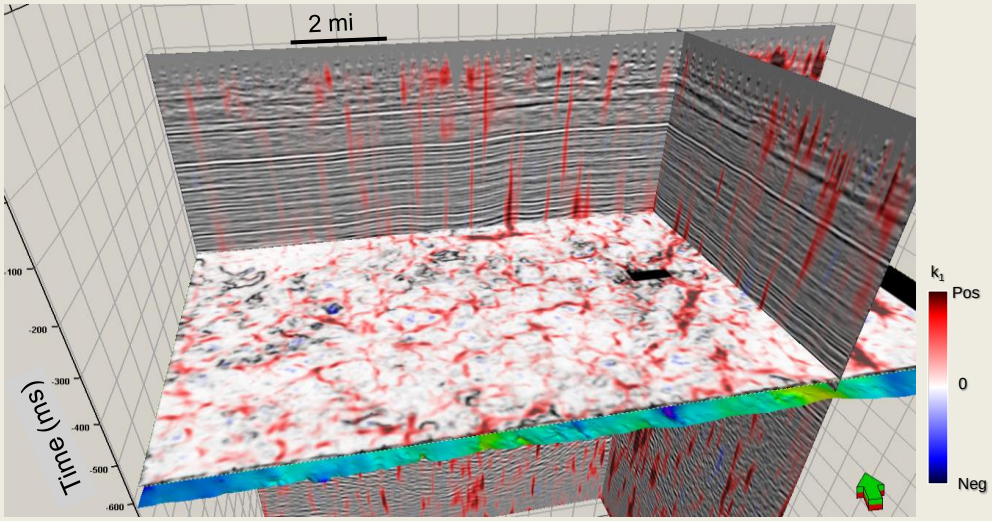
Time slice at 0.6 s

Coherence



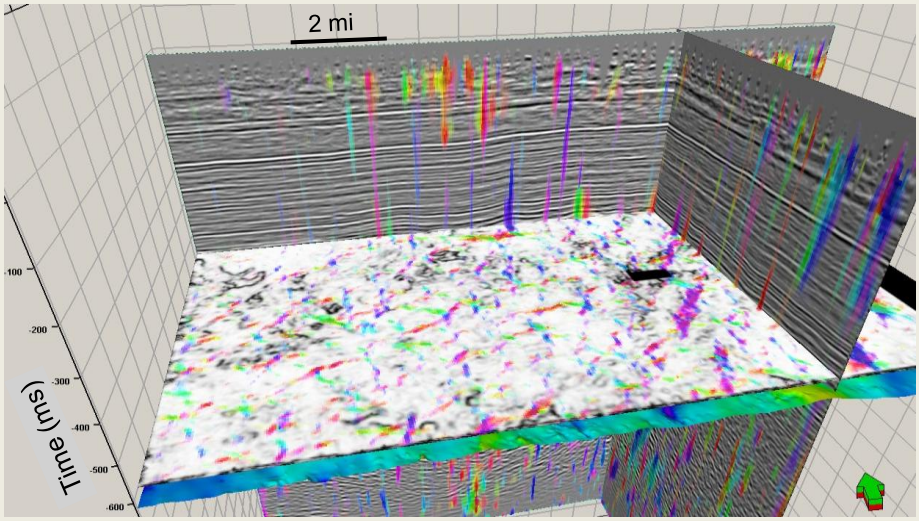
Time slice at 0.6 s

k_1 curvature co-rendered with coherence

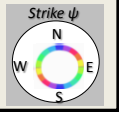


Time slice at 0.6 s

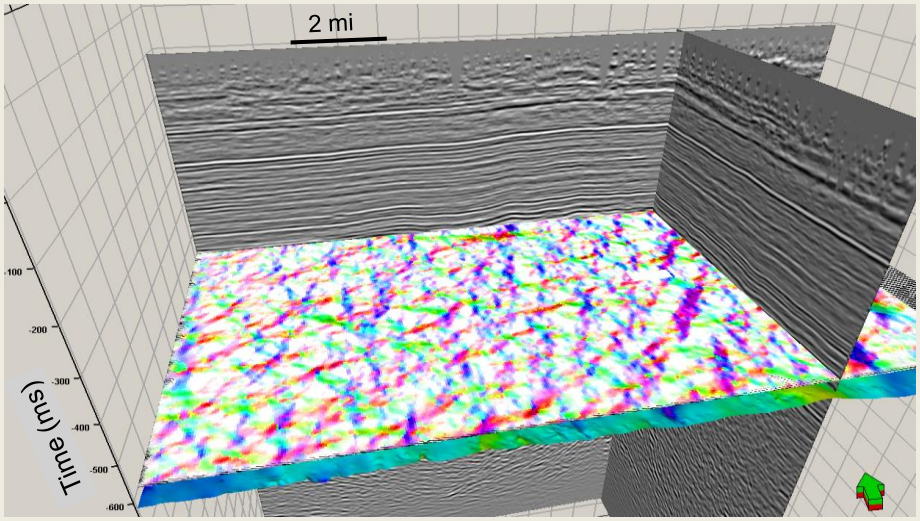
k_1 curvature vs. strike co-rendered with coherence



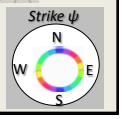
Time slice at 0.6 s



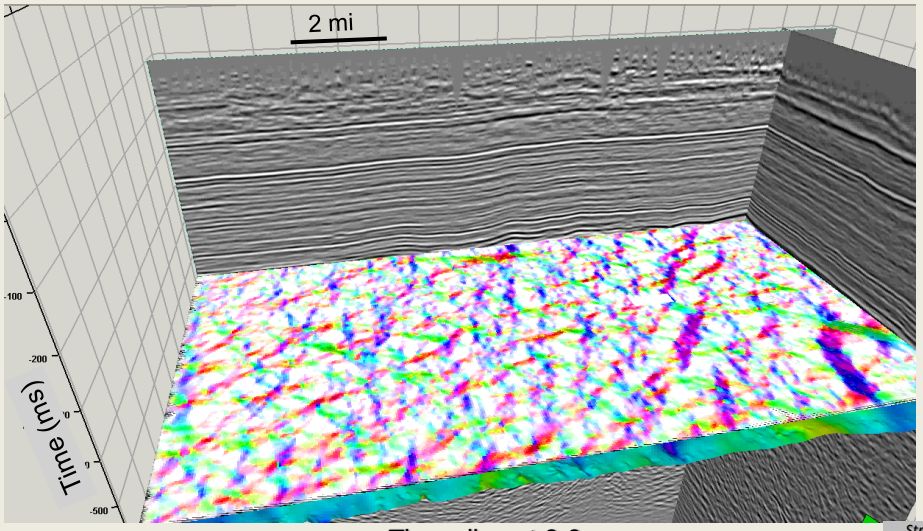
k_1 curvature vs. strike



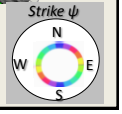
Time slice at 0.6 s



k_1 curvature vs. strike



Time slice at 0.6 s

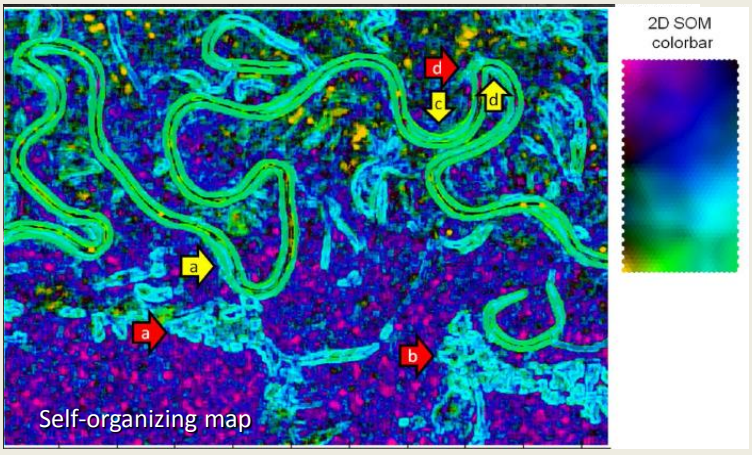


Attribute expression of the Mississippi Lime

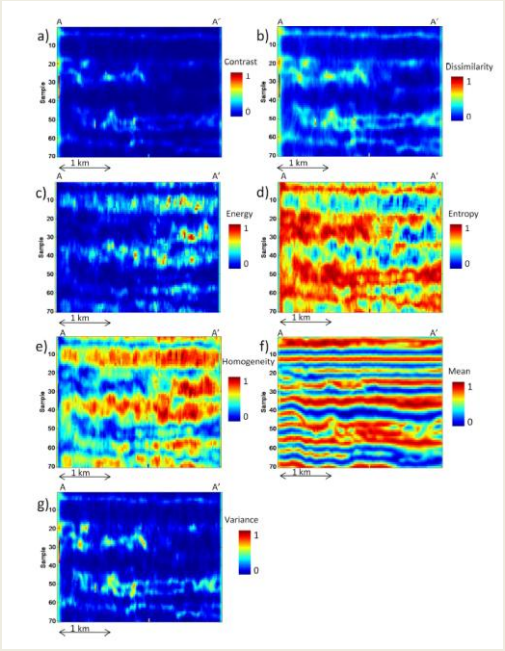
- Lithology ← Impedance
- Fractures
  - Strain ← Curvature
  - Thickness ← Spectral components
  - Lithology ← Impedance

Diagenesis ← Textures

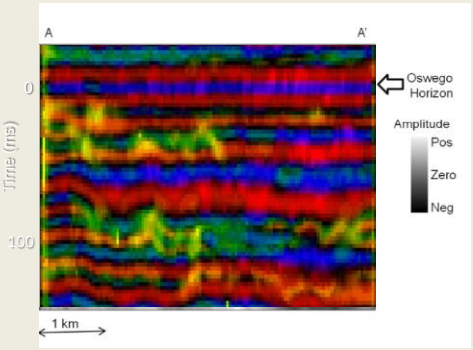
Texture analysis and self-organizing maps applied to satellite imagery

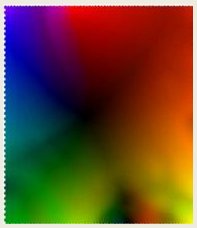


(Matos et al., 2011)



Vertical slices through texture attributes, Osage Co., OK

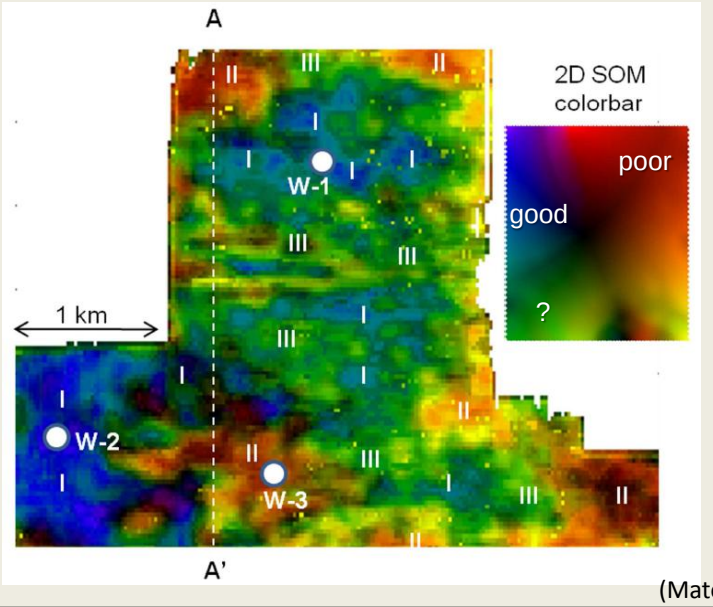




256 Cluster color bar

(Matos et al., 2011)

Texture analysis and self-organizing maps applied to Mississippi Lime, Osage Co, OK



(Matos et al., 2011)

Outline

- Correlation of fractures to curvature
  - Clay models
  - Outcrop analogues
  - Hunton Limestone – seismic with image logs

  A proposed workflow using post-stack data
  - Kansas fractured carbonate
- Attribute images of Osage County surveys
- Recommendations for future seismic acquisition

Recommendations for future seismic acquisition

Acquire high density, but less sweeps (more traces/mi^2)
- reduce coherent noise (e.g. ground roll, shallow diffractors, …)
- reduce acquisition footprint that overprints fractures

Acquire long offsets
- facilitate λρ-μρ inversion to map lithology (tripolite, dolomite, tight chert,…)

•

Acquire wide azimuth to facilitate AVAz and VVAz analysis
- map natural fractures
- map maximum/minimum horizontal stresses

Calibrate seismic predictions with image logs and microseismic data

These are fairly routine parameters in other resource plays (i.e. shale gas)

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