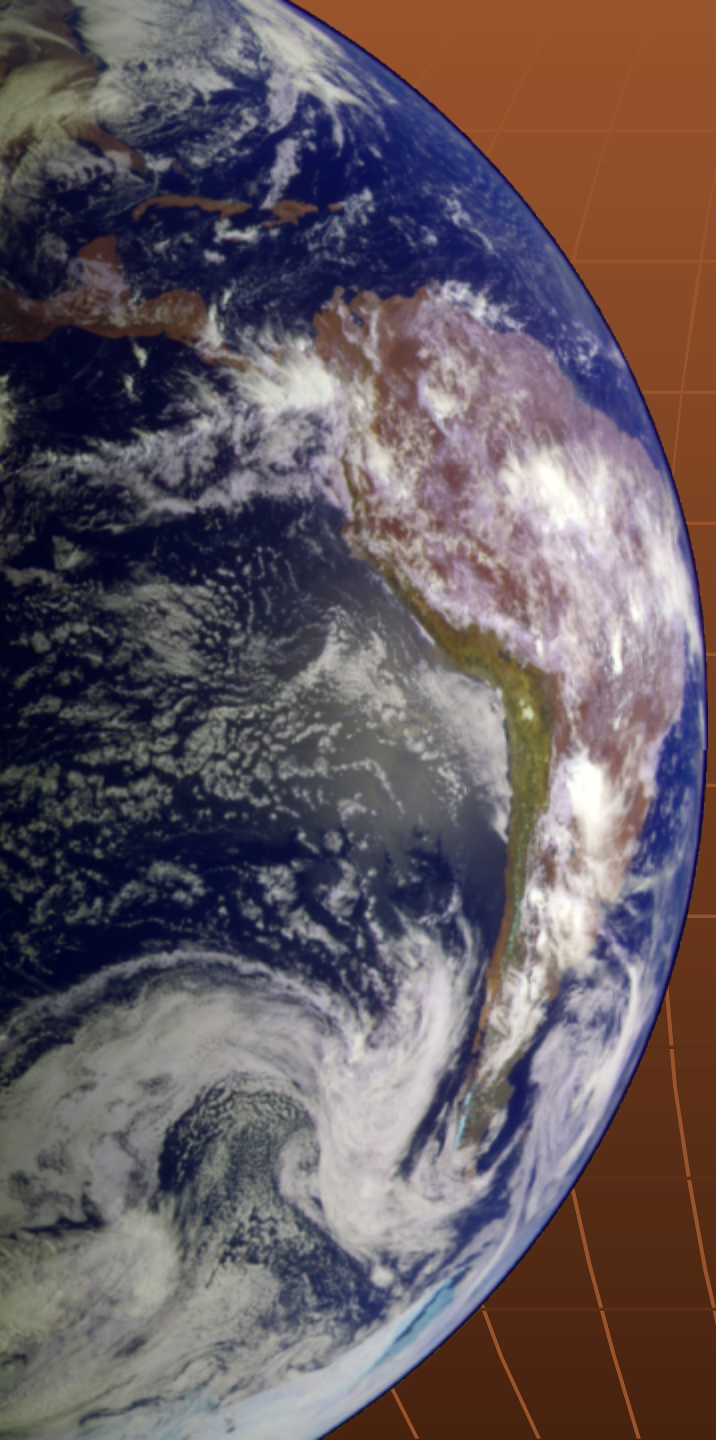

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Investigation of Anisotropy in the Woodford Shale

AVAZ and Rock Physics Modeling in the Anadarko Basin, OK

Alexander Lamb

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Outline

- Background
- Well Log Observations
- Seismic Data Observations
- Rock Physics Modeling
- Synthetic Seismic Data
- Results / Conclusions

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Background

- Woodford Shale Formation
- Anadarko Basin
- Canadian County, OK

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Background

- Woodford Shale
  - "Black" shale
  - Late Devonian / Early Mississippian
  - ~13,000 ft. deep
  - ~250 ft. thick

- Mississippian Limestone above
- Hunton Limestone below

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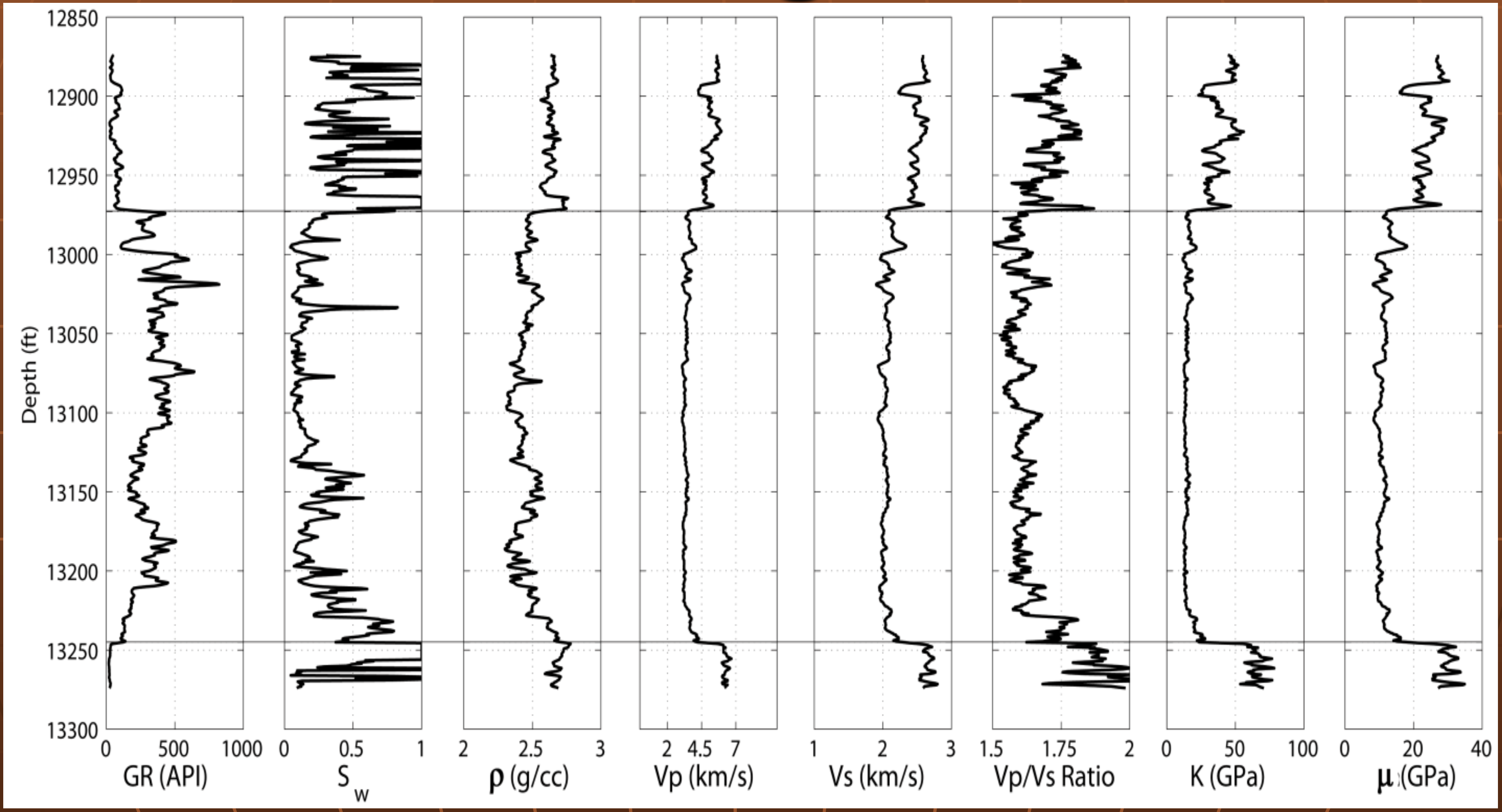
Well Log Data



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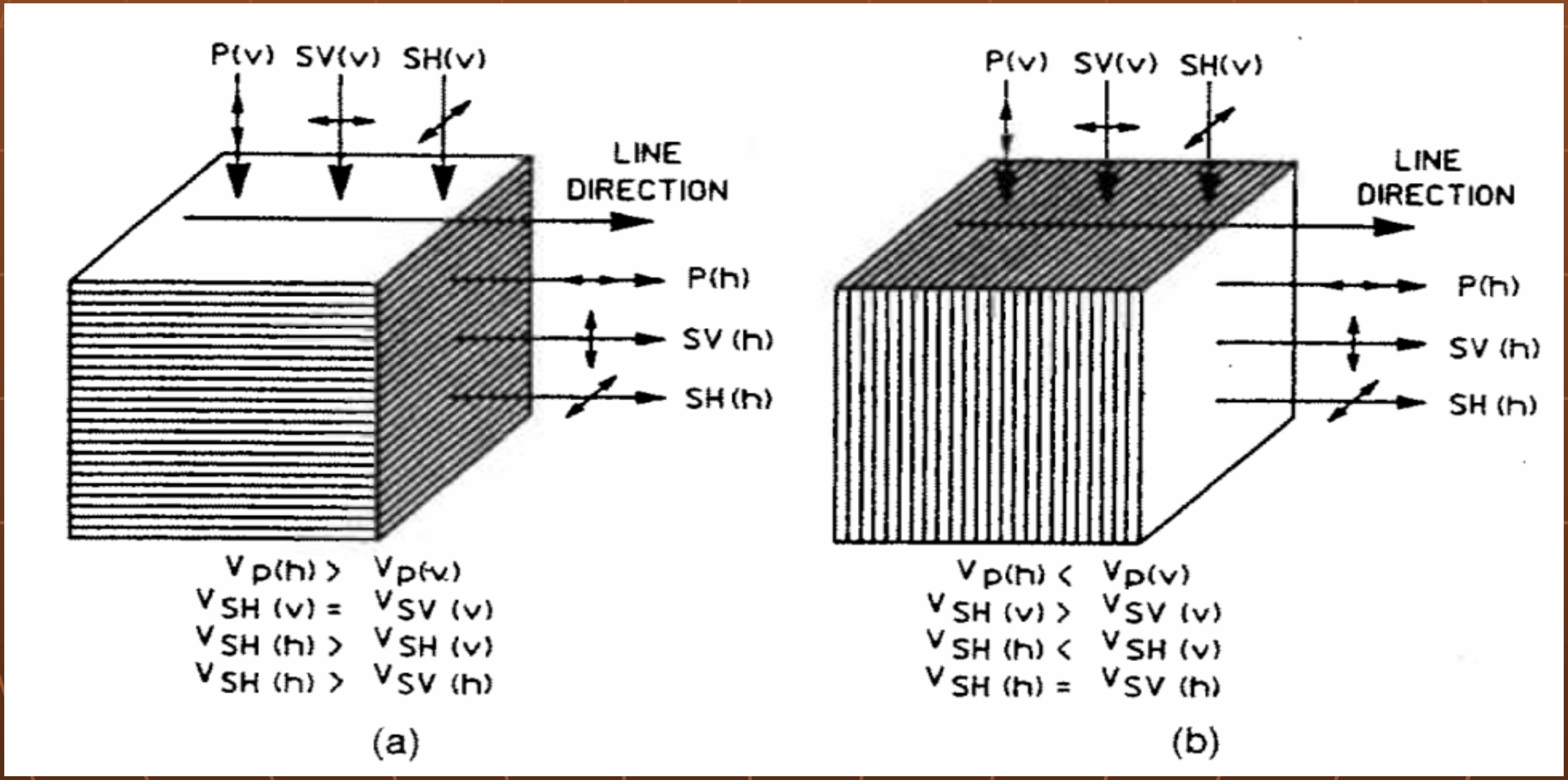
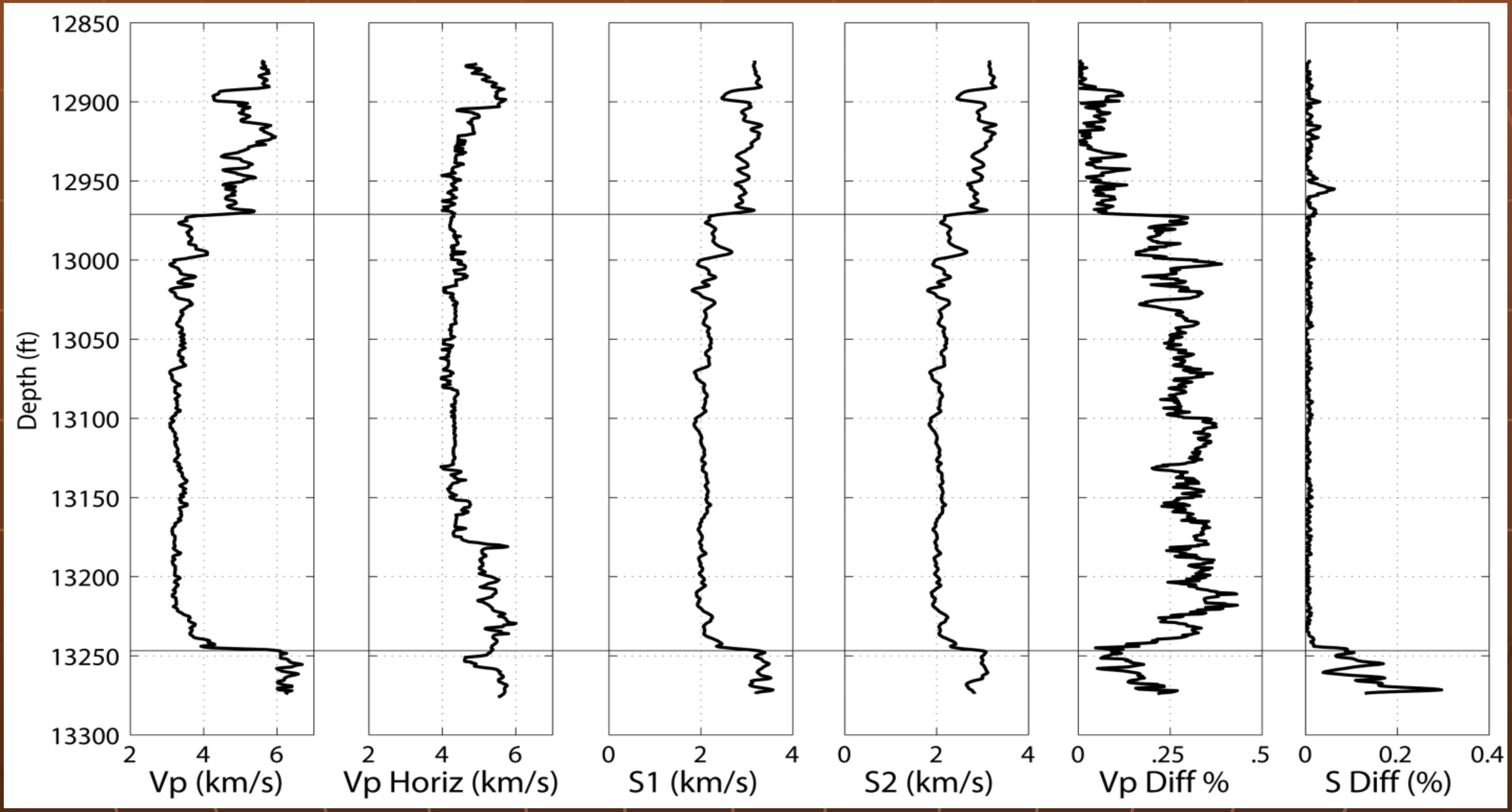
Anisotropy

VTI HTI



[from Tatham et al., 1992]

Well Log Data – VTI?



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Well Log Data

- Well Log Observations indicate VTI
- Considerations
  - Higher frequency of log data (2-10kHz)
  - Limited resolution
- What does seismic data tell us?

Seismic Data - AVAZ

- Amplitude varying with azimuth
- Does AVO response change as a function of azimuth?
- Necessary to use pre-stack data
- Key indicator of HTI

Seismic Data - Workflow

- Tie well log to seismic data
- Interpret Woodford horizon
- Gather seismic data by azimuth (10 degree sections)
- Convert from offset gathers to angle gathers
- Calculate AVO gradient (B) as a function of azimuth

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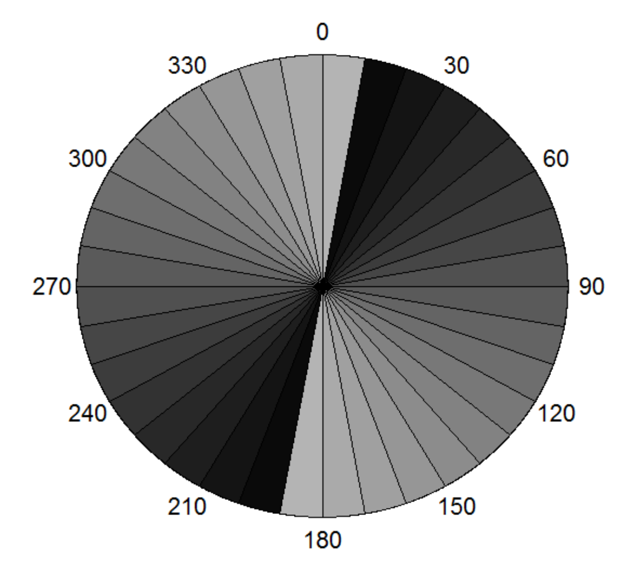
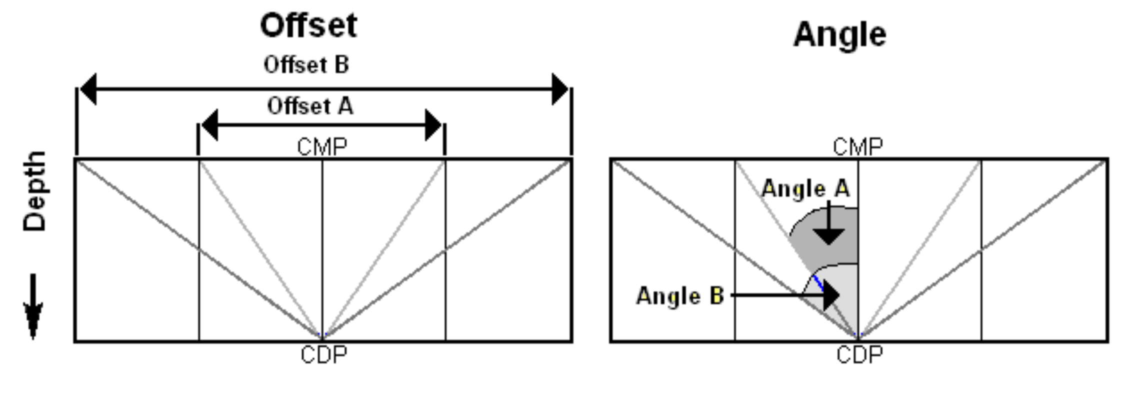
Seismic Data - Workflow



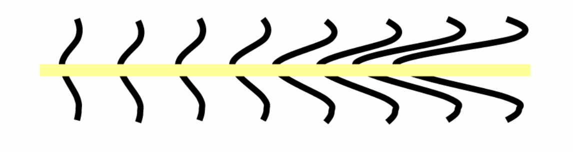
Gather Seismic Data into Azimuthal (10 degree) sections



Convert offset gathers into angle gathers (from Hampson-Russell)

Quantifying AVO

- $RC(\theta) = A + B \sin^2\theta$



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Quantifying AVO

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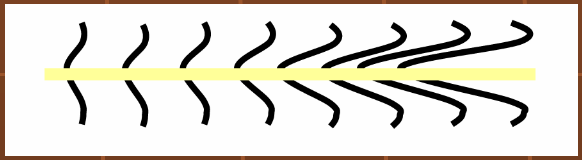
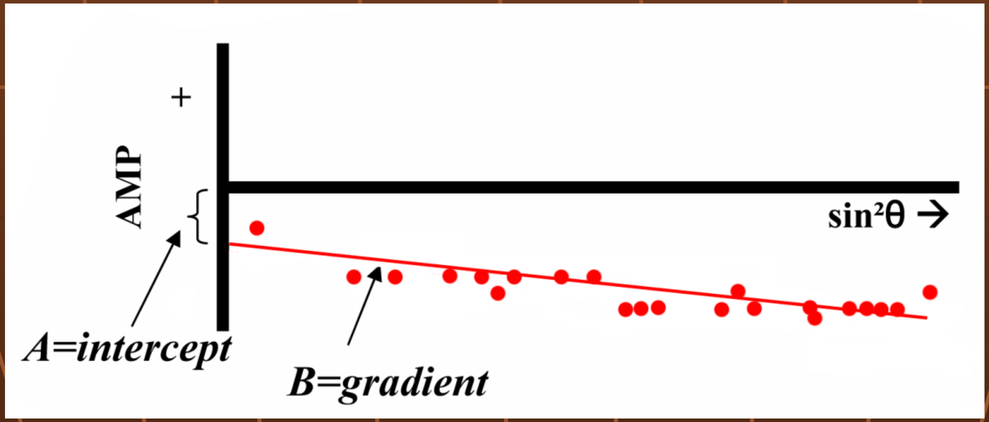
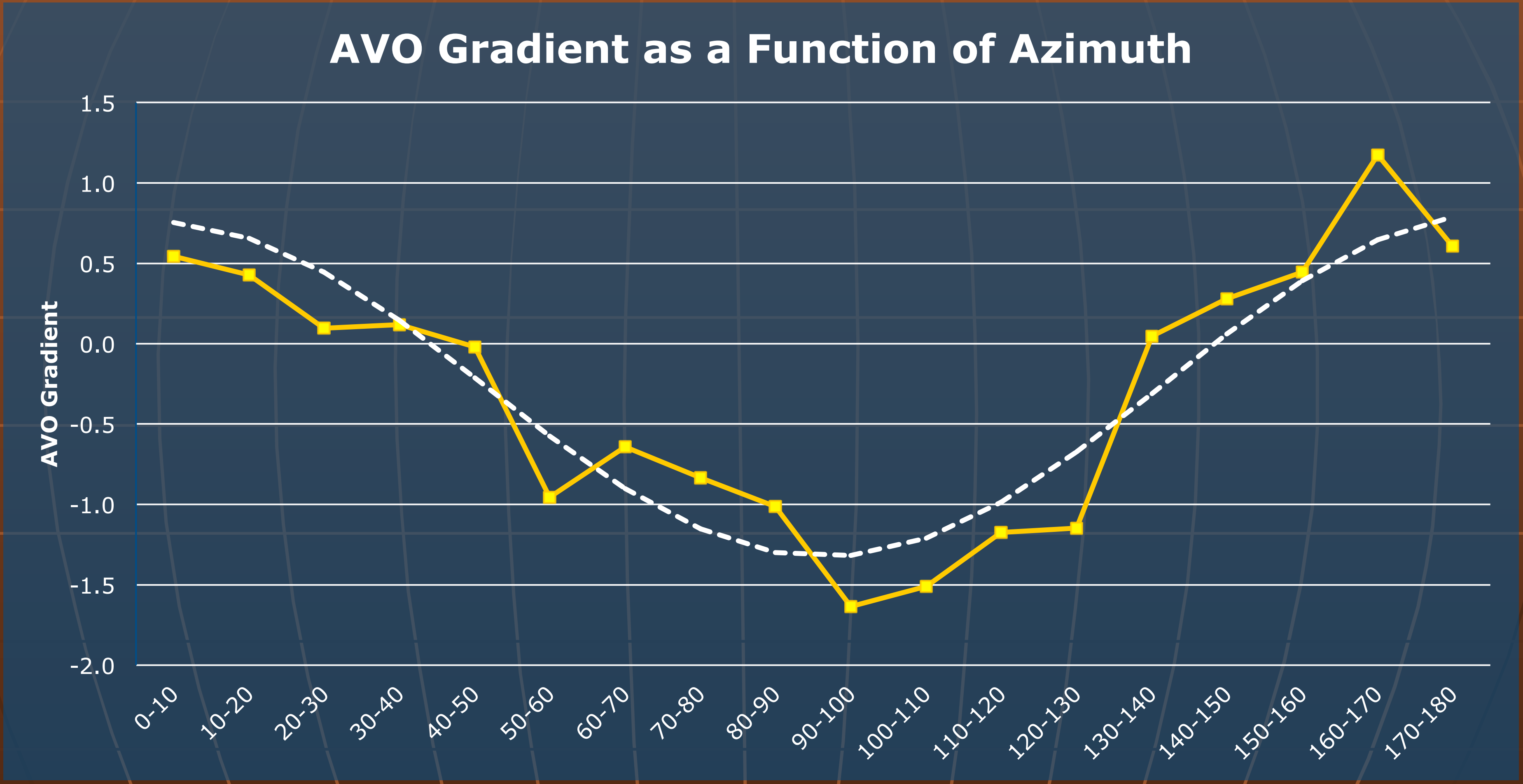




AVAZ Results

- Interpret B as a function of azimuth

AVAZ Results



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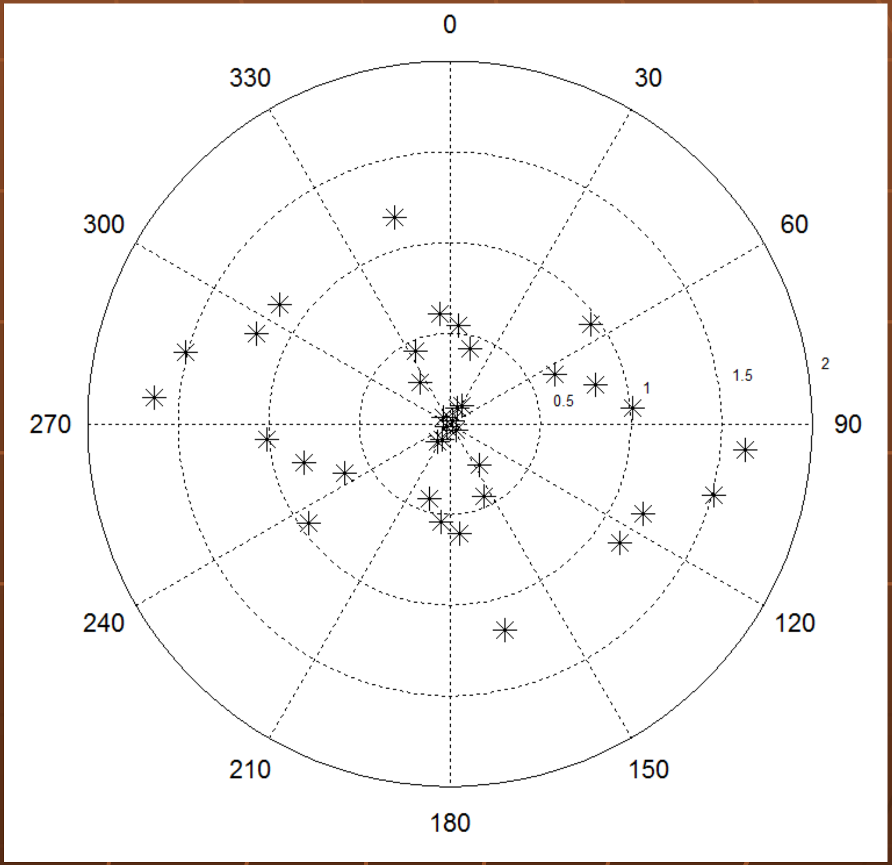
AVAZ Results

- Graph results of B on polar plot
- Fit ellipse to data
- Minor axis points to orientation
- Minor/major axis ratio indicates fracture density



AVAZ Results

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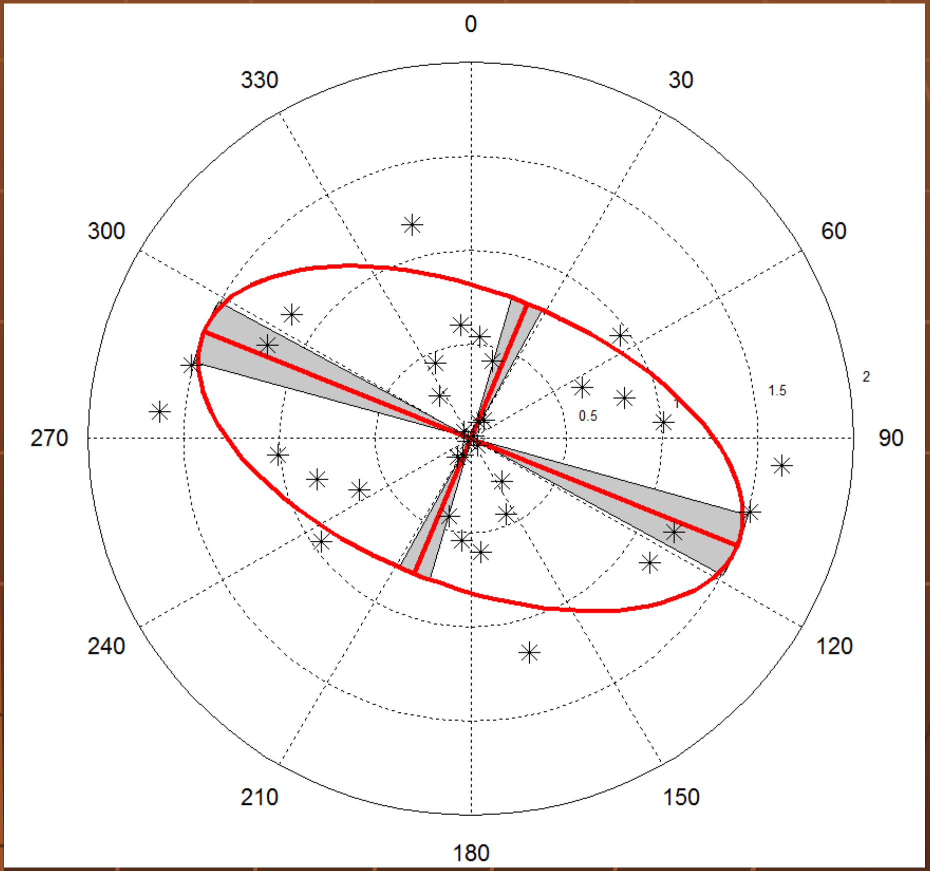

Seismic Data

- Seismic Observations indicate HTI
- Longer wavelengths ‘sample’ more rock, better for volumetric properties
- Relative fracture density from AVAZ
- Quantify fracture density?

Rock Physics - Workflow

- Composite Estimate
  - Created from well log data
- Hashin-Shtrikman-Walpole Bounds
  - Introduce Porosity
- Hudson Cracked Media Model
  - Introduce fractures
- Brown and Karringa Fluid Saturation
  - Add fluids

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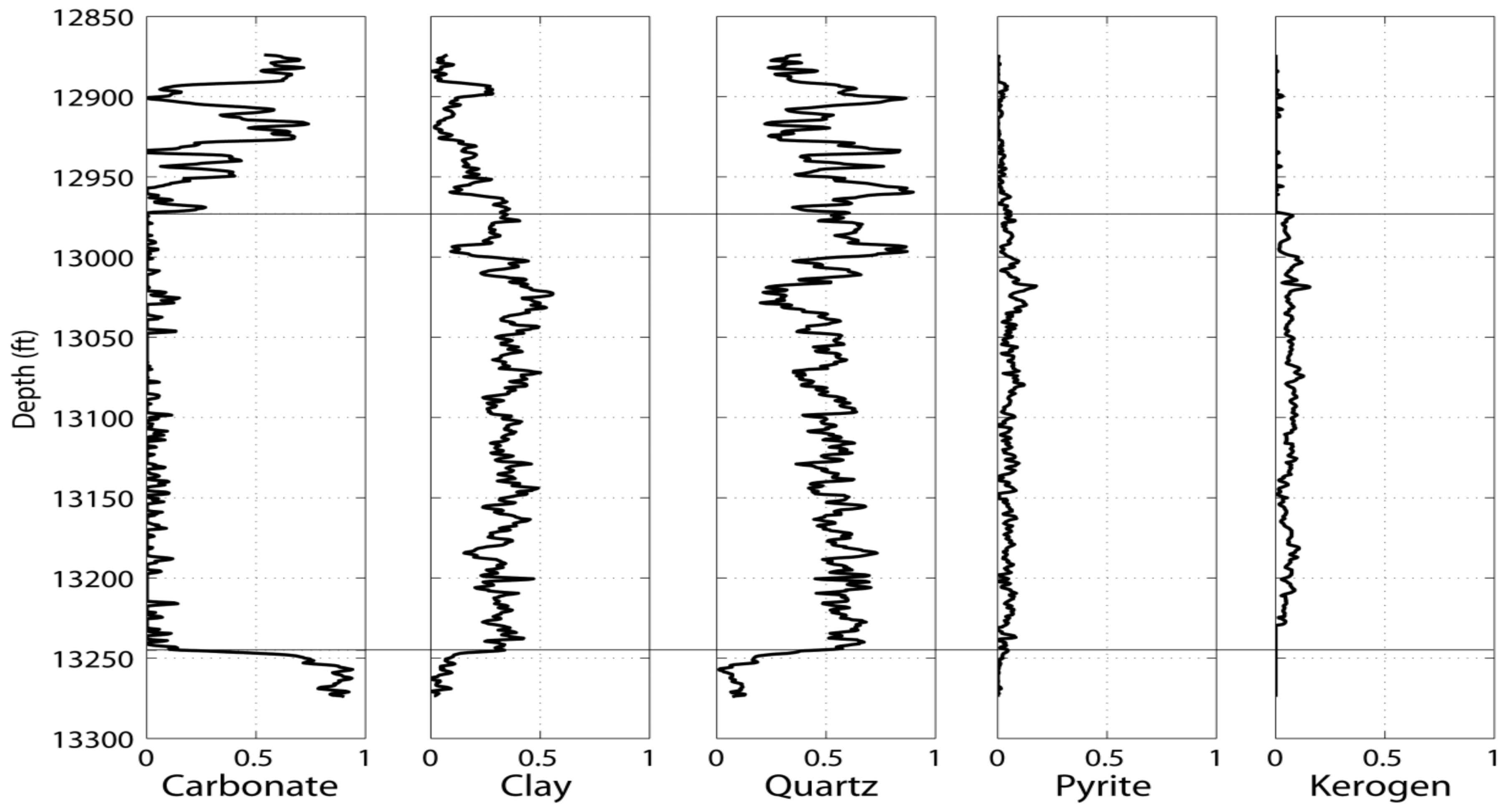
Rock Physics - Composition



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Rock Physics

Minerals
K_0, μ_0

HSW bounds →

Introduced Φ
K_1, μ_1

- From composition, created isotropic model of Woodford
- Hashin-Shtrikman-Walpole bounds show effect of porosity (Φ) on stiffnesses (K, μ)
- New density-porosity used

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Rock Physics

Introduced Φ
K_1, μ_1

Hudson Model →

Introduced cracks
C_{ij}^{dry}

- Porous media inserted into Hudson Cracked Media Model
- Specific crack density and aspect ratio used
- Crack density governed by $\epsilon = \frac{3\phi^{crack}}{4\pi\alpha} \leq 0.1$
- Stiffness tensor C_{ij}^{dry} returned

Rock Physics

Introduced cracks C_{ij}^{dry}	BK Fluid Saturation →	Introduced fluid C_{ij}

- Cracked model inserted into Brown and Karringa fluid saturation method
- Fluid determined by water/gas mixture governed by S_w log
- Stiffness tensor C_{ij} returned

Rock Physics - Recap

- Composite Estimate
  - Created from well log data
- Hashin-Shtrikman-Walpole Bounds
  - Introduce Porosity
- Hudson Cracked Media Model
  - Introduce fractures
- Brown and Karringa Fluid Saturation
  - Add fluids
- Result: C_{ij}

Synthetic Seismic Data

- From rock physics model: C_{ij}
- ANIVEC software generates synthetics
- In progress: Perform AVAZ on synthetics to determine relationship between ellipticity and crack density

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Results / Conclusions

- Well log data indicates VTI
- Seismic data indicates HTI
- Preliminary AVAZ results from seismic data show a SW/NE orientation
- Rock physics model based on well log data generates full stiffness tensor usable for synthetics

Future Work

- Establish quantified relationship between crack density and ellipticity
- Regional map of fracture orientation from AVAZ methods on seismic data
- Quantify effect of varying lithology

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Questions?

Thanks for listening!