Pore-stiffness, aspect ratio and composition effects on rock-physics modeling in the Haynesville Shale

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- Conclusion
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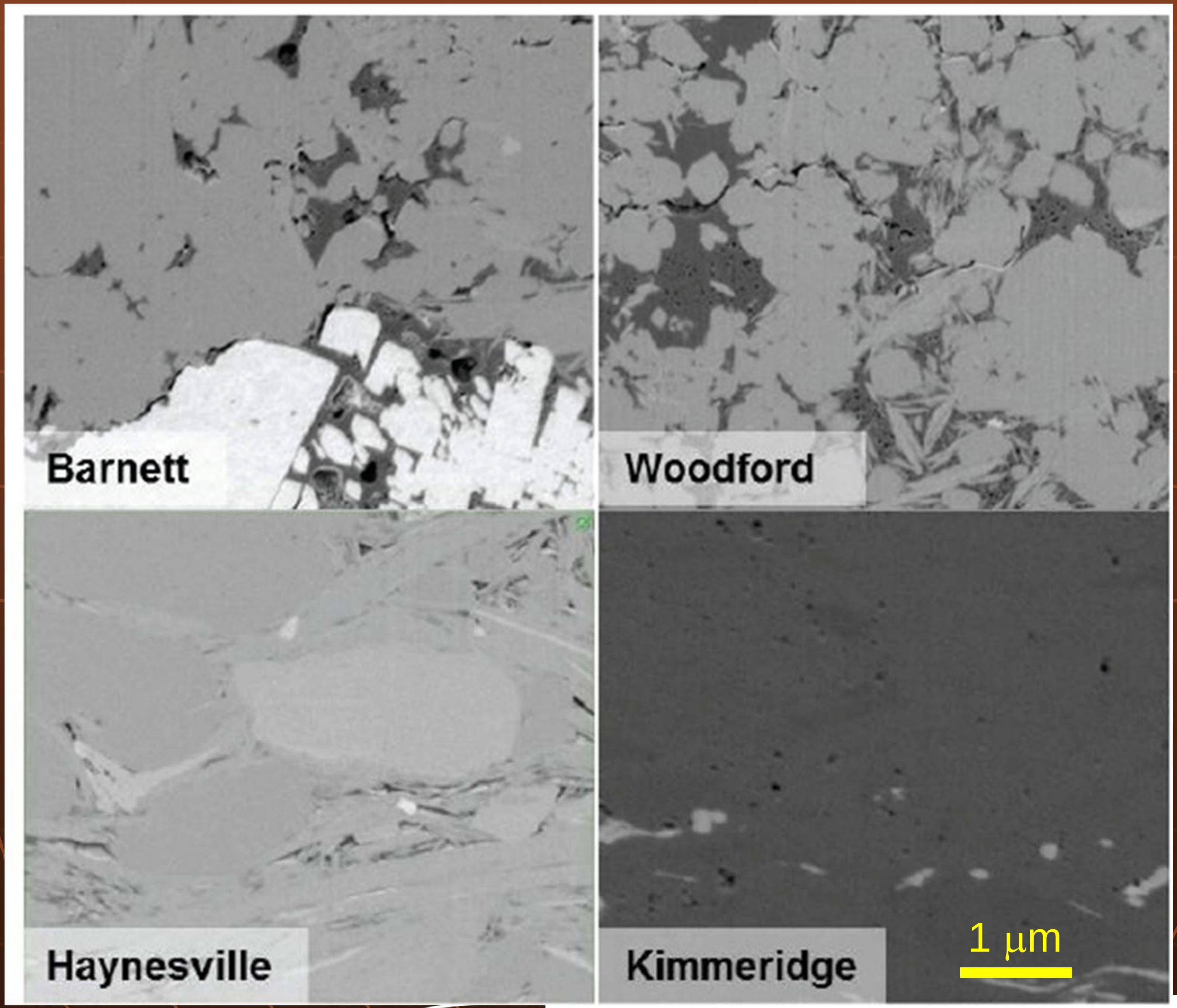
Motivation

BSE Image of different shales



Curtis, Ambrose, Sondergeld and Rai, 2010

Rock Physics Modeling

Individual Wells

Reservoir Properties

CLASTIC
Porosity
Water Saturation
Composition

SHALE
Porosity
Pore Stiffness
Aspect Ratio
Composition

RP Modeling

Elastic Properties

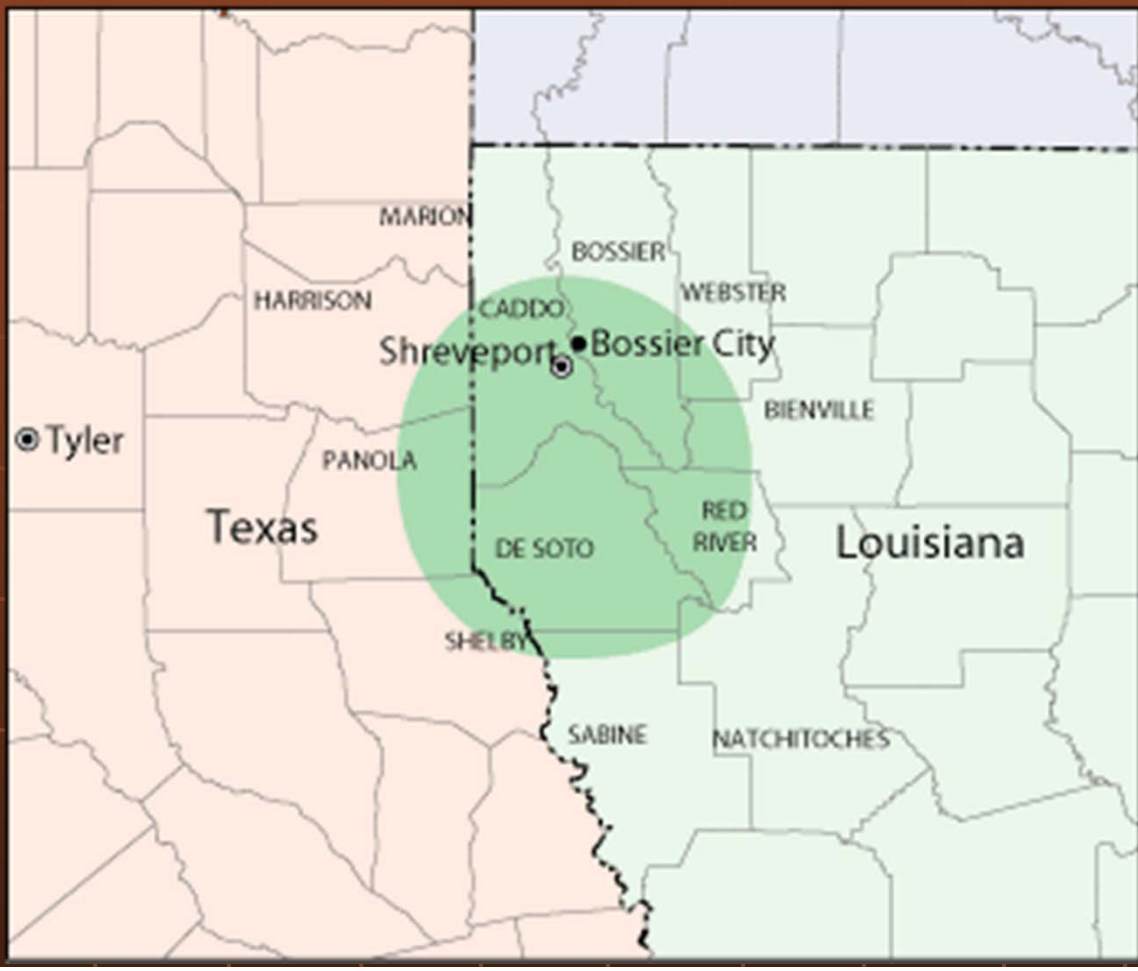
Bulk Modulus
Shear Modulus
Density

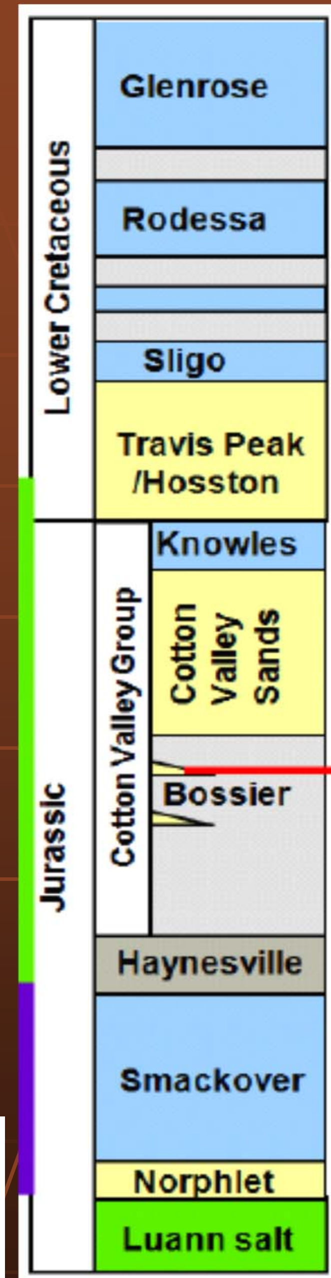
3D Volumes

Elastic Properties from Seismic Data

Reservoir Properties for 3D Volumes

The Haynesville Shale





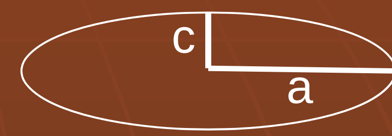
Age: ~ 150 ma, Jurassic;
Depth: 10,000 ft to 13,000 ft;

Capacity: ~ 60 trillion cubic feet;
Variable porosity, low permeability.

Map from:
http://petesplace-peter.blogspot.com/2008_08_01_archive.html

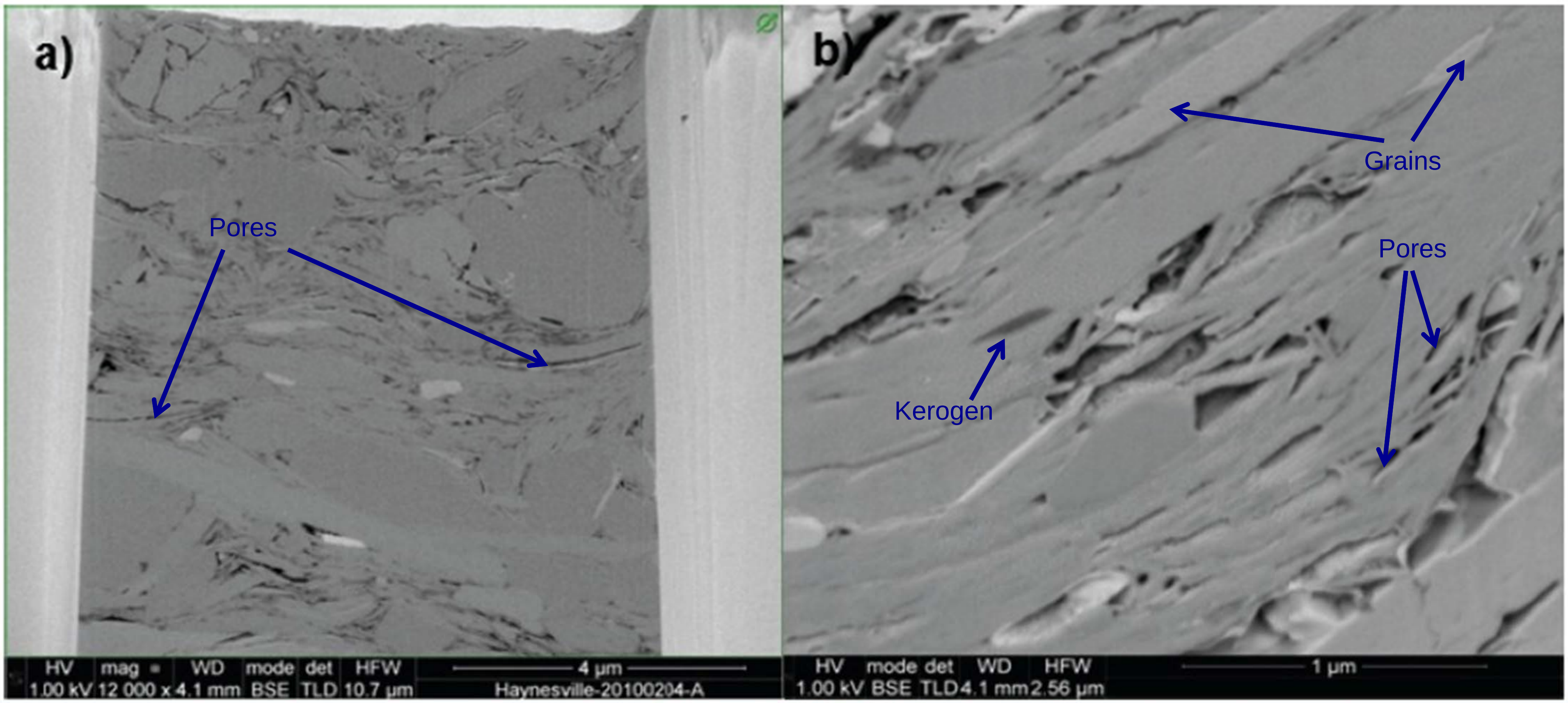
Brittenham, 2010

Microstructure of the Haynesville Shale



BSE Image of the Haynesville Shale

Aspect ratio = c/a



Curtis, Ambrose, Sondergeld and Rai, 2010

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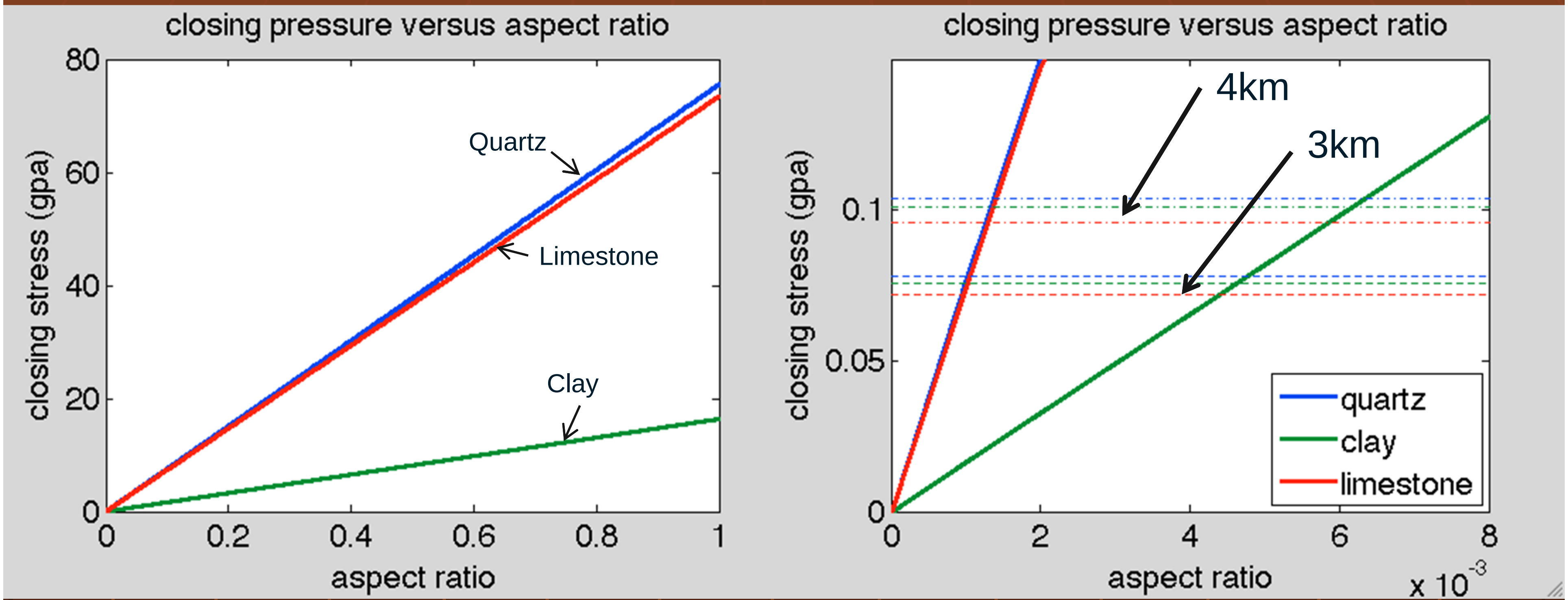
Closing Stress and Aspect Ratio



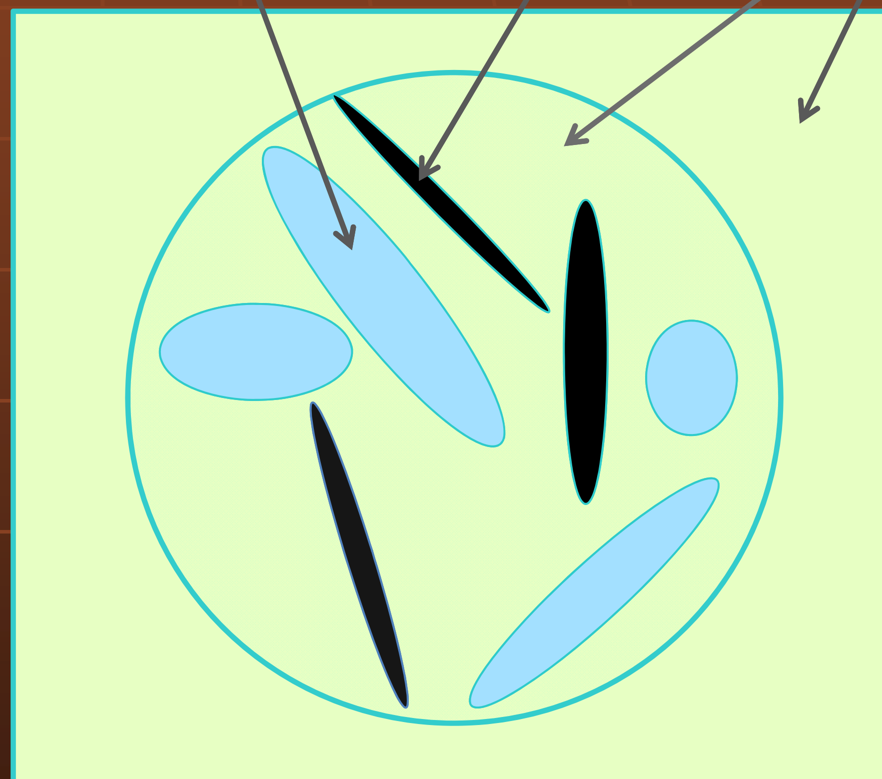
$$\sigma_{\text{close}} = \frac{3\pi(1-2\nu)}{4(1-\nu^2)}\alpha K_0 = \frac{\pi}{2(1-\nu)}\alpha\mu_0$$

Equation: Mavko et al., 2009

	K (Gpa)	μ (Gpa)	ρ (g/cc)
Quartz	36.6	45	2.65
Limestone	69	33	2.44
Clay	18	7	2.58

Self Consistent Model

Advantages:
--Not limited by certain composition
--Ability to model N phases, and their shapes and spatial distribution



$$\sum_{i=1}^{N} x_i (K_i - K^*_{SC}) P^{*i} = 0$$

$$\sum_{i=1}^{N} x_i (\mu_i - \mu^*_{SC}) Q^{*i} = 0$$

Equations: Mavko et al., 2009

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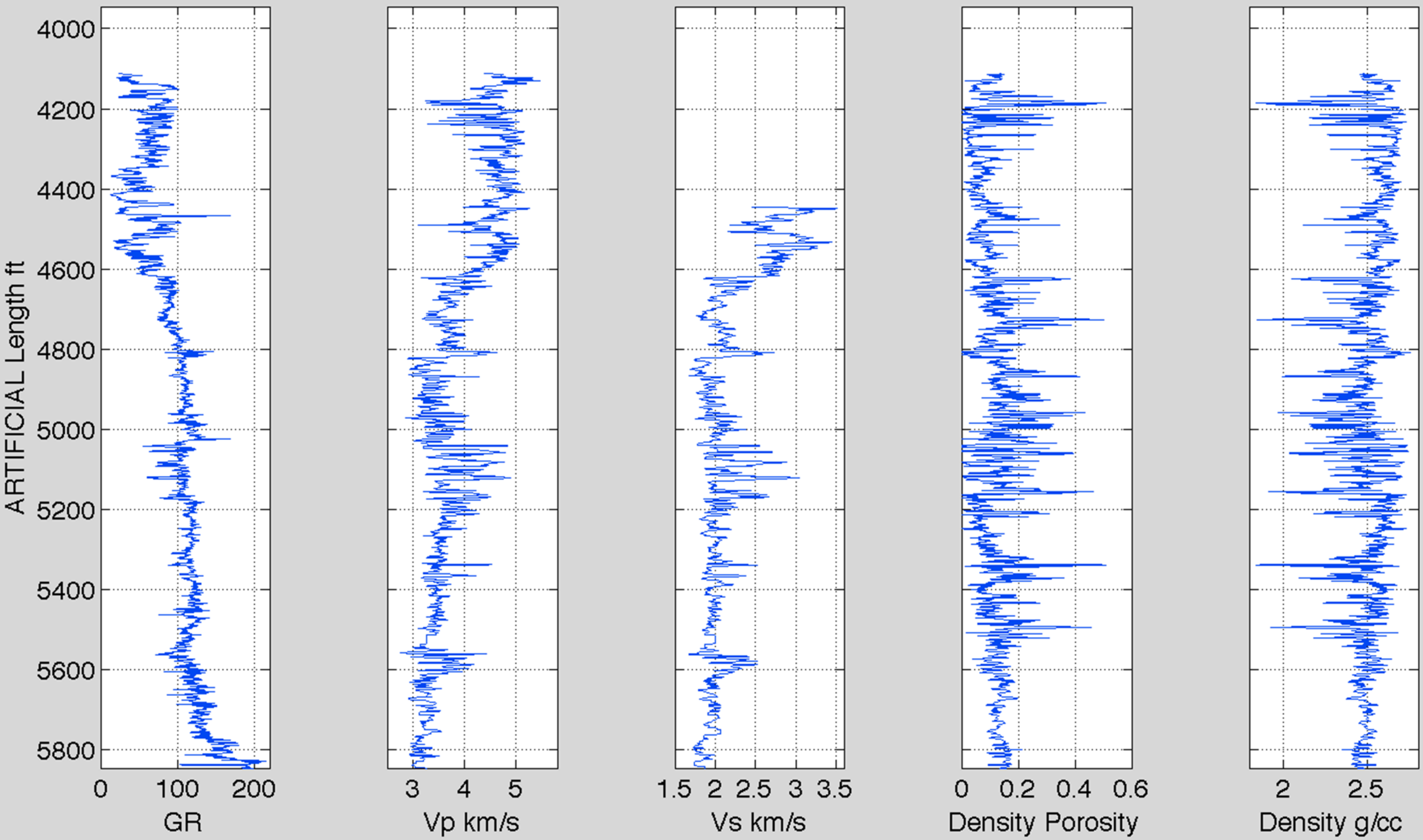
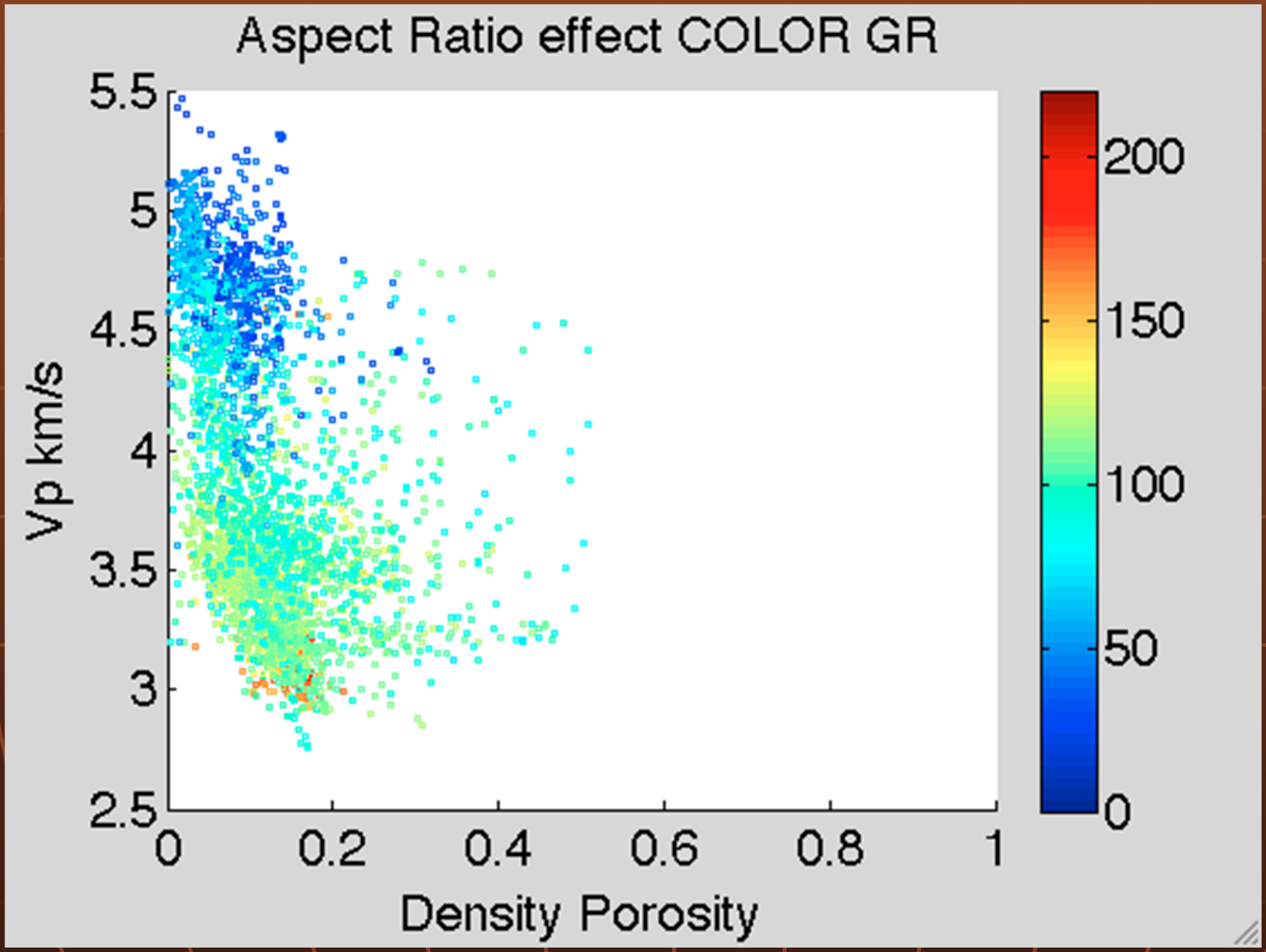
Well Log Data: Horizontal Well



Well Log Data: Horizontal Well



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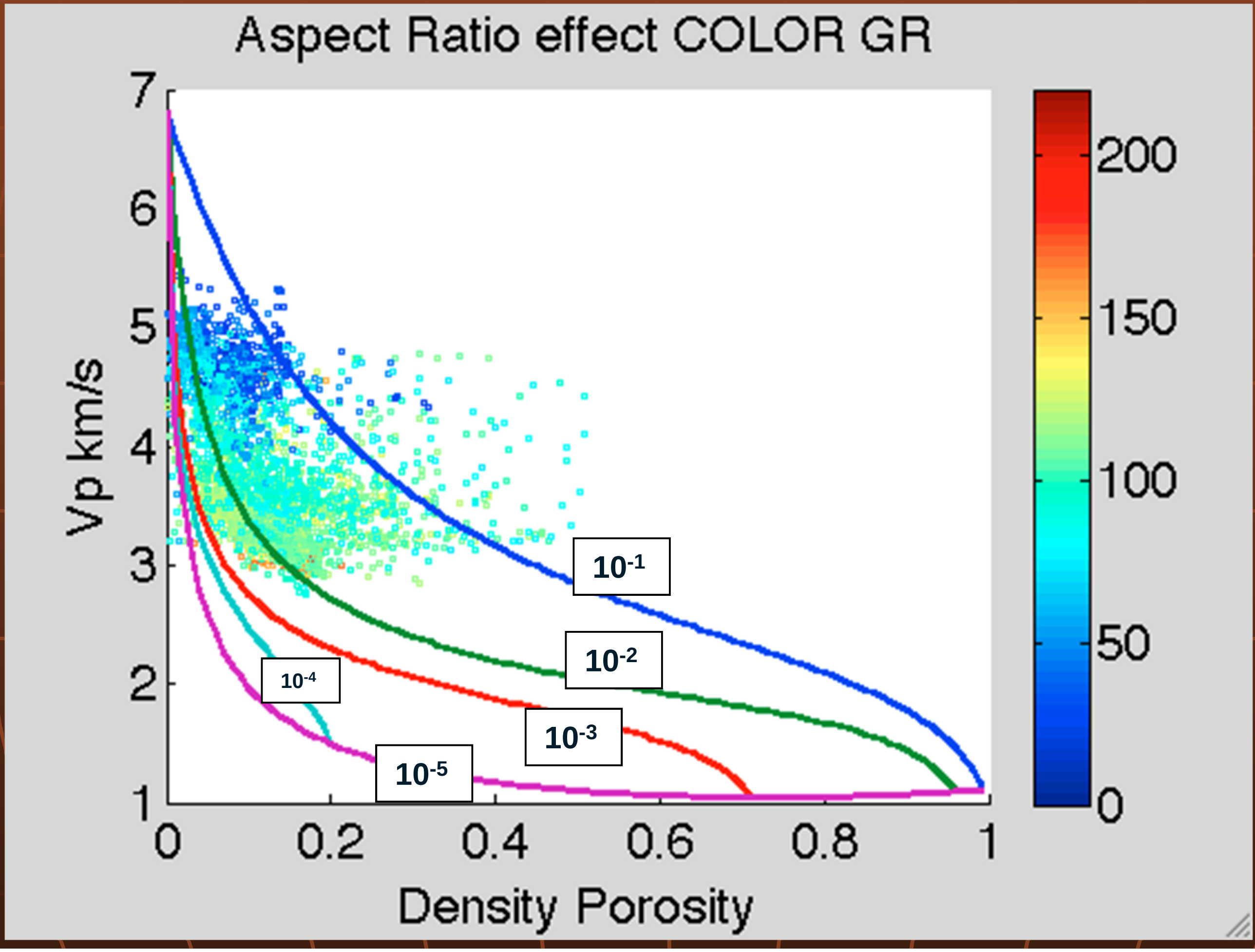
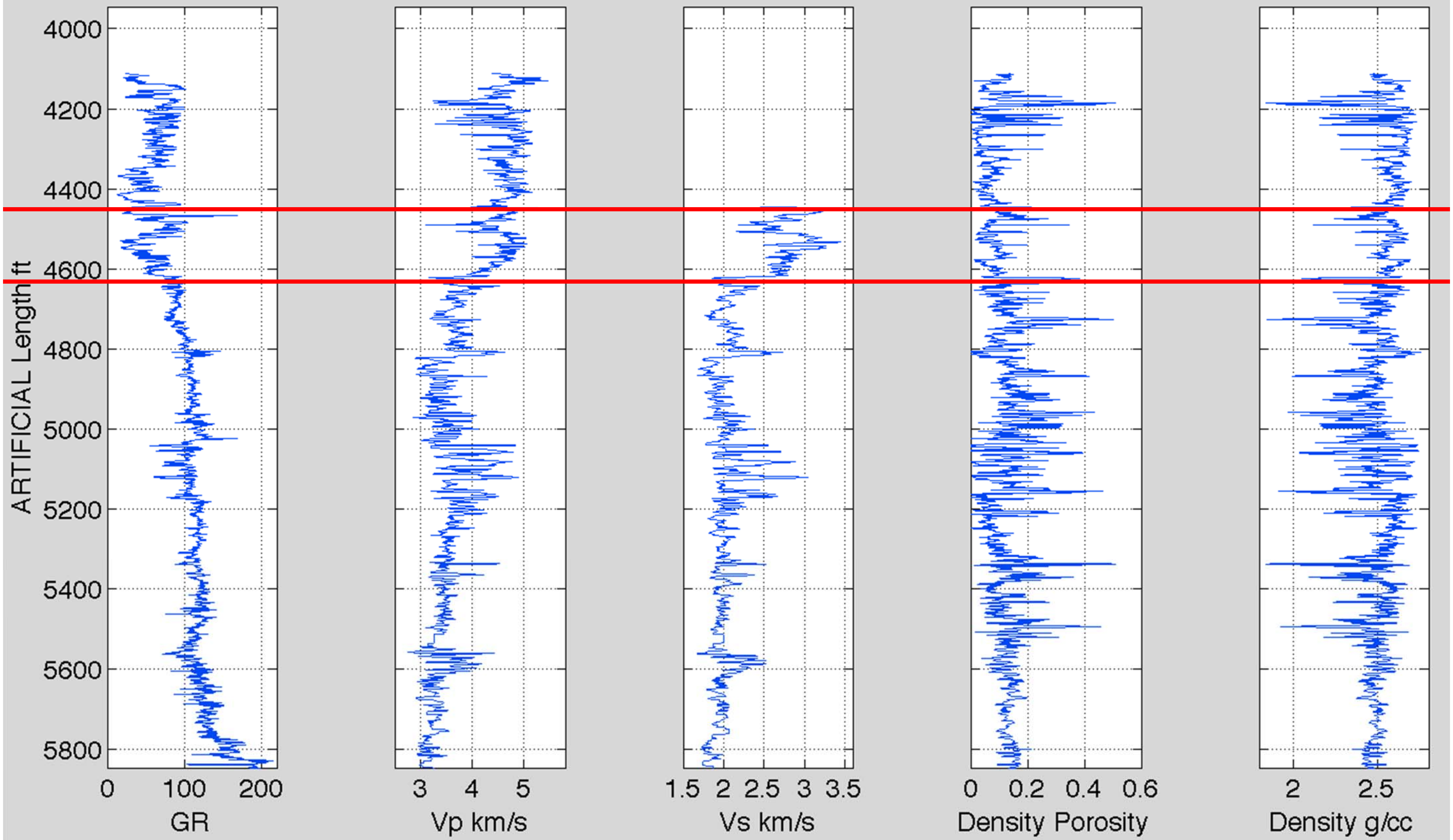
Horizontal Well: Aspect Ratio Effect

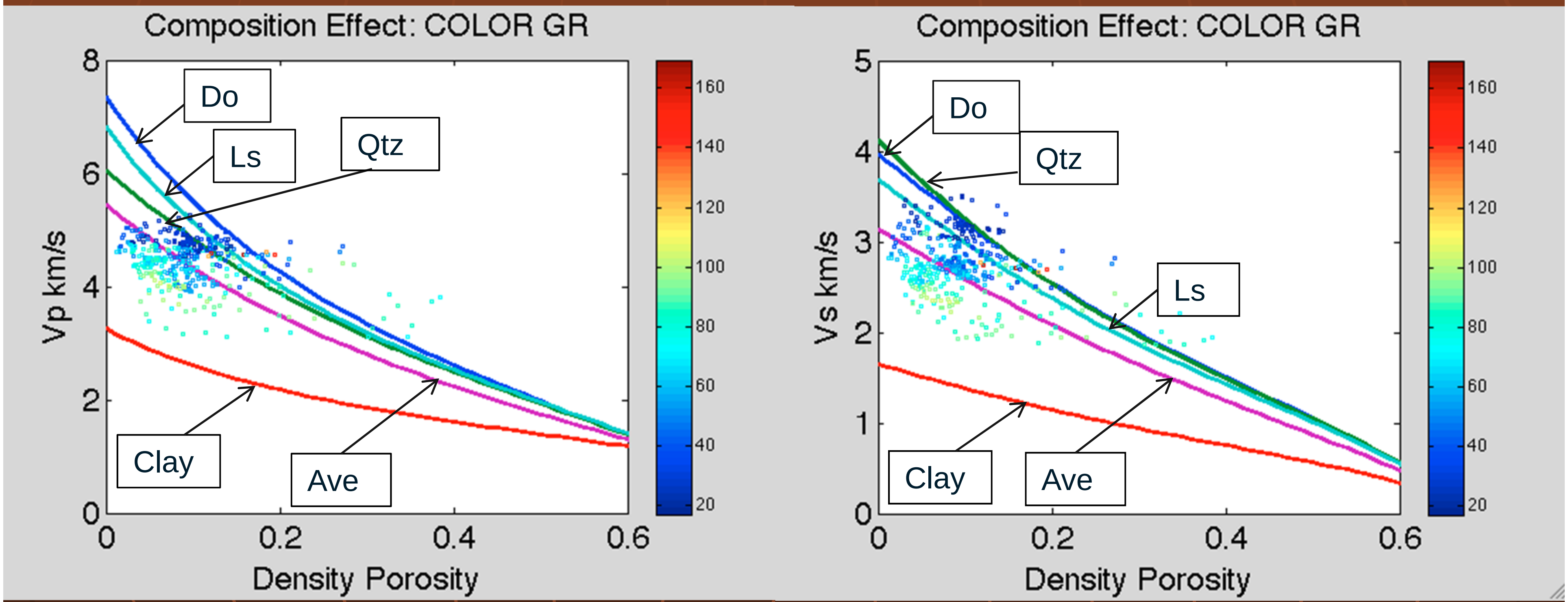


Aspect Ratio for solid phases are fixed as 0.001; for pores, five lines are corresponding to five groups of aspect ratios.
Composition is limestone – Not examine the composition effect here

Well Log Data: Horizontal Well



Horizontal Well: Composition Effect



Aspect Ratio
Solid: 0.1;
Pores: $N(0.1, 0.01^2)$

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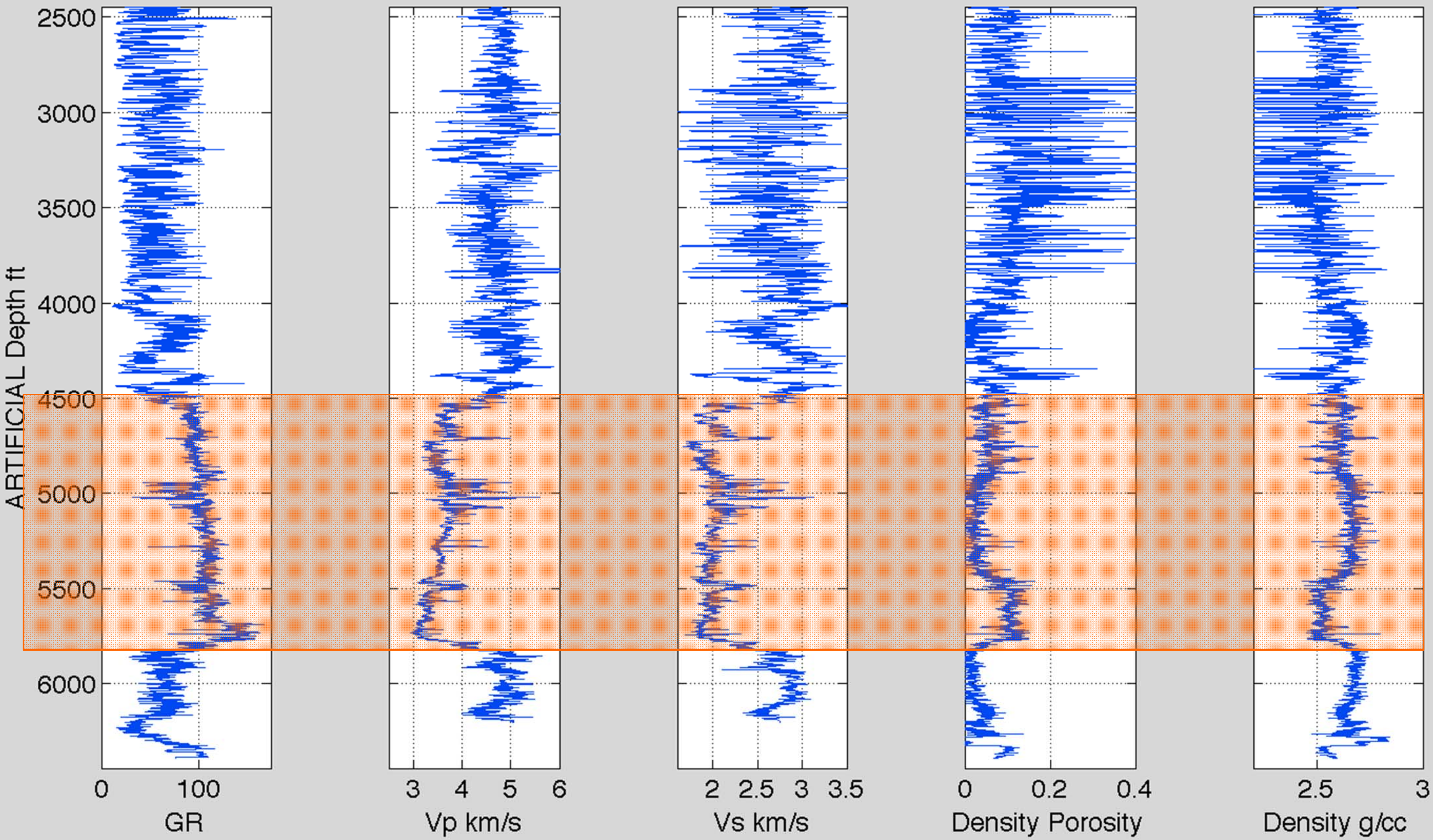
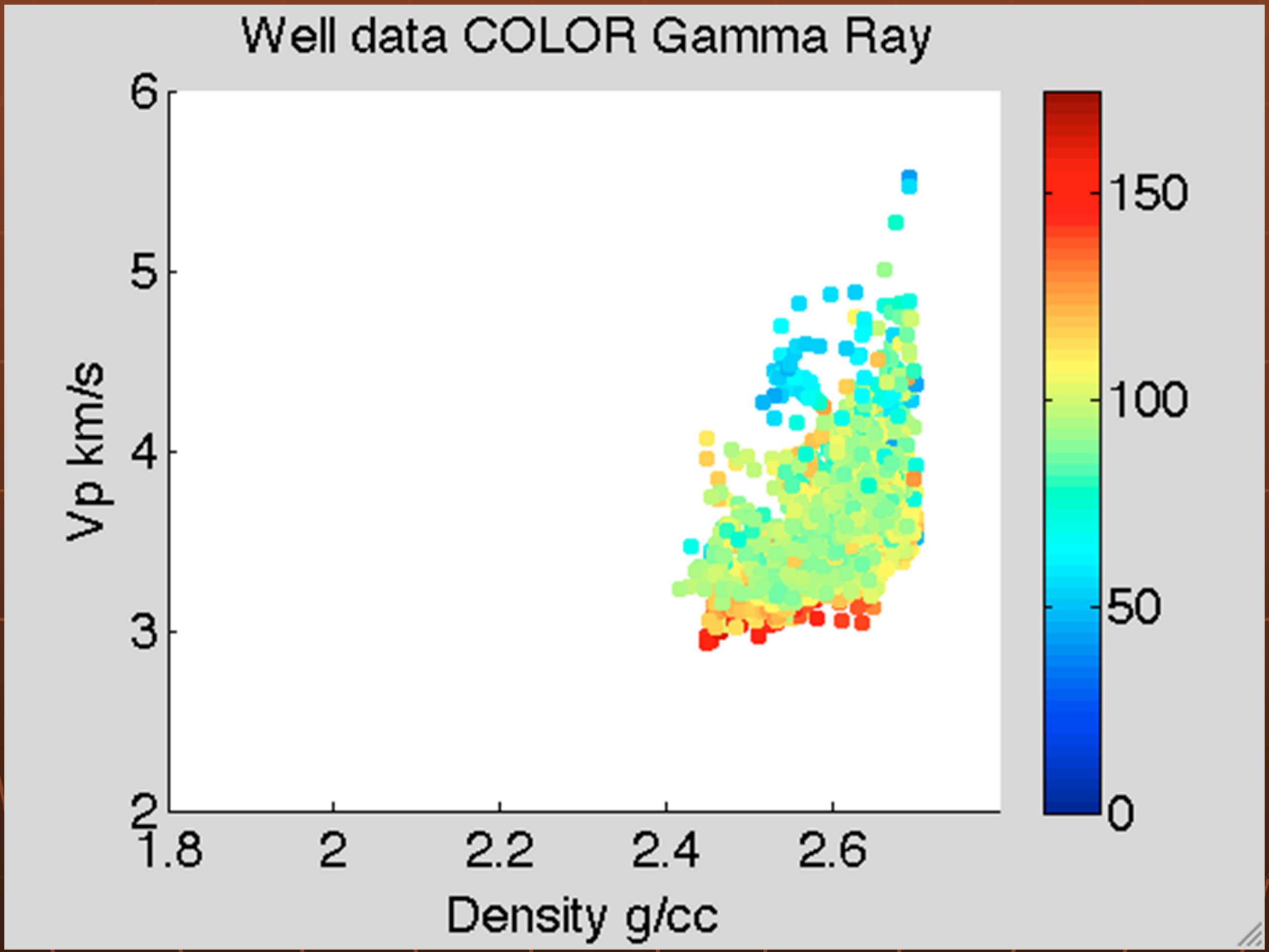
Well Log Data: Vertical Well



Well Log Data: Vertical Well for the Haynesville Shale



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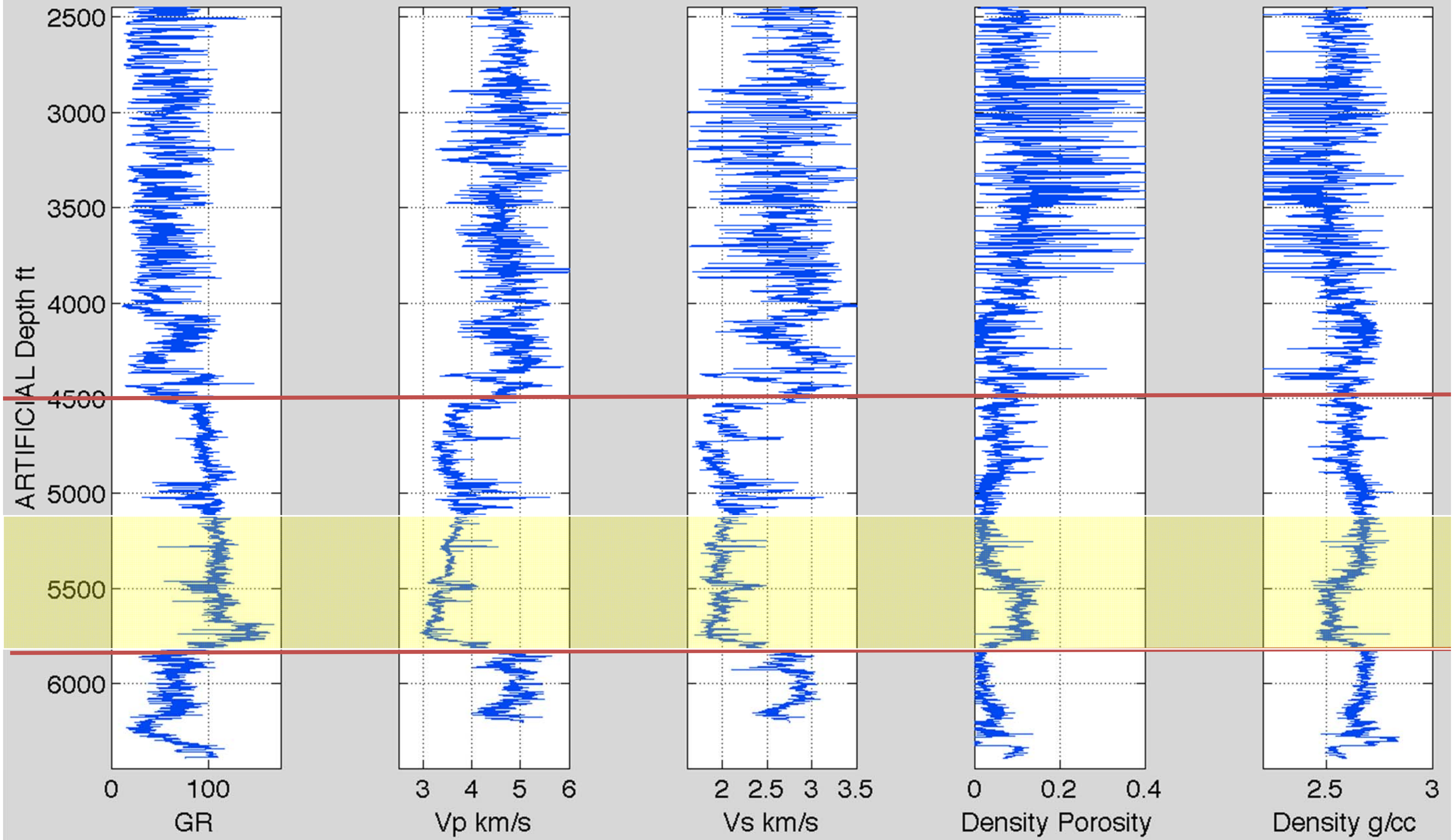
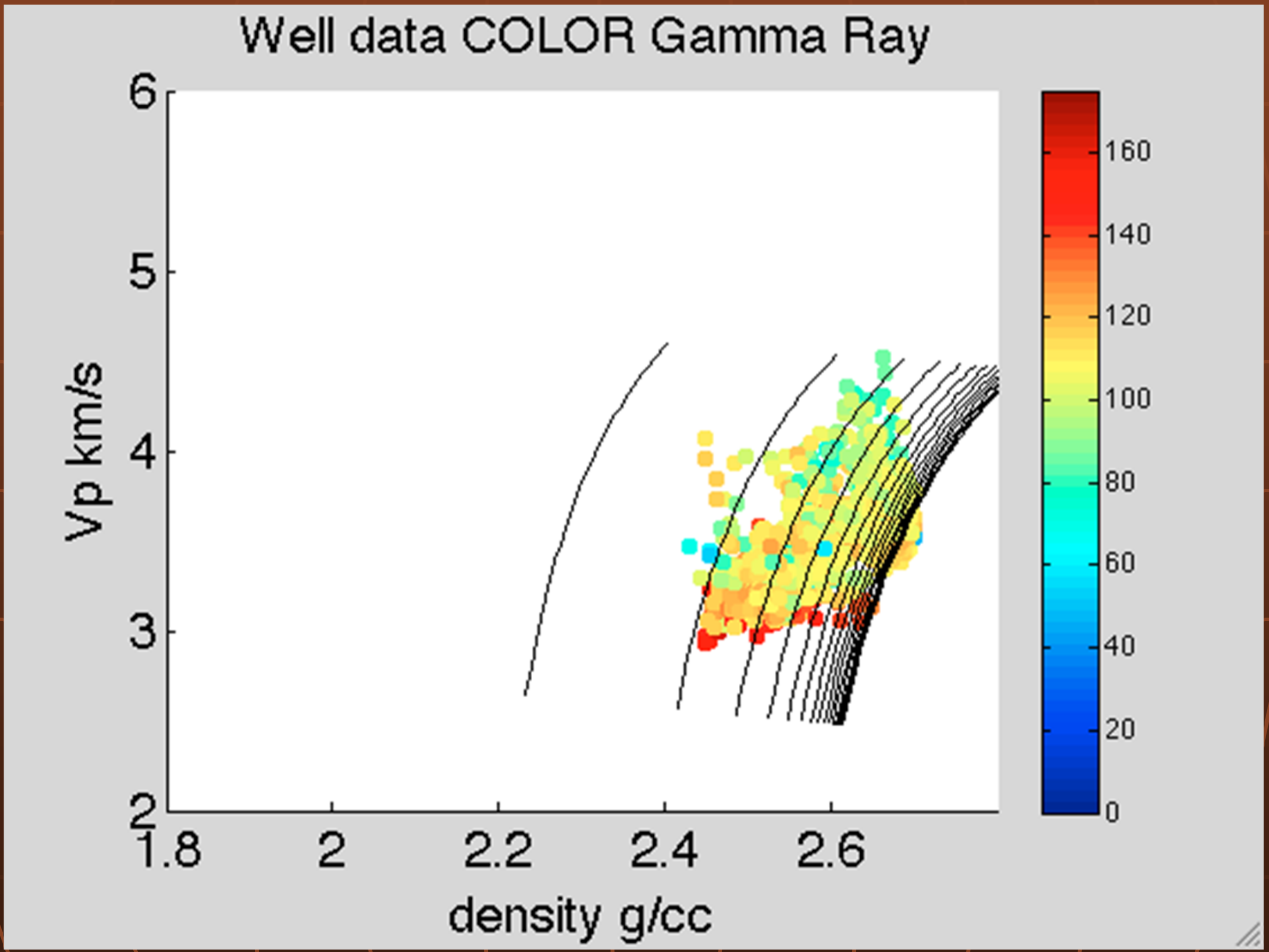
Well Log Data: Vertical Well



Vertical Well
Self Consistent Model



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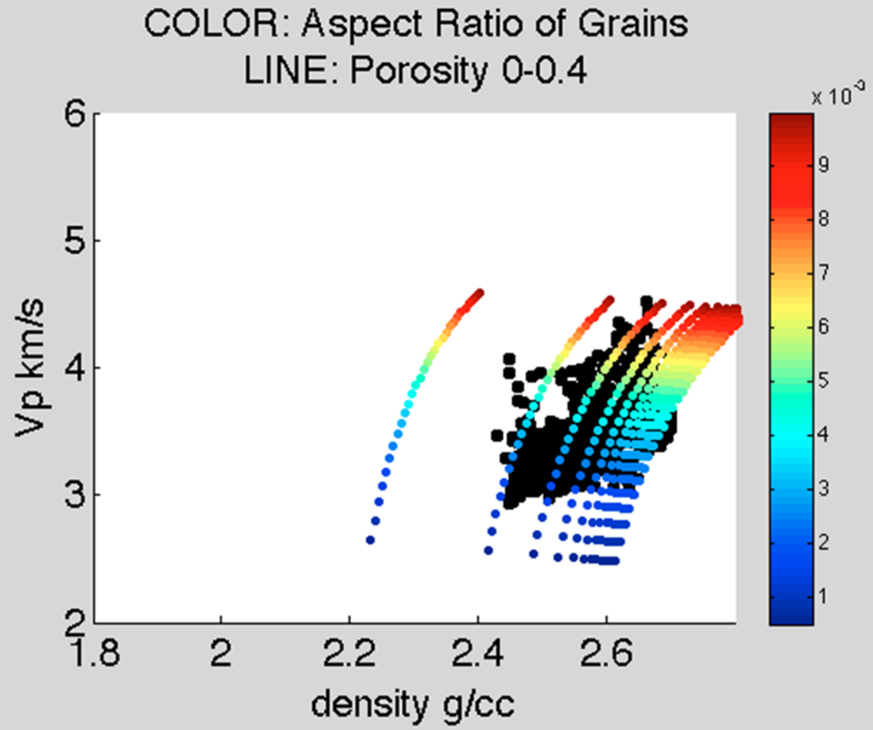
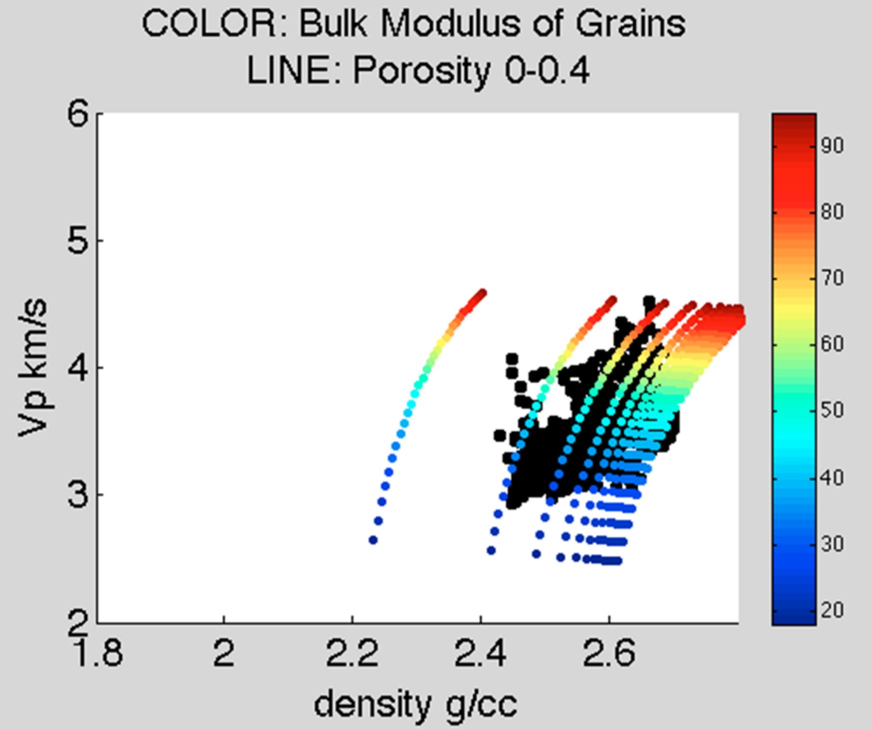
Vertical Well
Aspect Ratio and Composition Effect





Composition (K, μ, ρ): Dolomite to Clay
Aspect Ratio: Solid: 0.01 to 0.0005; Pores: ~10^-5

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Conclusion

- Within certain composition and aspect ratio ranges, the self consistent model qualitatively explained the Haynesville data sets from both horizontal and vertical wells.
- The uncertainty in composition can be reduced by studying core data set.
- Limitation of the model: isotropic media; idealized ellipsoidal inclusion shapes; high frequency model.

Future Work

- Consider effective pressure effect
- Analyze different depth ranges using Self Consistent Model
- Try other models, e.g. Differential Effective Medium Model
- Combine with elastic properties inverted from seismic data to identify locations corresponding to sweet spot and increase the fluid conductivity

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