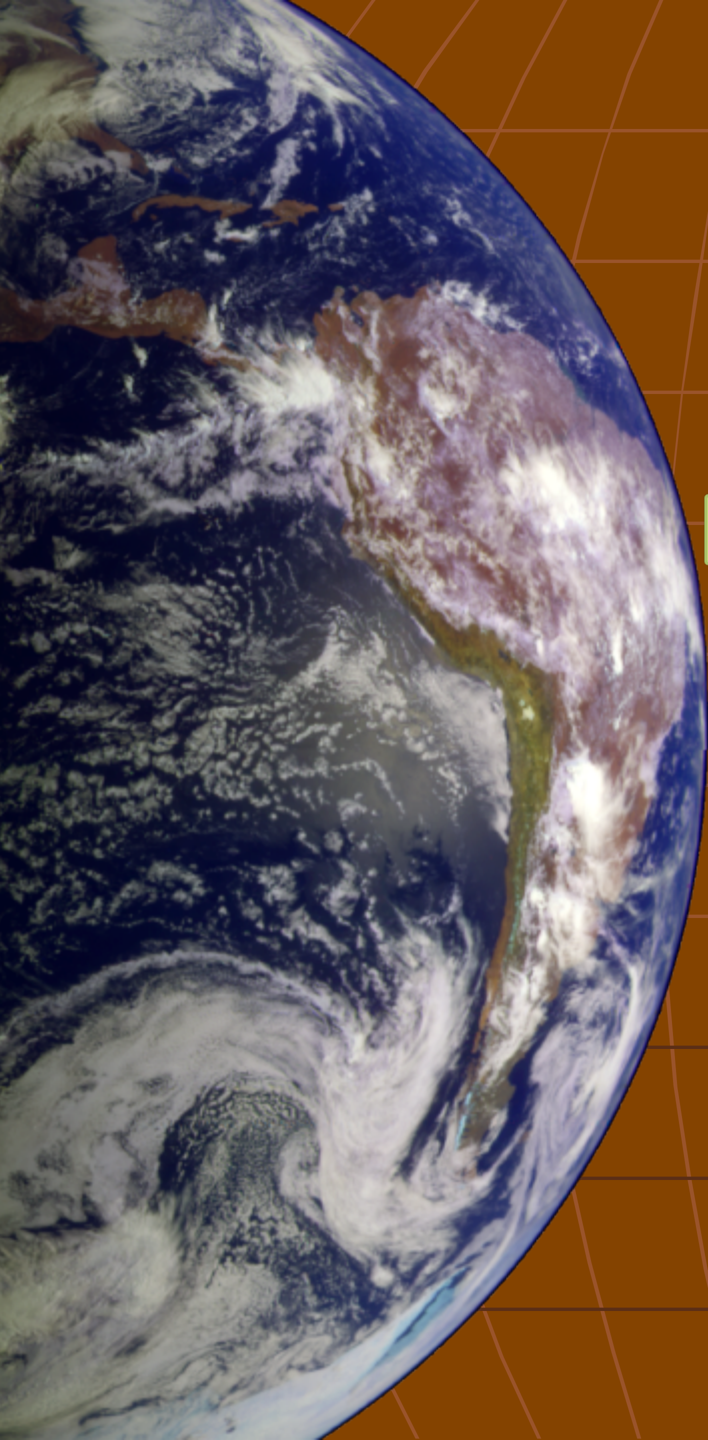

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Estimation of the Porosity and Pore Shape of the Haynesville Shale using the Self-Consistent Model and a Grid Search Method

Meijuan Jiang
Advisor: Kyle Spikes

EDGER Forum Presentation
02/27/2012

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MOTIVATION

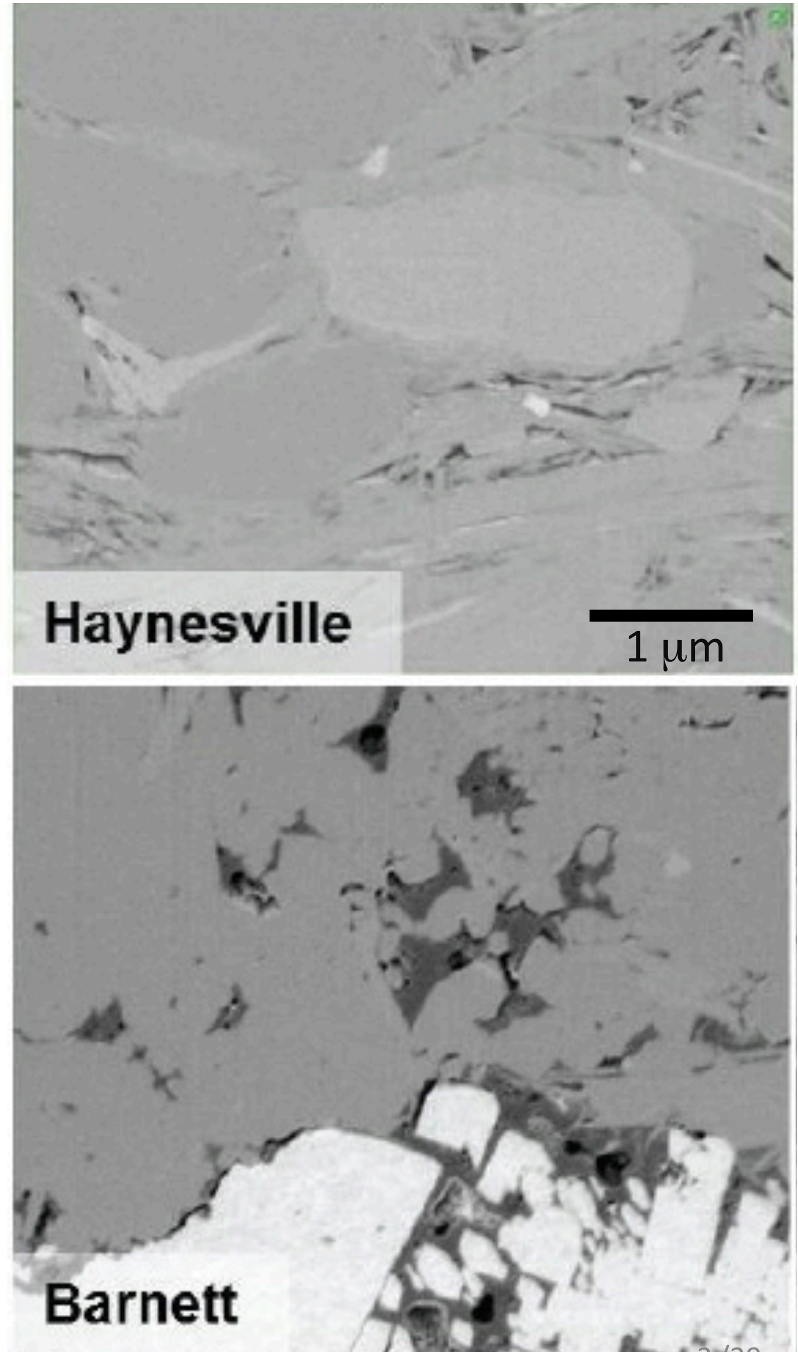
Reservoir Characterization for Unconventional Gas Shale:

What properties to characterize?

What data to use?

What method to use?

How to address uncertainty?



Images from: Curtis et al.,2010

MOTIVATION

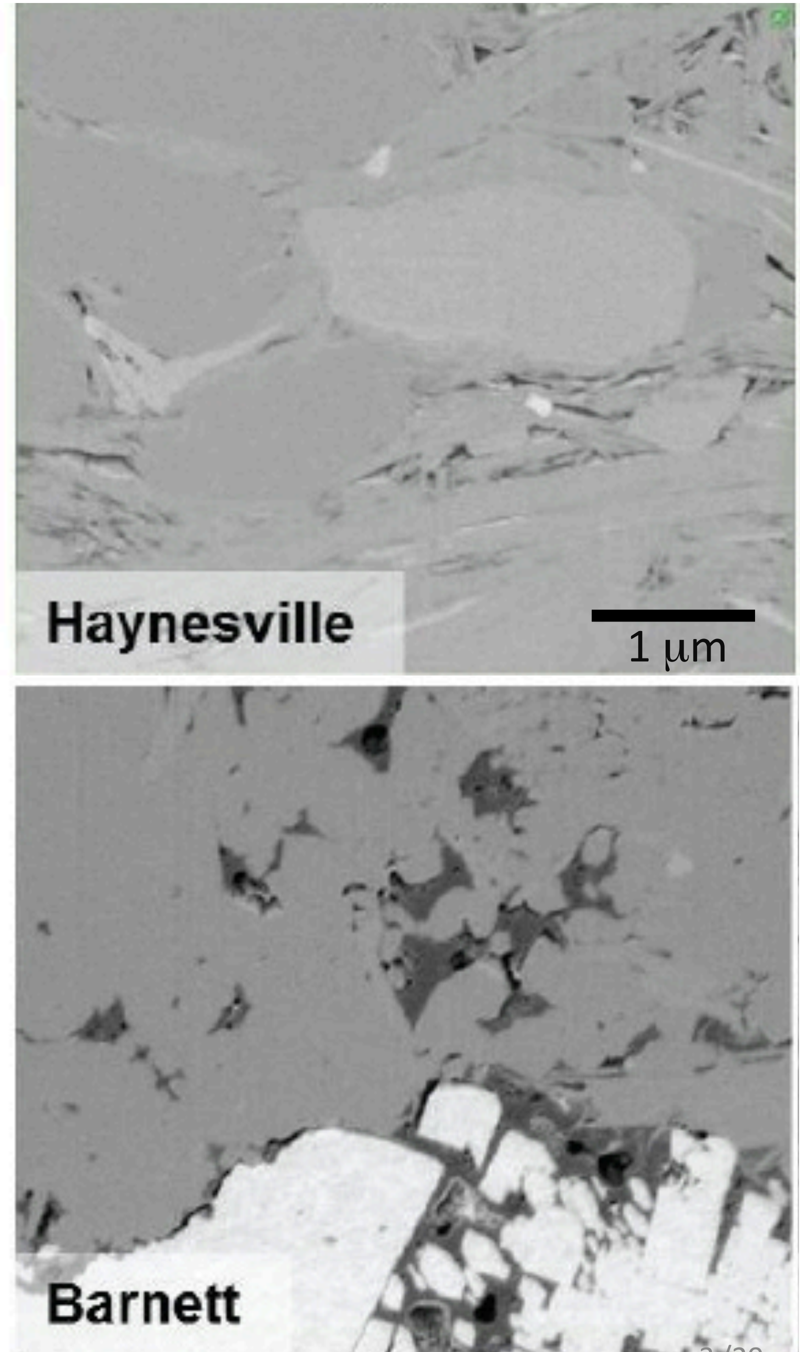
Reservoir Characterization for Unconventional Gas Shale:

What properties to characterize?
Porosity
Pore Shape

What data to use?
Well Log Data (Well A and B)
Core Data (Well A)
Seismic Data

What method to use?
Self-Consistent Model
A Grid Search Method

How to address uncertainty?



Images from: Curtis et al.,2010

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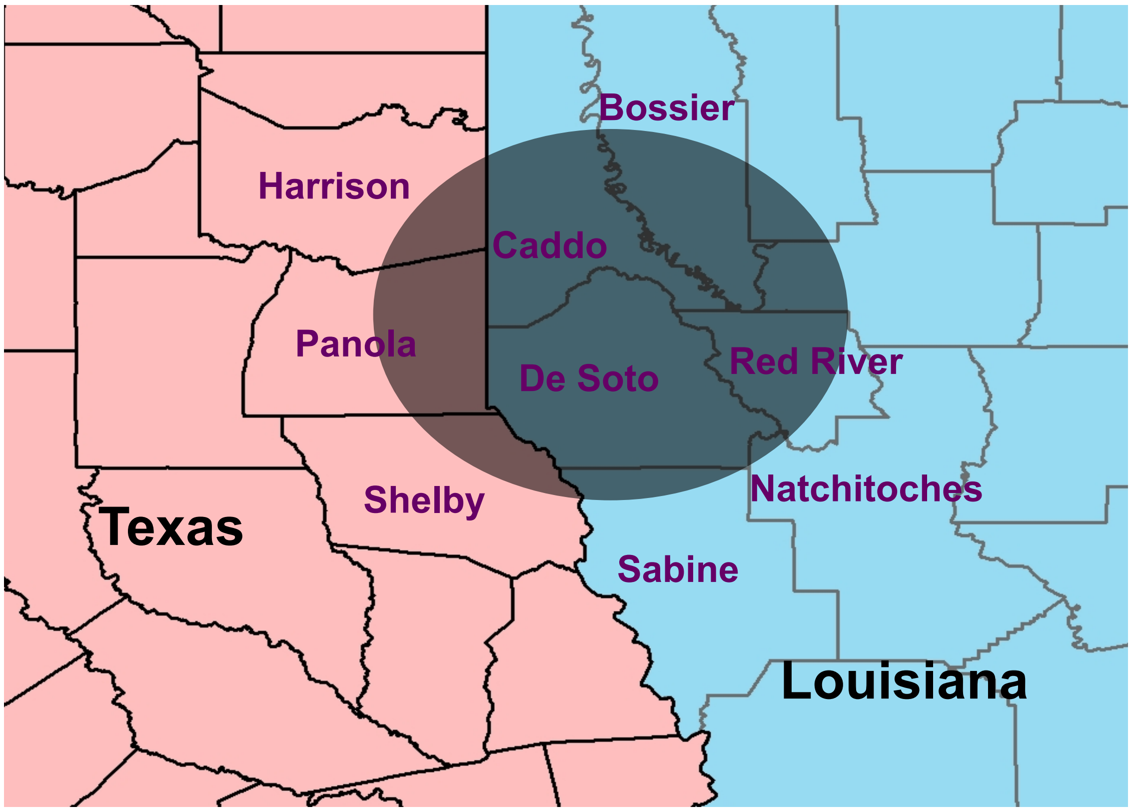
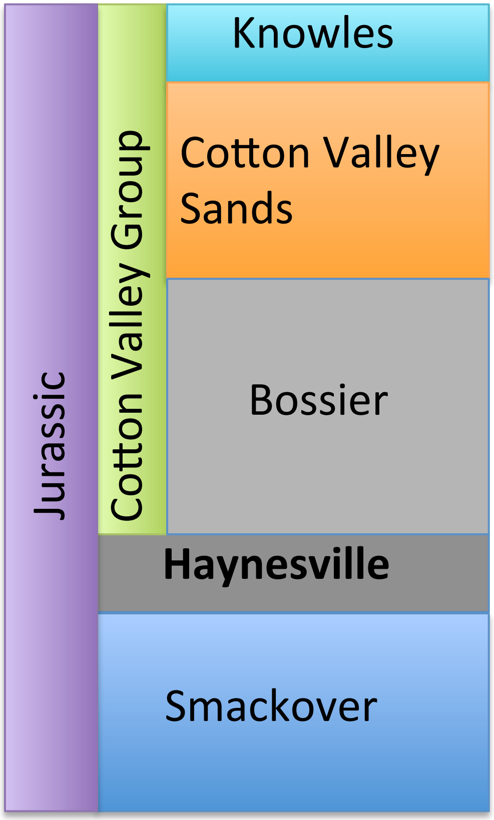
THE HAYNESVILLE SHALE





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

Capacity: TOC ~ 5% on average; ~ 100 tcf;
Variable porosity, low permeability.

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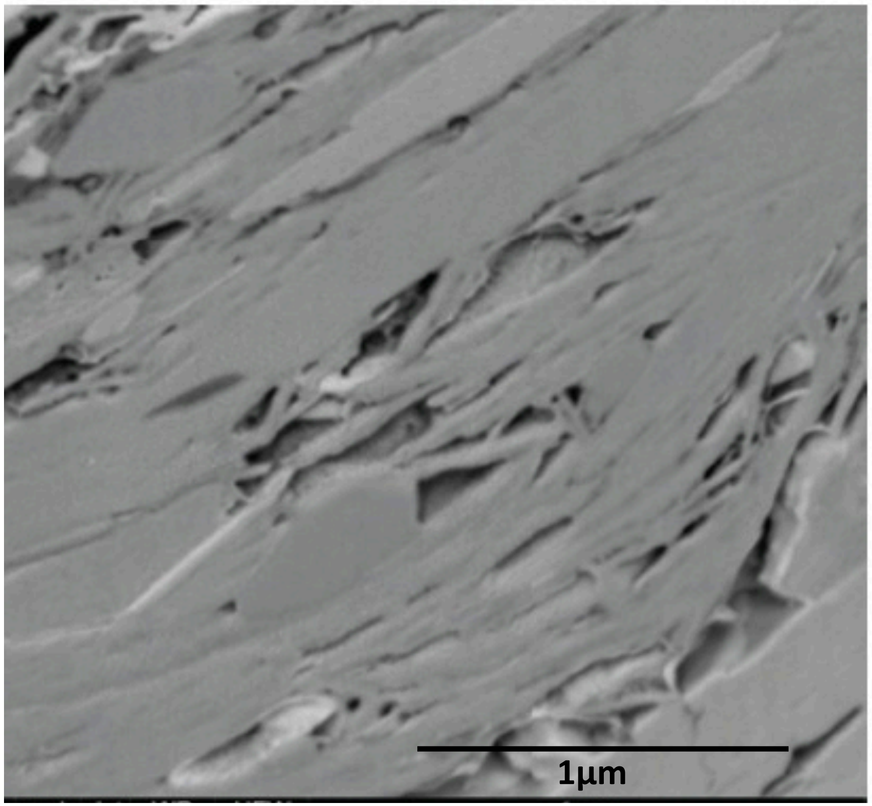
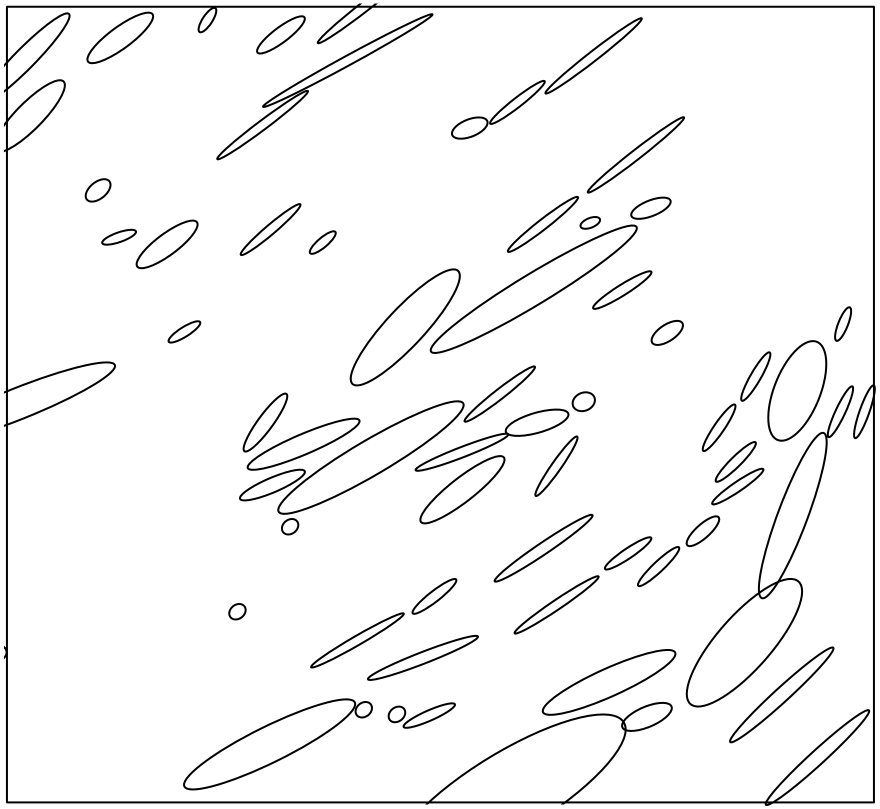
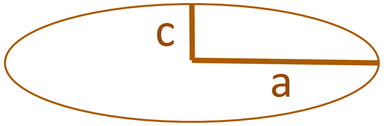
THE HAYNESVILLE SHALE: MICROSTRUCTURE





Images from: Curtis et al.,2010



Aspect ratio = c/a

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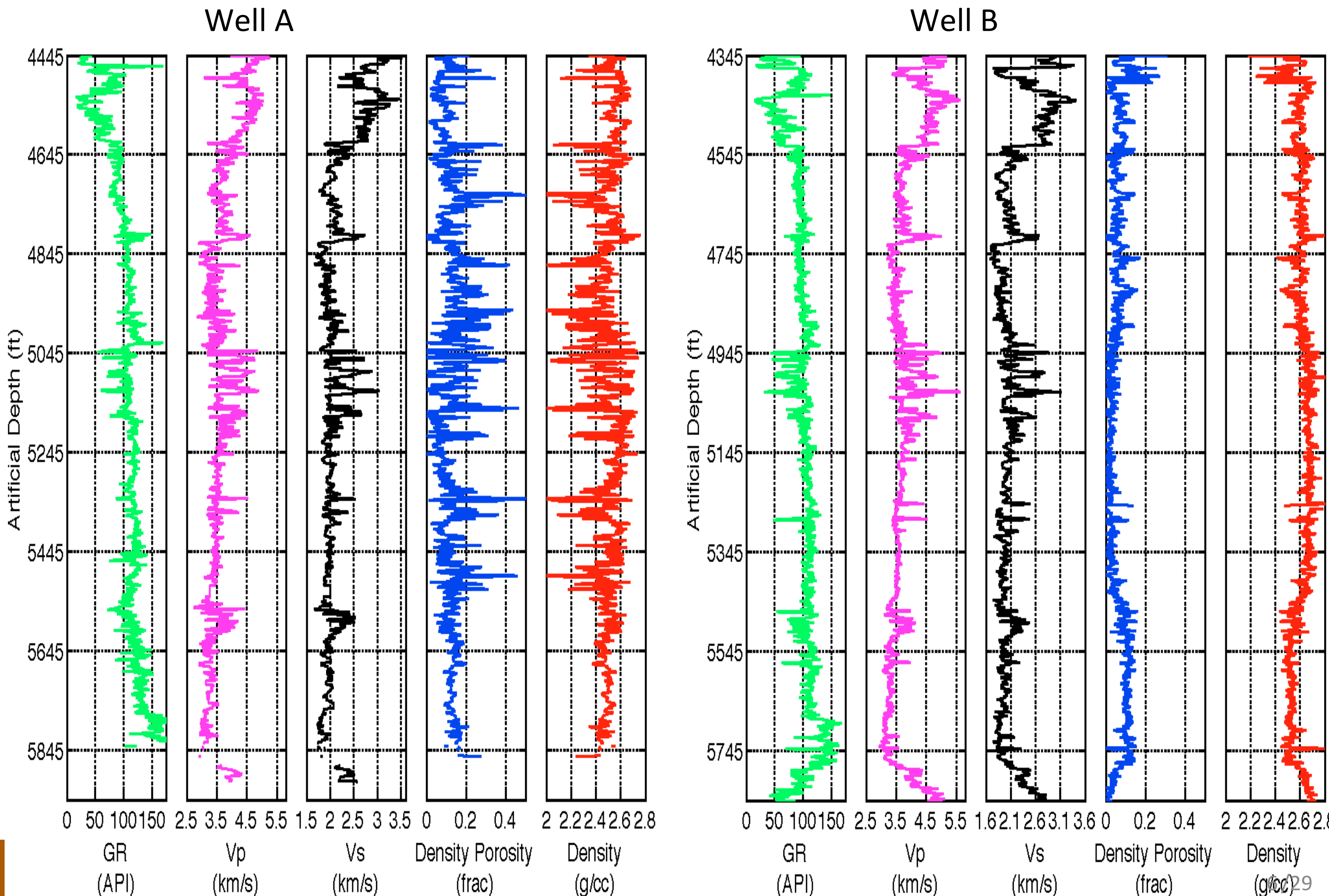
WELL LOG DATA: WELL A & B



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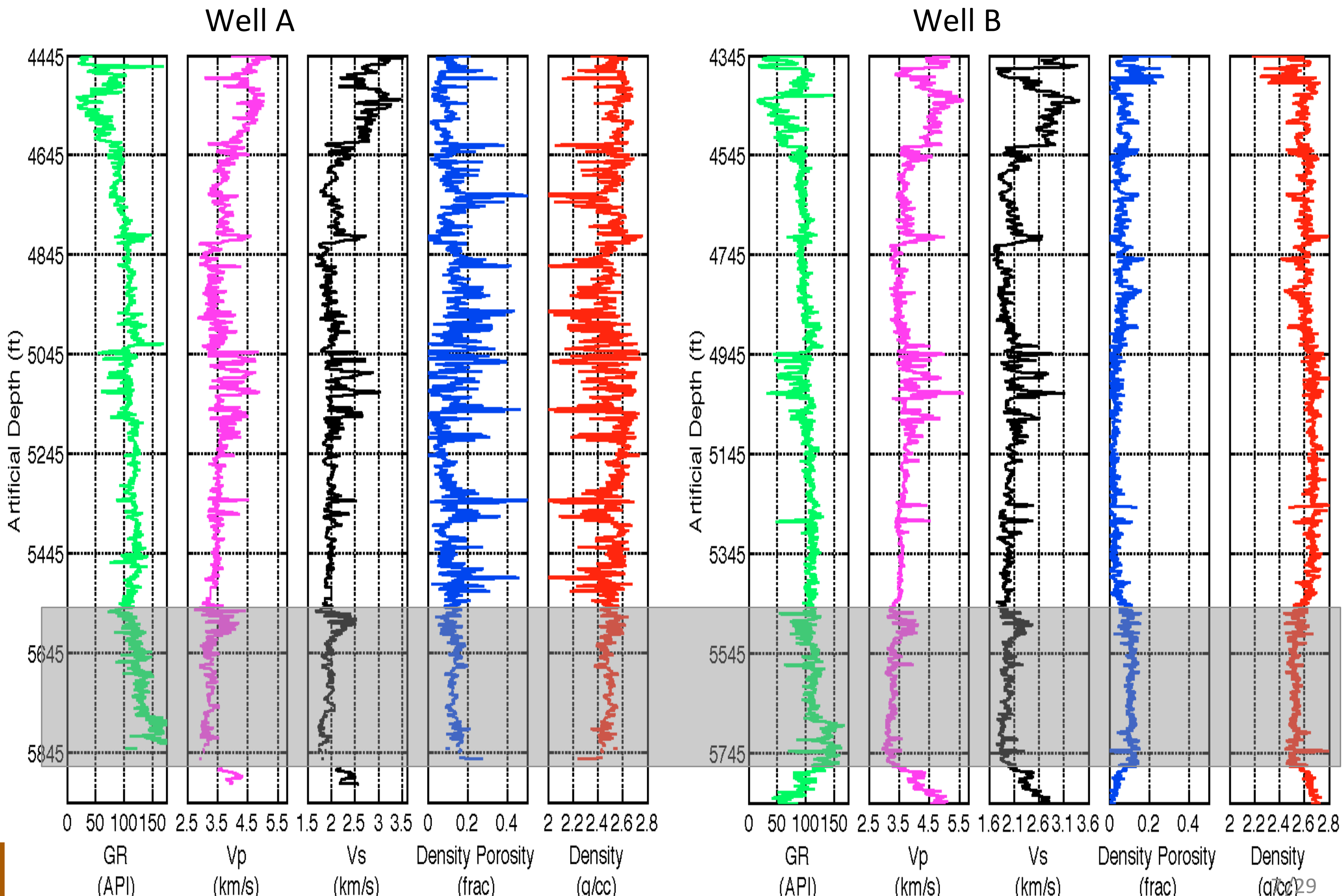
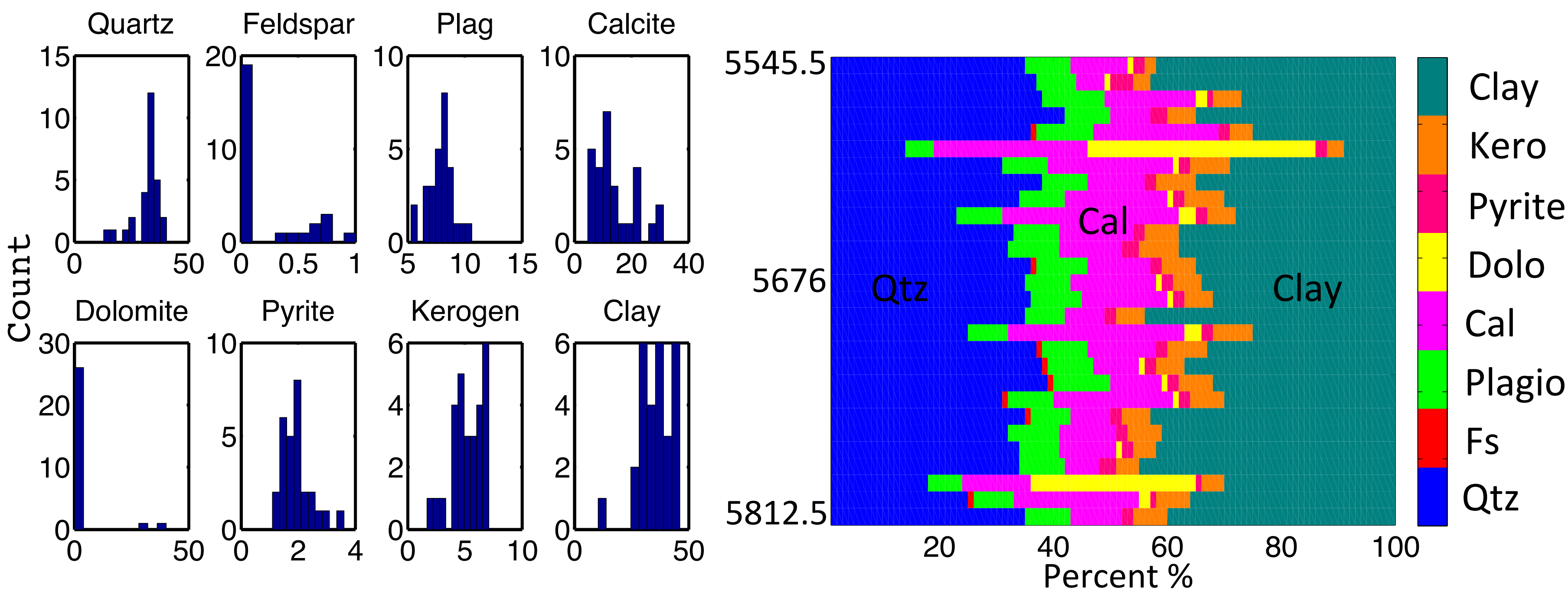
WELL LOG DATA: WELL A & B



COMPOSITION: XRD RESULT FROM CORE MEASUREMENT

Data from Dr. Ursula Hammes in BEG



28 samples at different depths within the Haynesville formation

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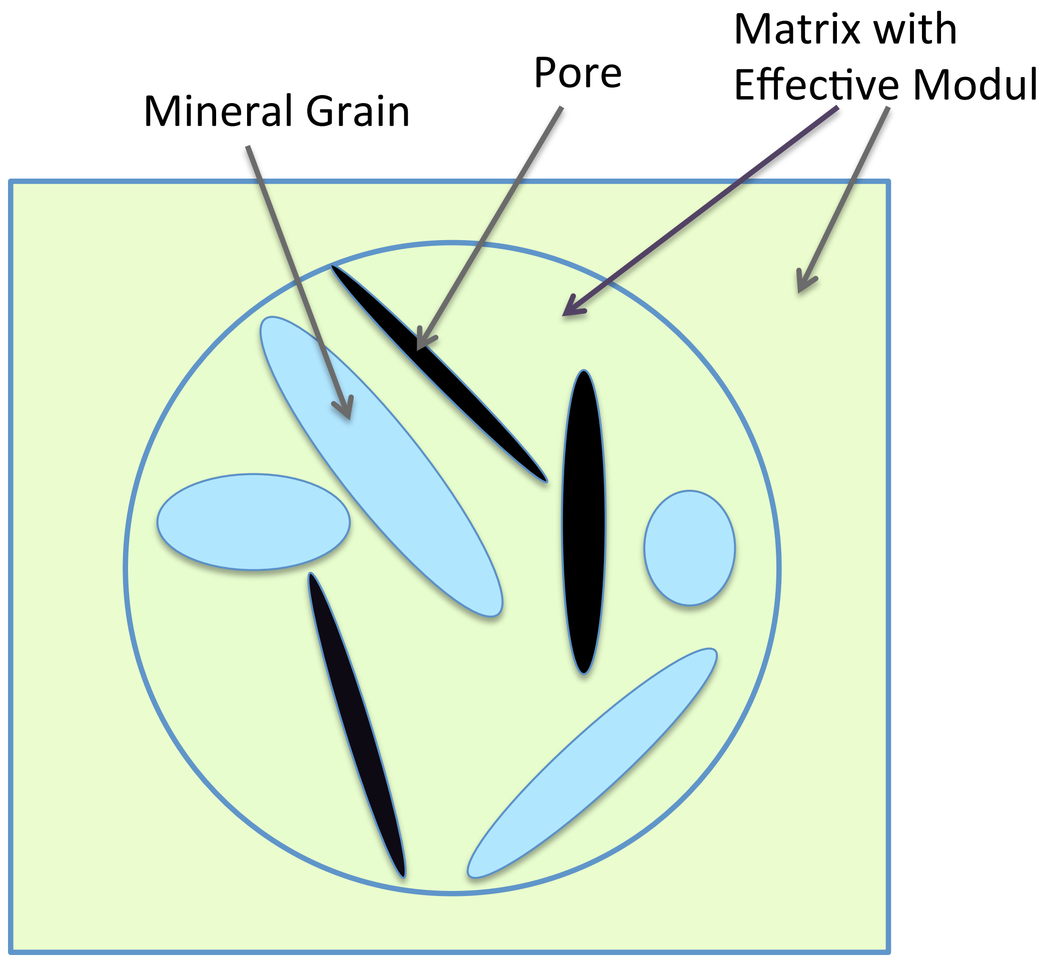
SELF CONSISTENT MODEL (SCM)

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

Equations: Mavko et al., 2009

$$\sum_{i=1}^{N} f_i(K_i - K_{sc})U_i = 0$$

$$\sum_{i=1}^{N} f_i(\mu_i - \mu_{sc})V_i = 0$$



In-situ pore fluid bulk modulus of 1 is used

POROSITY ESTIMATION

Calibration well (Well A)
Porosity, P-Impedance, and Composition (from XRD)

The Self-Consistent Model

Well Data (Well A and B)
P-Impedance (Ip_{obs})

Grid Search Method

Porosity Distribution
$\Phi \sim U(0, 0.25)$

Calculate P-Impedance (Ip_{model}) as decision space

Evaluate the Objective Function
$|Ip_{model} - Ip_{obs}|$

Obtain the porosity estimation for the wells (Well A and B)

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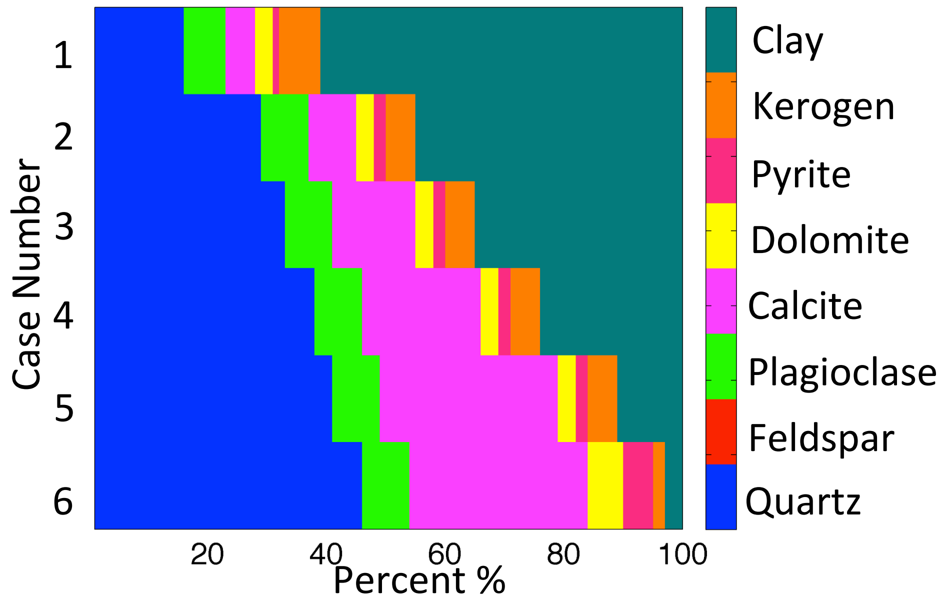
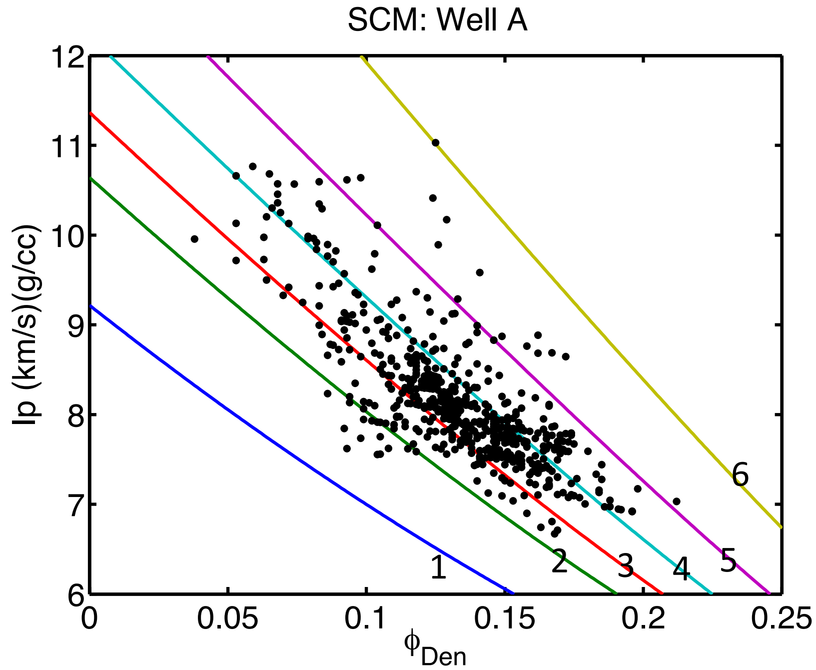
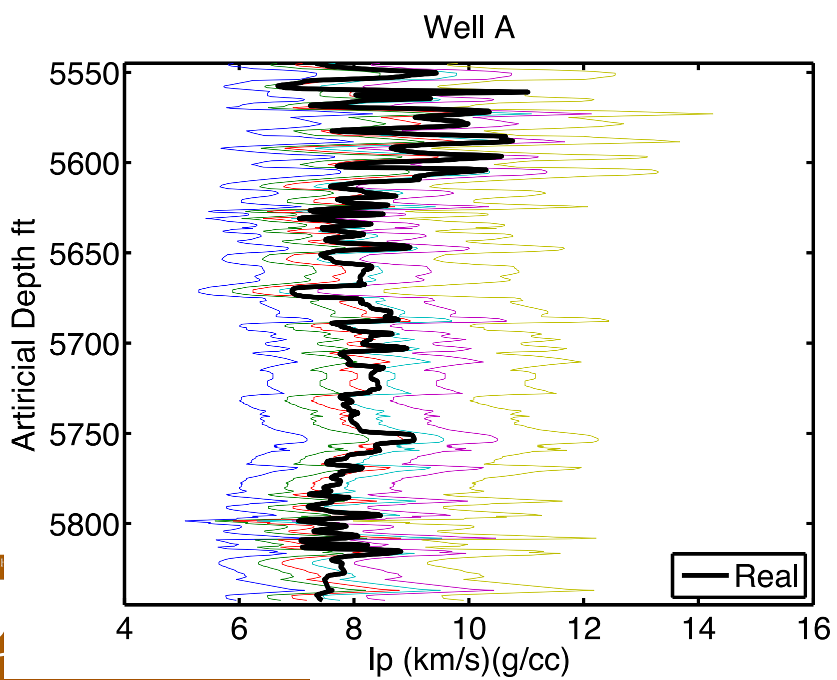
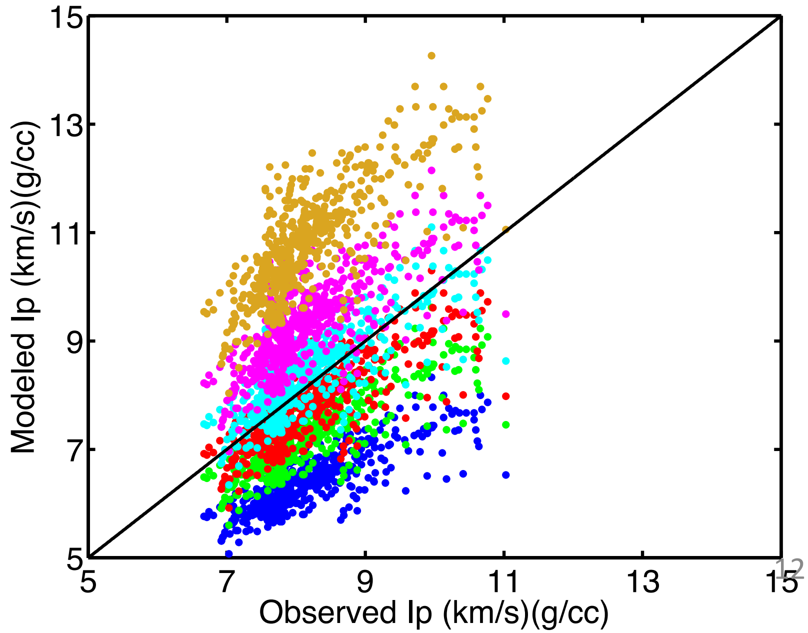
CALIBRATE SCM FROM WELL A: COMPOSITION CONSTRAINT

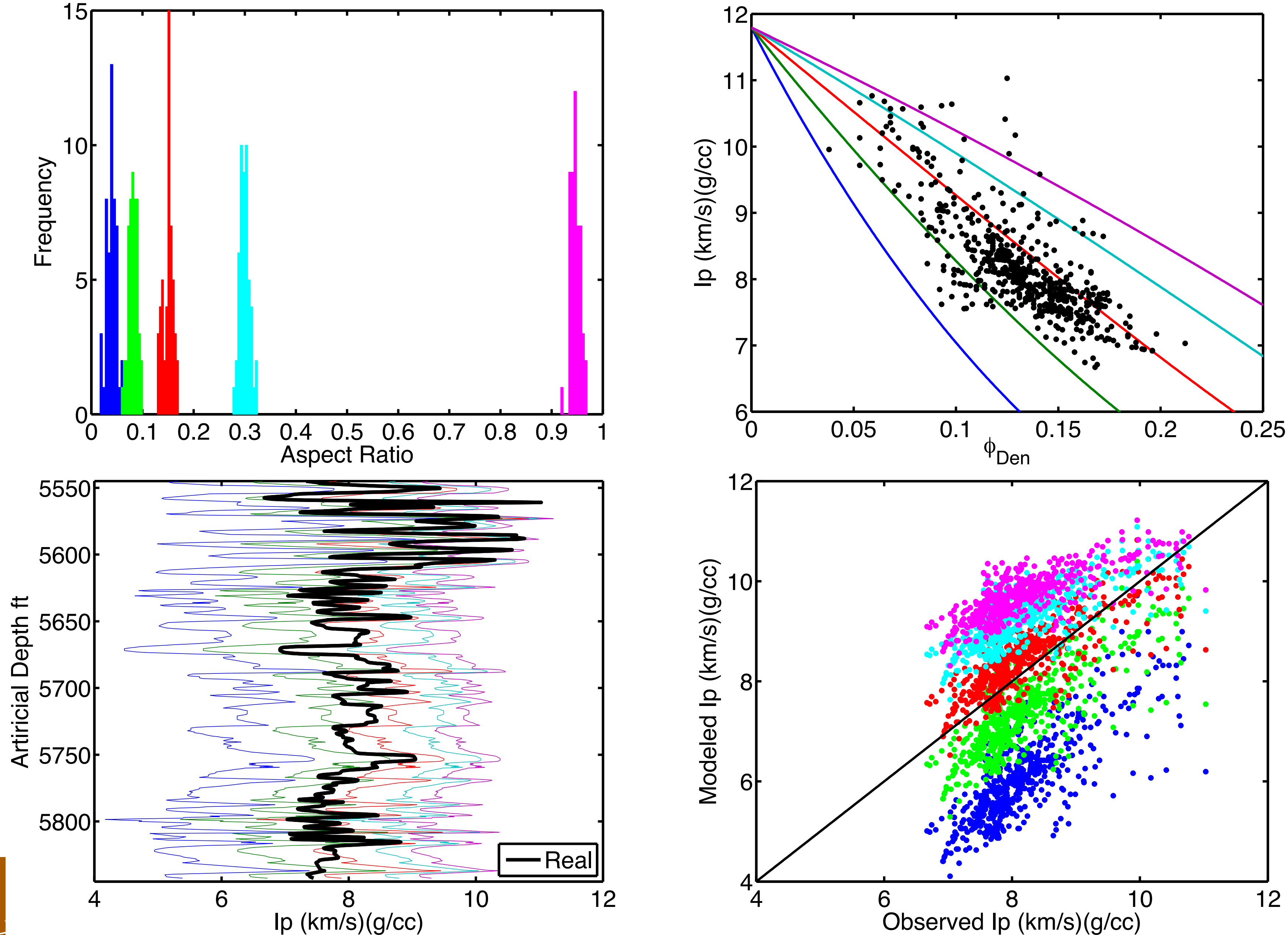




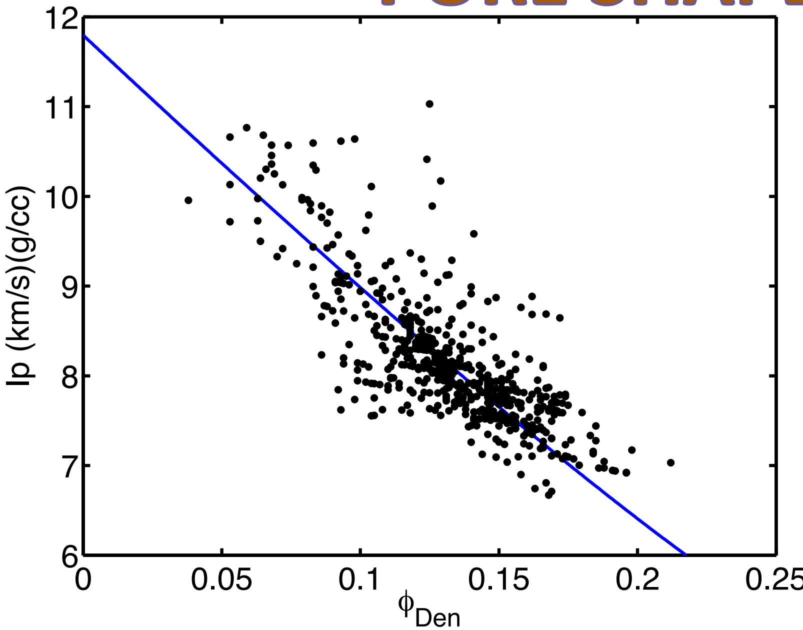


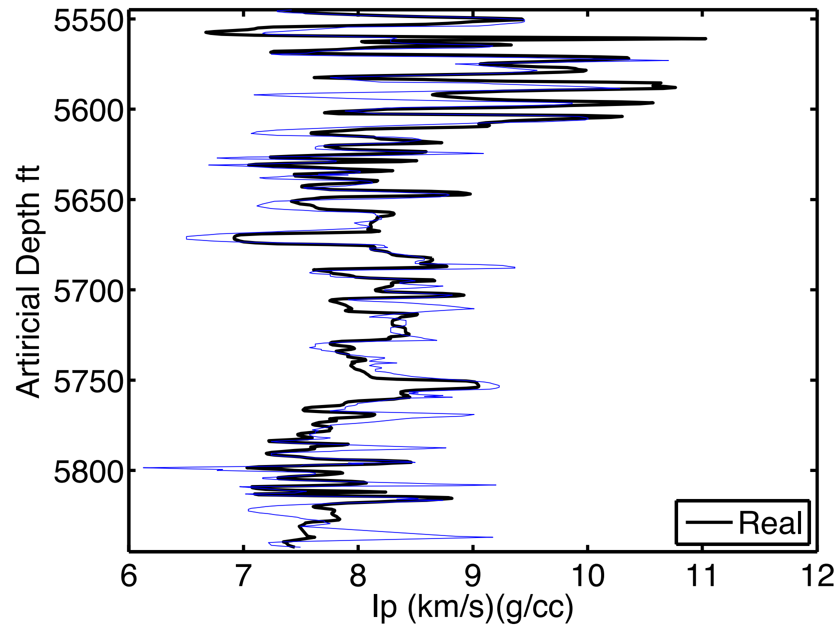


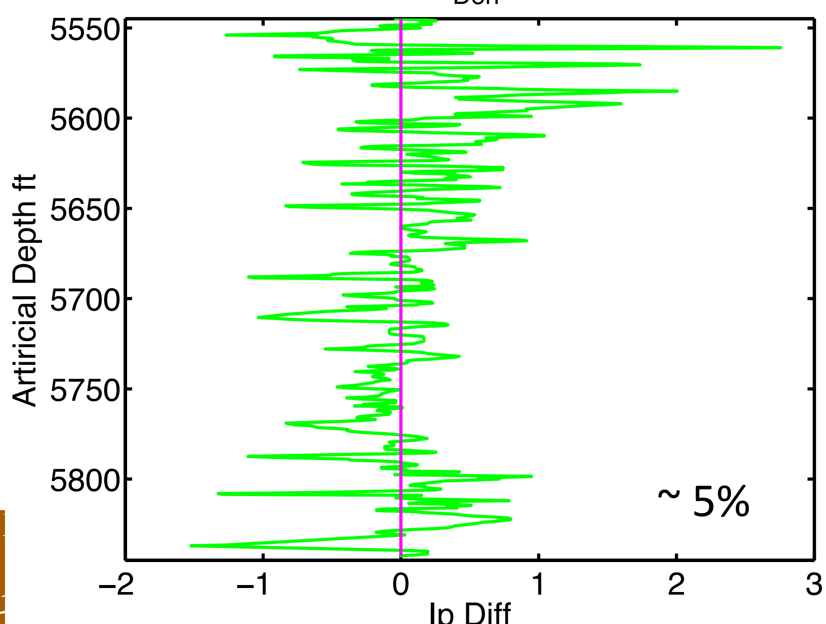
CALIBRATE SCM FROM WELL A: PORE SHAPE CONSTRAINT



CALIBRATE SCM FROM WELL A: COMPOSITION AND PORE SHAPE CONSTRAINTS



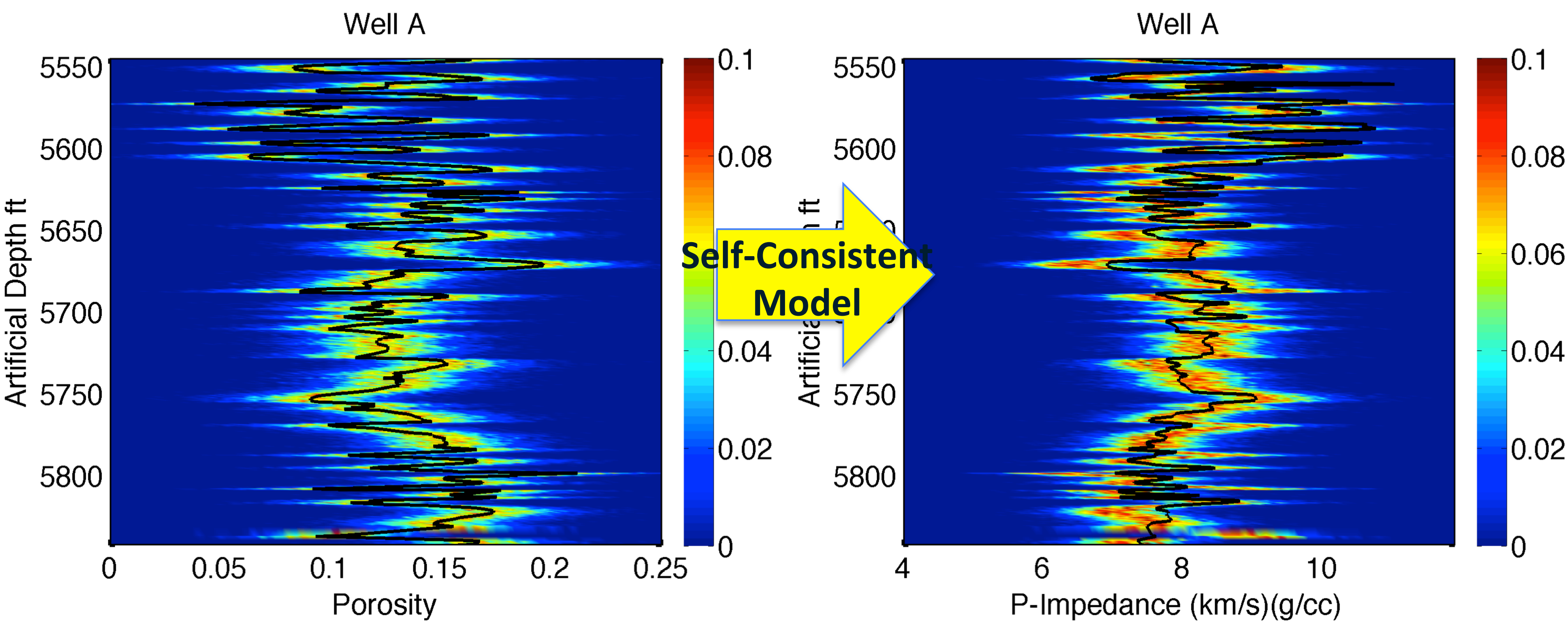




The composition assemblage:
38% quartz, 30% clay, 14% limestone, 7.8% plagioclase, 5% kerogen, 3% dolomite, 2% pyrite, and 0.2% feldspar

The pore aspect ratios ~ $N(0.12, 0.01^2)$

UNCERTAINTY ANALYSIS IN THE FORWARD PROBLEM



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POROSITY ESTIMATION

Grid Search Method

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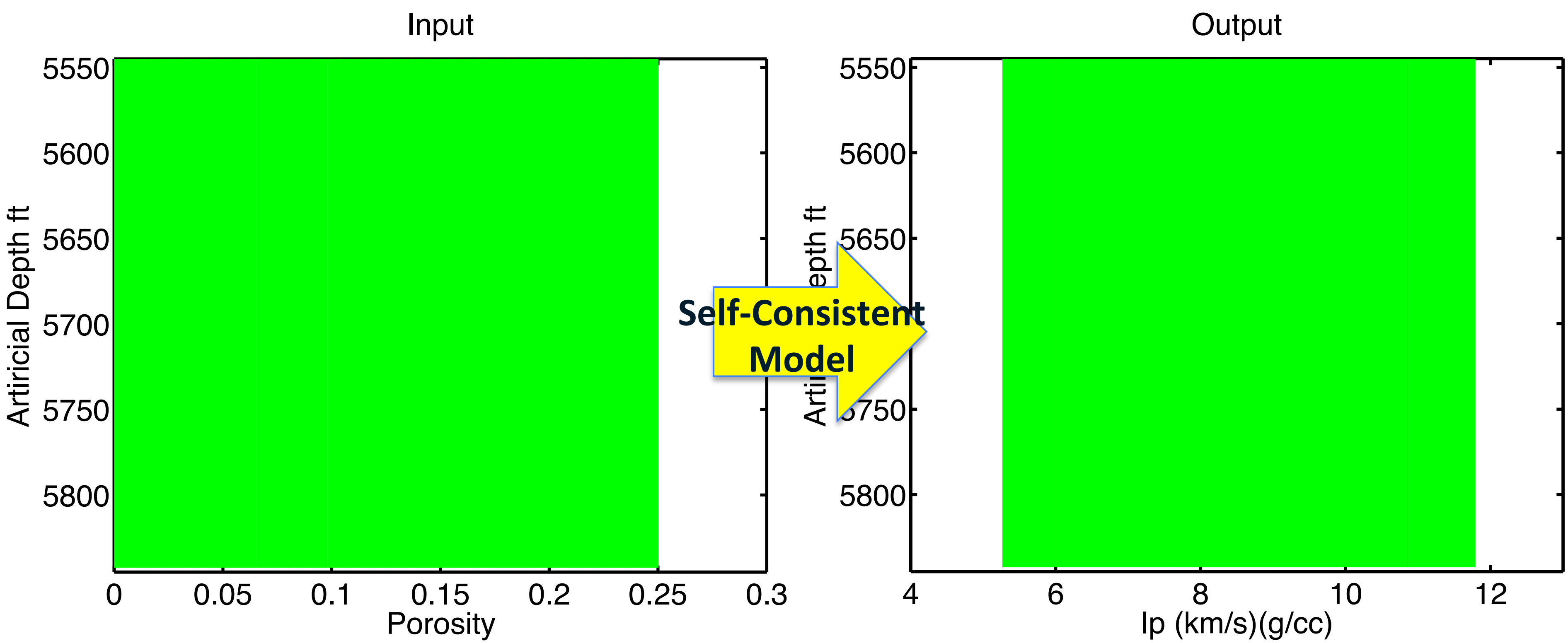
GRID SEARCH METHOD



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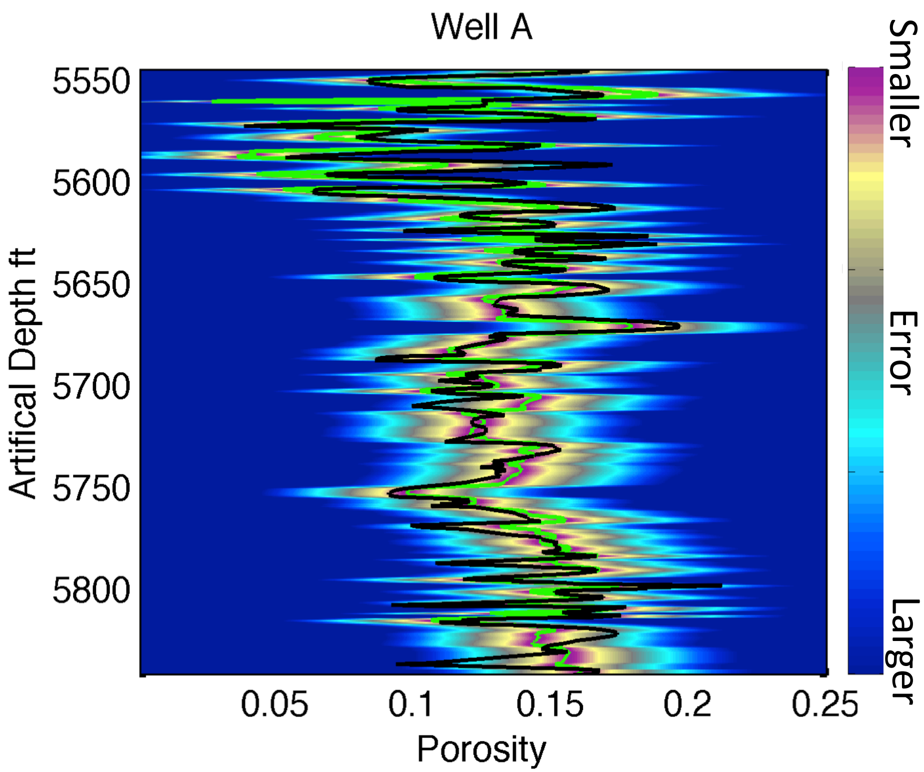
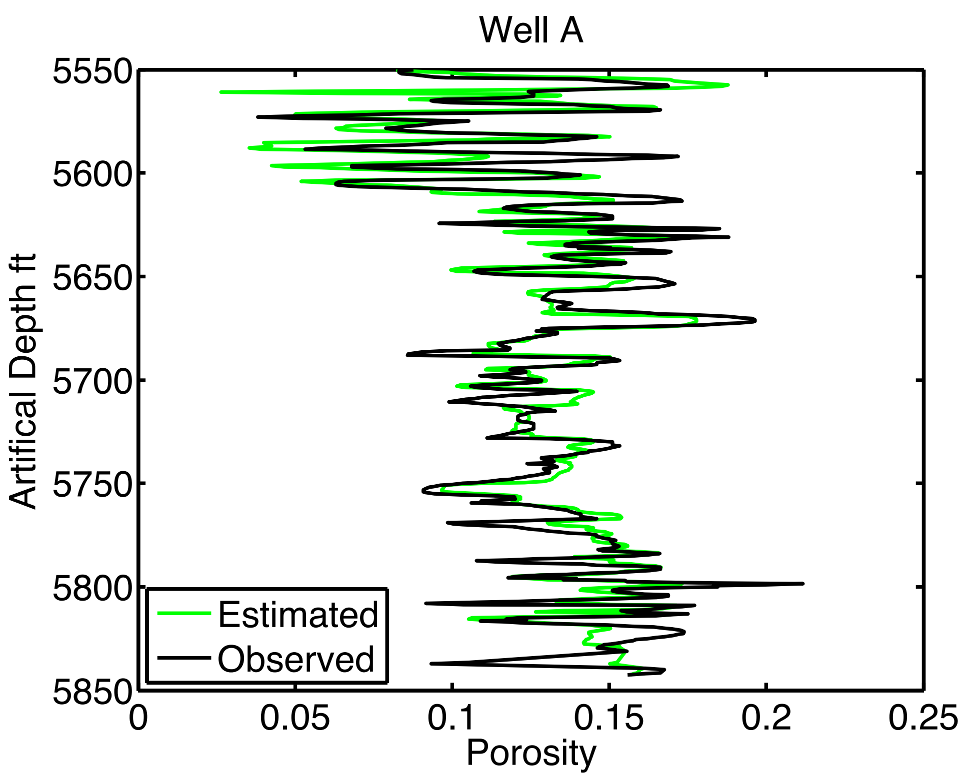
GRID SEARCH METHOD: WELL A RESULT





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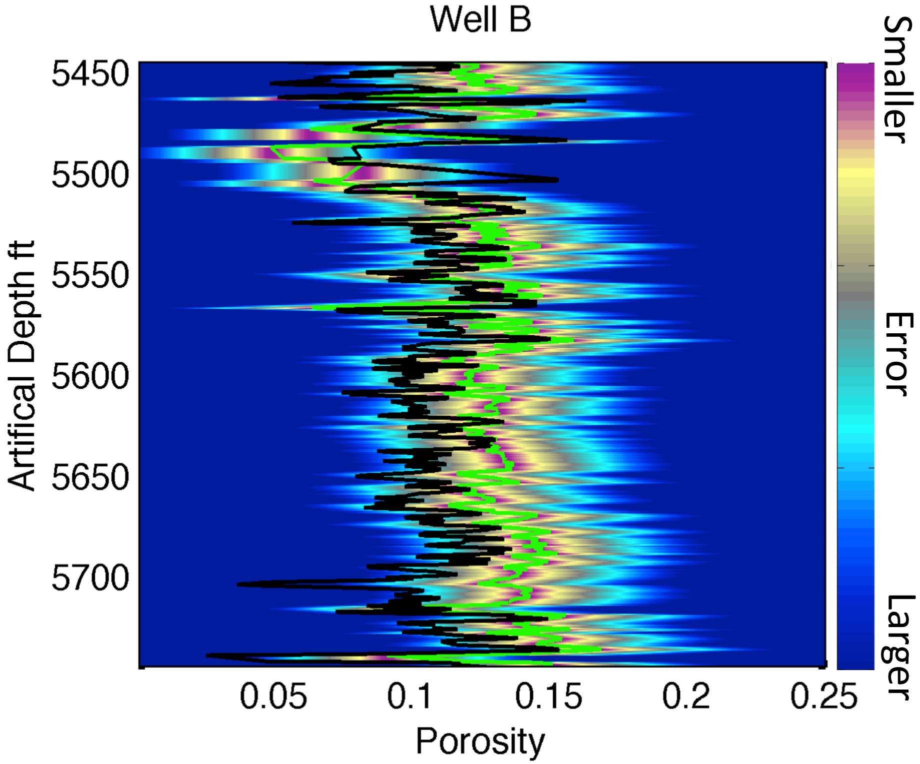
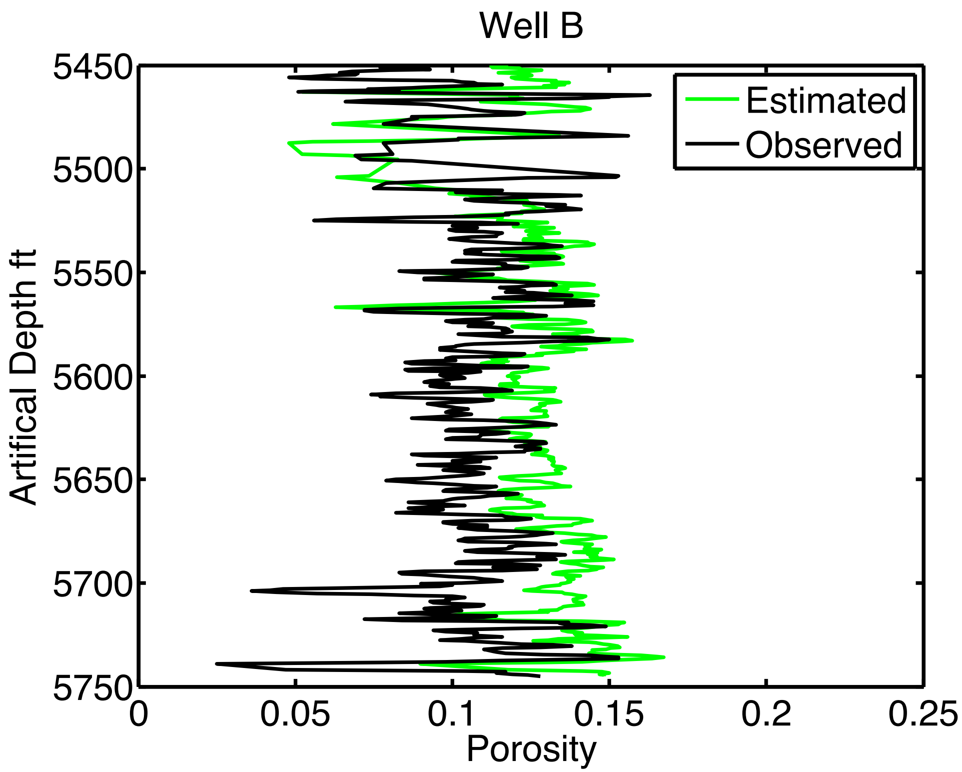
GRID SEARCH METHOD: WELL B RESULT





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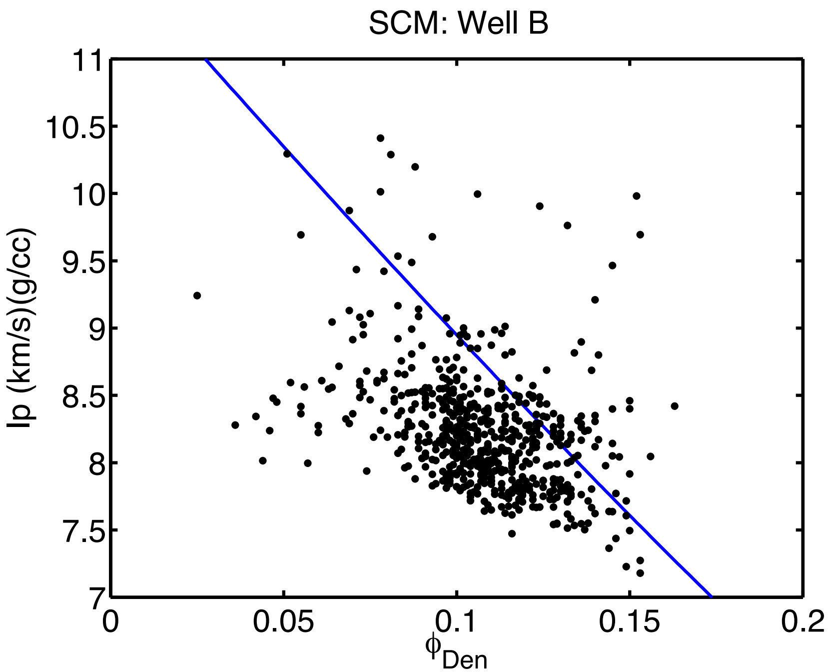
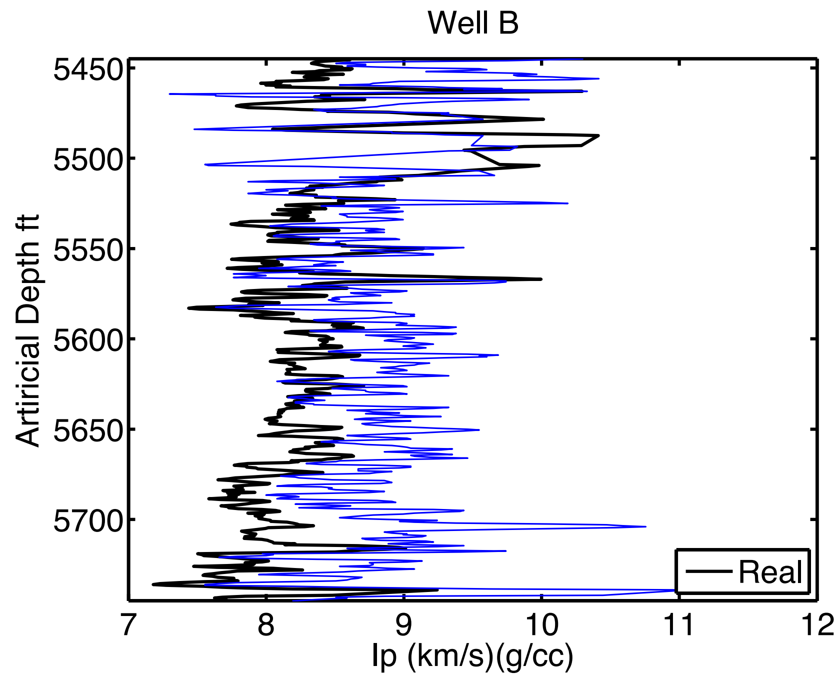
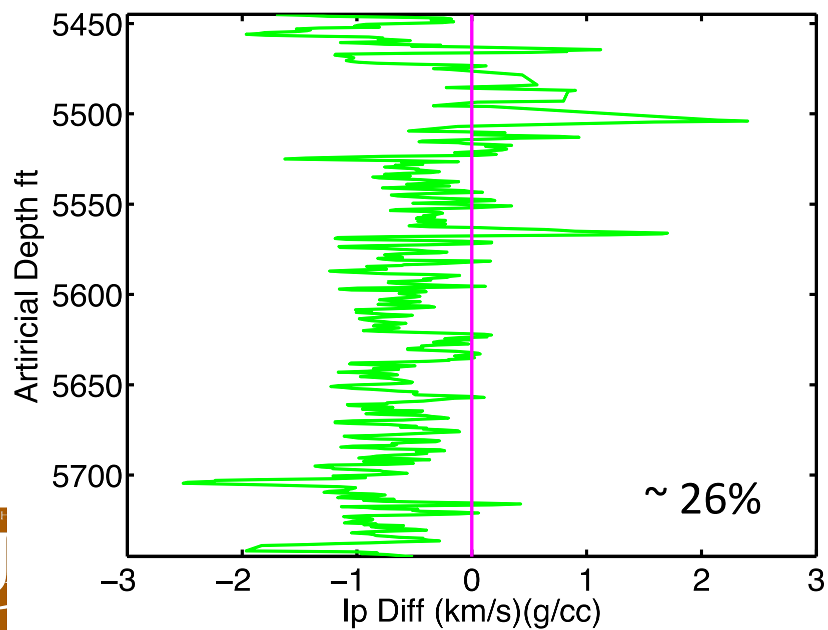
DISCUSSION: SPATIAL VARIATION

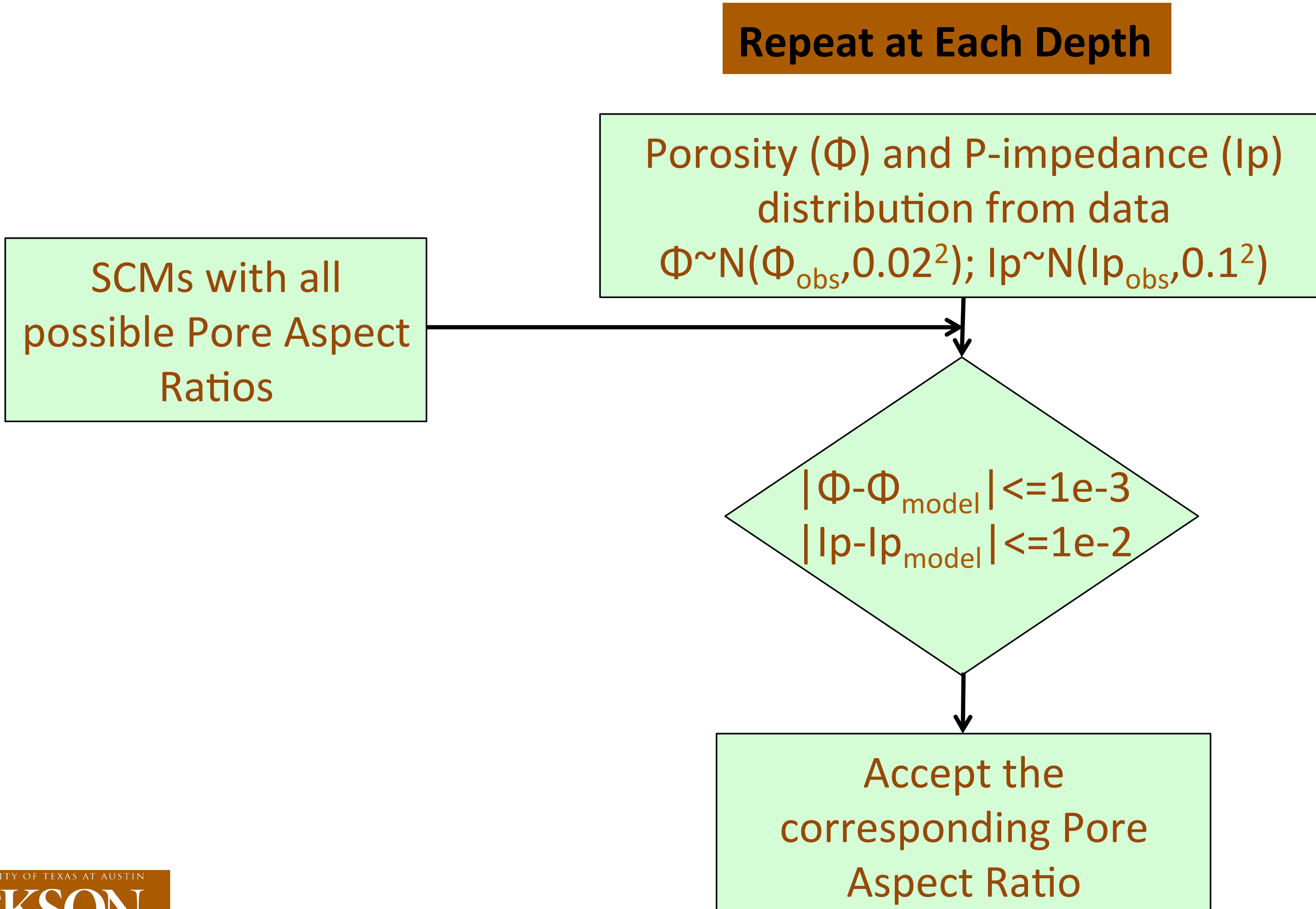




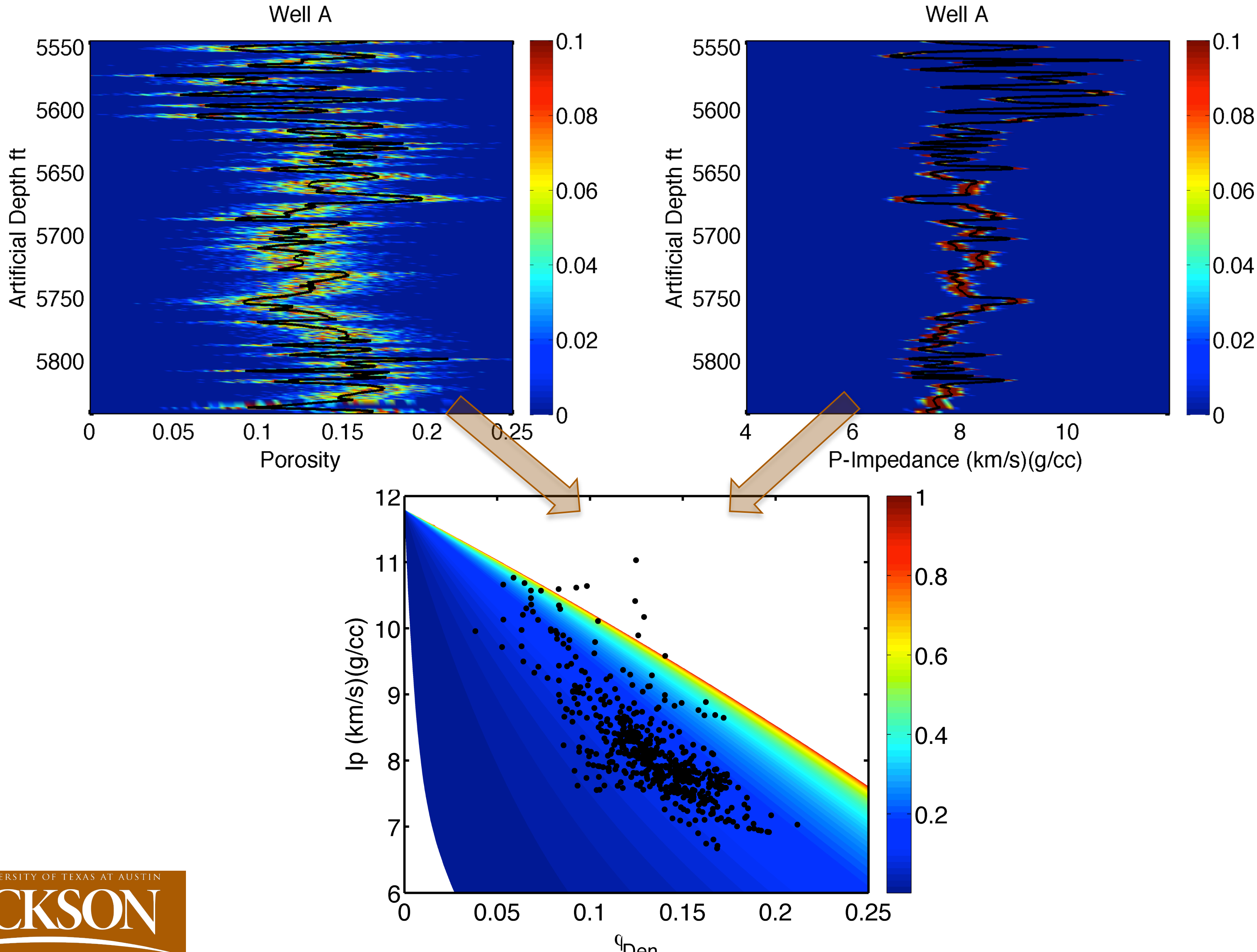


The pore size, pore shape, and composition may vary spatially within the Haynesville Shale formation

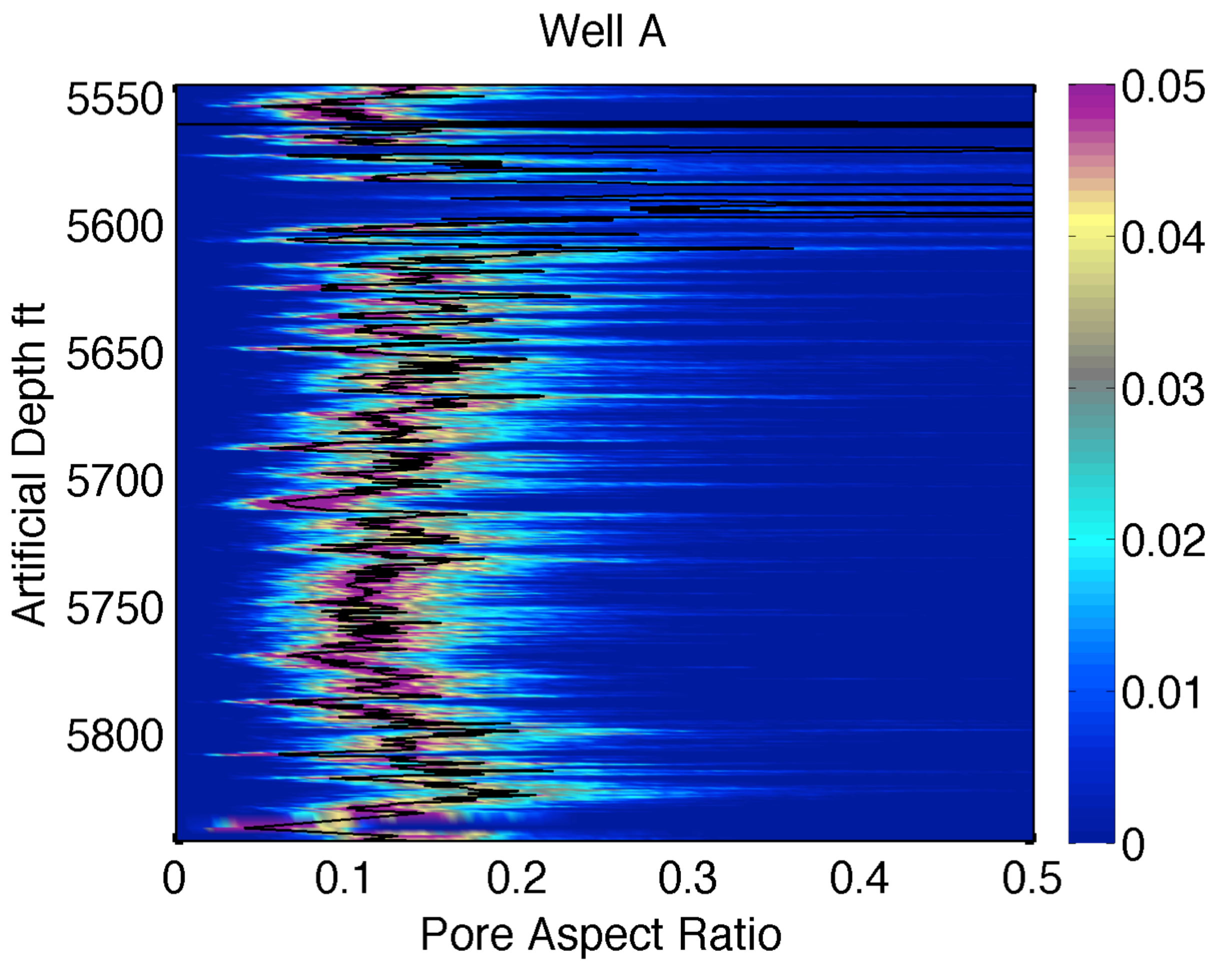
PORE SHAPE ESTIMATION



PORE ASPECT RATIO ESTIMATION: WELL A INPUTS AND MODEL



PORE ASPECT RATIO ESTIMATION: WELL A RESULT



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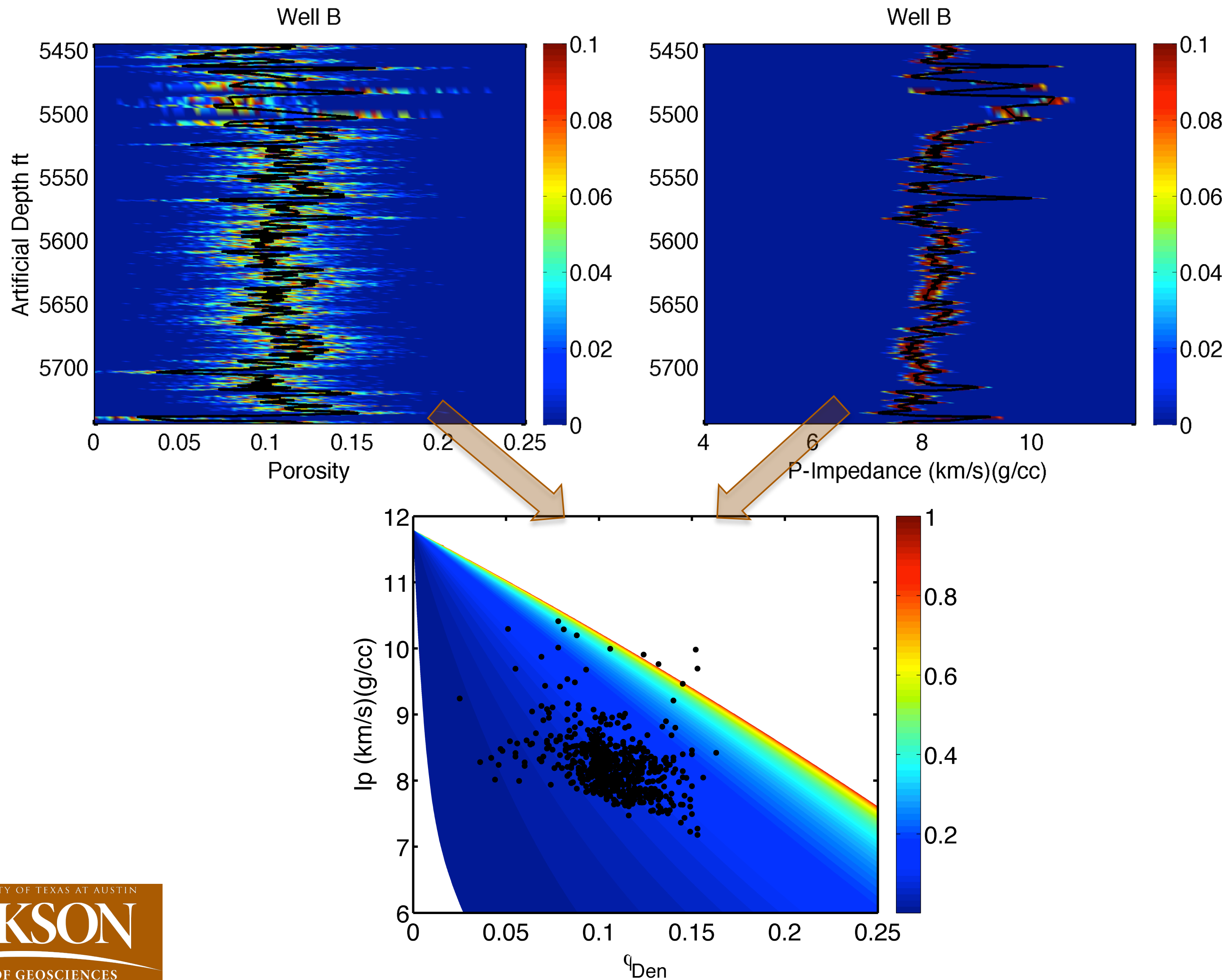
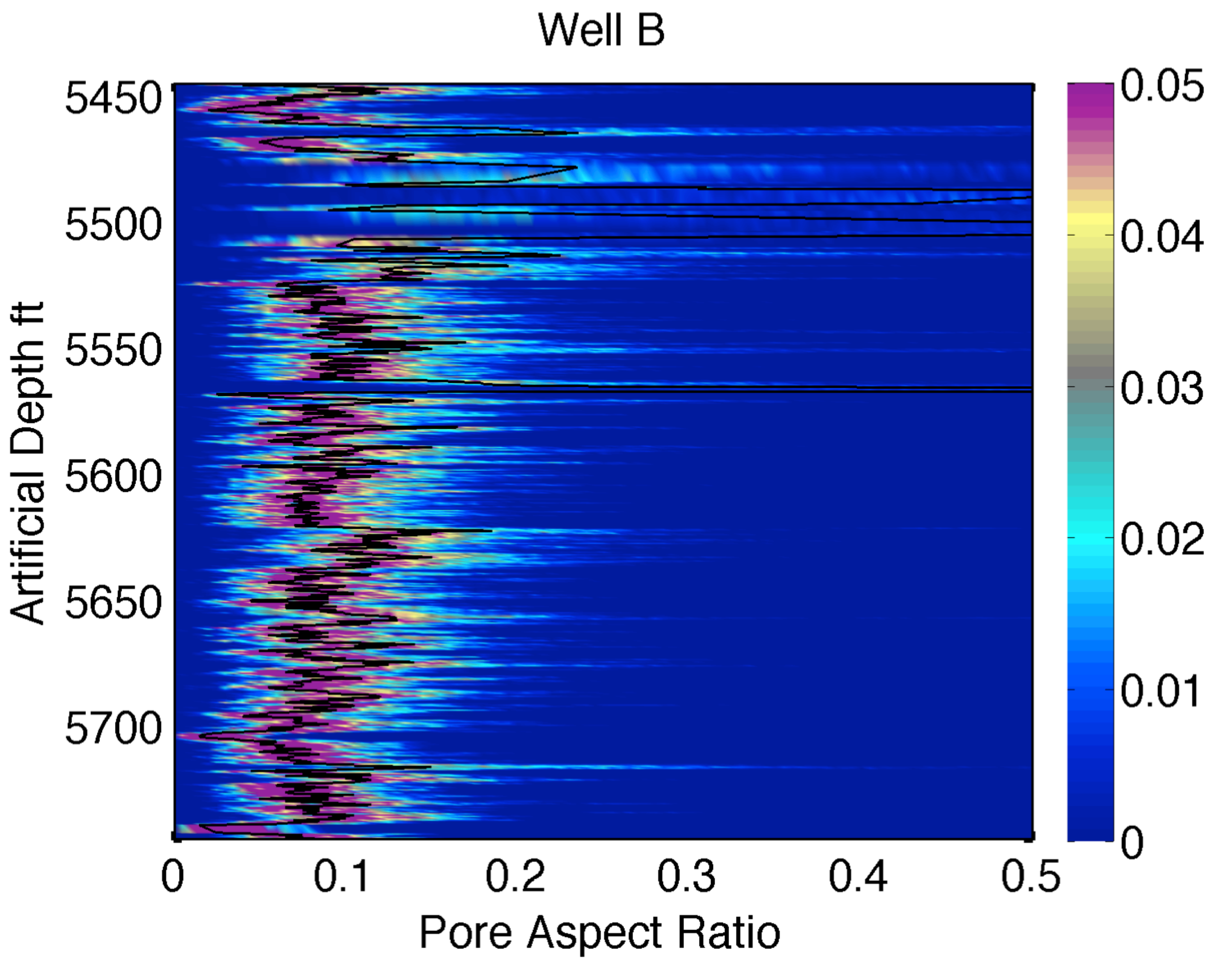
PORE ASPECT RATIO ESTIMATION: WELL B INPUTS AND MODEL



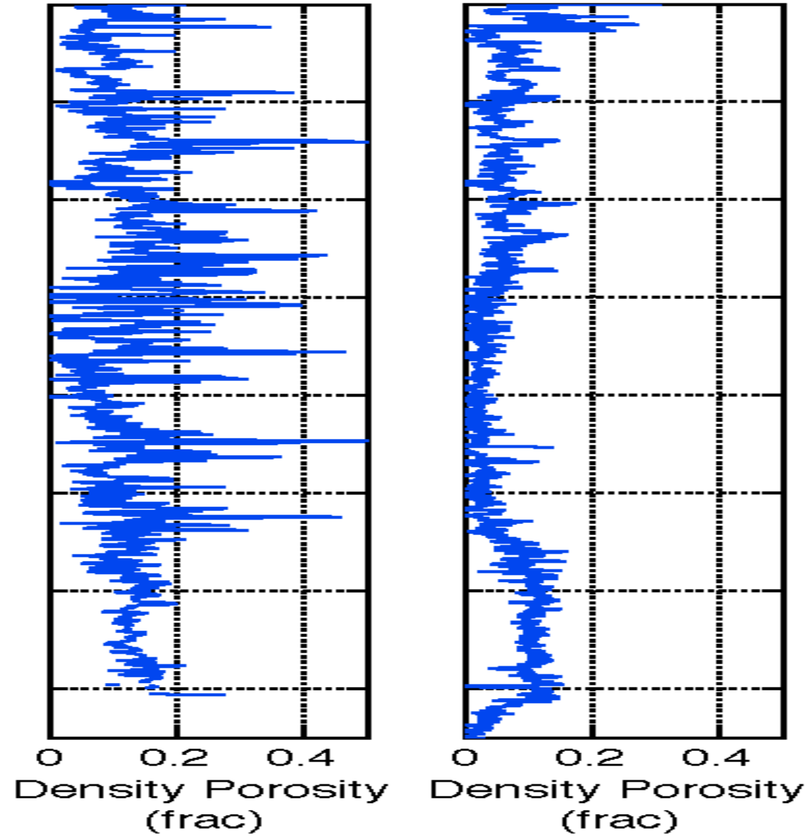
PORE ASPECT RATIO ESTIMATION: WELL B INPUTS AND MODEL

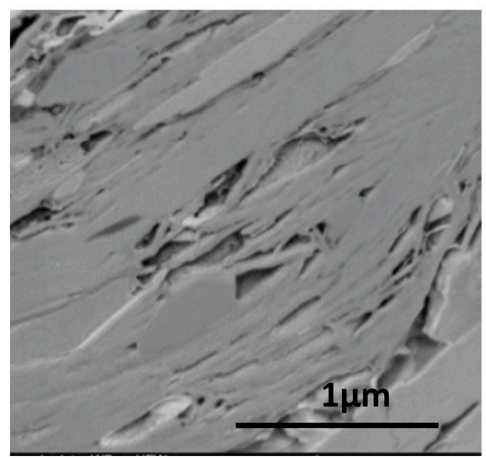


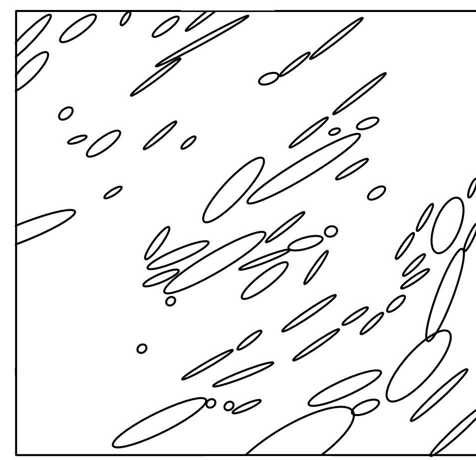
DISCUSSION

- Porosity estimation can be verified at the well locations

- Pore aspect ratio estimation cannot be verified. However, microstructure images of core samples provide helpful information



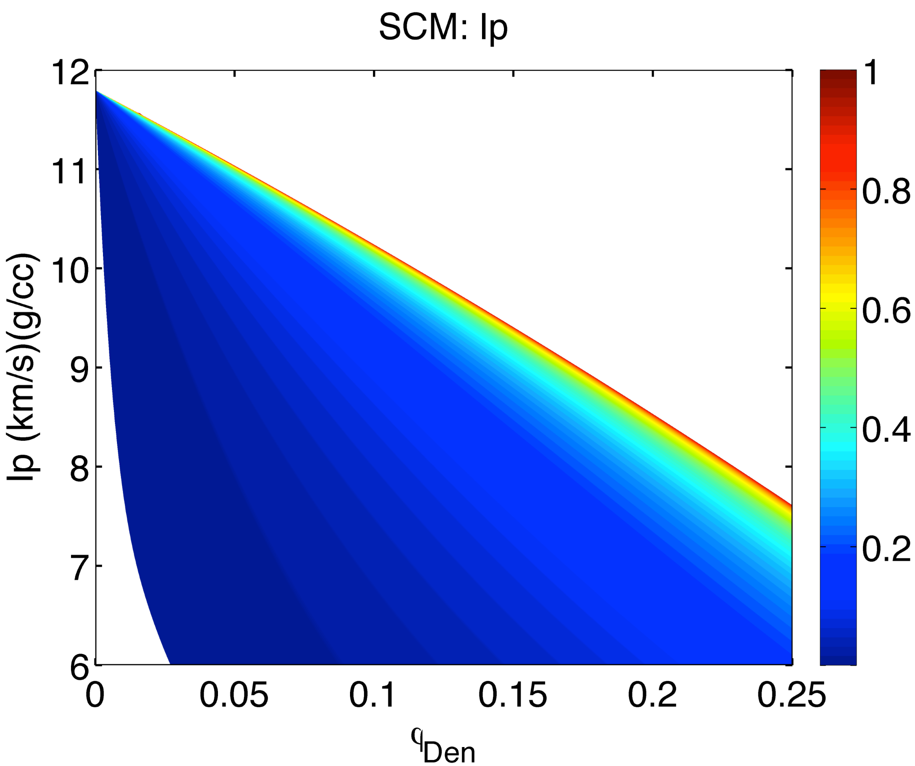


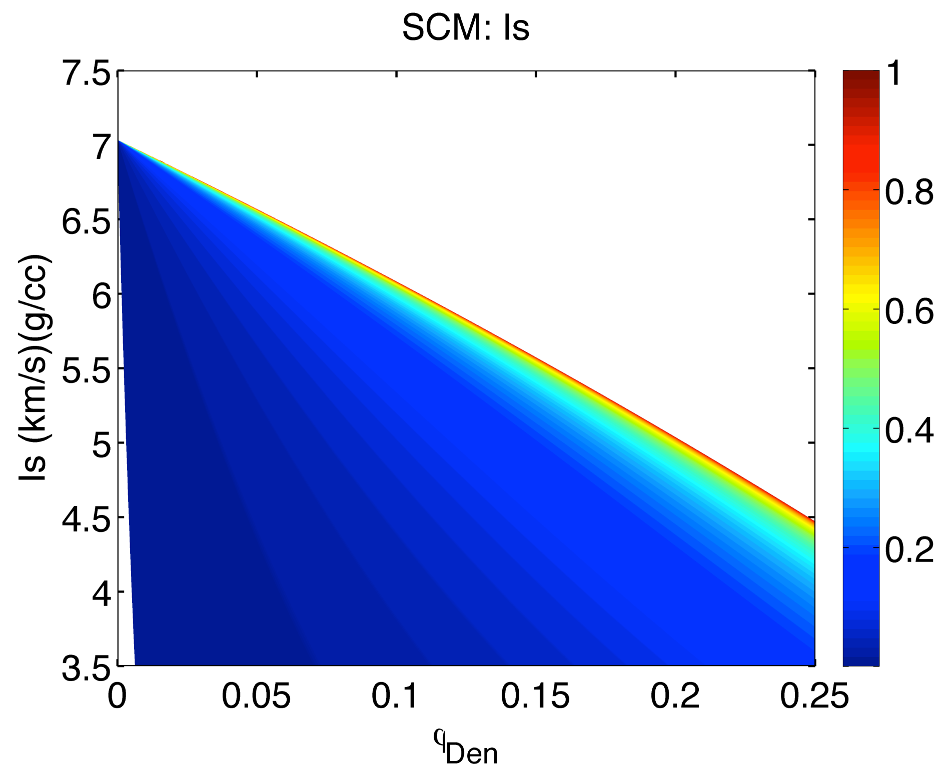


Images from: Curtis et al.,2010

DISCUSSION

Simultaneously estimate Porosity and Pore Aspect Ratio, using both P- and S-Impedance





Invert 3D seismic data to obtain spatially continuous distributions of P- and S-impedances

Estimate continuous porosity and pore aspect ratio distributions for 3D volume

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CONCLUSIONS

- The self-consistent model provided constraints on the composition and pore shape based on P-impedance for the Haynesville Shale

- Porosity and pore shape for the Haynesville Shale has been characterized by the rock physics modeling and a grid search method

- Invert 3D seismic data to obtain spatially continuous distributions of P- and S-impedances, and therefore obtain 3D porosity and pore aspect ratio distributions

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