UT-AUSTIN EDGER FORUM

KYLE T. SPIKES
Research Group

THE UNIVERSITY OF TEXAS AT AUSTIN
JACKSON
SCHOOL OF GEOSCIENCES

WELCOME TO THE MEETING

- Welcome everyone!
- Currently we have 8 PhD and 3 MS students in total
- Presentations today cover a variety of topics in various stages of development
- Collaborator, Nicola Tisato, is currently building his laboratory, to be and running sometime this year
- Integrating his work with EDGER work is in the plans

Group Members

- Kyle T. Spikes, Associate Professor
- Dr. Kelvin Amalokwu, Post-Doctoral Fellow
- Mr. Tom Hess, Research Engineering Scientist Associate

Student Members

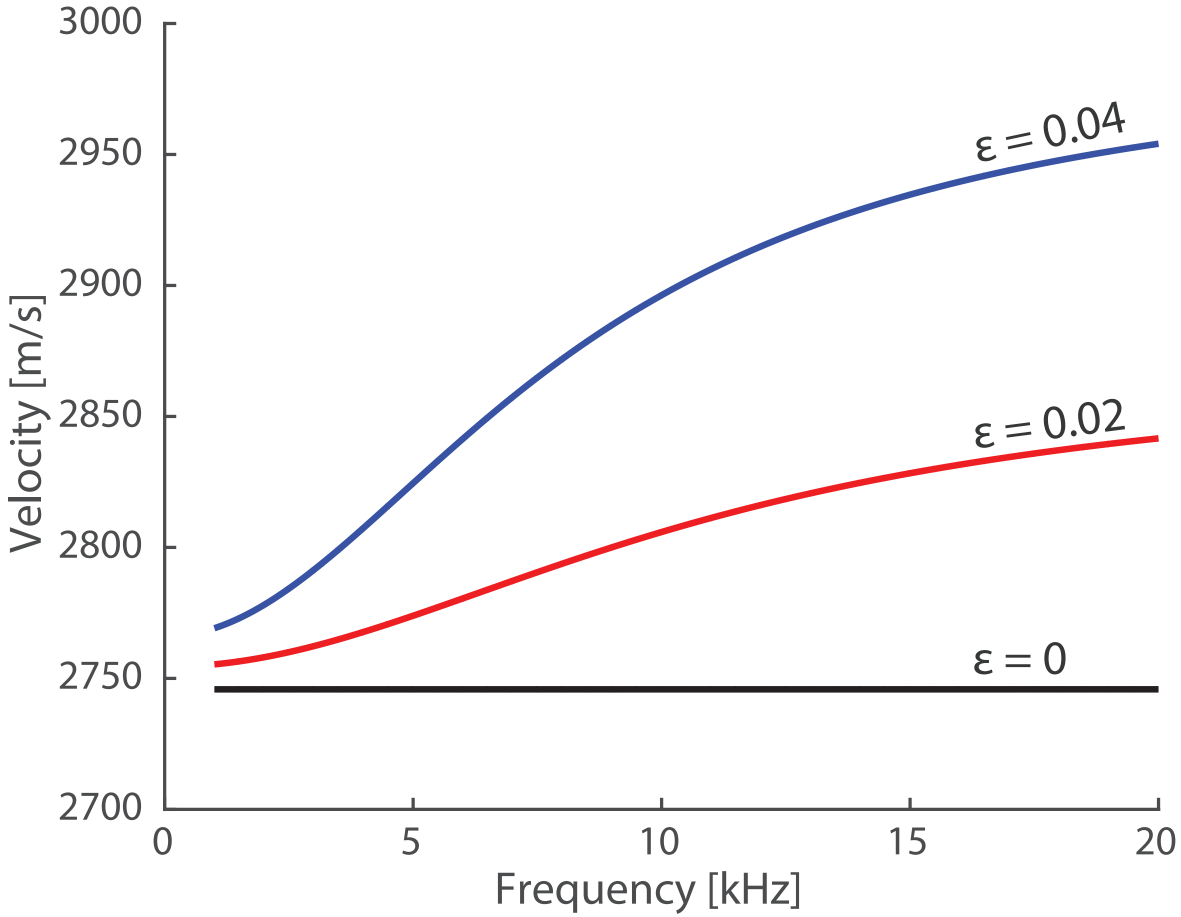
1. Elliot Dahl, PhD Student (EDGER)
2. David Tang, PhD Student (EDGER)
3. Wei Xi, PhD Student (EDGER)
4. Michael McCann, MS Student (EDGER)

Funding

- Effective medium model of shale properties: BP (PI: Spikes)
- Big data challenges – subsurface fracture characterization: NSF (Wheeler and Sen)
- EDGER

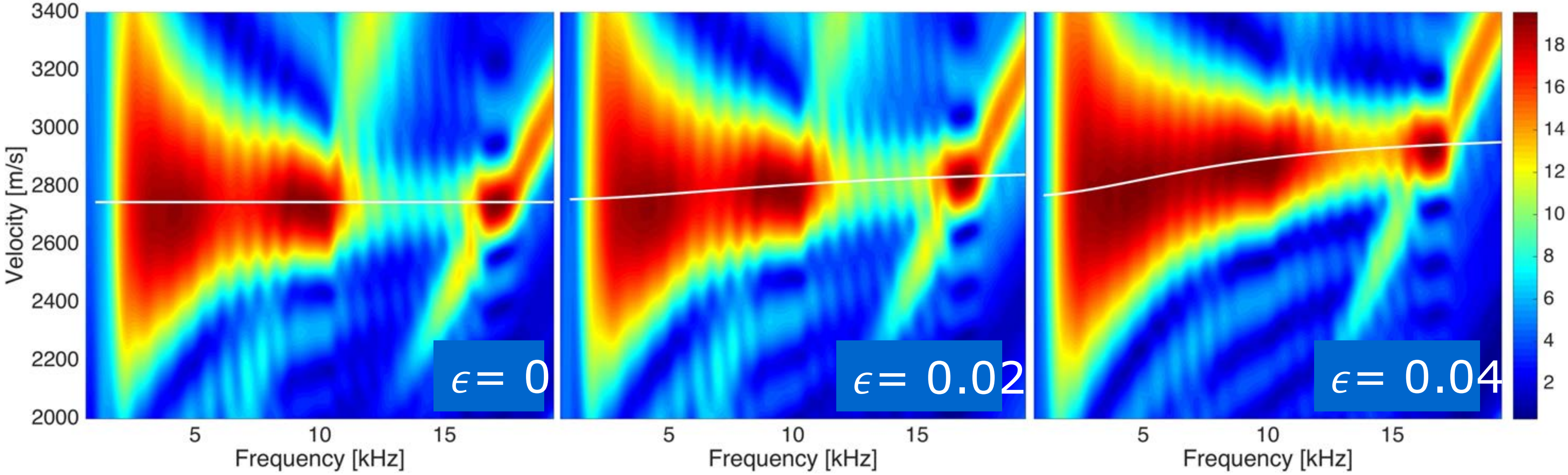
CURRENT WORK – ELLIOT DAHL

P-wave velocity



CURRENT WORK – ELLIOT DAHL

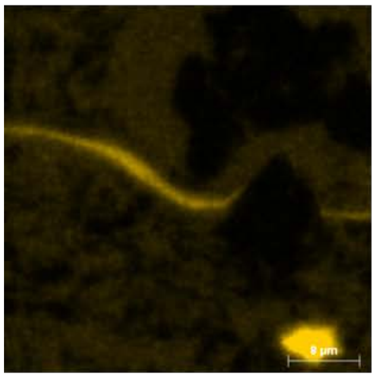
P-wave dispersion



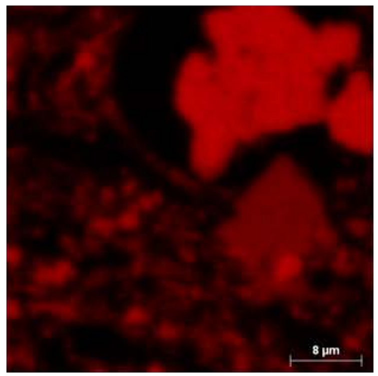
CURRENT WORK – DAVID TANG

Energy Dispersive X-ray Spectroscopy (EDS)

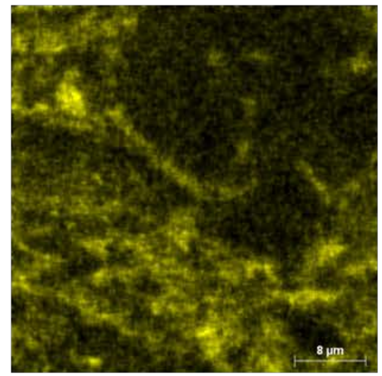
Carbon



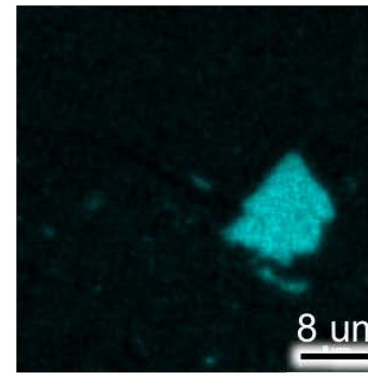
Silicon



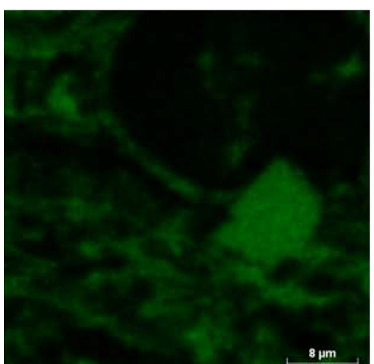
Potassium



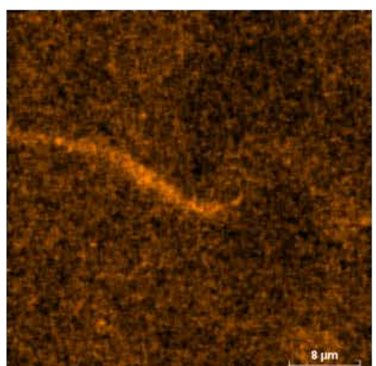
Sodium



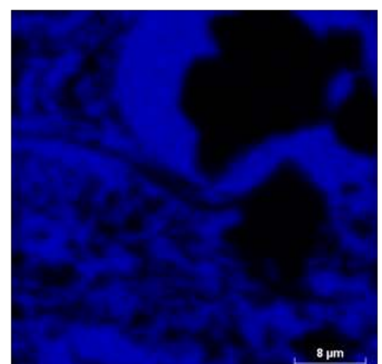
Aluminum



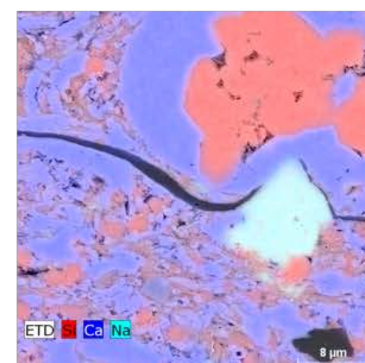
Sulfur



Calcium

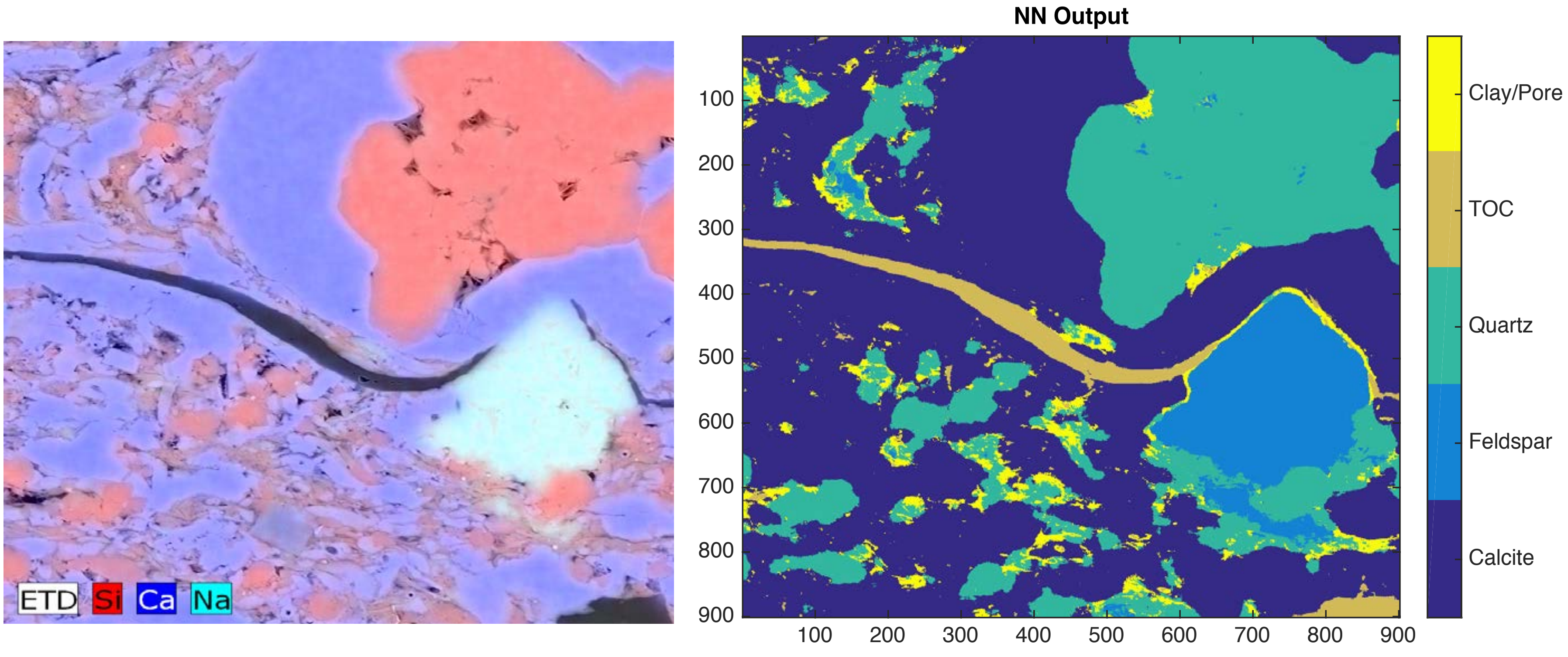


RGB Composite



CURRENT WORK – DAVID TANG

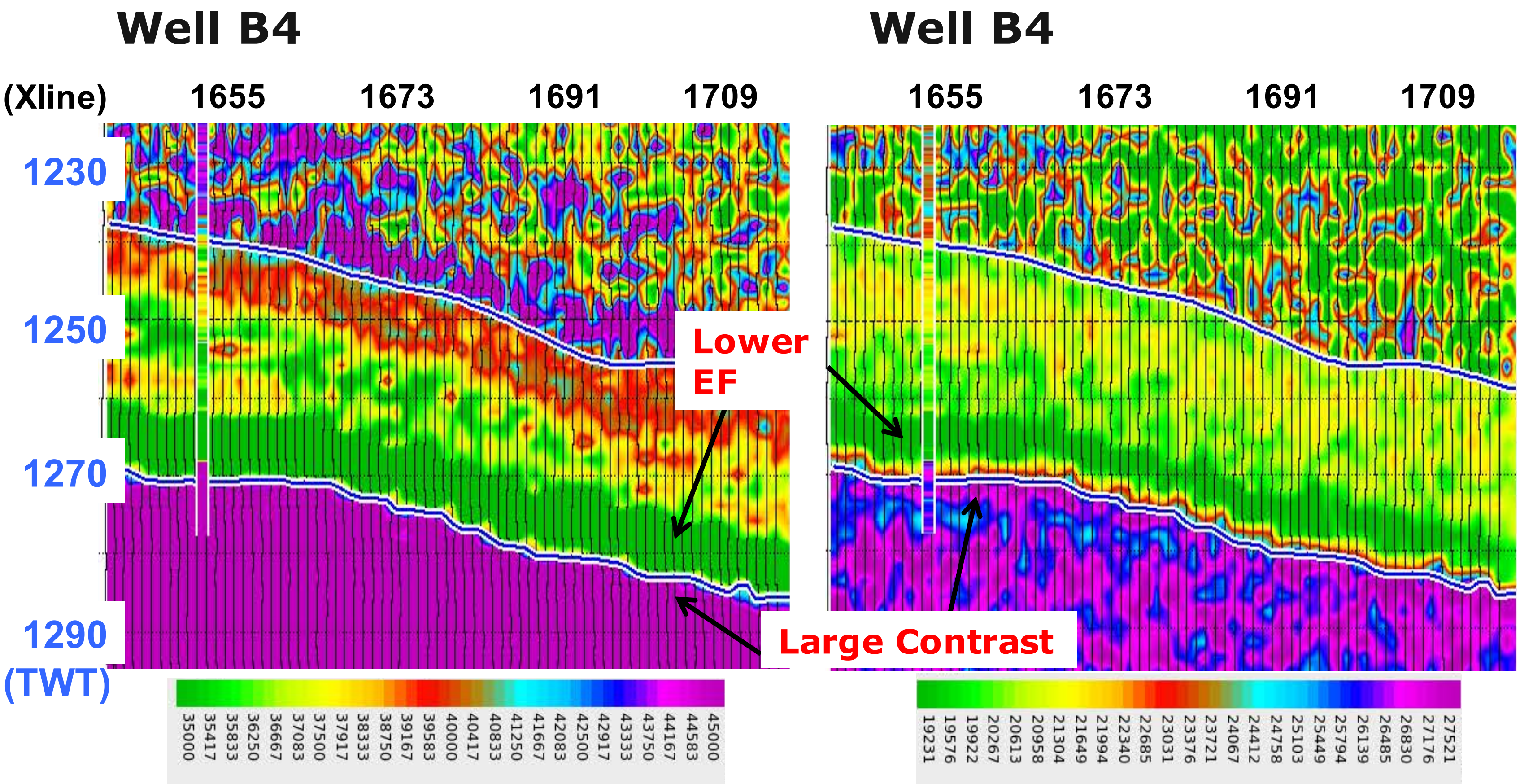
Segmentation Results



CURRENT AND ONGOING WORK

- Unconventionals
- Segmentation-less digital rock physics
- Probabilistic rock physics templates

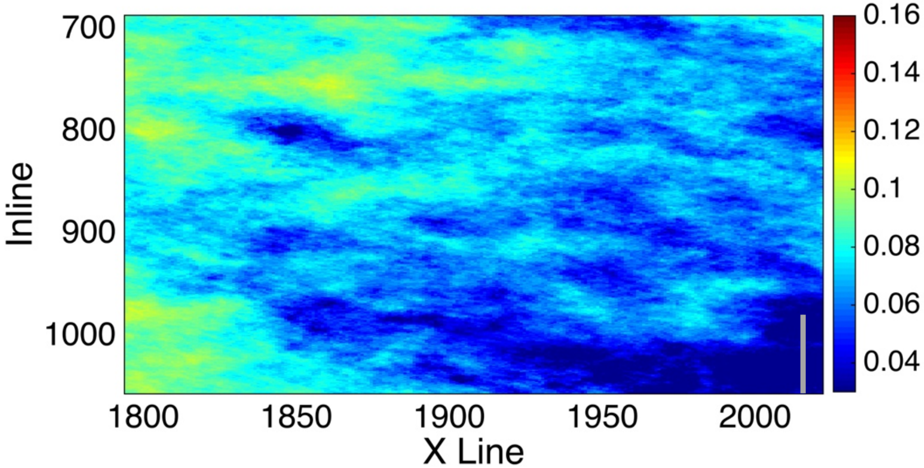
UNCONVENTIONALS



P-Impedance **S-Impedance**

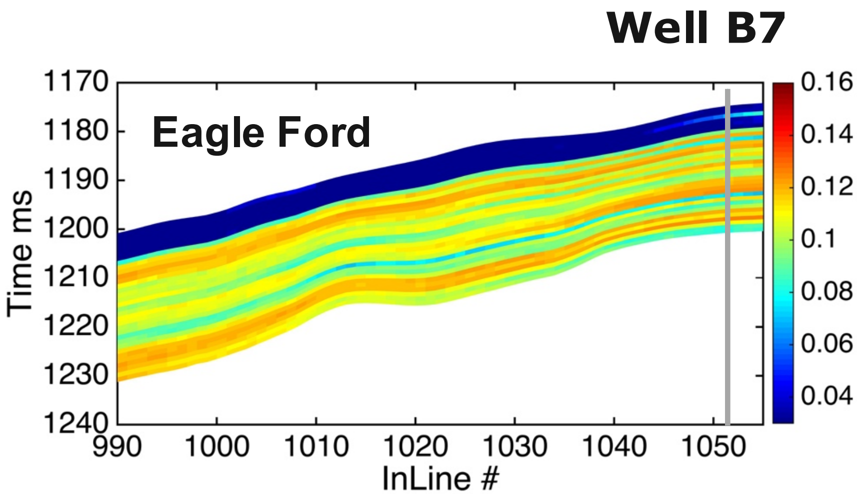
UNCONVENTIONALS

Top of Eagle Ford



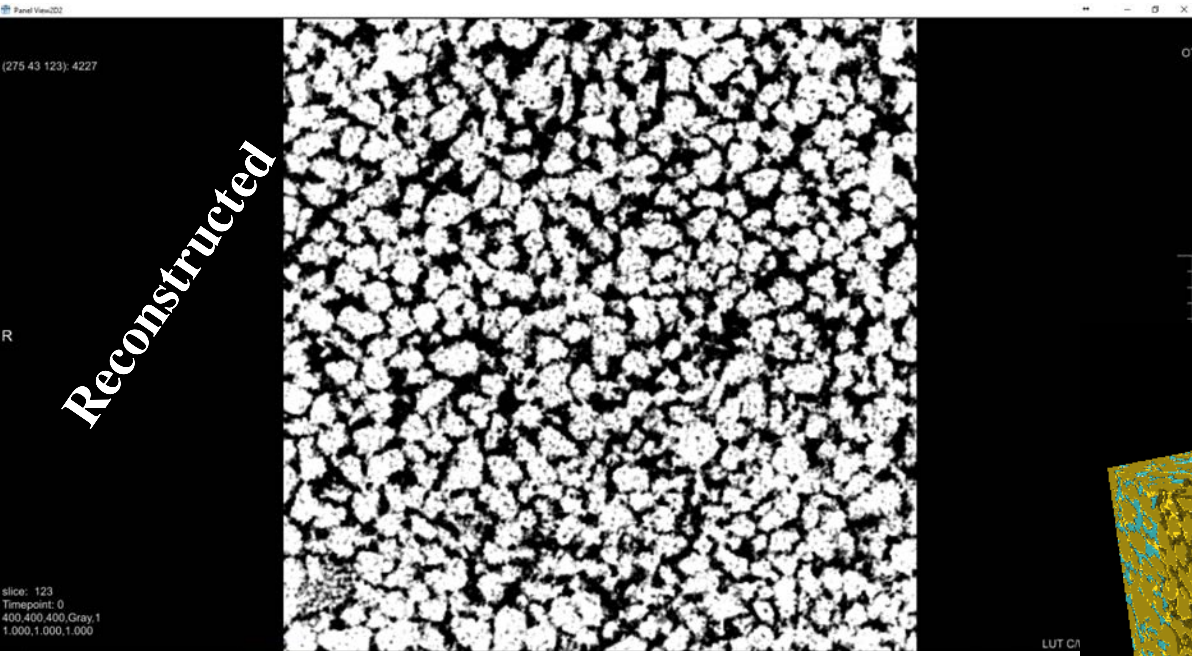
Porosity plus kerogen

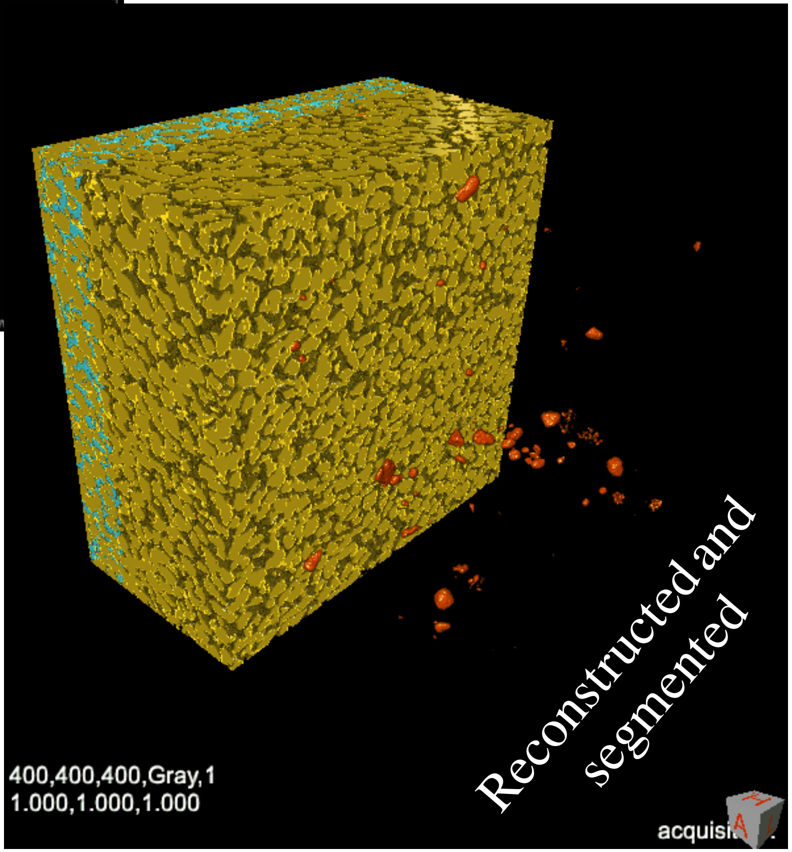
Xline 2012



Porosity plus kerogen

SEGMENTATION-LESS DRP





SEGMENTATION-LESS DRP

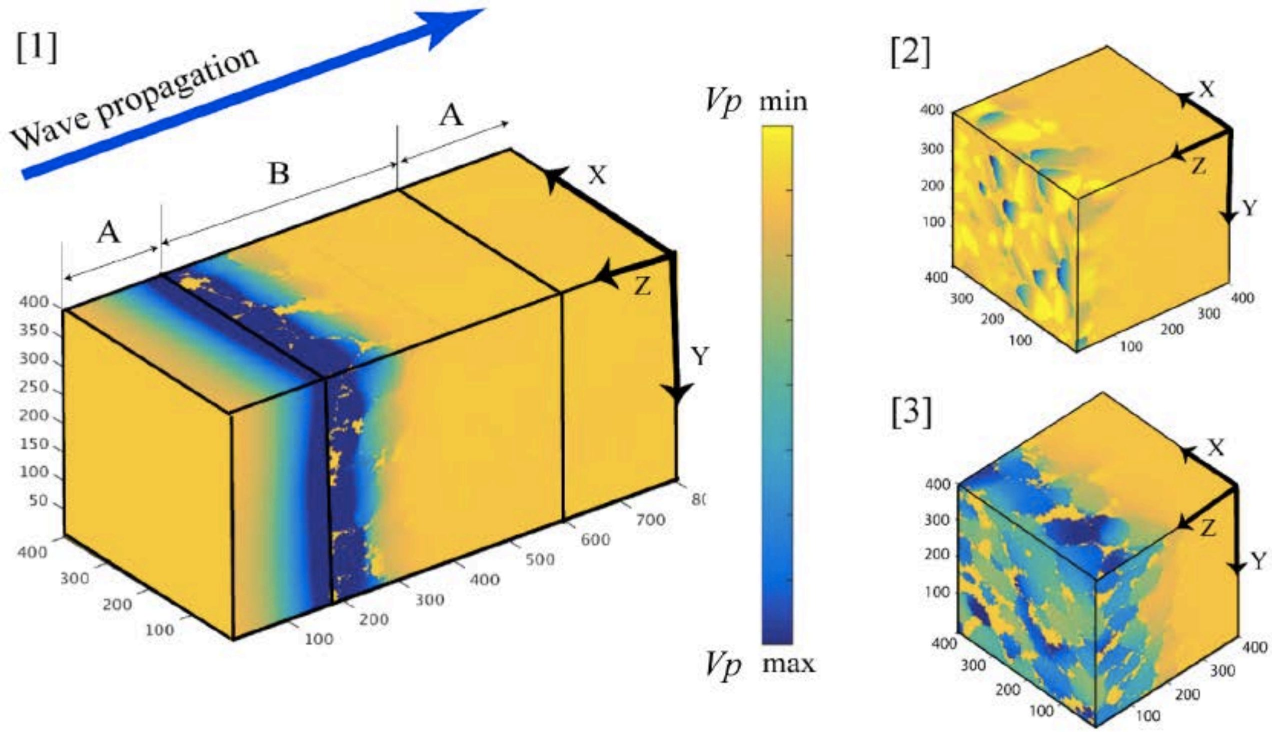


Figure 13. (1) Visualization of the RSG model where A is a predefined homogenous solid in which the $400 \times 400 \times 400$ size volume is embedded. The plane wave propagates in z direction. (2) Visualization of the V_p in a sample containing roughly 7 % of hydrate. (3) Visualization of the V_p in a sample bearing 17 % of hydrate where the V_p is significantly higher due to the increased hydrate bulk.

Typically, segmentation-based DRP overestimates velocities.

Sell et al., 2016, Solid Earth

SEGMENTATION-LESS DRP

Can we eliminate segmentation?

(At least for ~mono-mineralic rocks)

The premise:

1) Using "ghosts" or targets with known densities, we can calibrate our CT imagery to obtain a density model;
2) For mono-mineralic rocks, density can be easily translated to porosity;
3) Total density and porosity should match density and porosity from laboratory measurements.

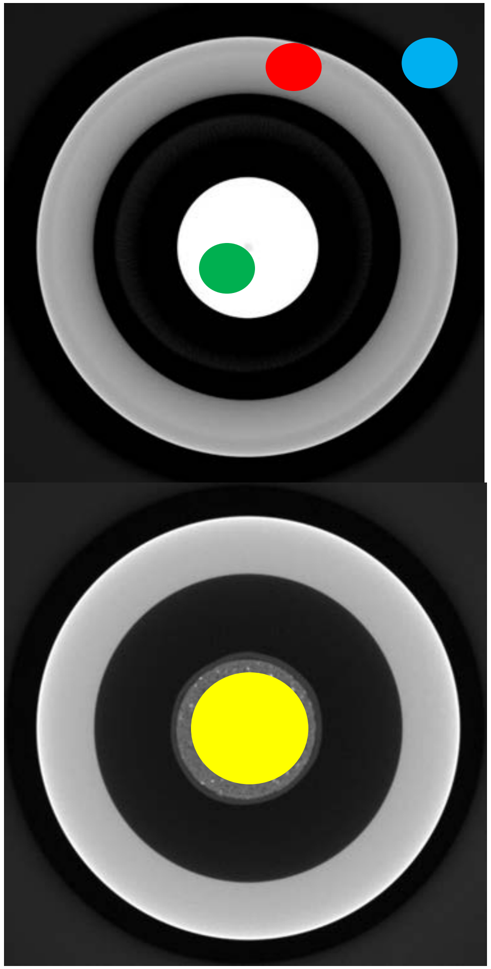
The concept:

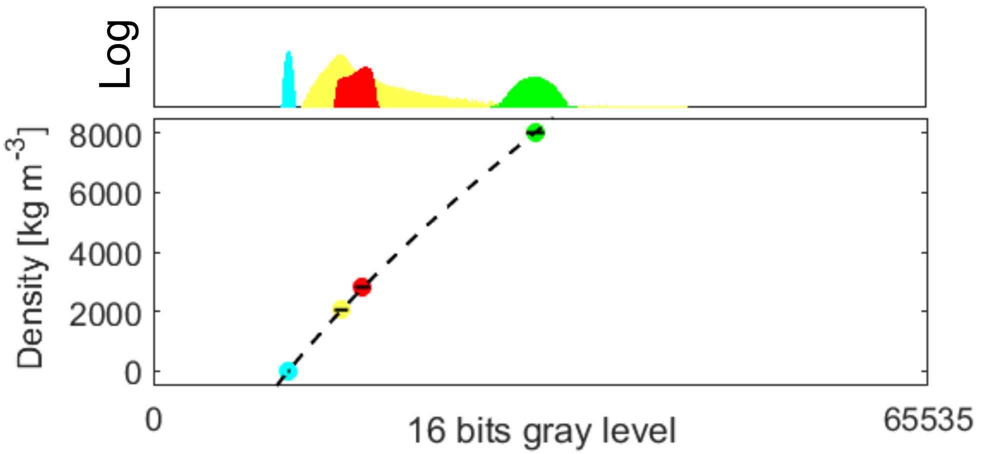
1) Each voxel can be considered as an elementary volume whose effective elastic properties can be described by effective medium theory, e.g. Hashin-Shtrikman;

2) Thus the model does not depend upon the geometry of pores and grains but rather upon the distribution of porosity.

SEGMENTATION-LESS DRP

Gray Level to Density





Air
AISI304
Al alloy

$$\rho_L(kg/m^3) = 36.79 \cdot GL^{0.593} - 9405.3$$

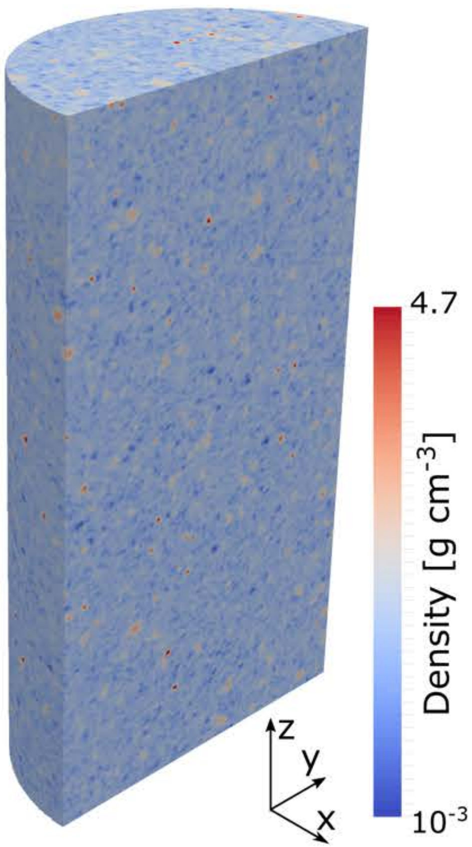
In addition, the rock is a target as we know its average density:

Applied the calibration formula to a sub-sample ~22x12 mm

Sample

Calculated density: 2038 kg/m³ (-1.1% measured, ~error)

SEGMENTATION-LESS DRP



$\rho_{qtz} = 2650\ \mathrm{kg/m^3}$

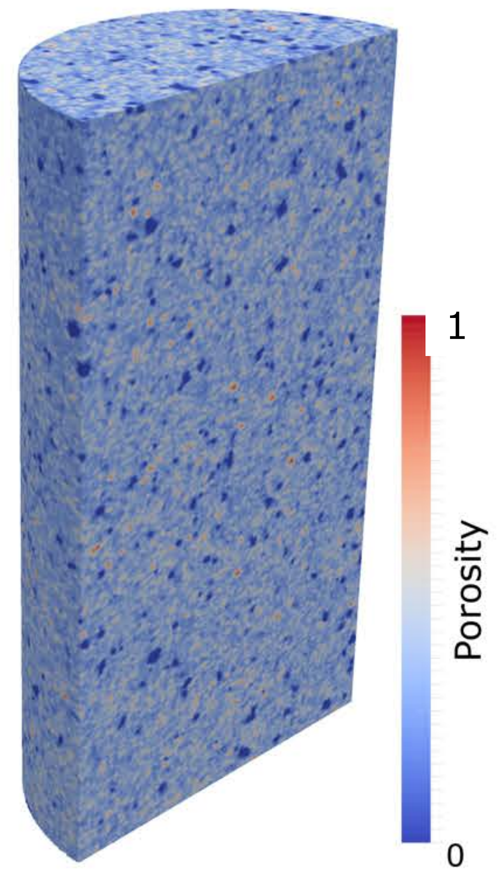
ρ_L = voxel density

$\Phi_L = 0$ for $\rho_L \geq \rho_{qtz}$

$\Phi_L = 1$ for and $\rho_L = \rho_{air}$

$$\Phi_L = \frac{Vol_p}{Vol_g} = 1 - \frac{\rho_L}{\rho_{qtz}}$$

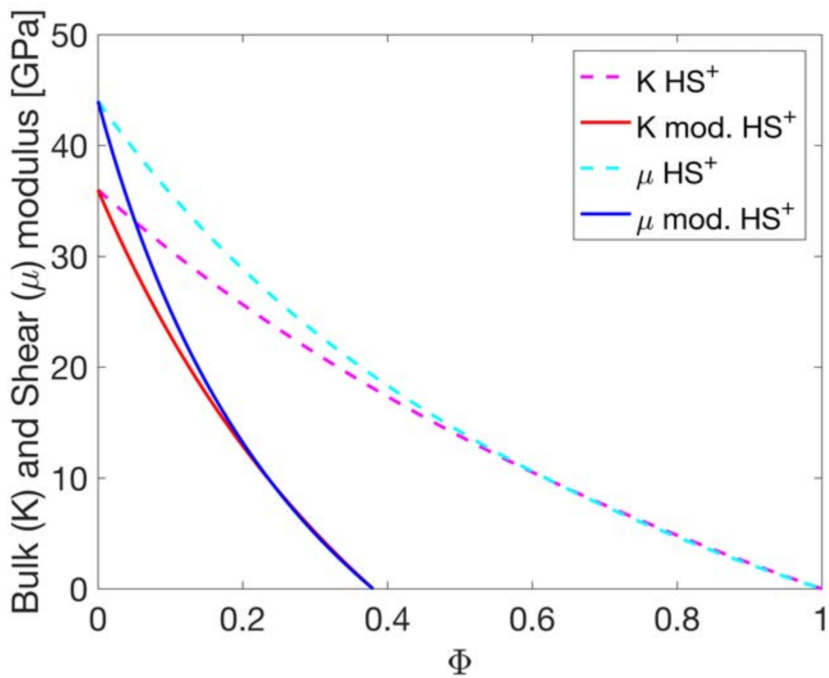
Calculated total porosity 0.23 (~ +8%)

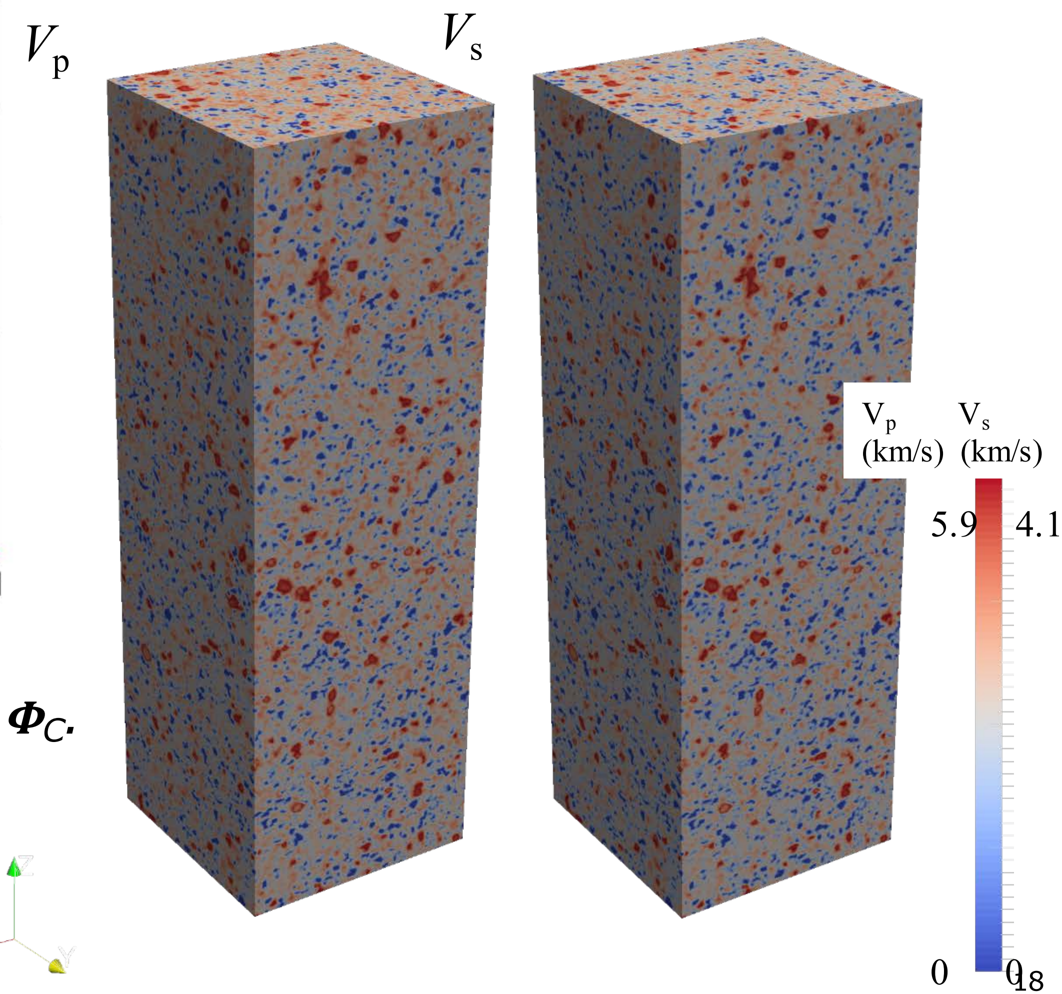


SEGMENTATION-LESS DRP

Modified upper Hashin-Strikman bound (Nur et al., 1991,1995) with critical

Quartz density ($\boldsymbol{\rho}_{qtz}$)	2650	kg/m^3
Quartz Bulk modulus (K_{qtz})	36	GPa
Quartz Shear modulus (G_{qtz})	44	GPa
Critical porosity ($\boldsymbol{\Phi}_c$)	0.38	

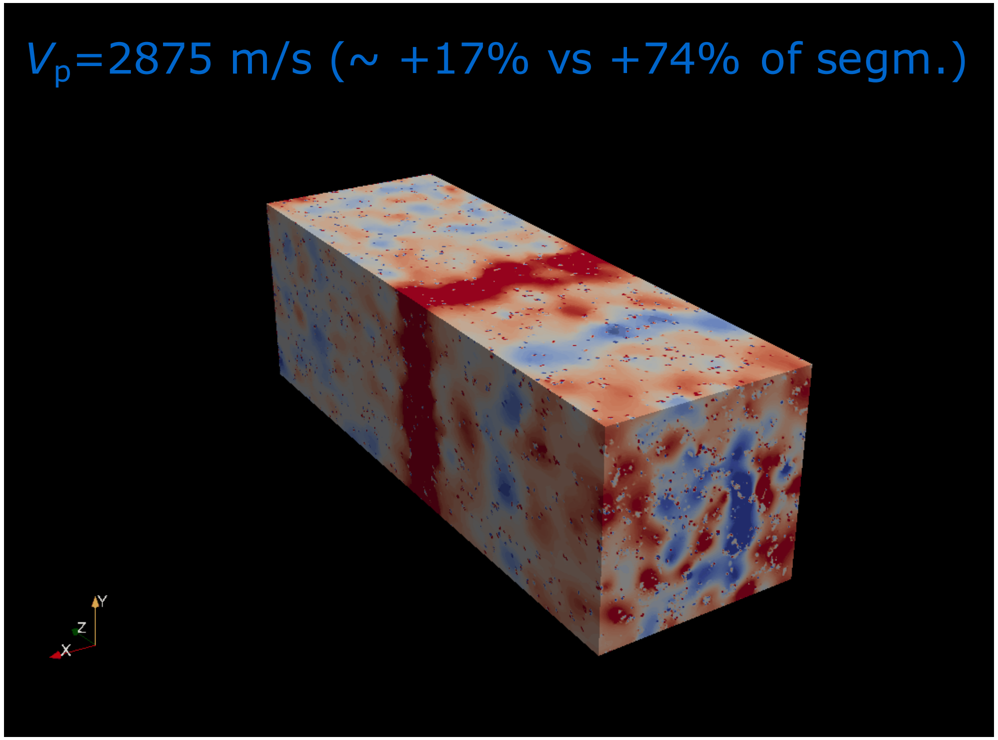


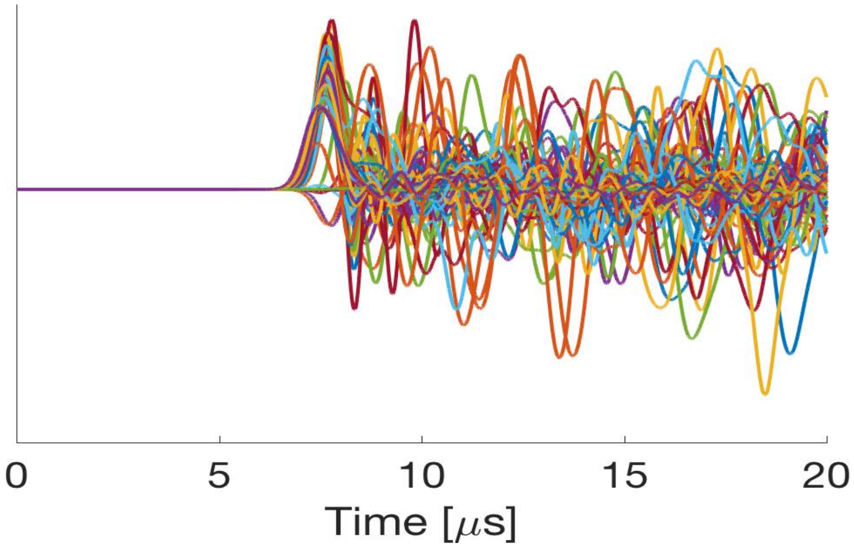


Note: ~3% of the voxels had $\boldsymbol{\Phi}_L > \boldsymbol{\Phi}_C$. $\boldsymbol{\Phi}_L$ forced to be = $\boldsymbol{\Phi}_C$

SEGMENTATION-LESS DRP

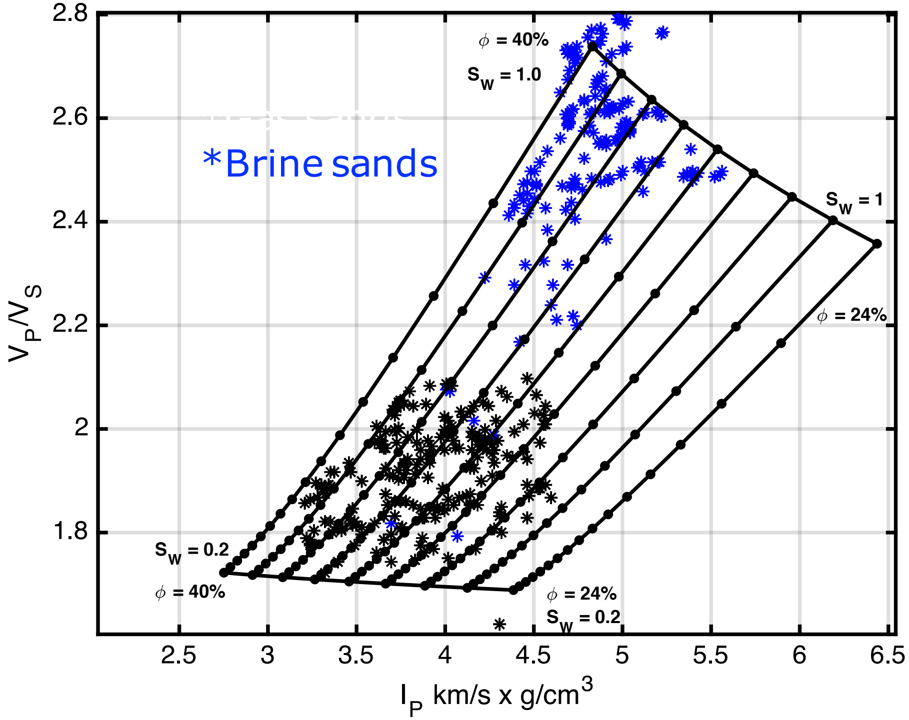
- Sofi3D to propagate elastic waves (Bohlen, 2002, Computers and Geosciences);
- Compressive wave generated at Z=0 mm (f=1MHz, $\sin^3$);
- Measured the arrival time. Average of the displacement at Z=19.96 mm.





Note: The modified upper Hashin-Shtrikman bound calculated on the entire sample (i.e,. only considering Φ and not Φ_L) provided a P-wave velocity of 3680 m/s.

CONVENTIONAL ROCK PHYSICS TEMPLATE



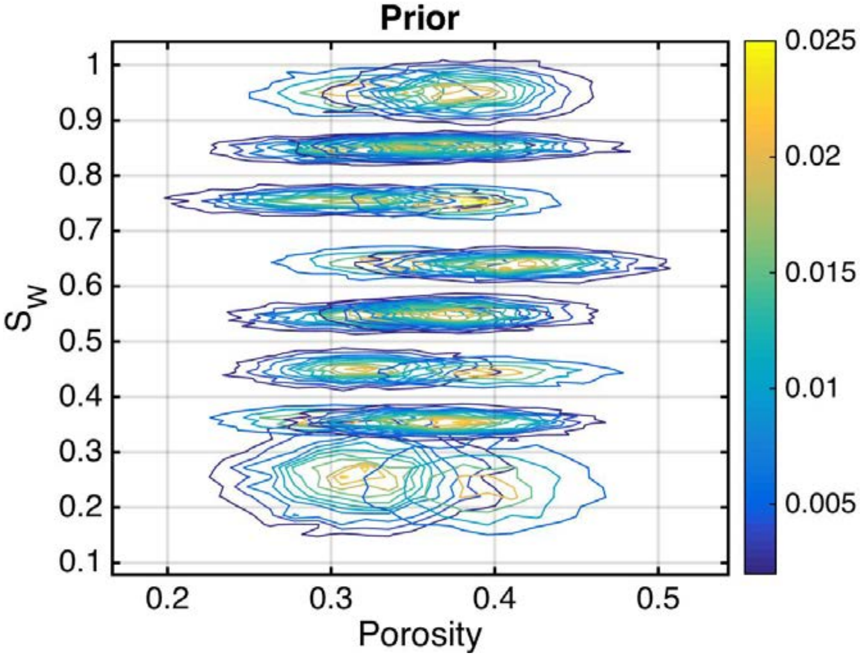
Establish a range of models that qualitatively explains the elastic properties as a function of the rock properties.

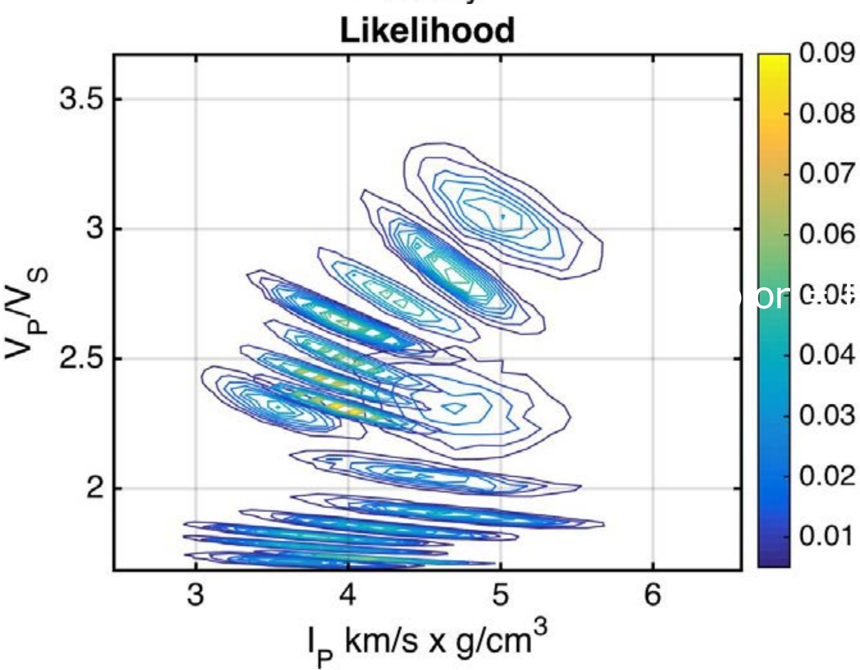
In this case, lithology, porosity and saturation are the most dominant rock properties.

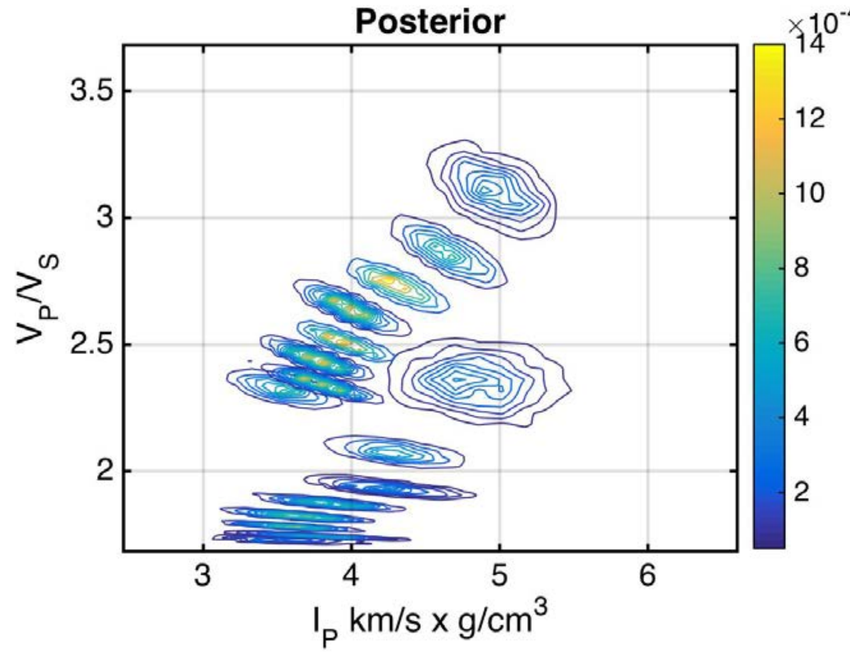
We then argue that the model does a decent job of explaining the data.

What about the uncertainty or error in the model?

PROBABILISTIC ROCK PHYSICS TEMPLATE





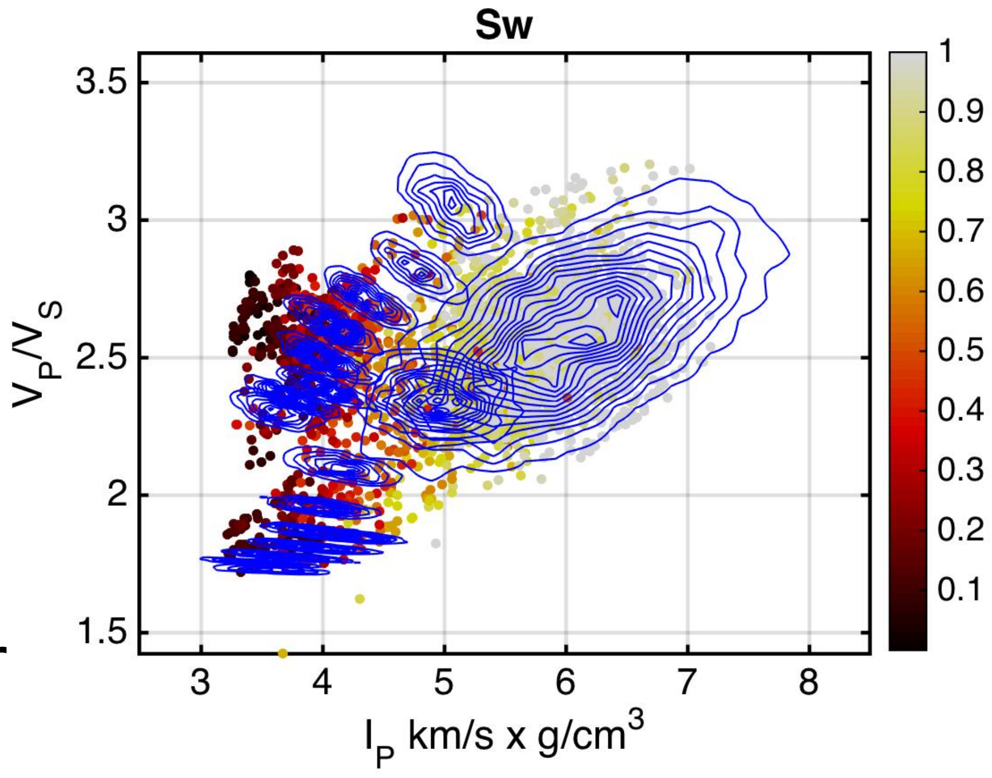


PROBABILISTIC ROCK PHYSICS TEMPLATE

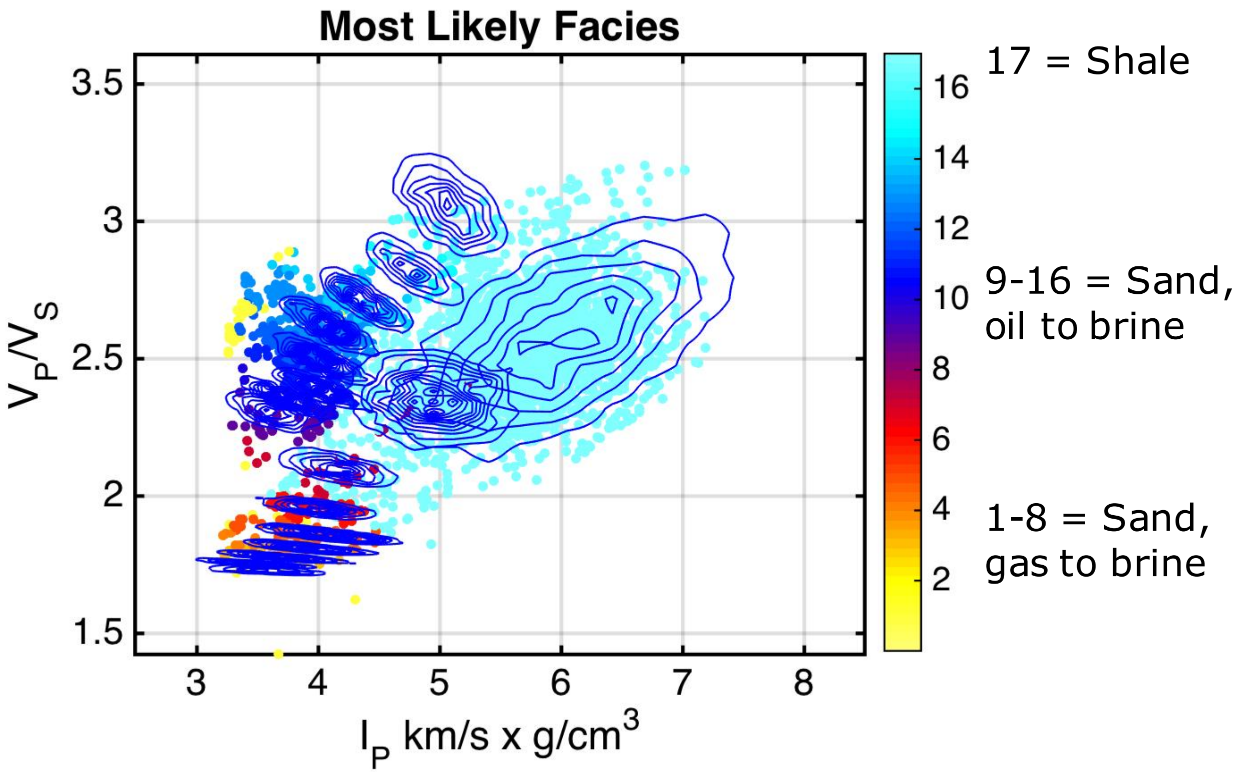
How do you fill the model space?

How do you determine how many distributions to have?

How much overlap or lack thereof should occur from one distribution to the next?



CLASSIFICATION OF LOG DATA



$$P(m) = P\left(\phi, Sw \middle| Ip, \frac{Vp}{Vs}\right)$$

$$L(d|m) = \frac{\exp\left(-\frac{1}{2}(\boldsymbol{x}-\boldsymbol{\mu})^{T}\Sigma^{-1}(\boldsymbol{x}-\boldsymbol{\mu})\right)}{\sqrt{|2\pi\Sigma|}}$$

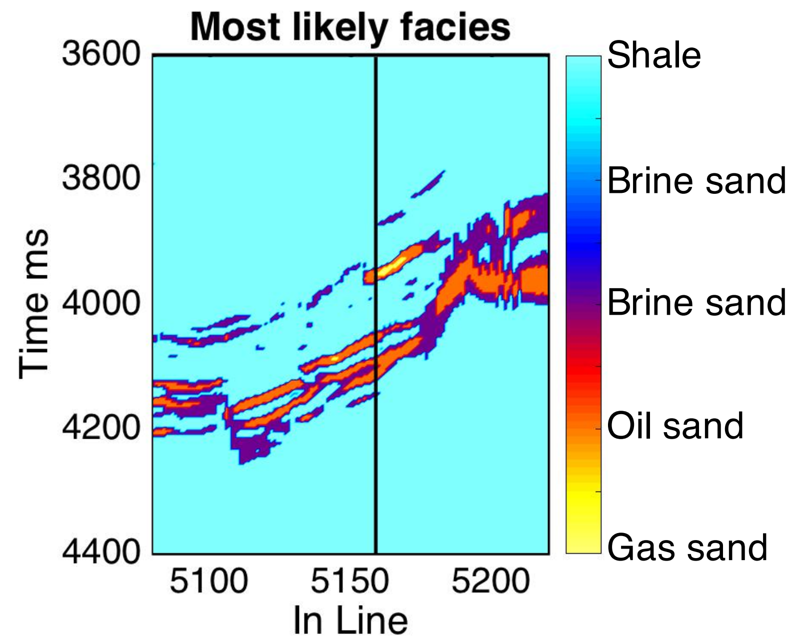
$$P(m|d) \sim L(d/m)P(m)$$

IMPLICATIONS

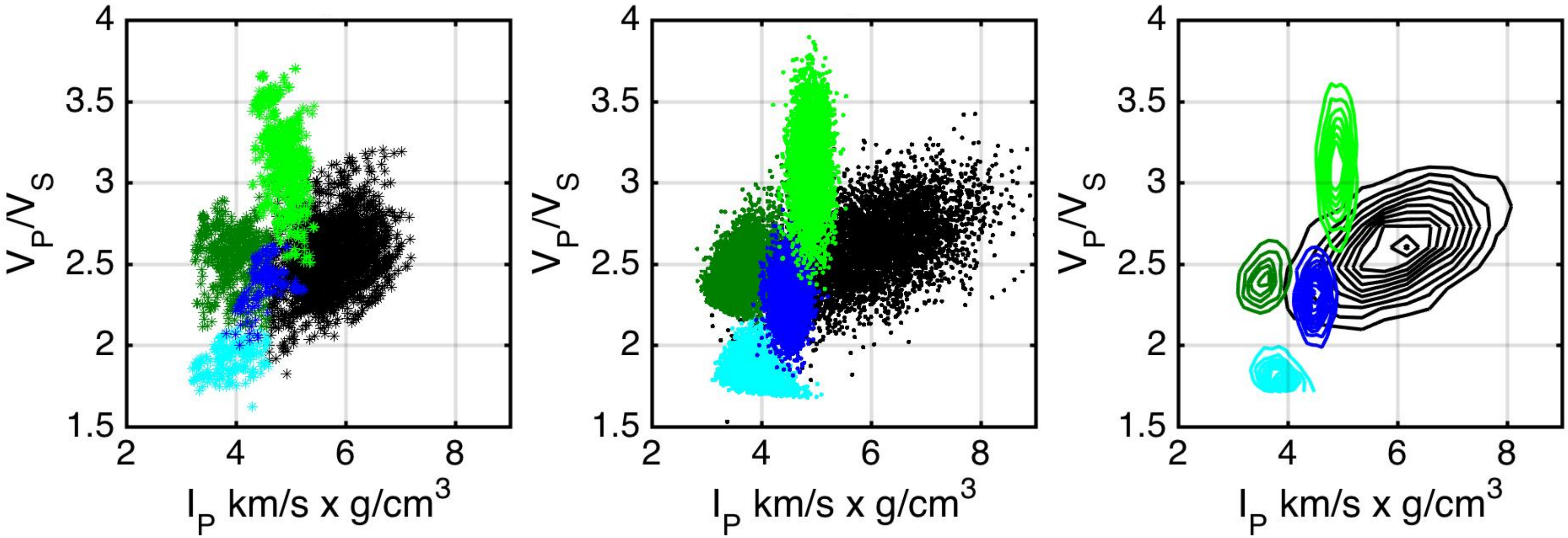
Integrate inverted seismic data with rock physics models for quantitative seismic interpretation.

Combine rock physics information with seismic information through Bayesian classification techniques.

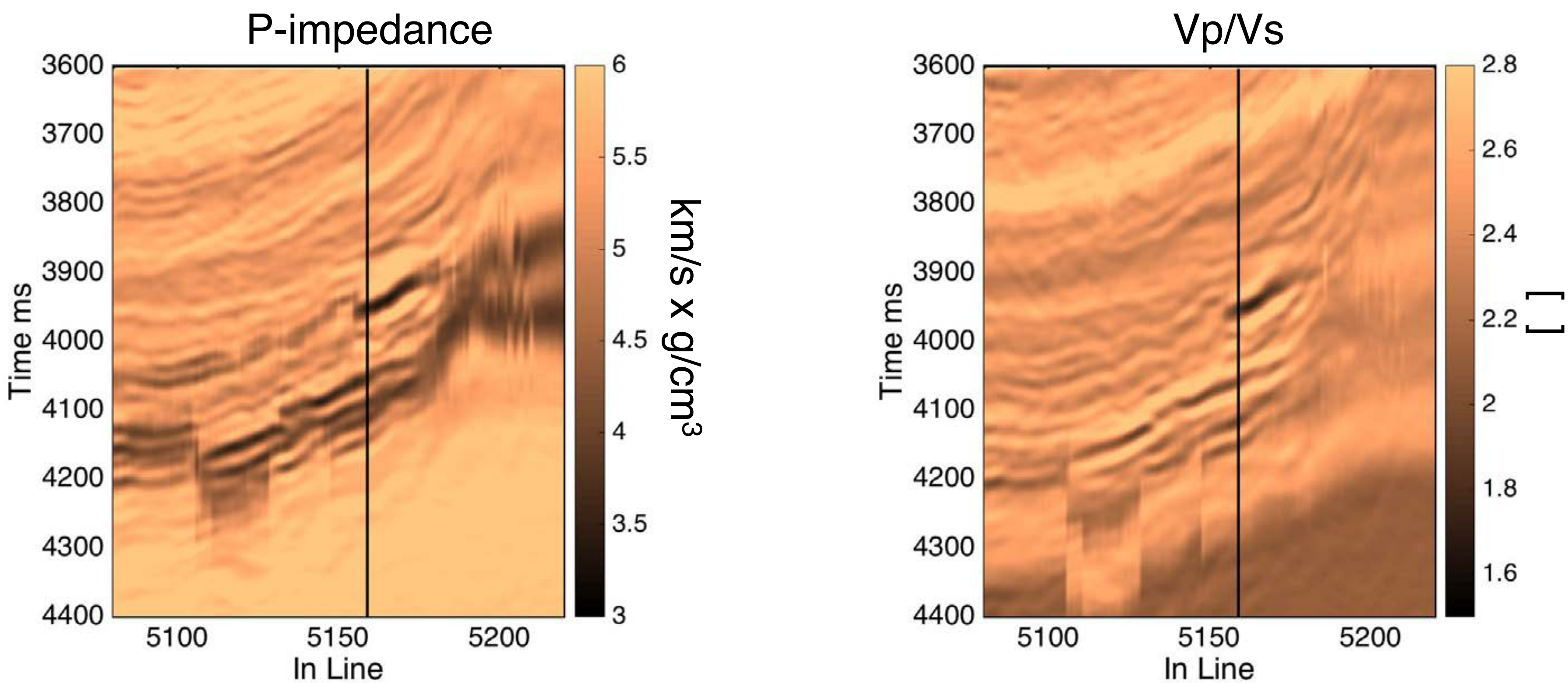
Account for non-unique relationships between rock and elastic properties.



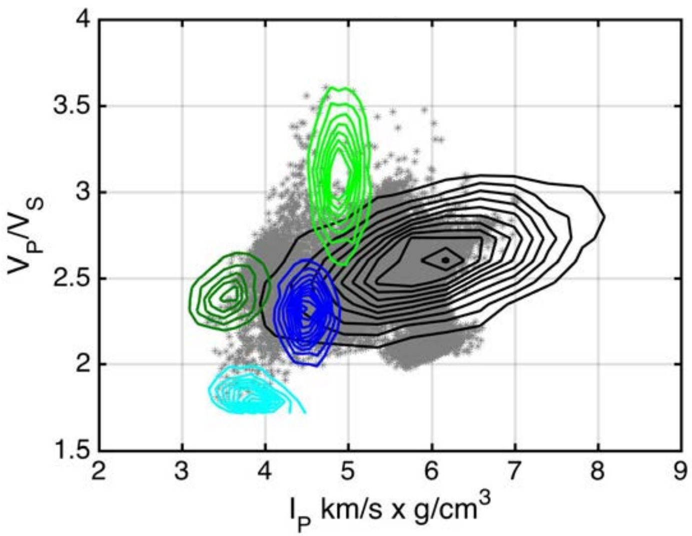
SIMULATION OF THE 5 FACIES

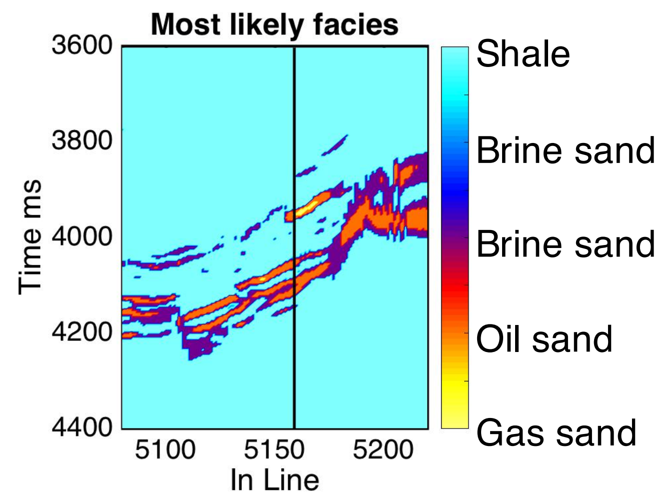


INVERTED SECTIONS



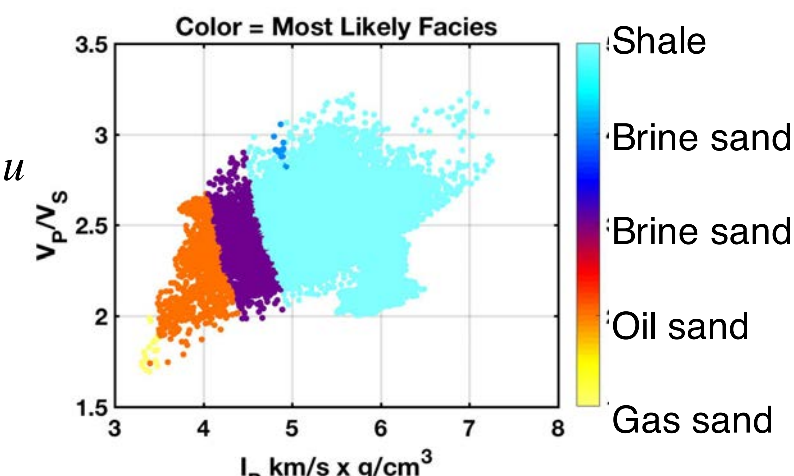
BAYESIAN CLASSIFICATION FOR MOST LIKELY FACIES



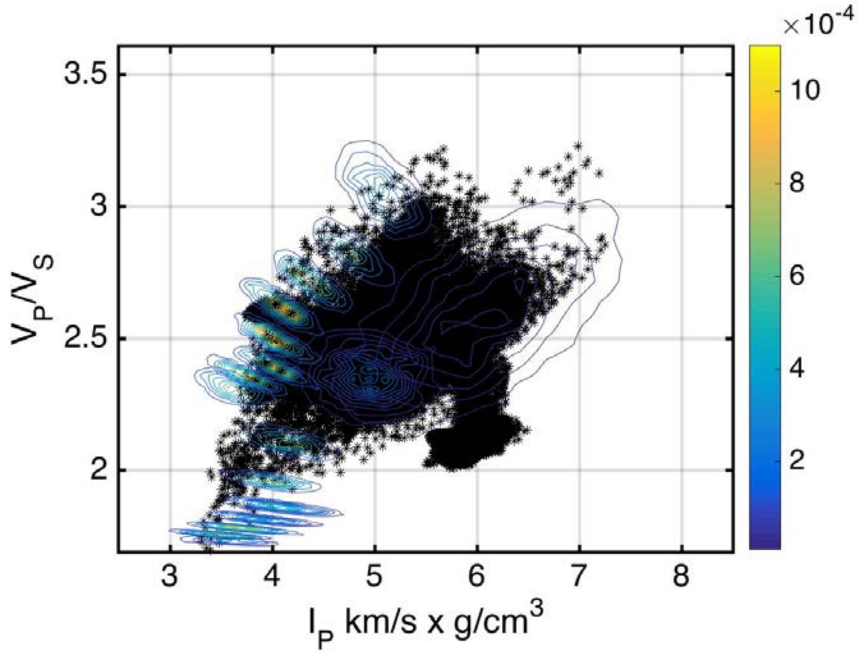


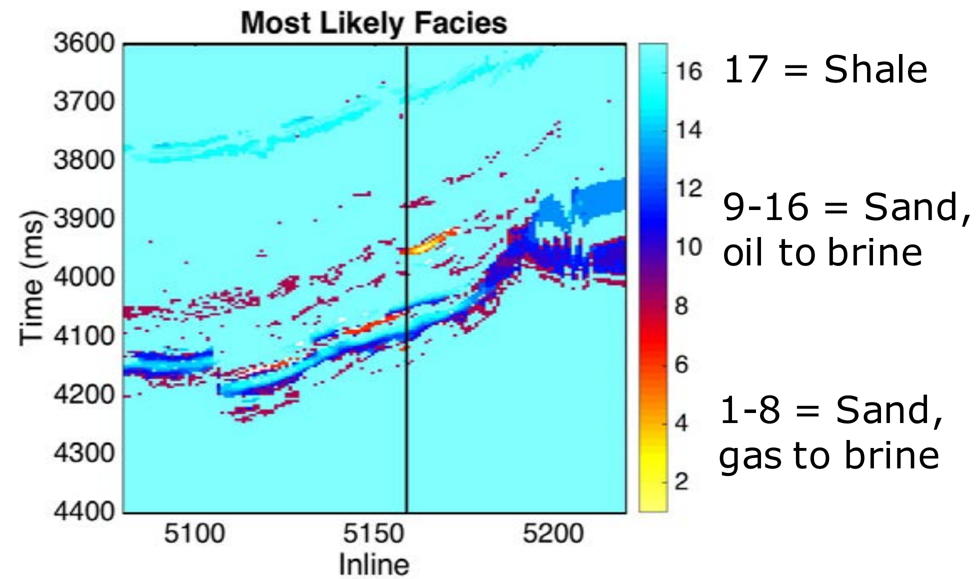
$$P(m \mid d) = \frac{P(m)P(d \mid m)}{P(d)} \quad P(m \mid d) \propto P(m)P(d \mid m)$$

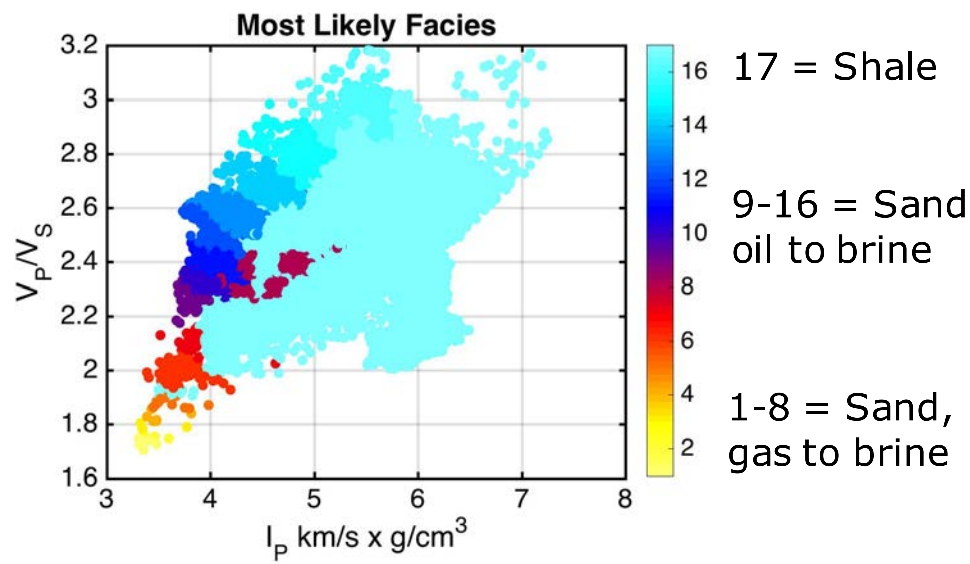
$$P(c_j \mid d) = P(c_j)P(d \mid c_j) \quad P(c_j \mid d) > P(c_u \mid d) \text{ for all } j \neq u$$



BAYESIAN CLASSIFICATION AND PROBABILISTIC MODELS







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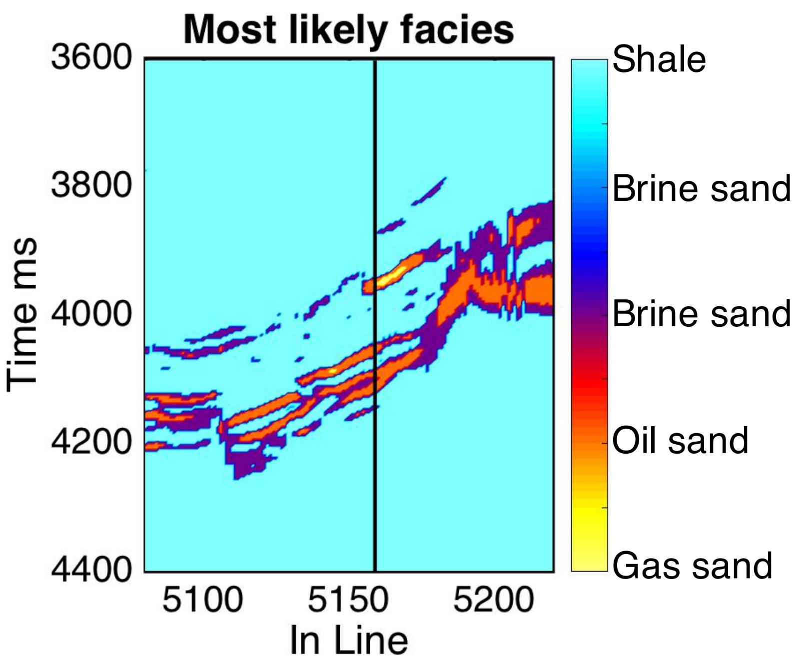
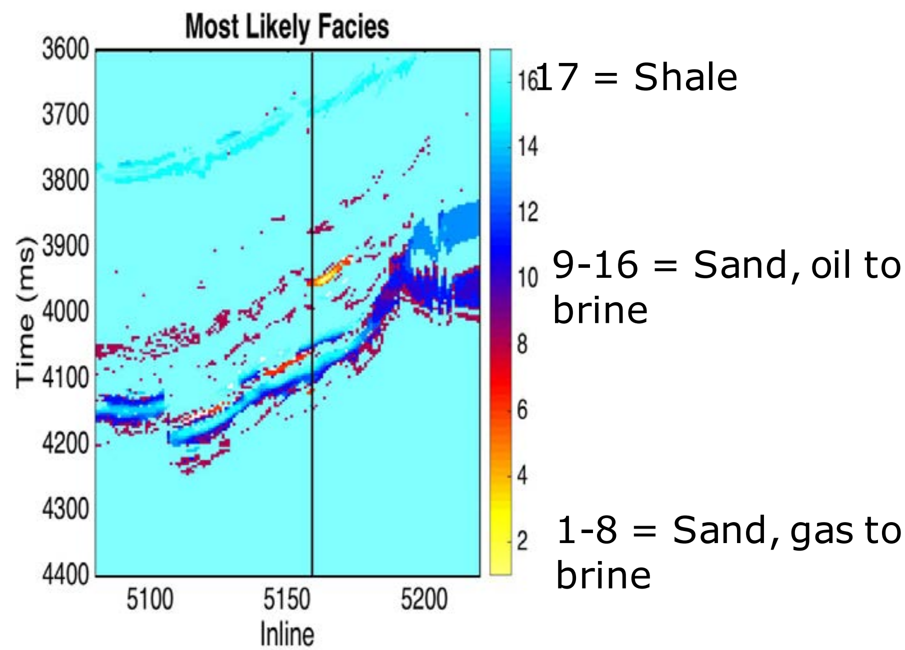
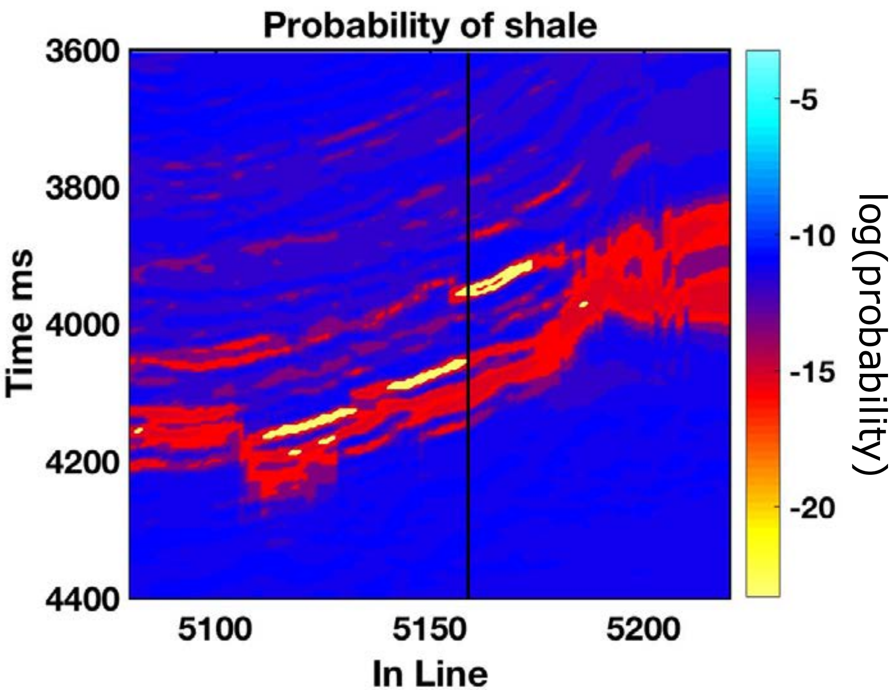
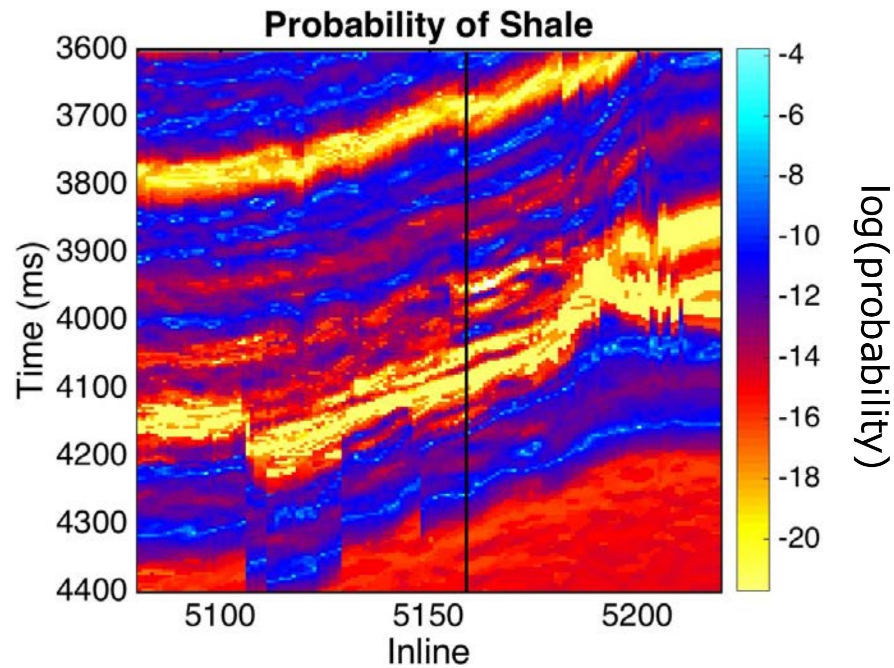




BAYESIAN CLASSIFICATION AND PROBABILISTIC MODELS





SUMMARY

- Current research activities in
  - Reservoir characterization
  - Digital rock physics
  - Dispersion and attenuation modeling
  - Probabilistic RPTs

- Incoming students will take part in these continuing and in new areas
- Collaborator, Nicola Tisato, is currently building his laboratory, to be and running sometime this year
- Integrating his work with EDGER work is in the plans