

# Rock physics perspectives on unconventional resources— Conventional or unconventional analysis?

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# Motivation

Parameterize a rock-physics model

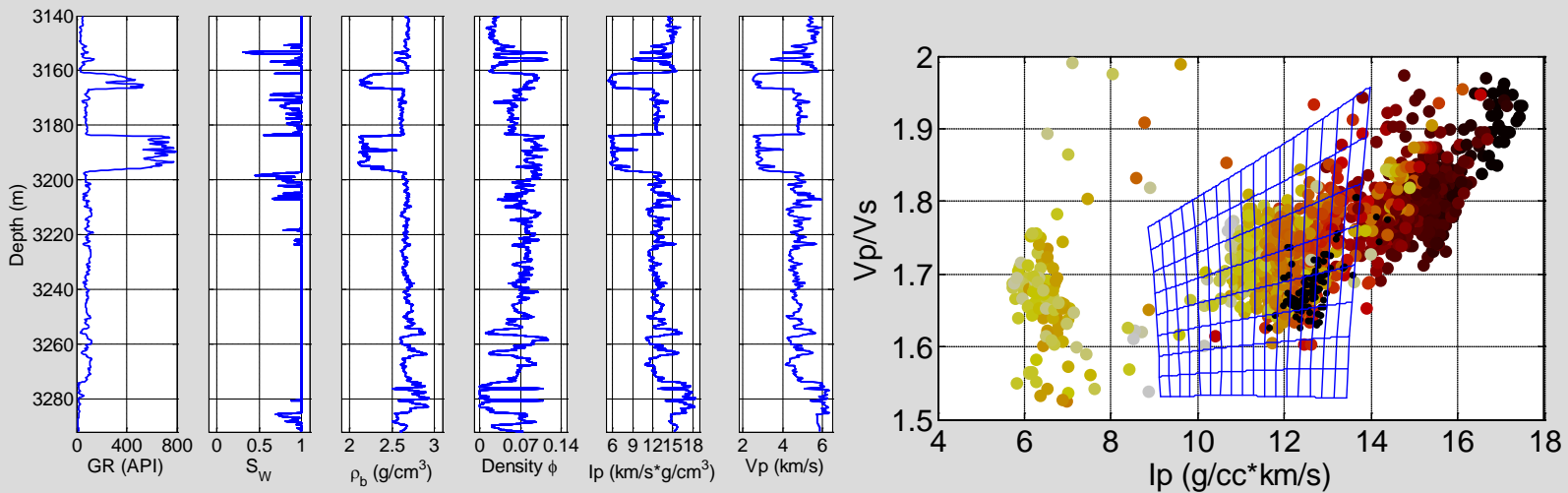
Account for mineralogy/lithology

Recognize porosity effects

Isolate fluid effects

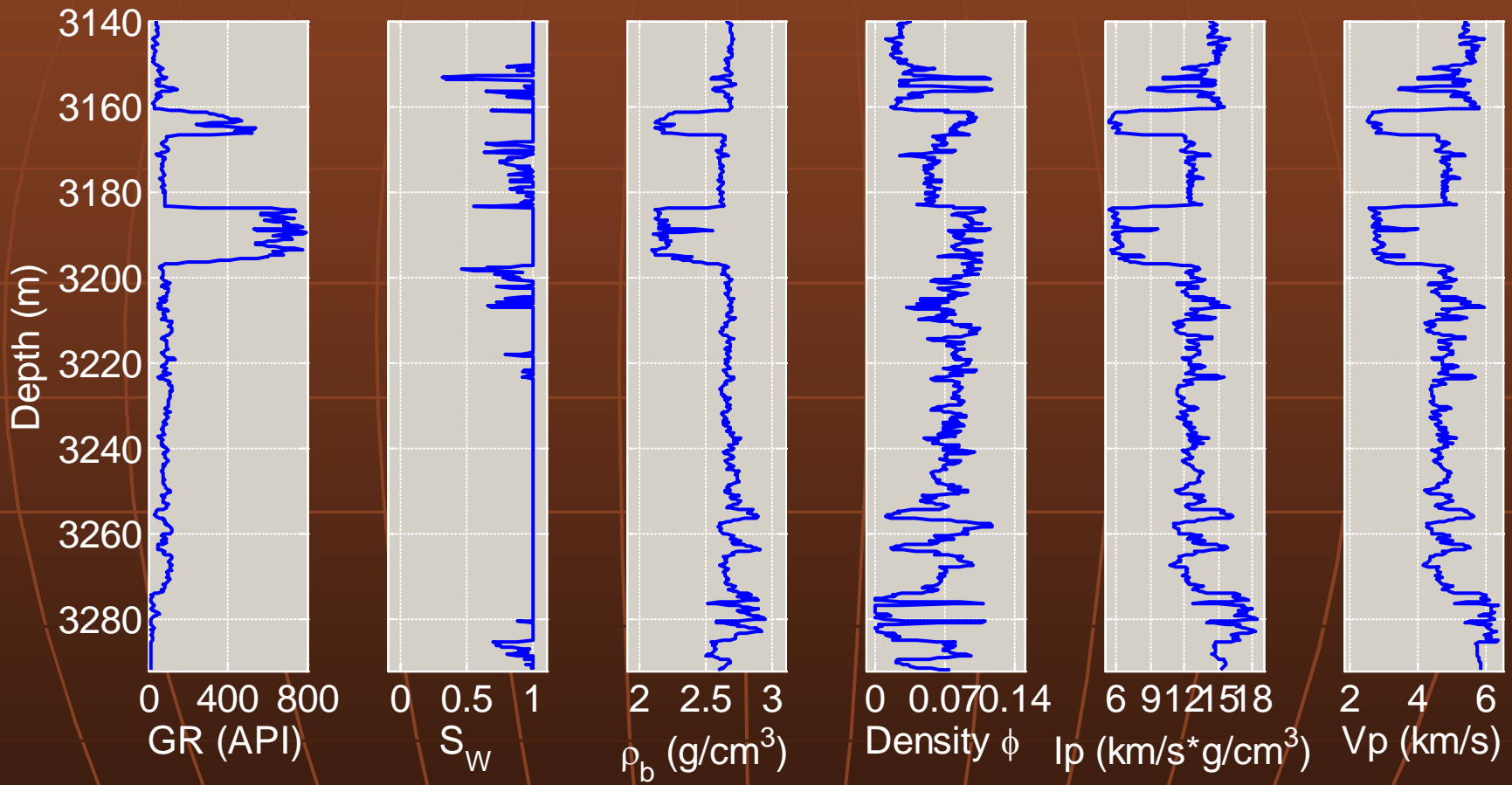
Identify additional factors that affect the elastic properties

Establish distributions of such properties to incorporate in seismic-inversion methodologies



# Well data

Annala 11-36H, Sanish Field



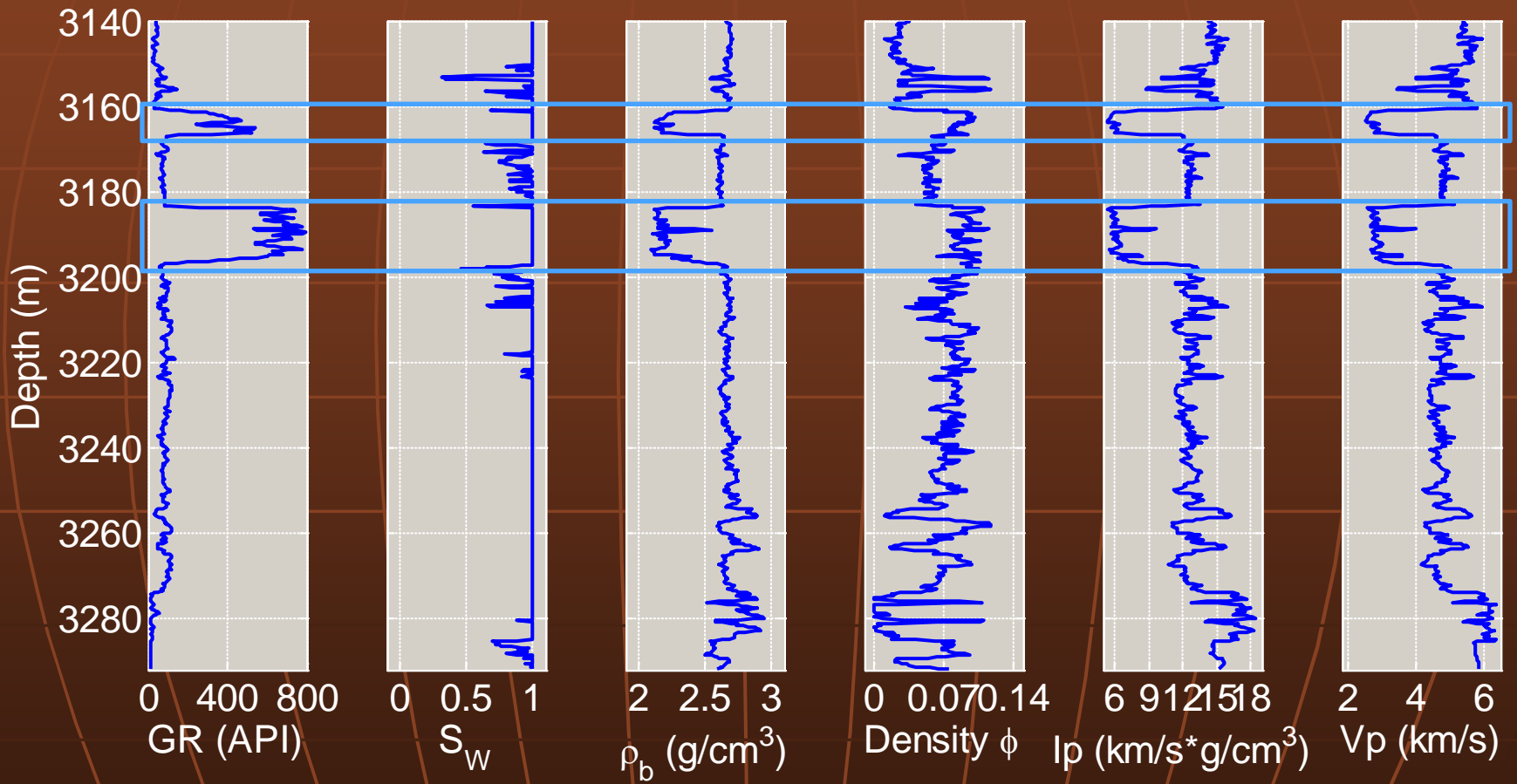
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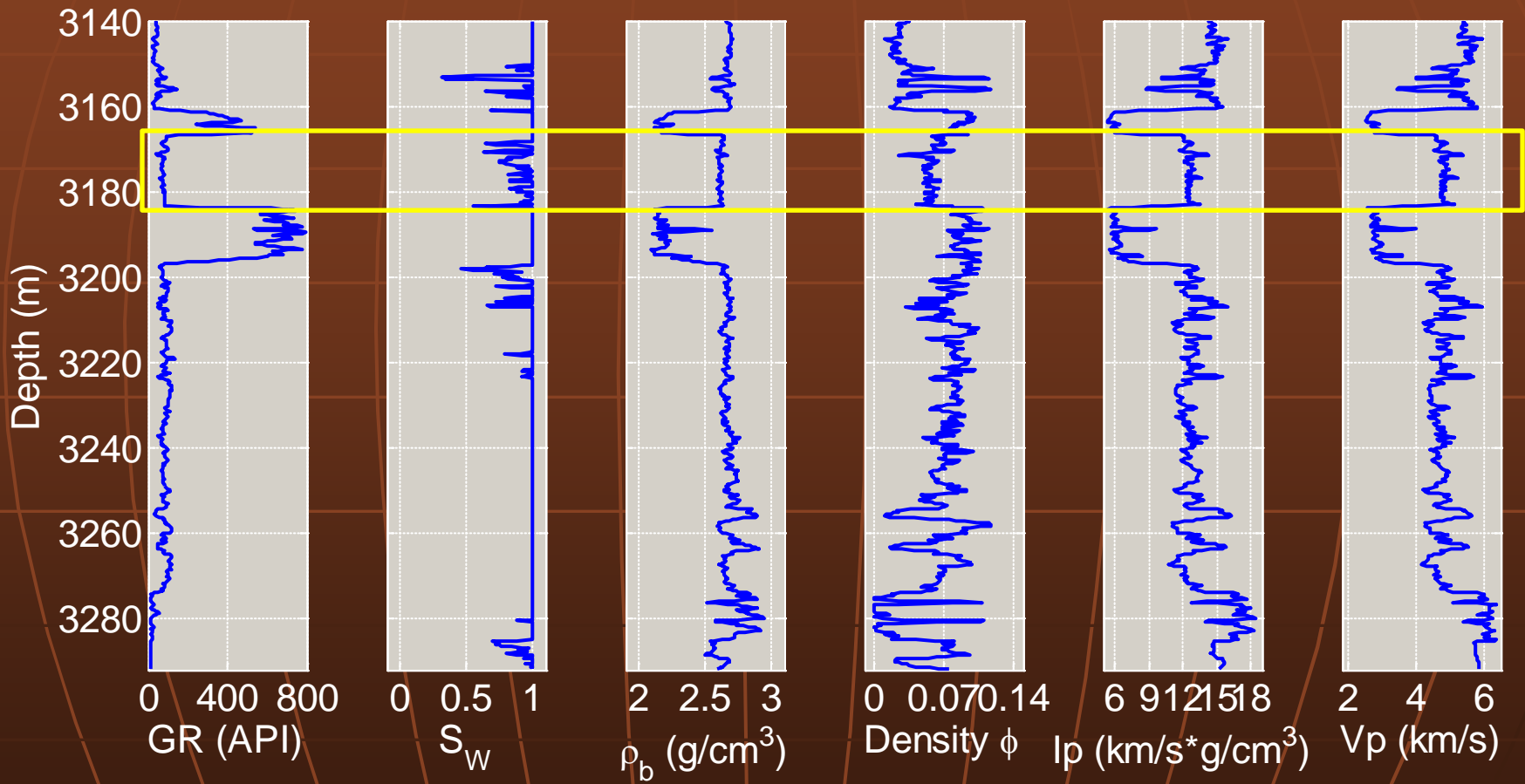
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# Well data

Annala 11-36H, Sanish Field

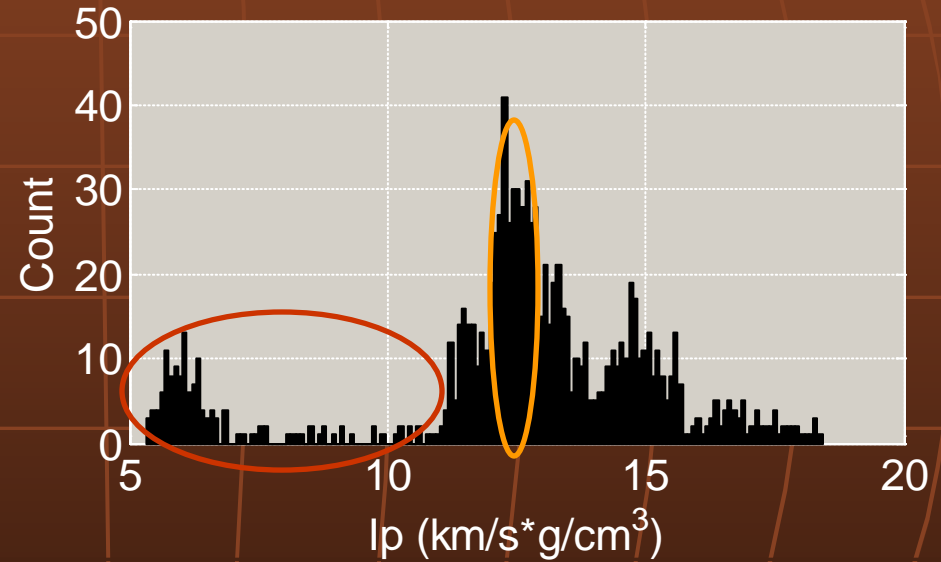
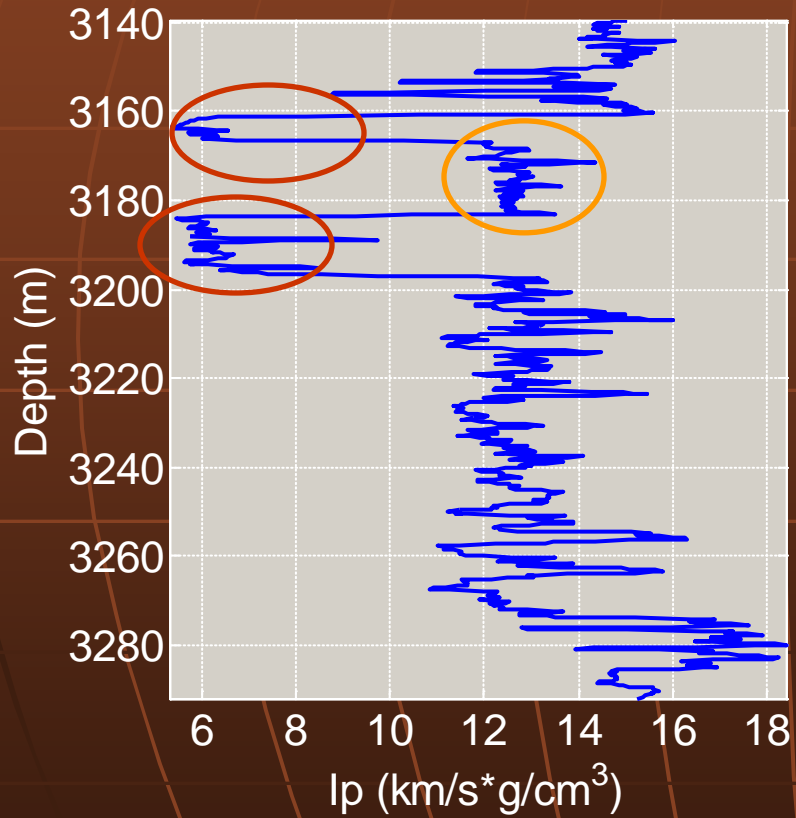


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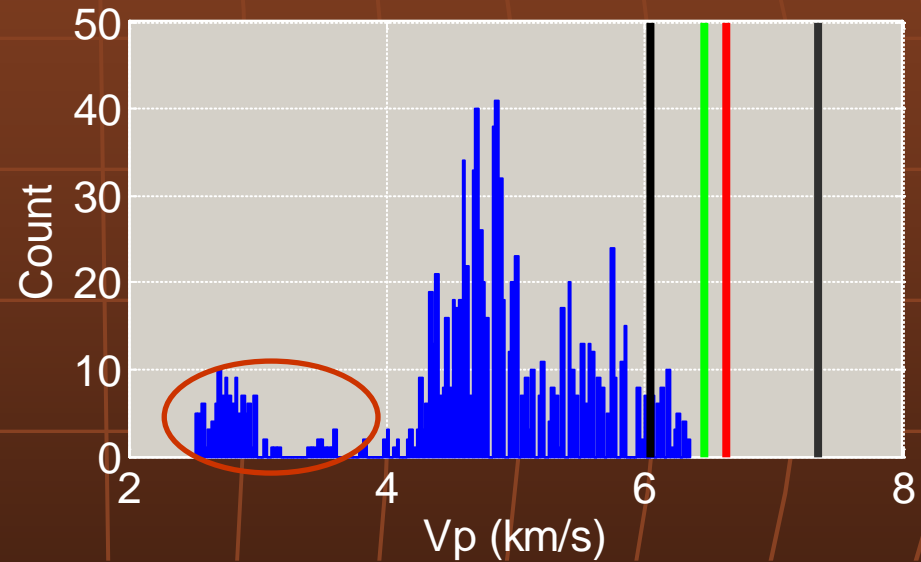
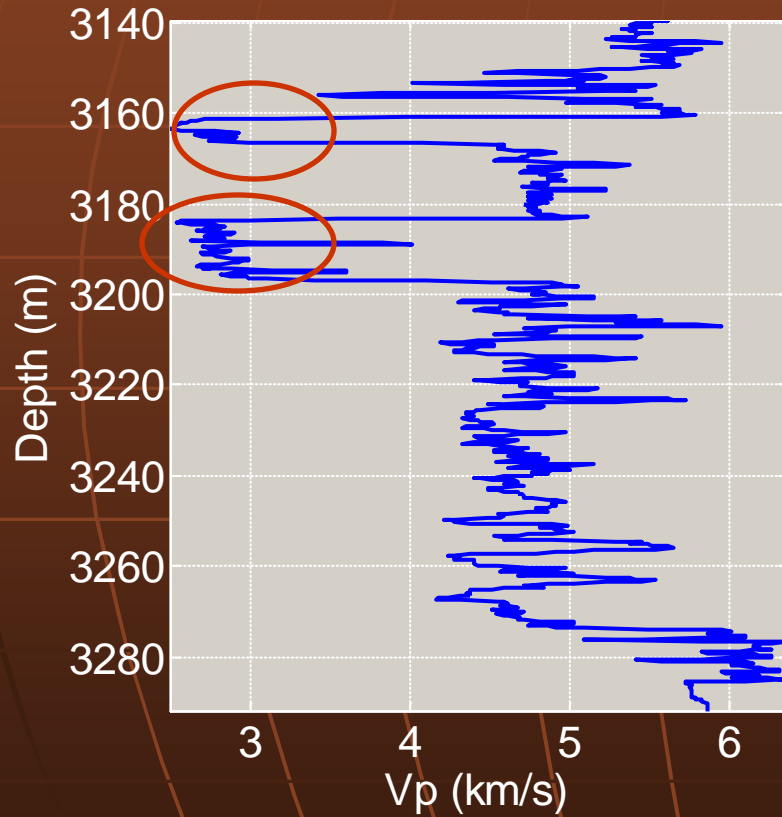
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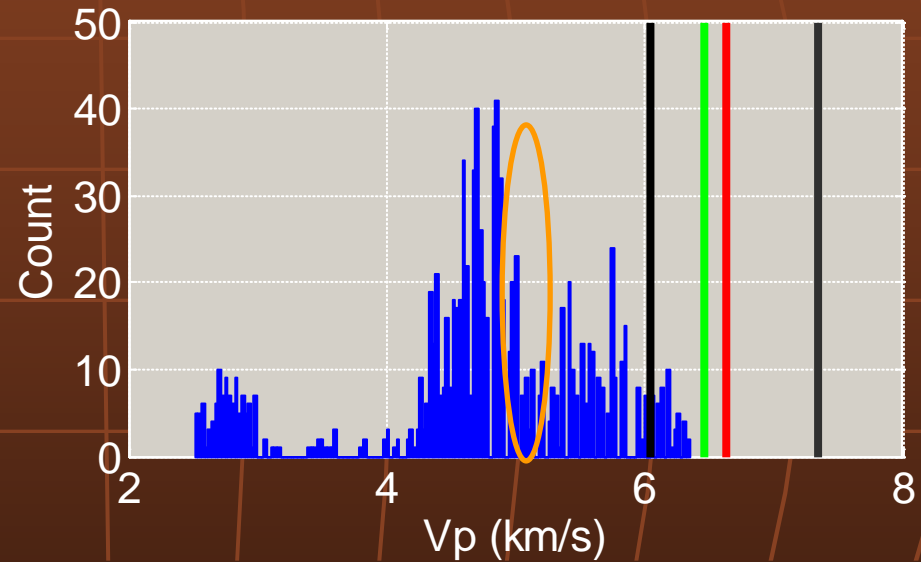
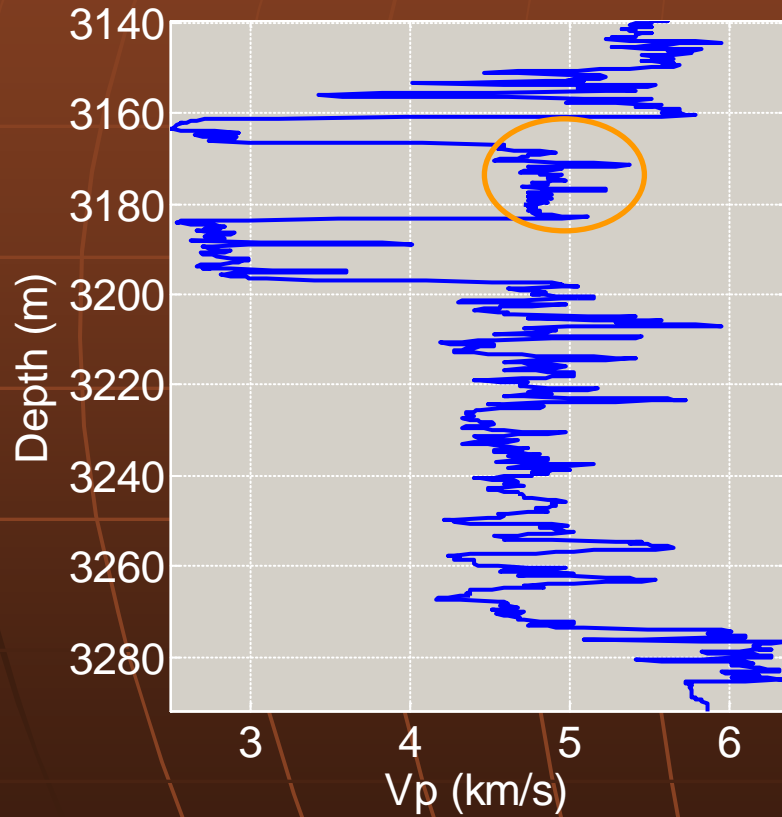
# Rock properties—Impedance



# Rock properties—Velocity (P)

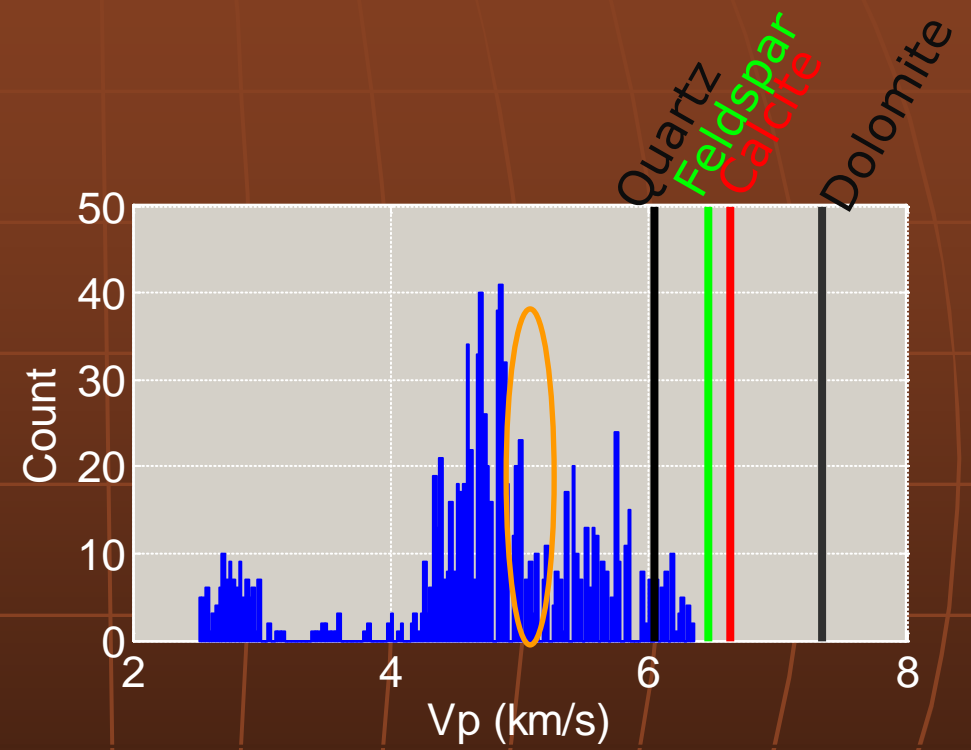
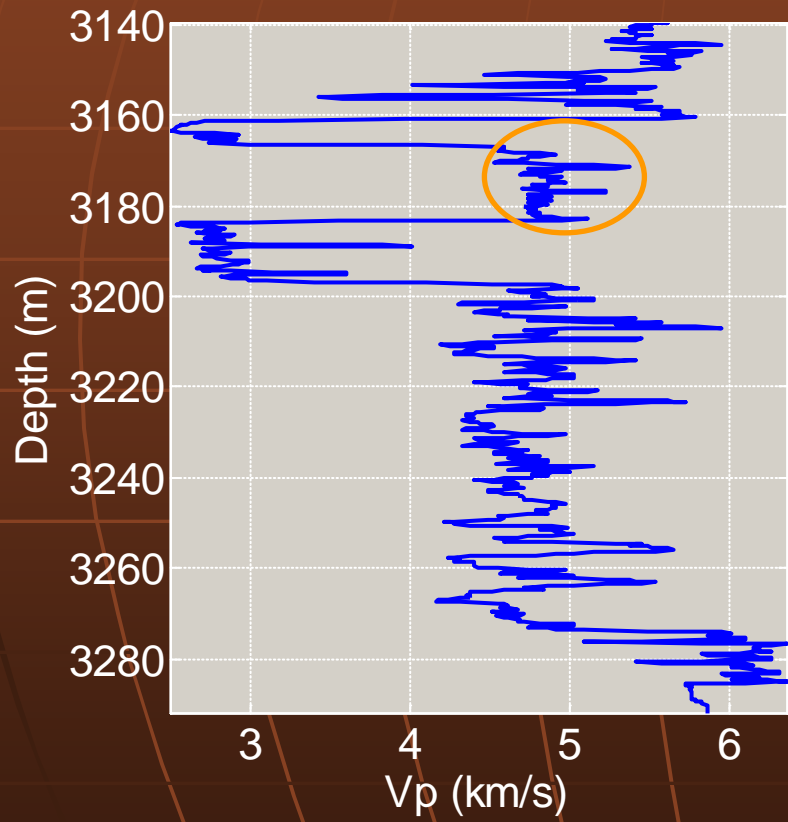


# Rock properties—Velocity (P)

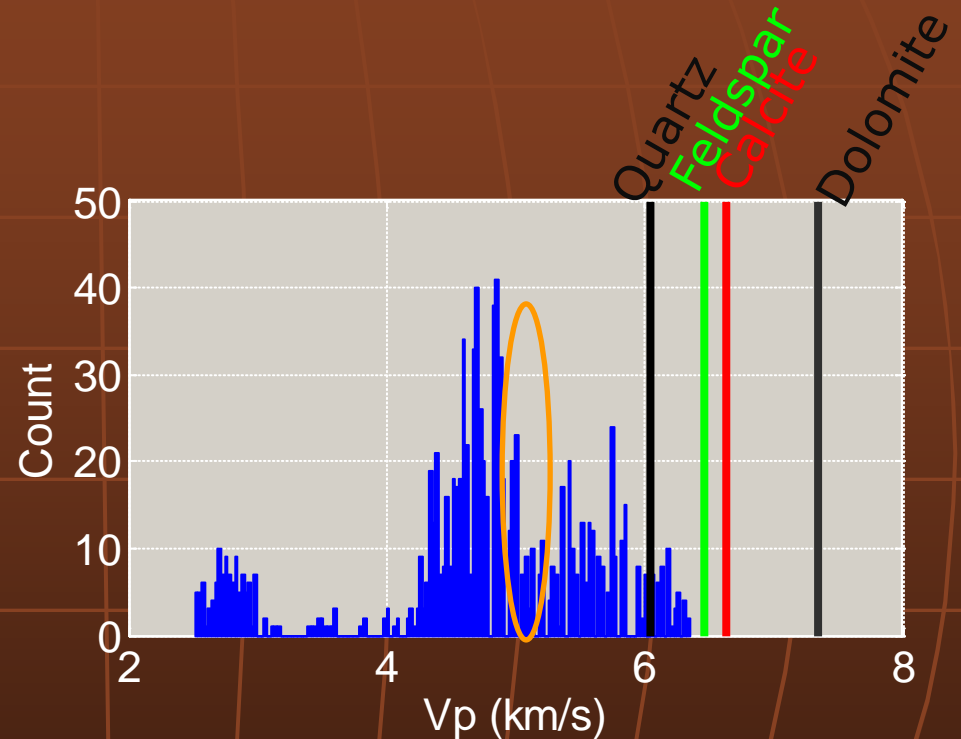
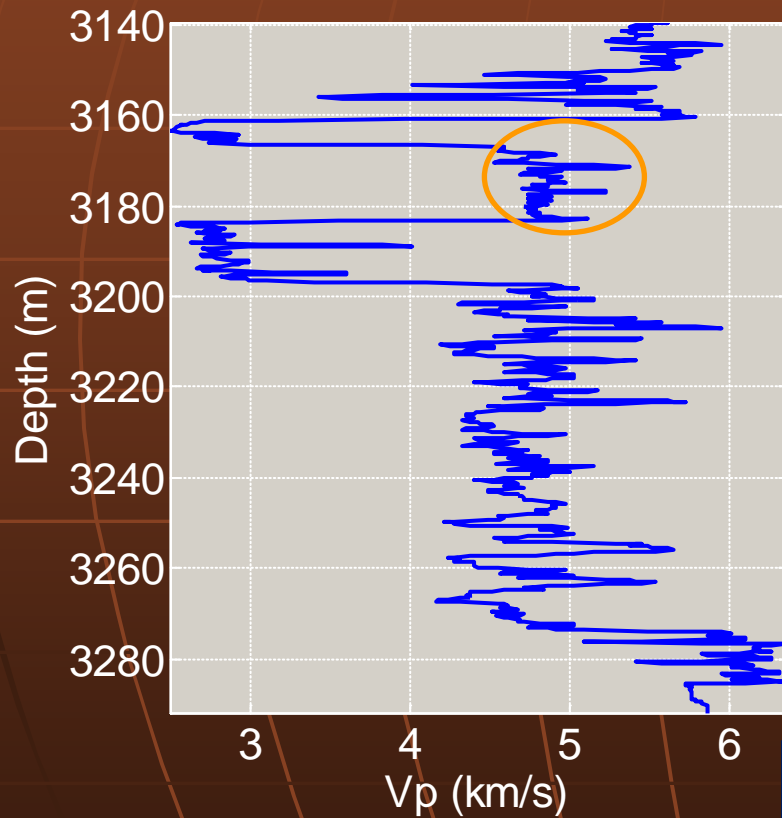




# Rock properties—Velocity (P)

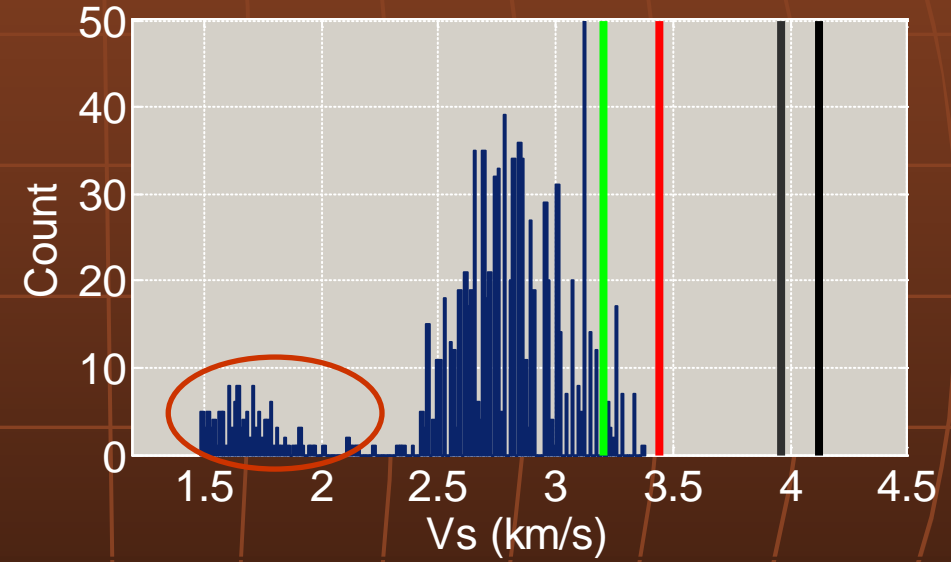
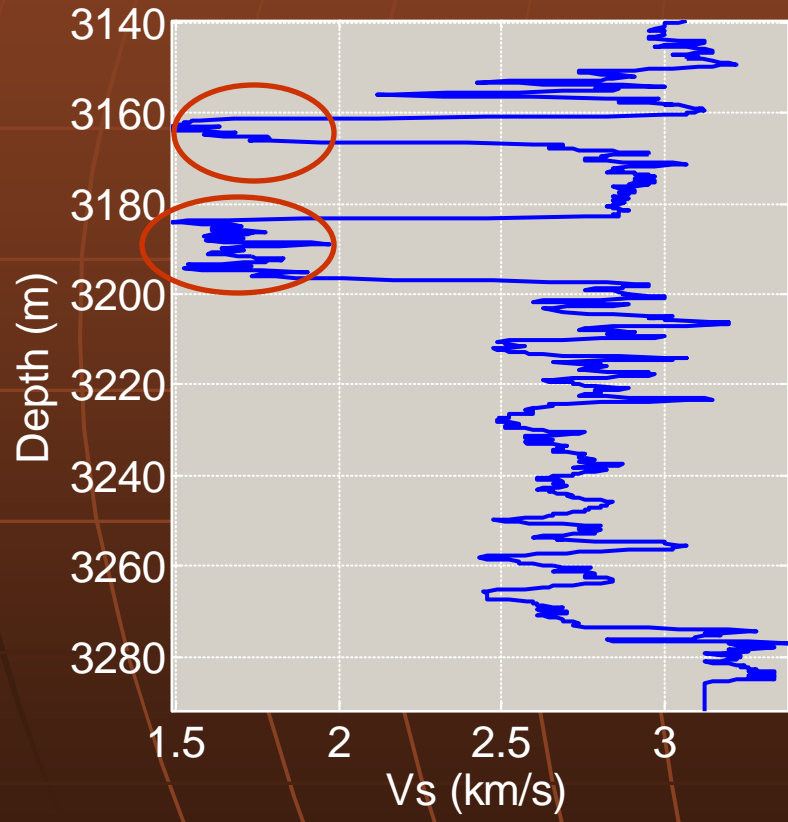


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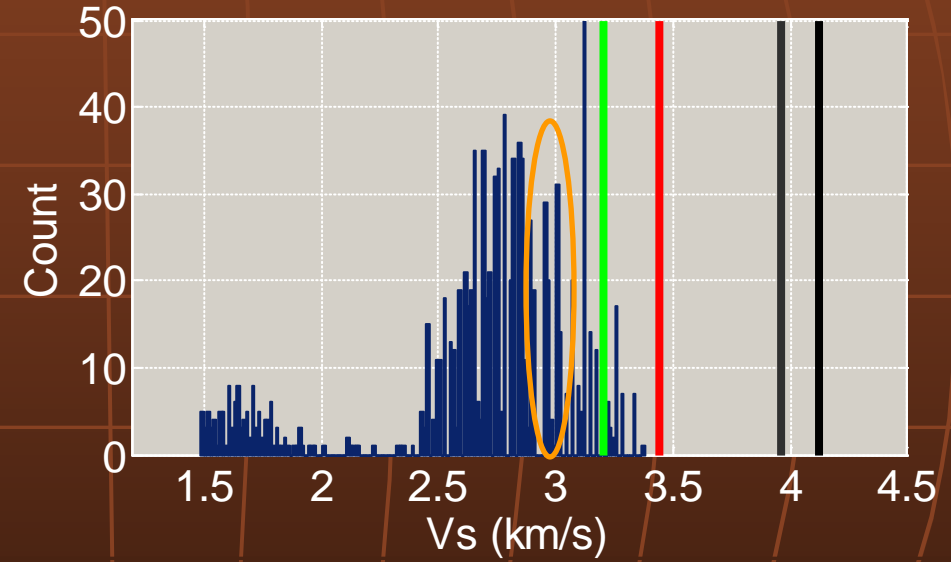
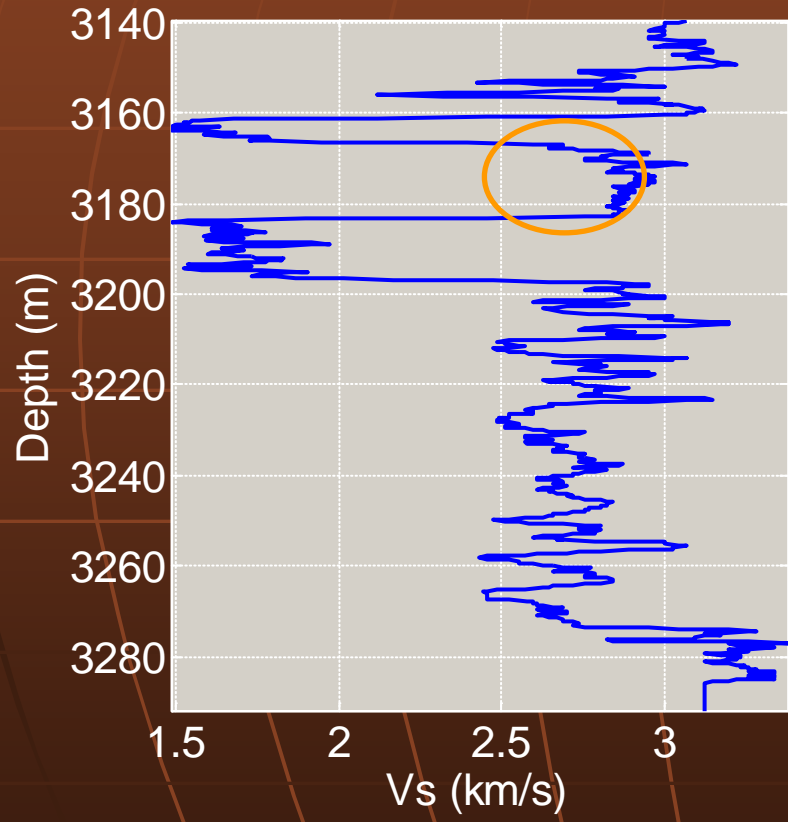


Porosity is low ( $< 10\%$ )  
 $V_p$  should be close to mineral velocities  
Do fluids reduce the velocity?  
Which geometric properties cause this?

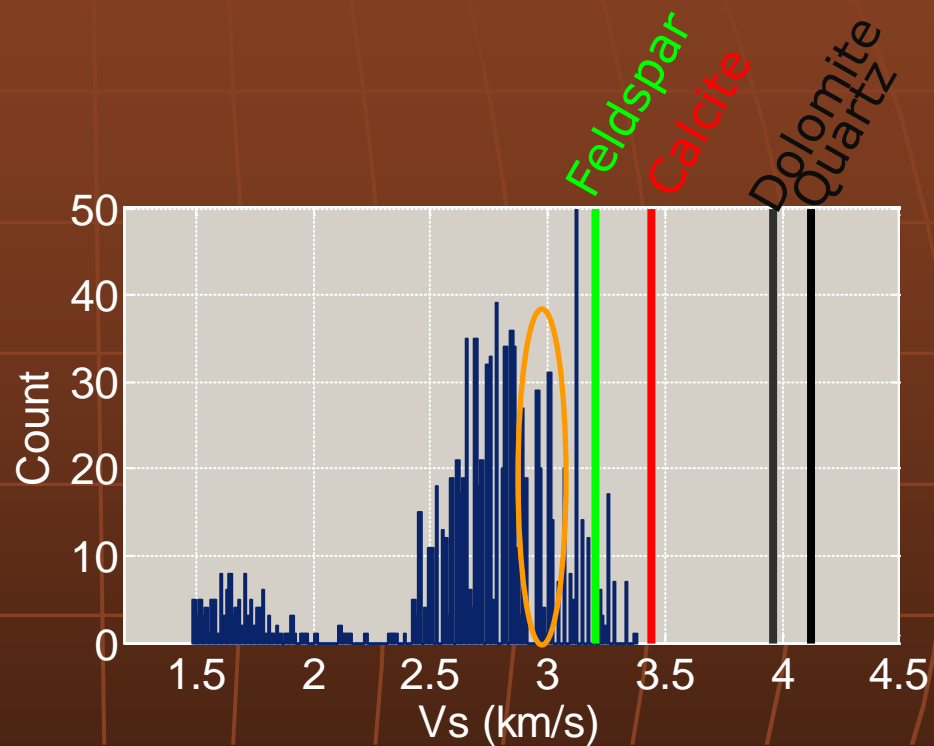
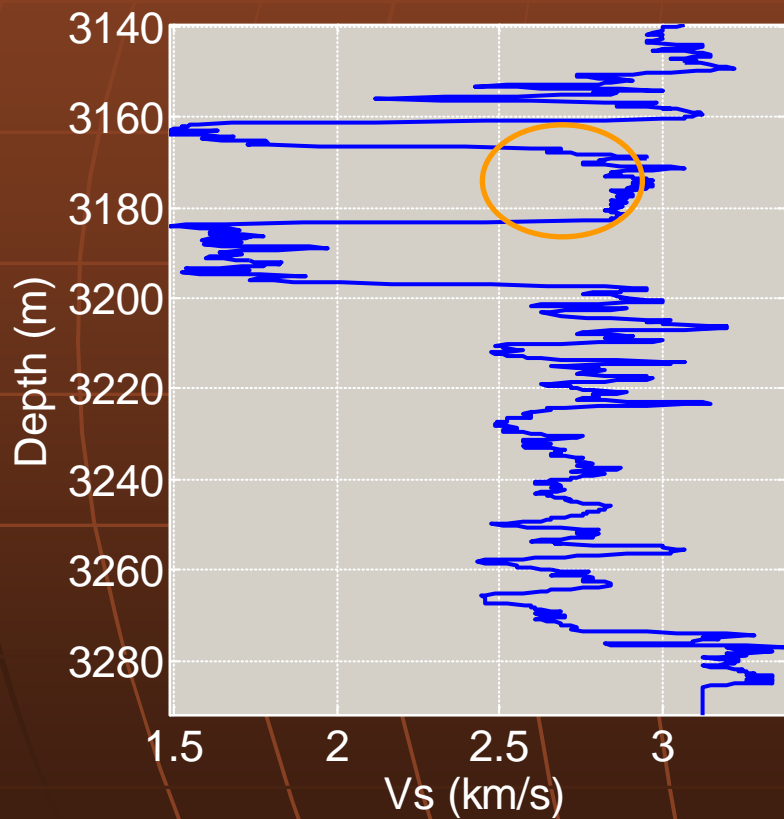
# Rock properties—Velocity (S)



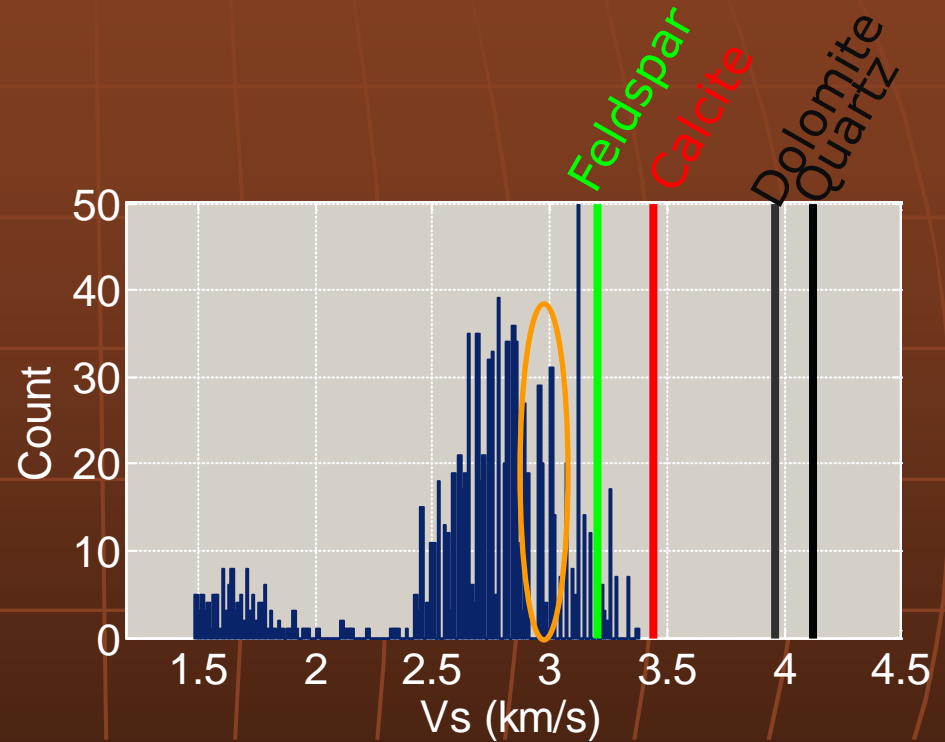
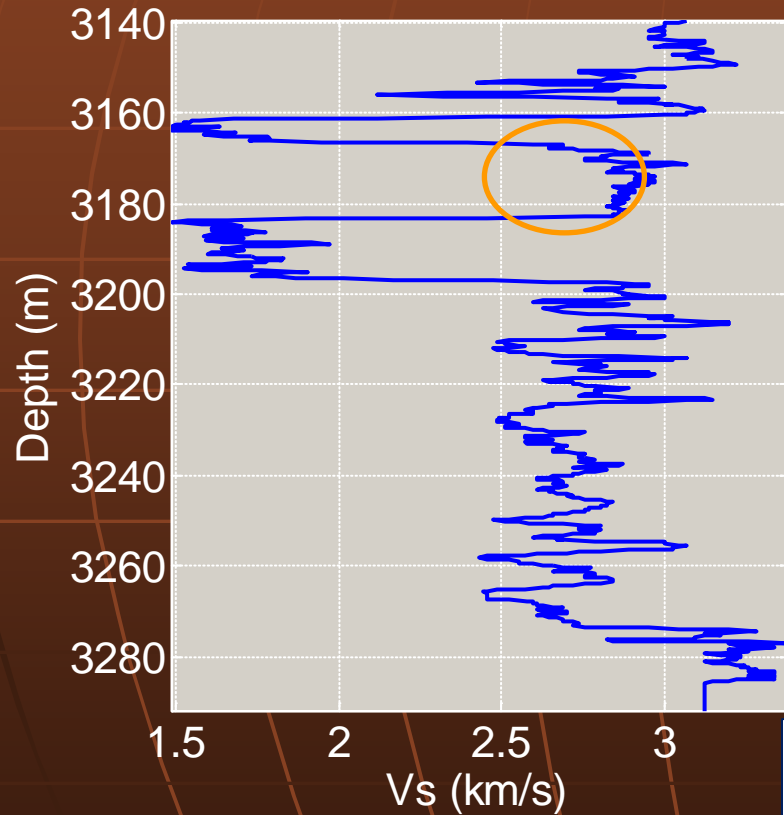
# Rock properties—Velocity (S)



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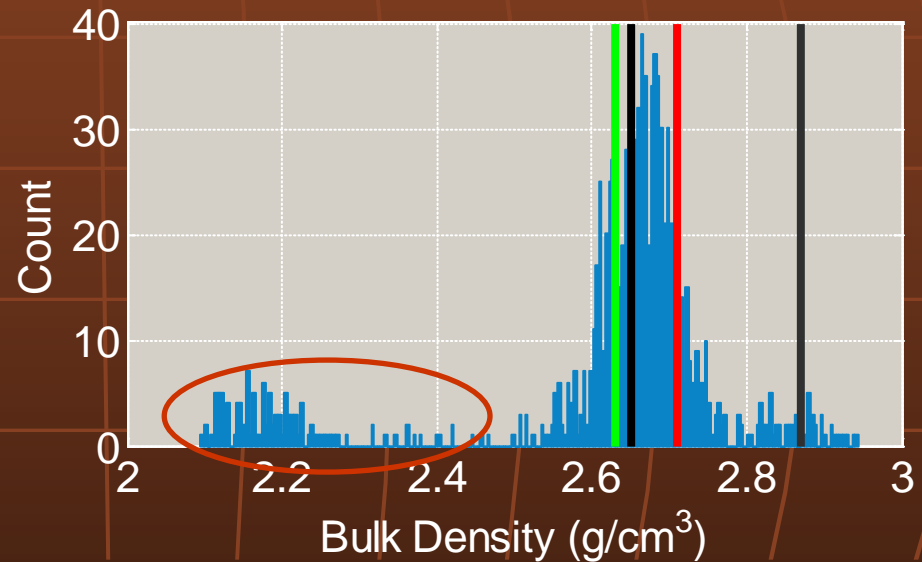
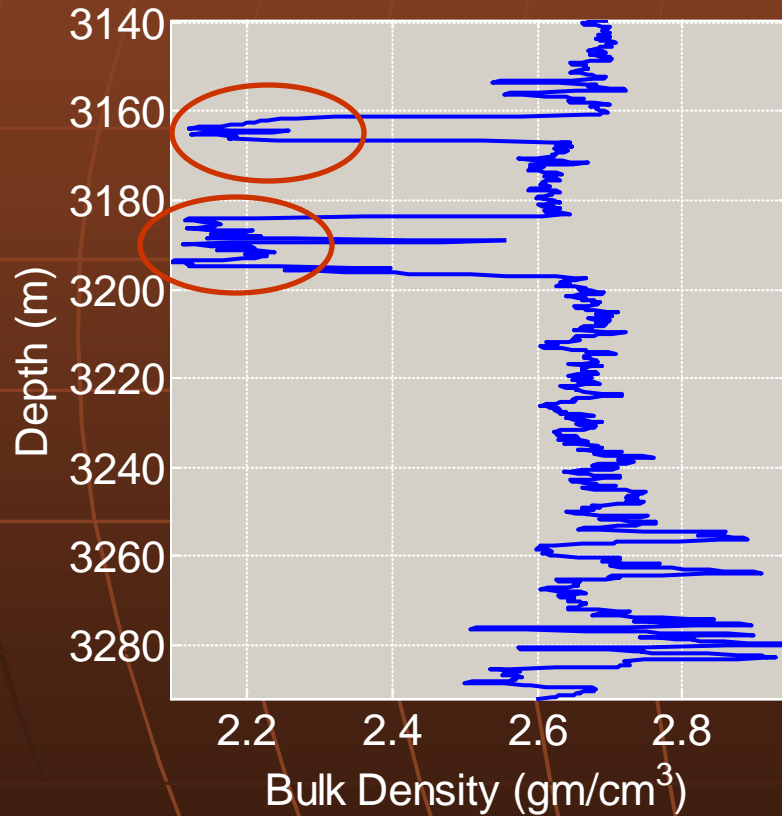


# Rock properties—Velocity (S)

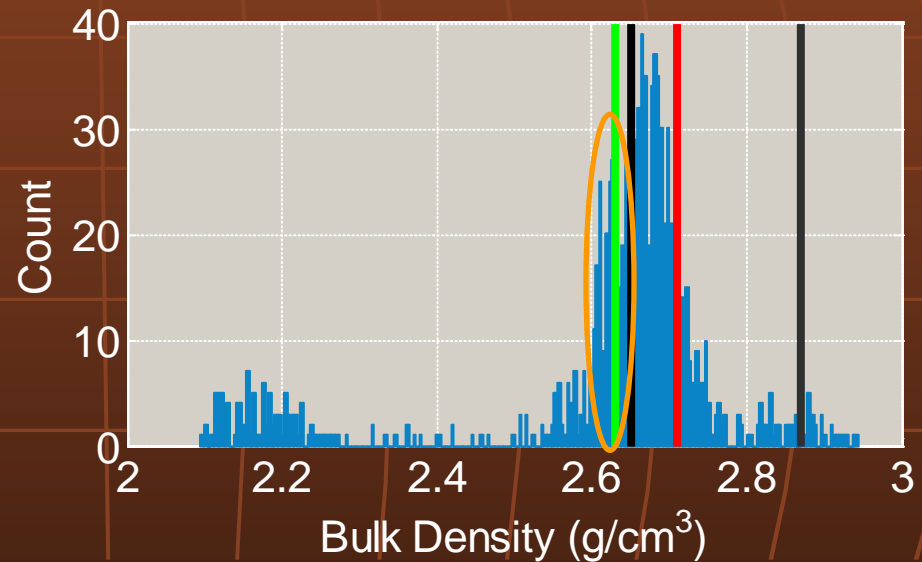
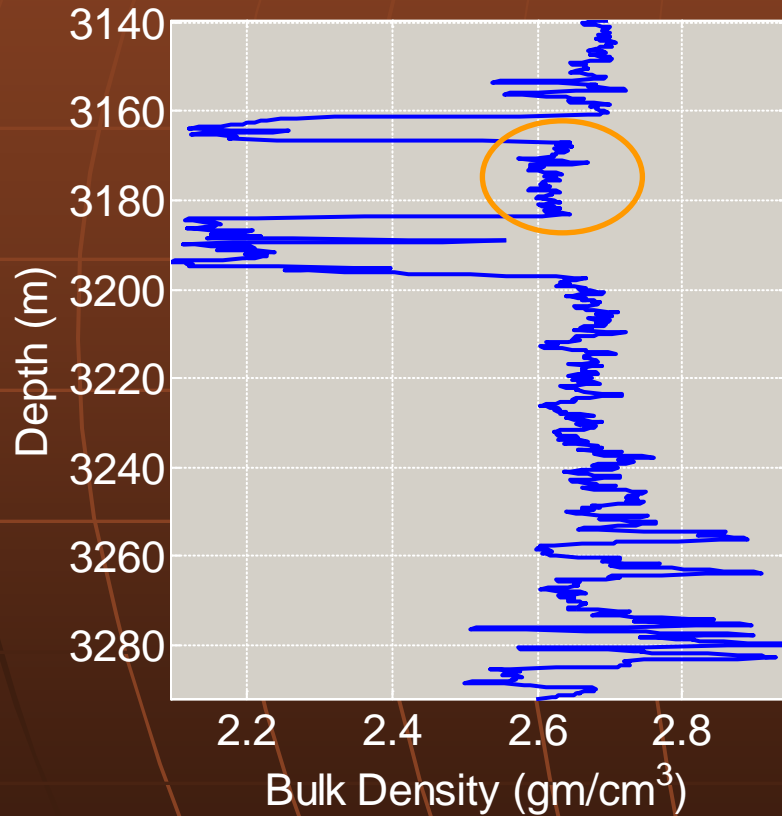


$V_s$  values similar to feldspar velocity  
Are fluid effects responsible for  $V_p$ ?  
Can texture account for disparity in  $V_p$   
and  $V_s$  velocity?

# Rock properties—Density

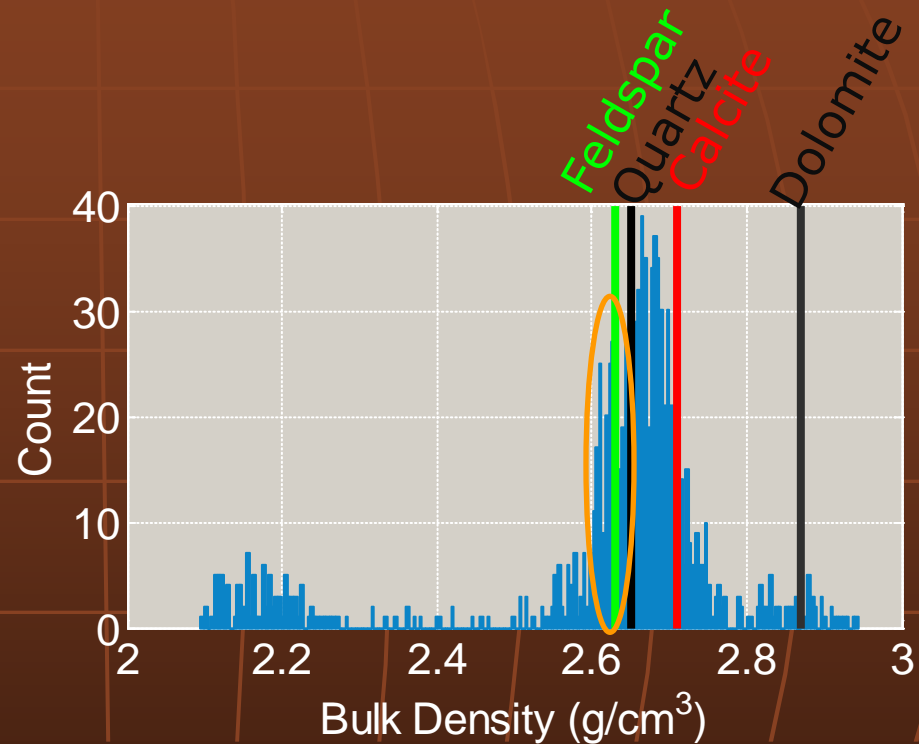
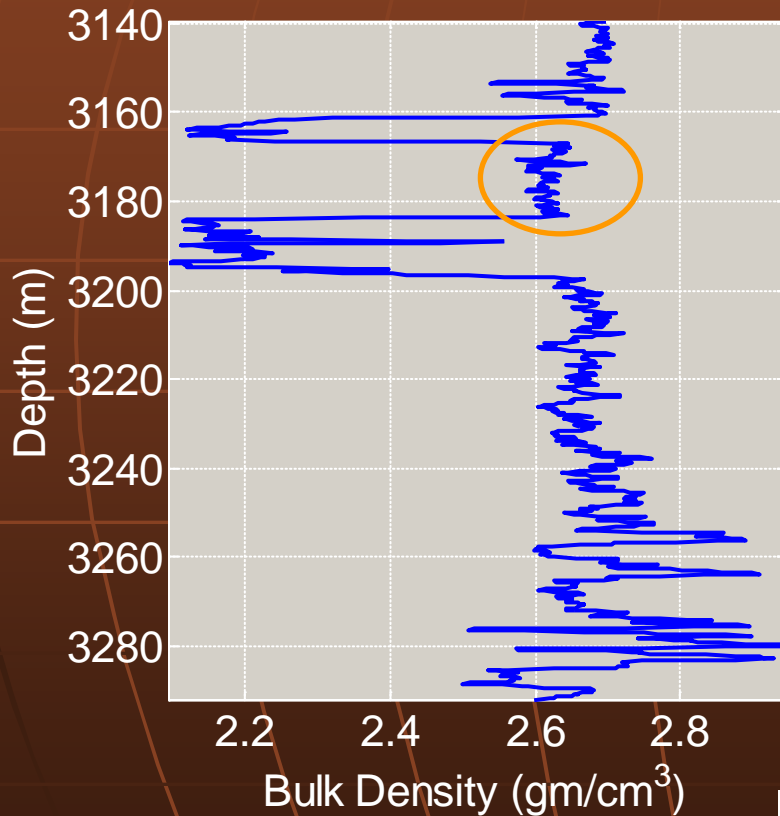


# Rock properties—Density





# Rock properties—Density



Density values indicate feldspar and quartz mineralogy  
What causes the scatter?

# Initial analysis

- P-impedance is relatively high  
Predominantly a density effect
- S-wave velocity consistent with feldspathic composition
- High density reflects mineralogy
- P-wave velocity appears to be relatively low
- Partly an effect of the high density

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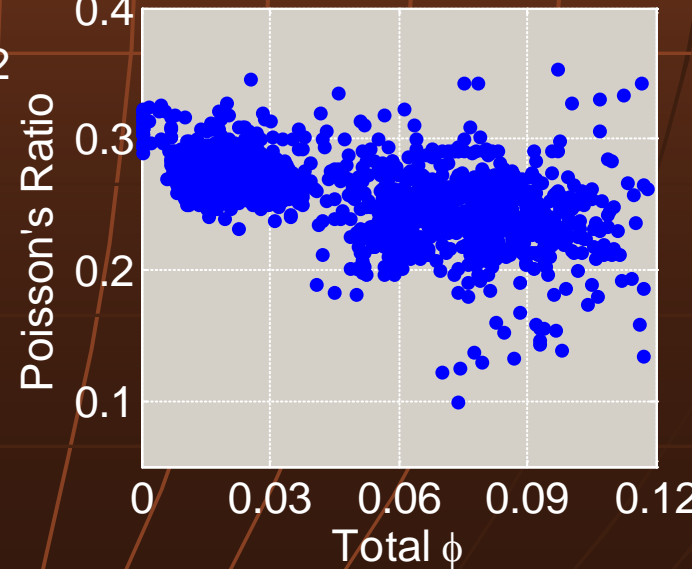
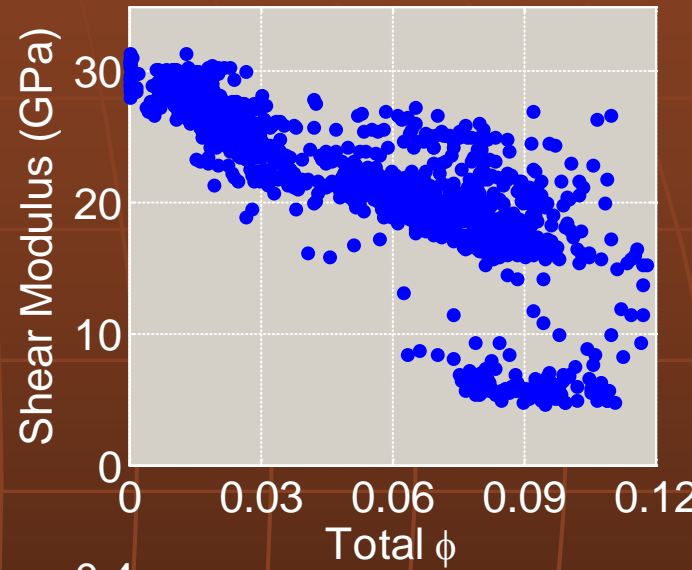
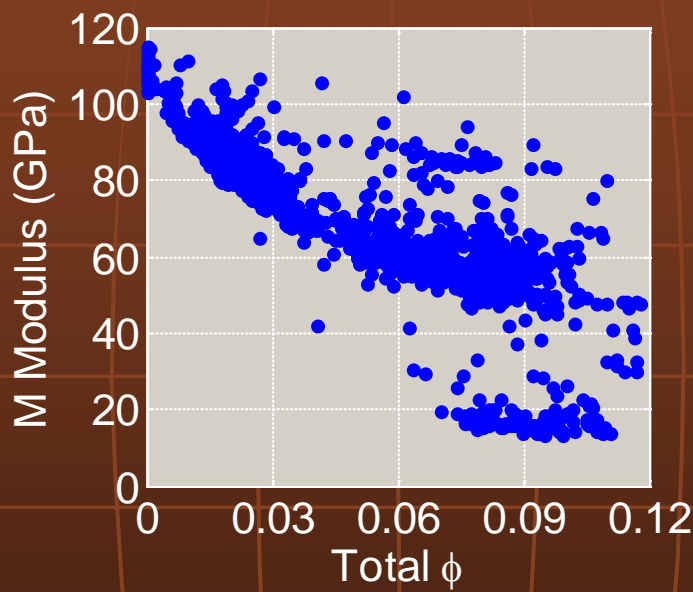
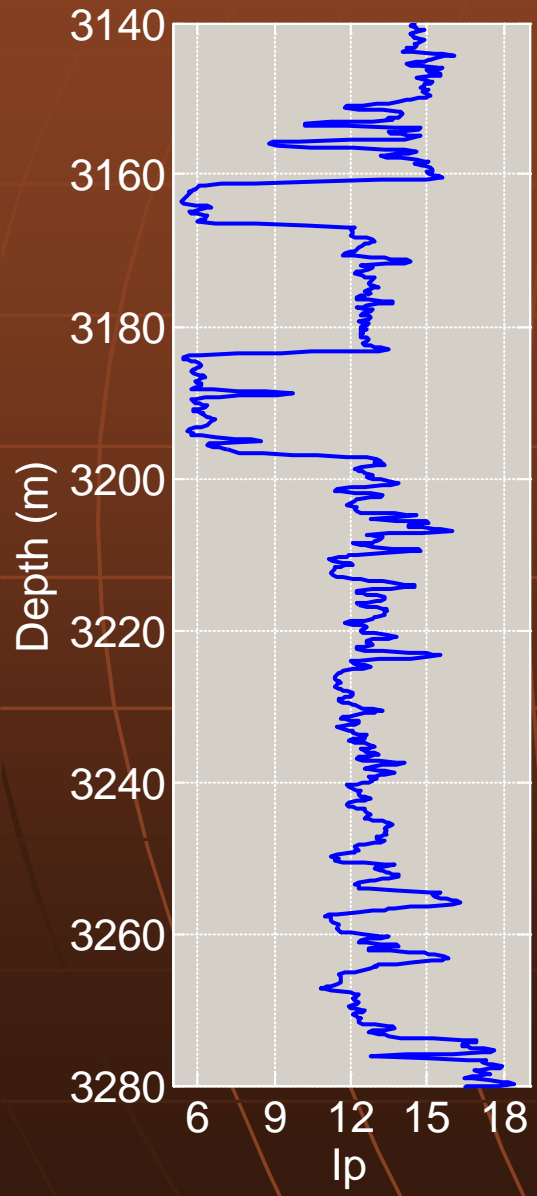
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# Elastic moduli and Poisson's ratio

$$\mu = V_S^2 \rho_b$$

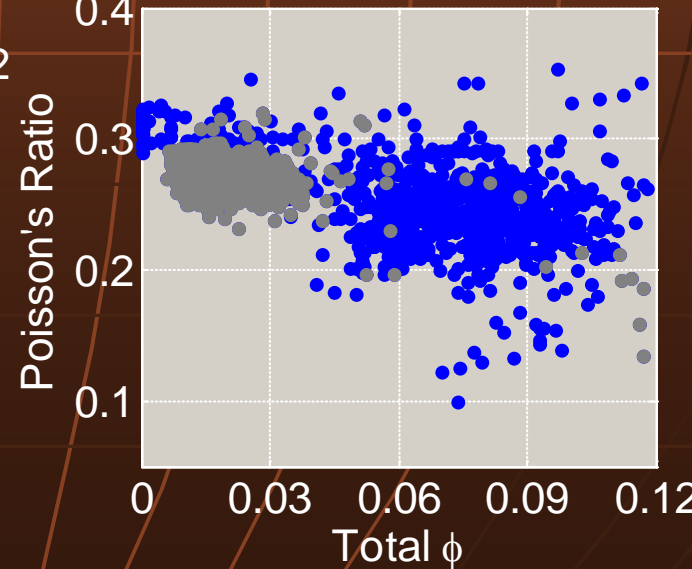
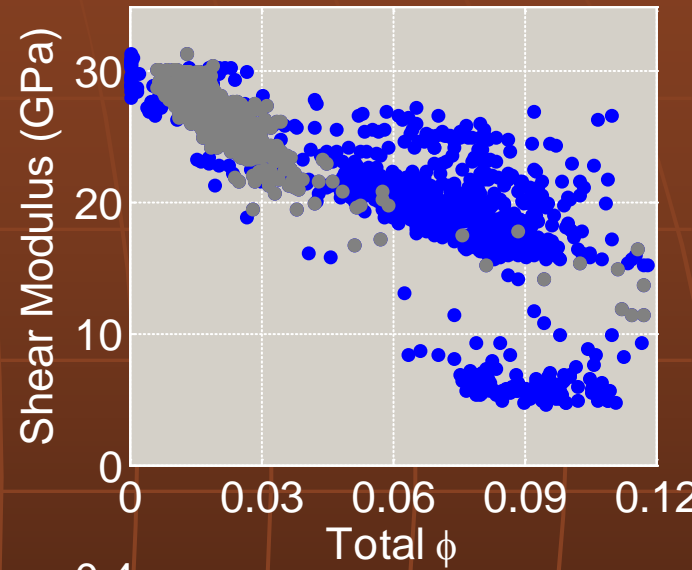
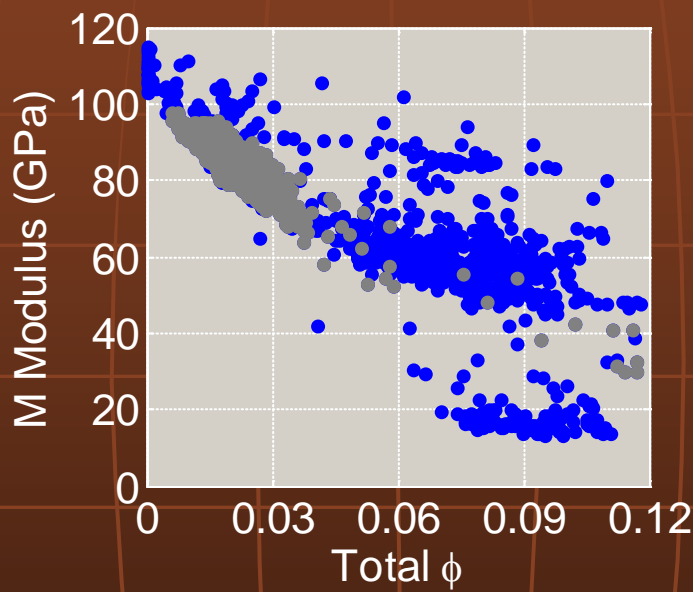
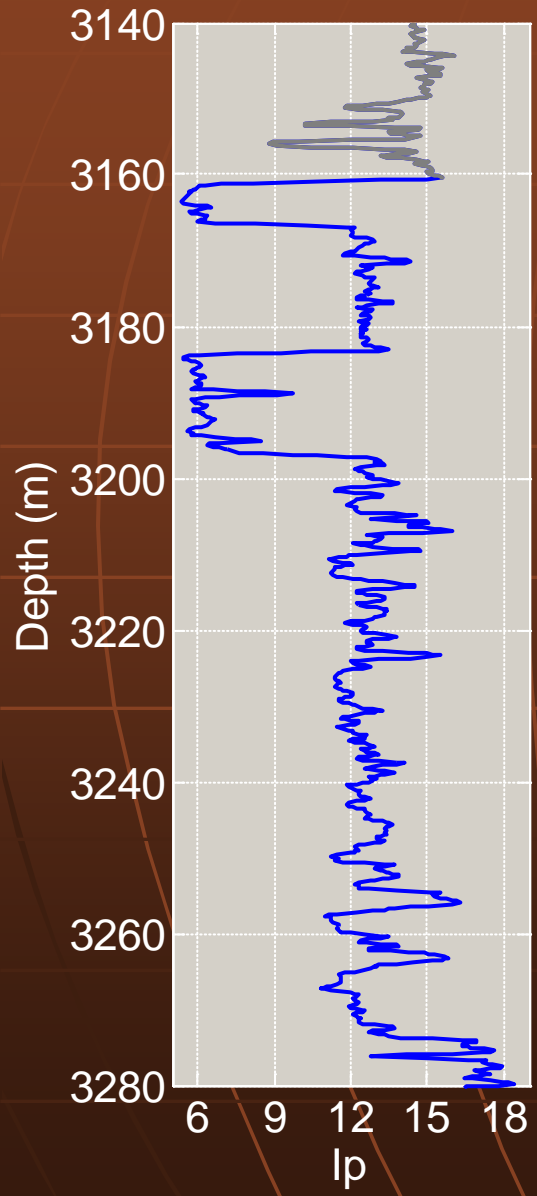
$$M = V_P^2 \rho_b$$



# Elastic moduli and Poisson's ratio

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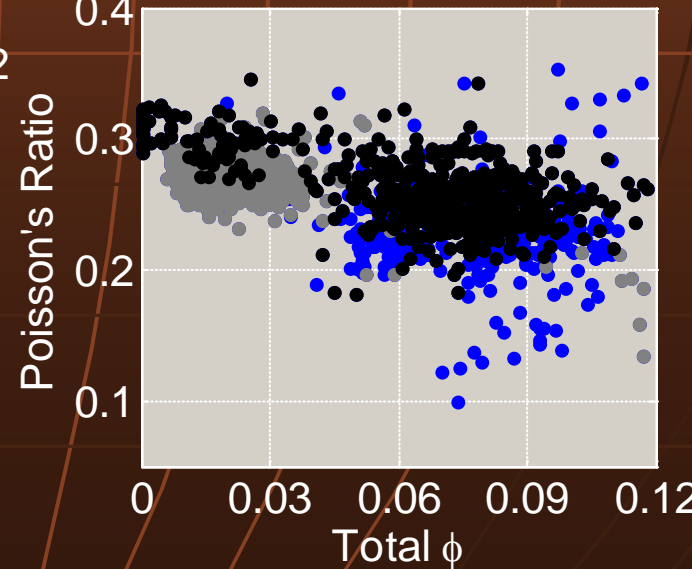
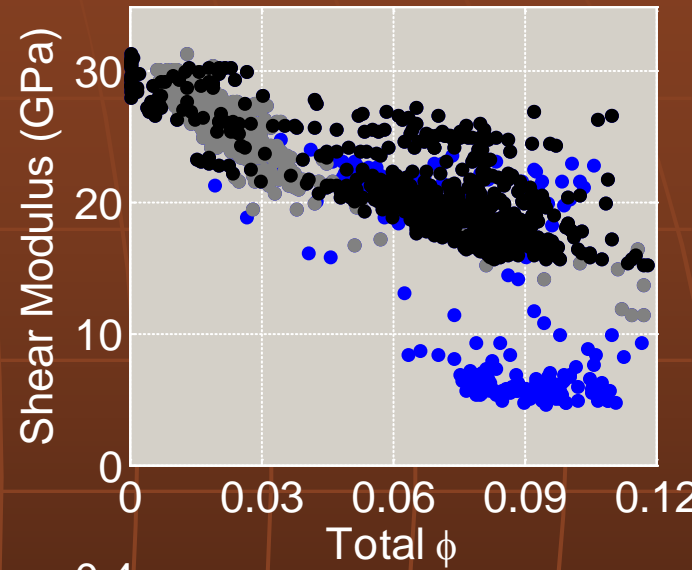
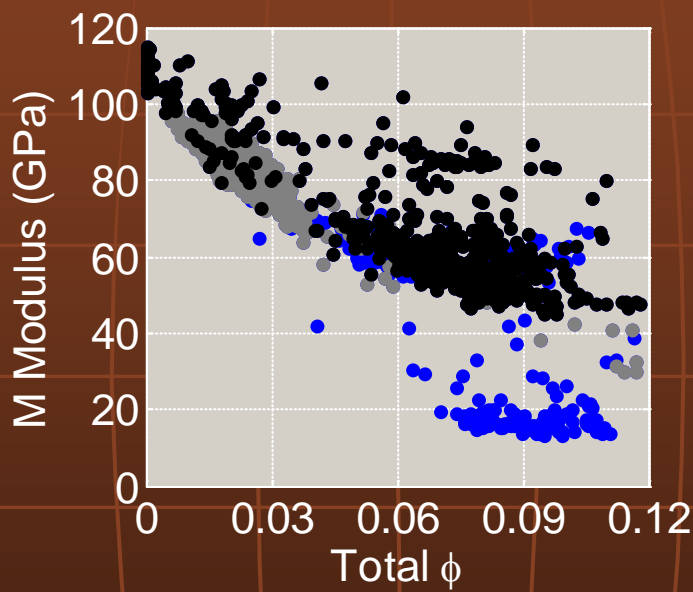
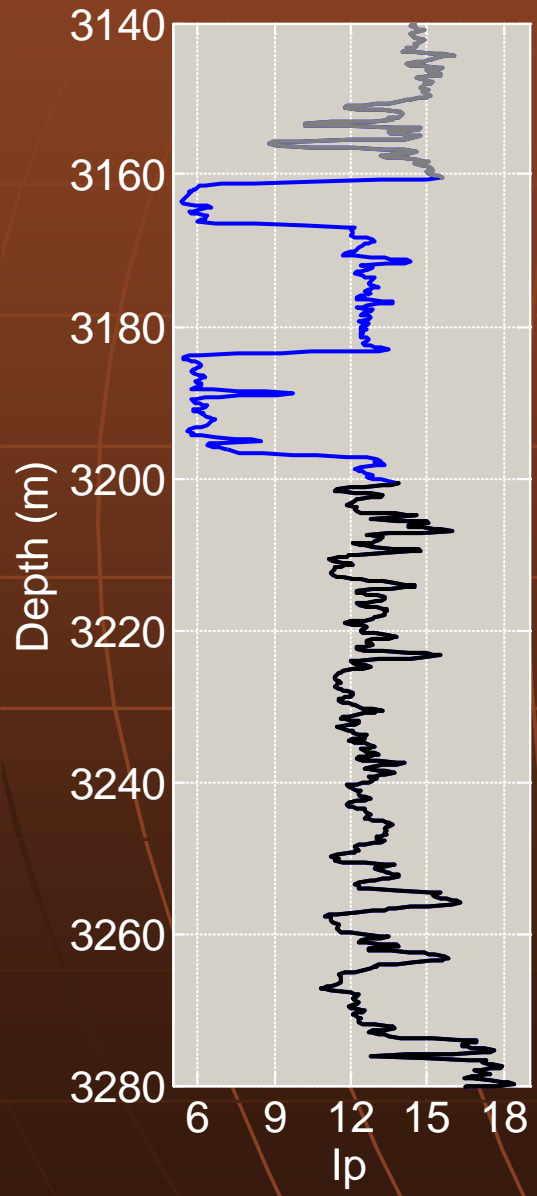
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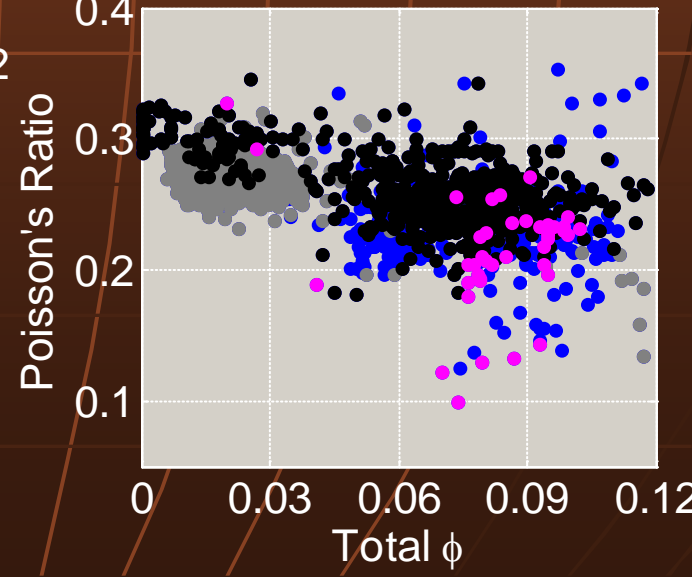
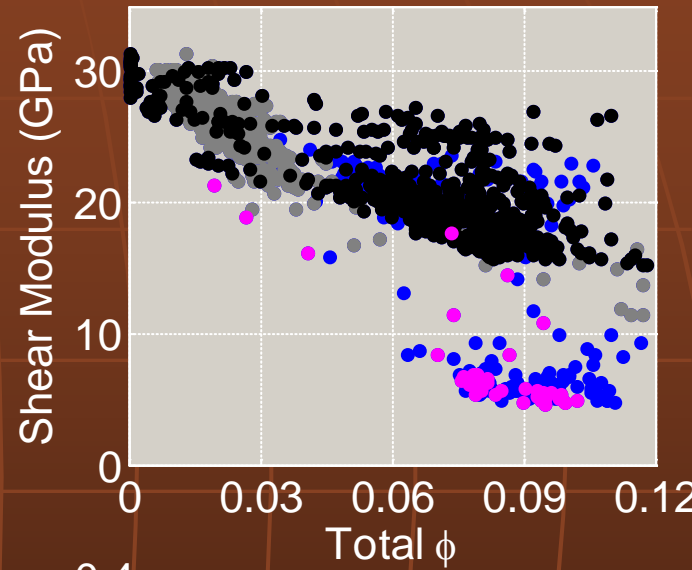
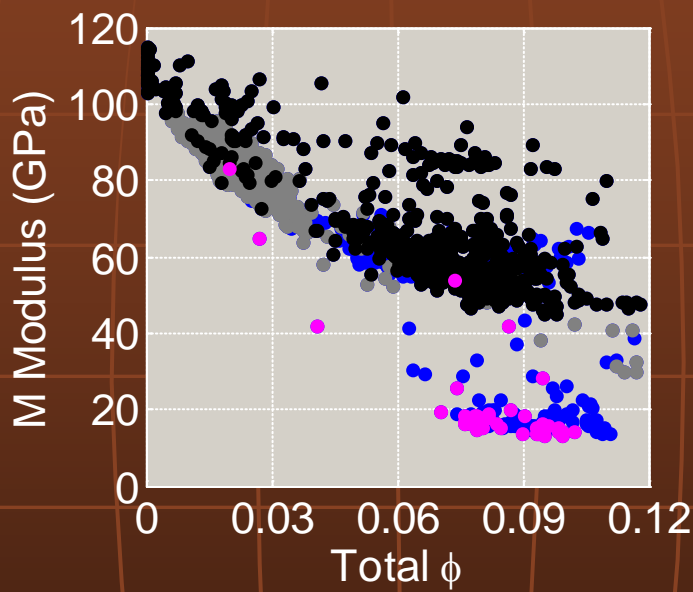
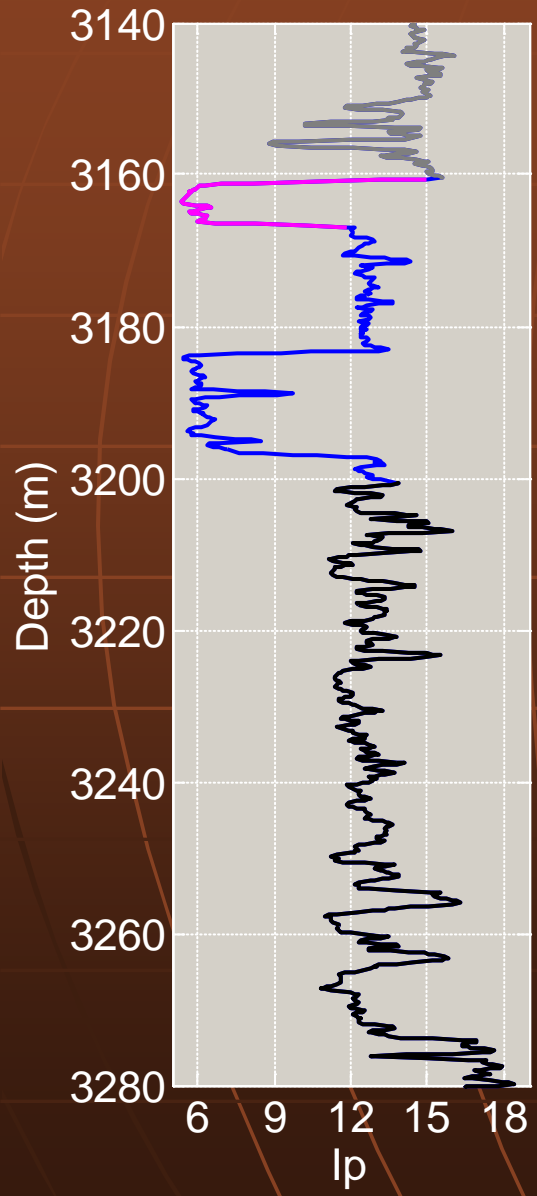
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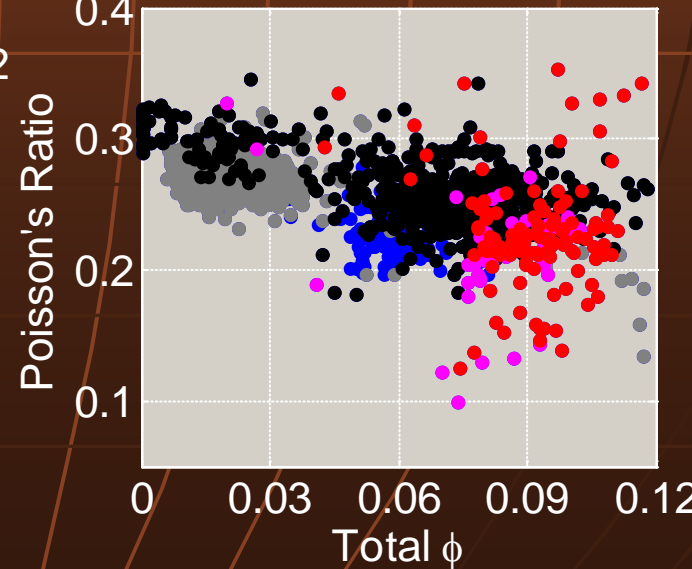
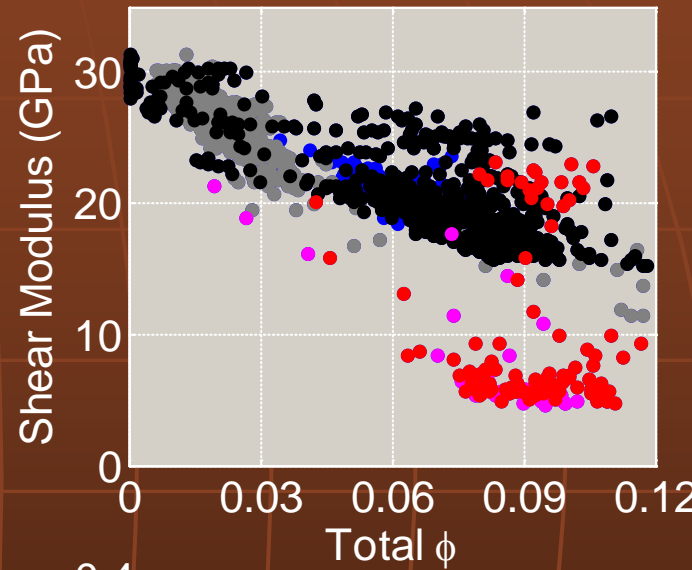
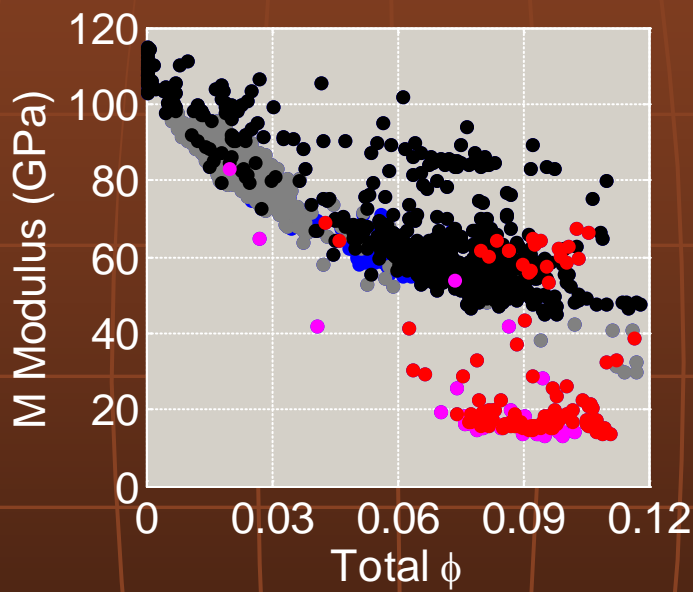
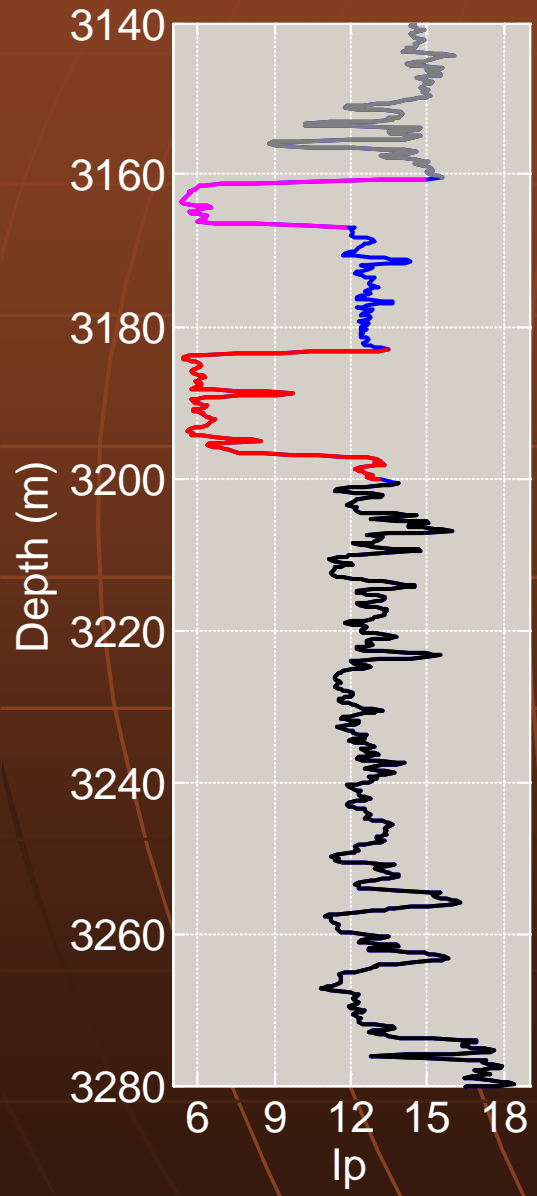
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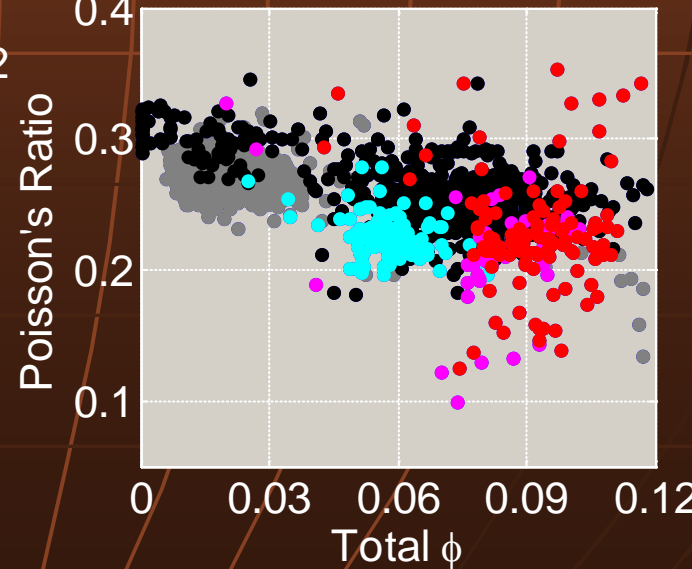
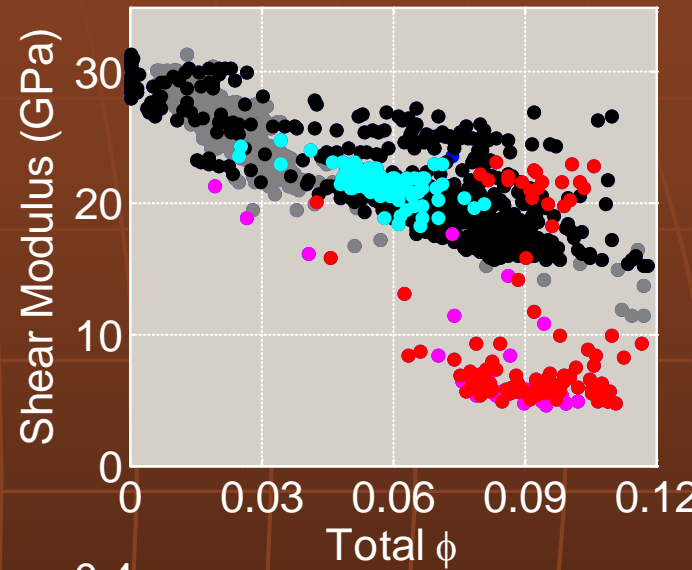
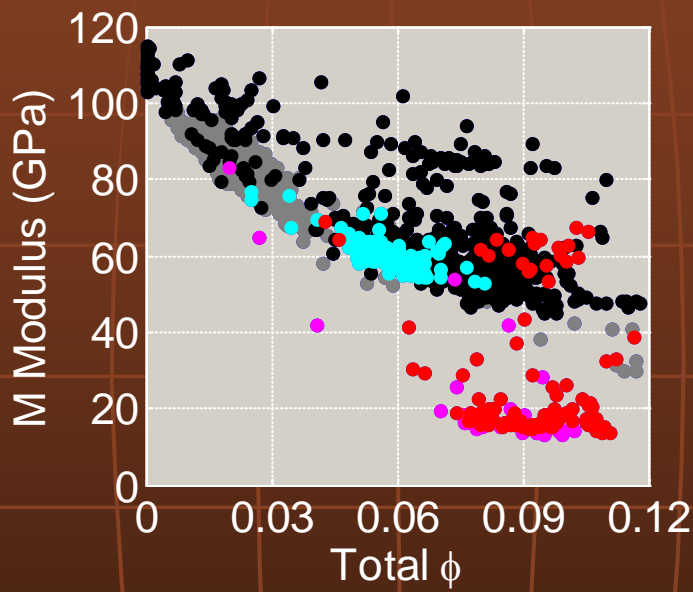
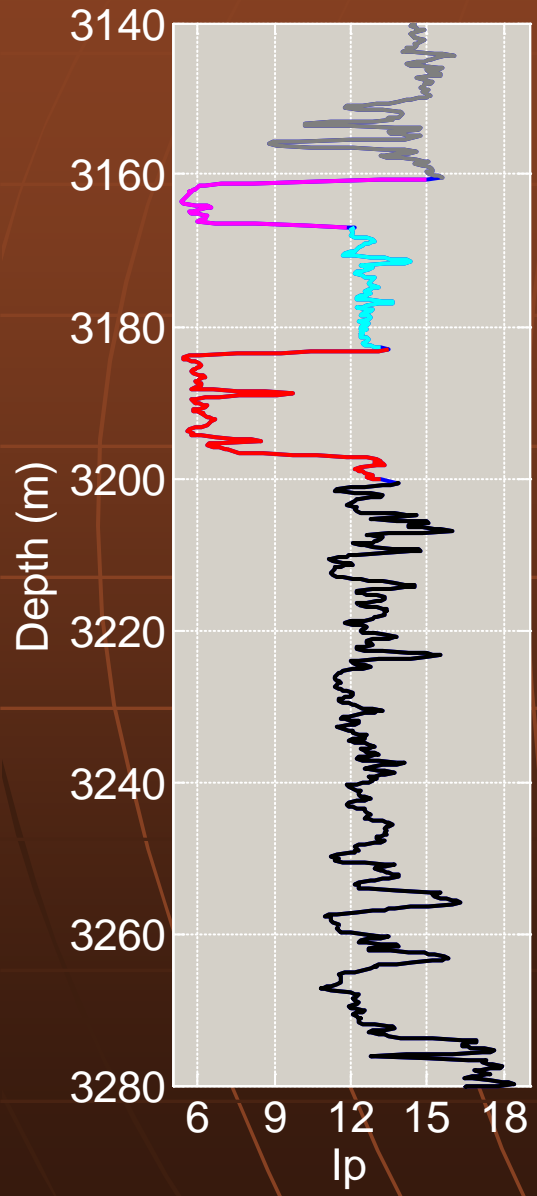
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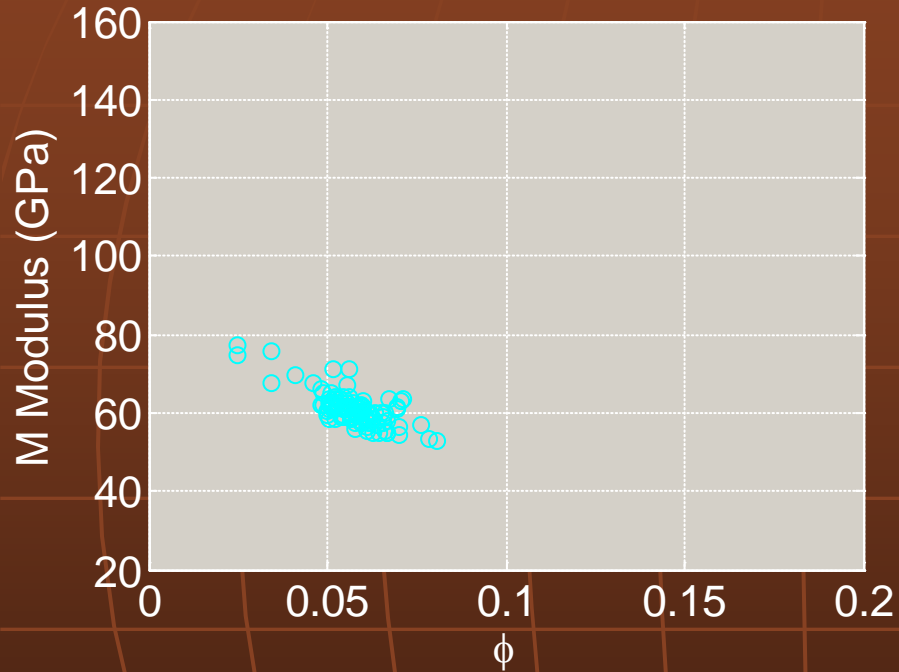
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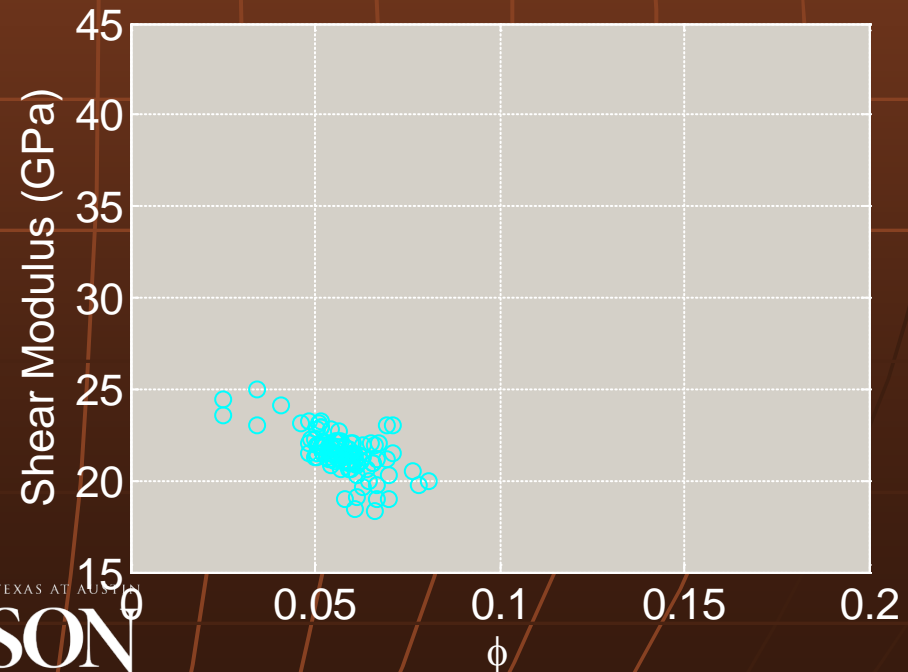


# Elastic bounds

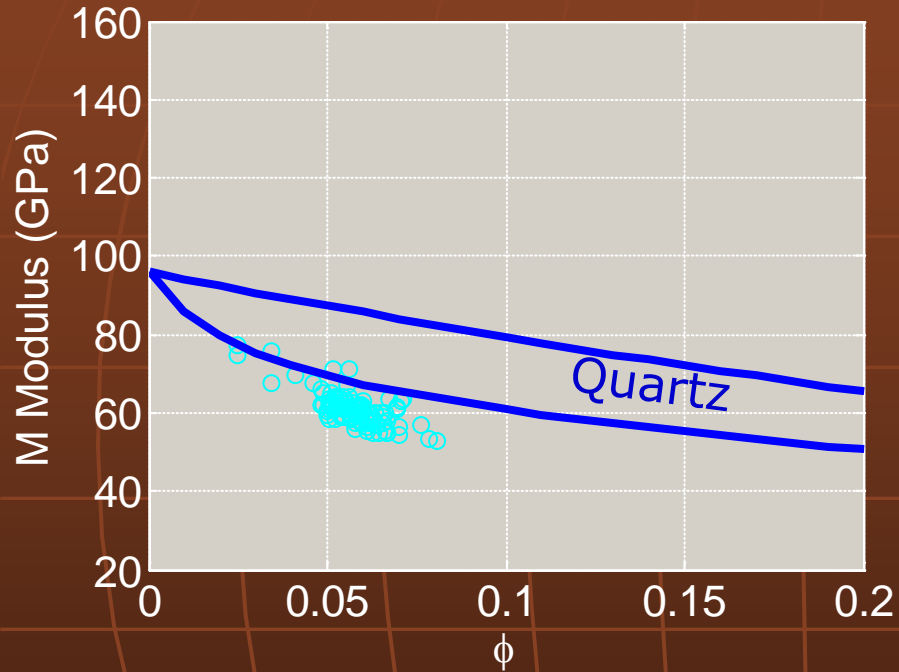


o Middle Bakken

How does the mineralogy vary laterally?

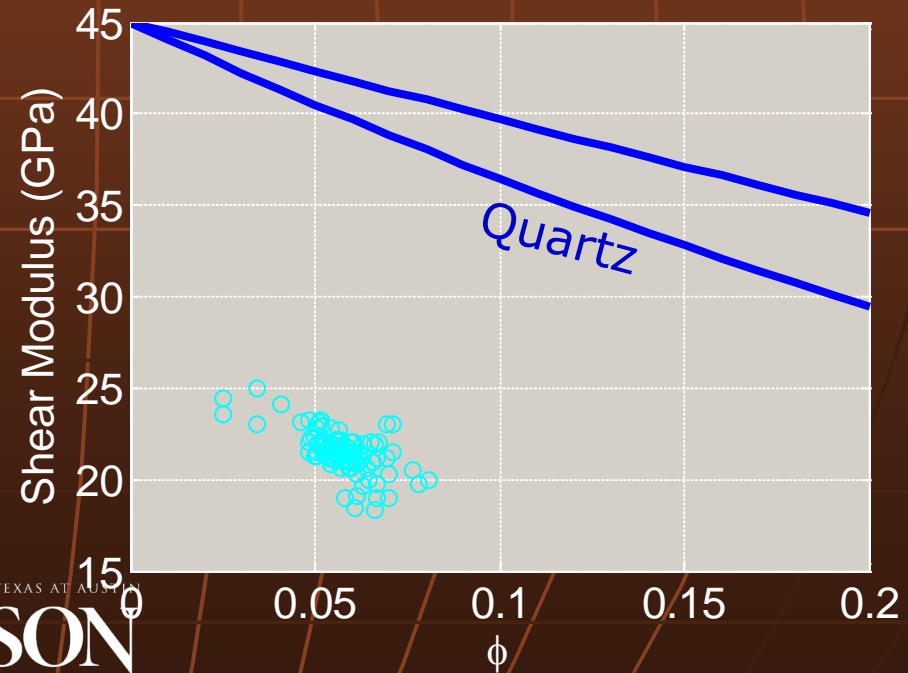


# Elastic bounds



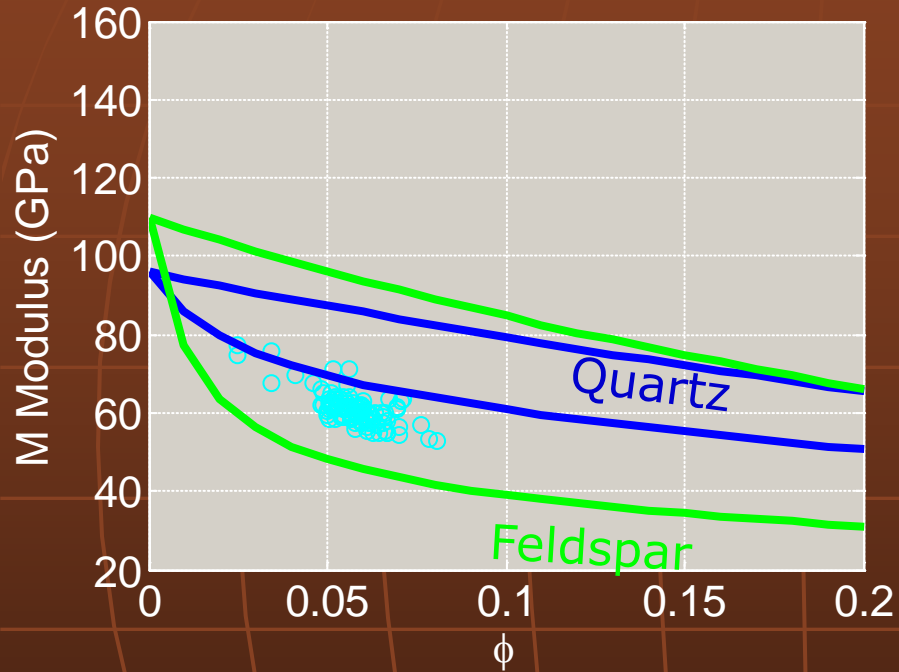
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How does the mineralogy vary laterally?



Upper and lower Hashin-Shtrikman bounds

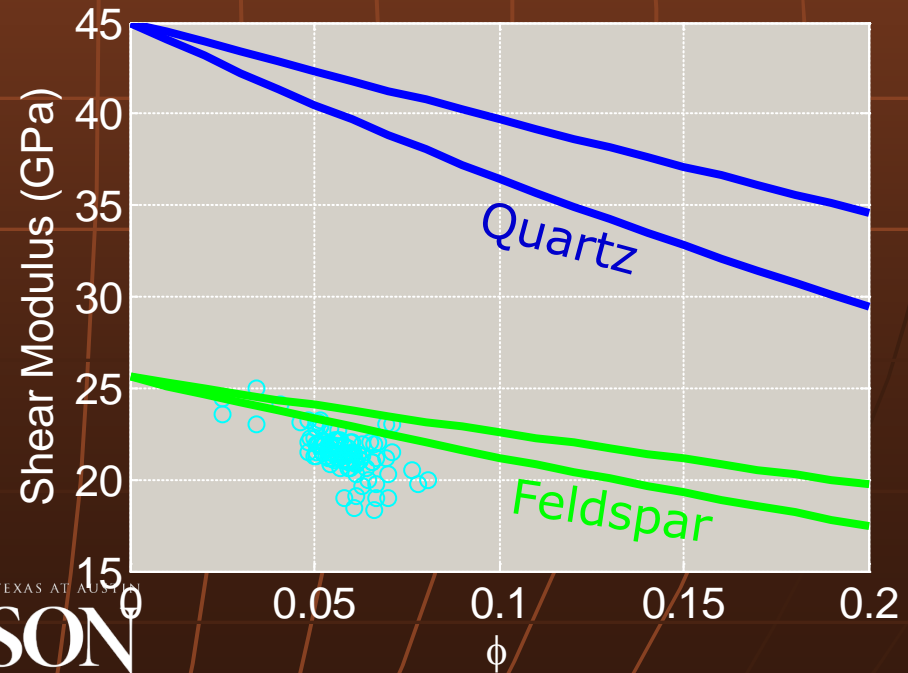
# Elastic bounds



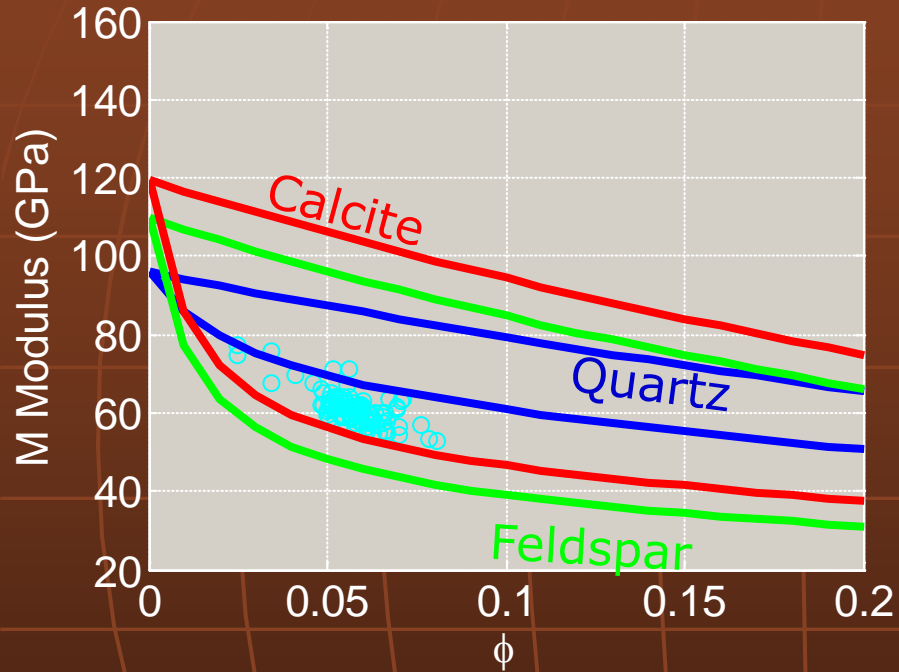
Upper and lower Hashin-Shtrikman bounds

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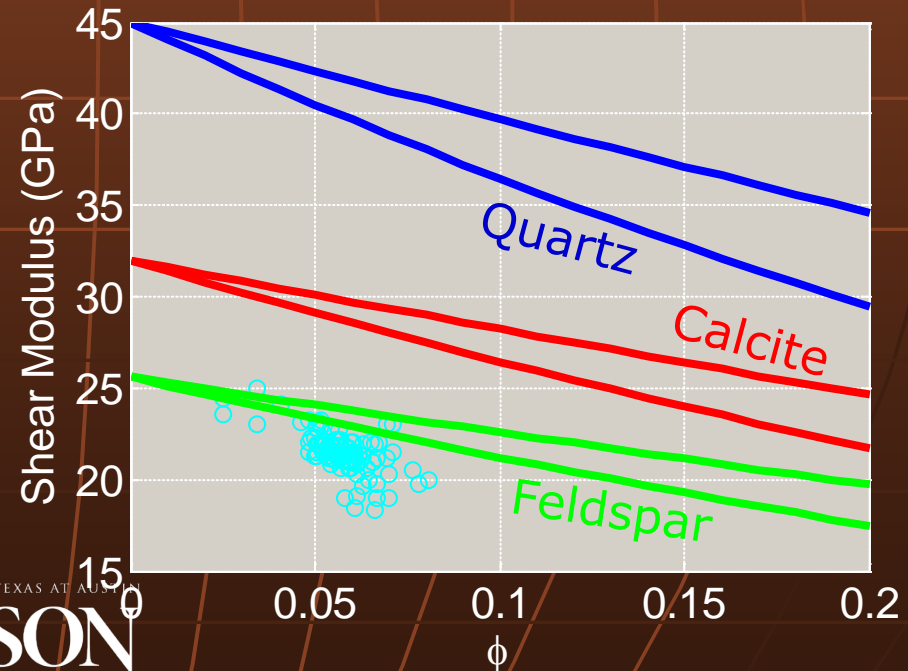
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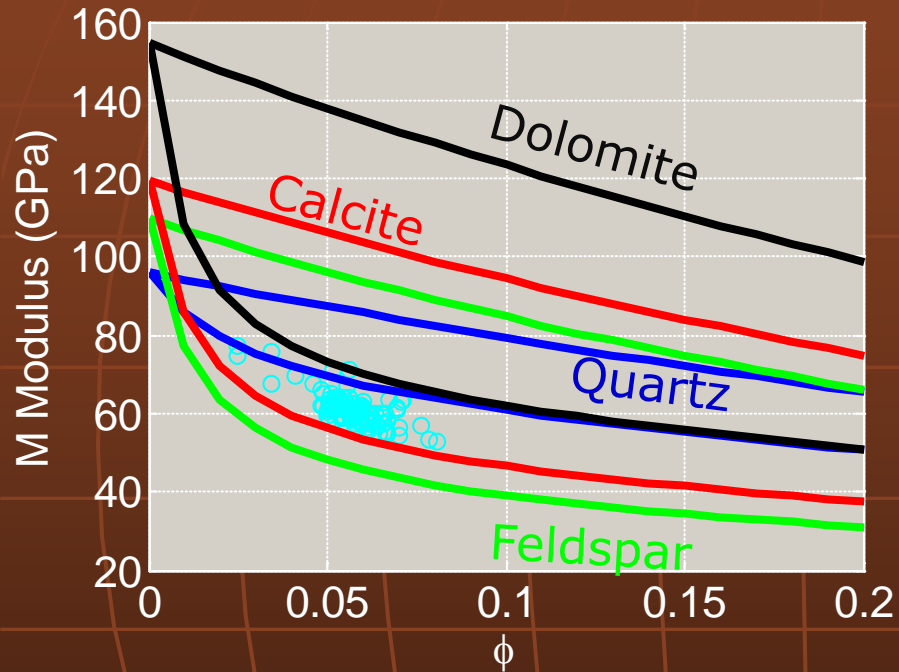
Upper and lower Hashin-Shtrikman bounds

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# Elastic bounds

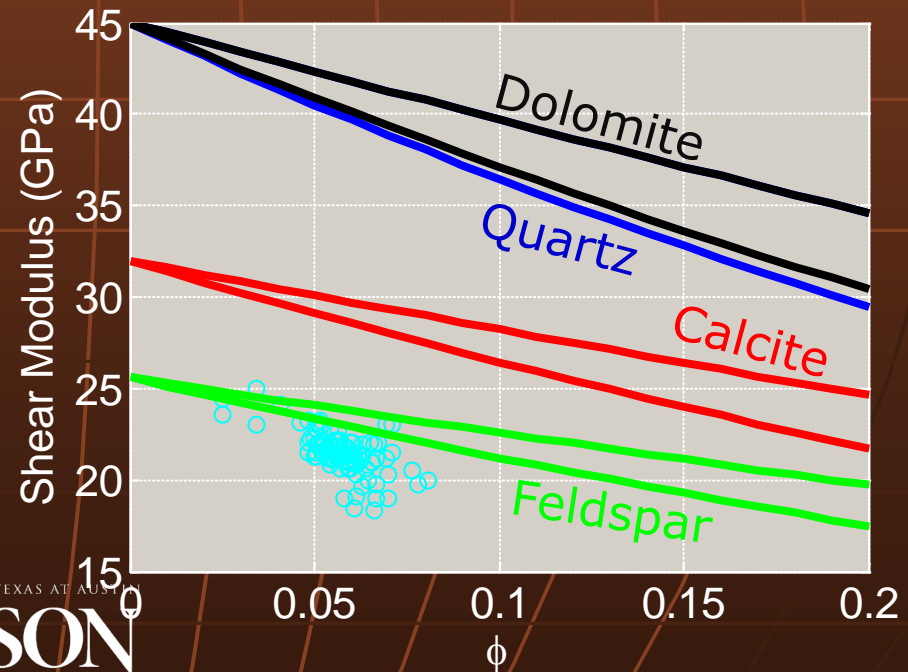


Upper and lower Hashin-Shtrikman bounds

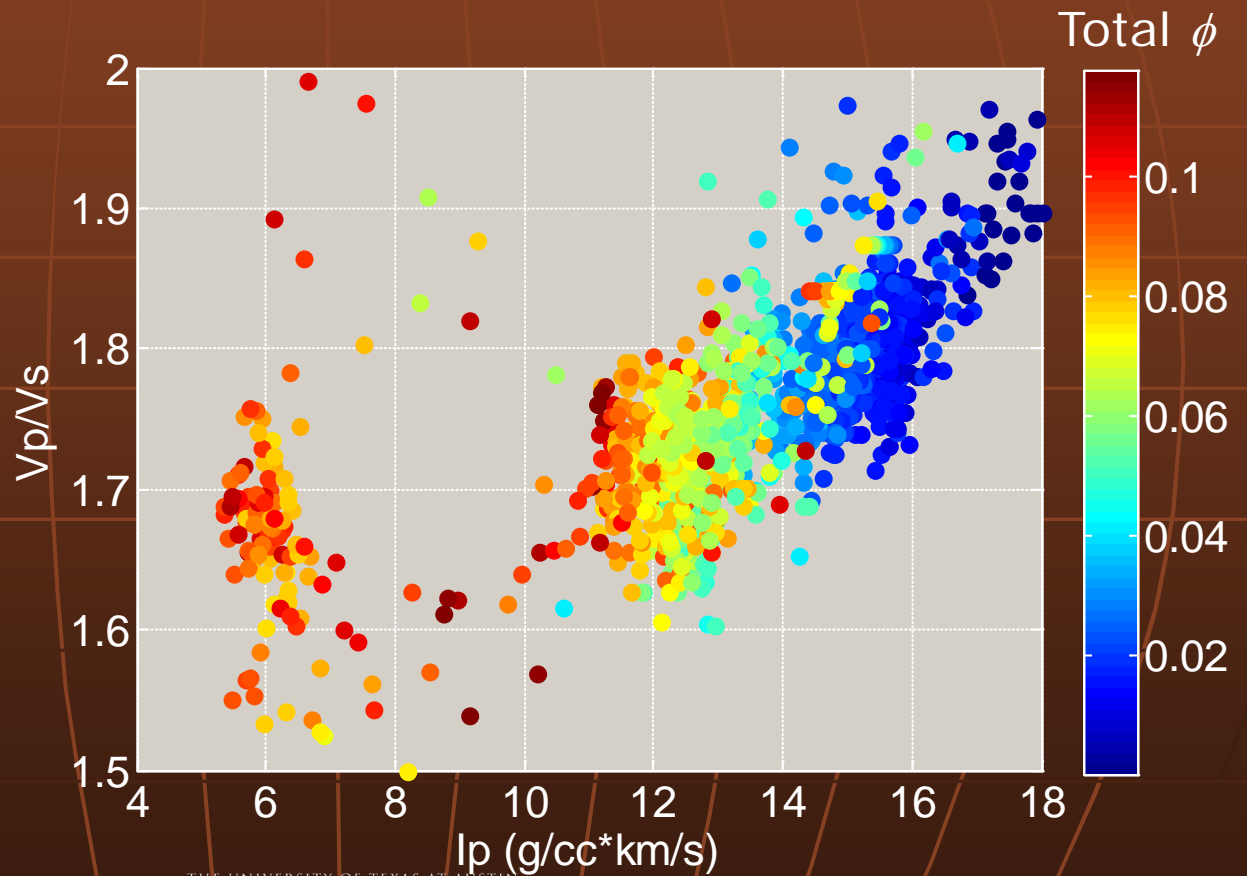
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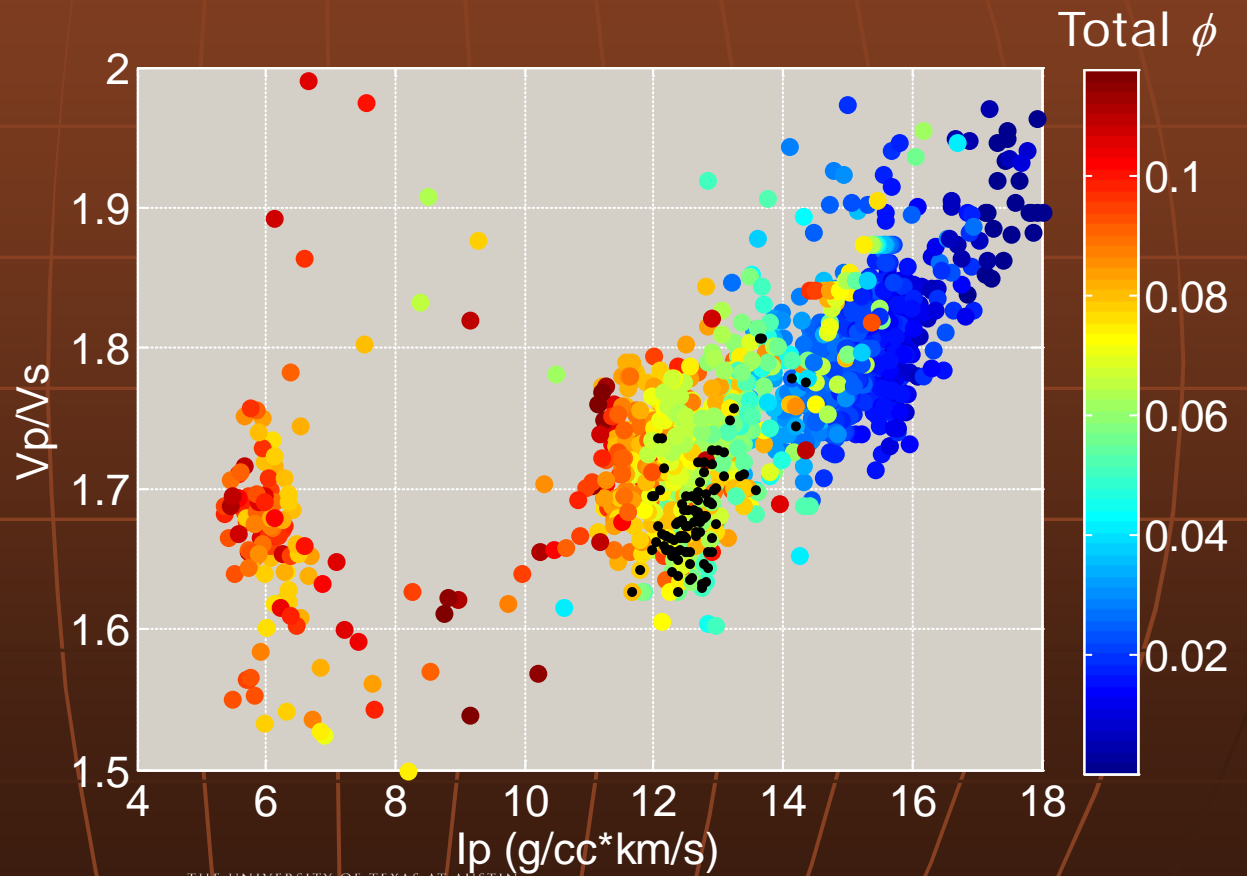
How much dolomite is present?  
Middle Bakken appears to be feldspathic.



# Rock physics model



# Rock physics model



# Rock physics model

Contact theory model for a stiff rock

## Parameters

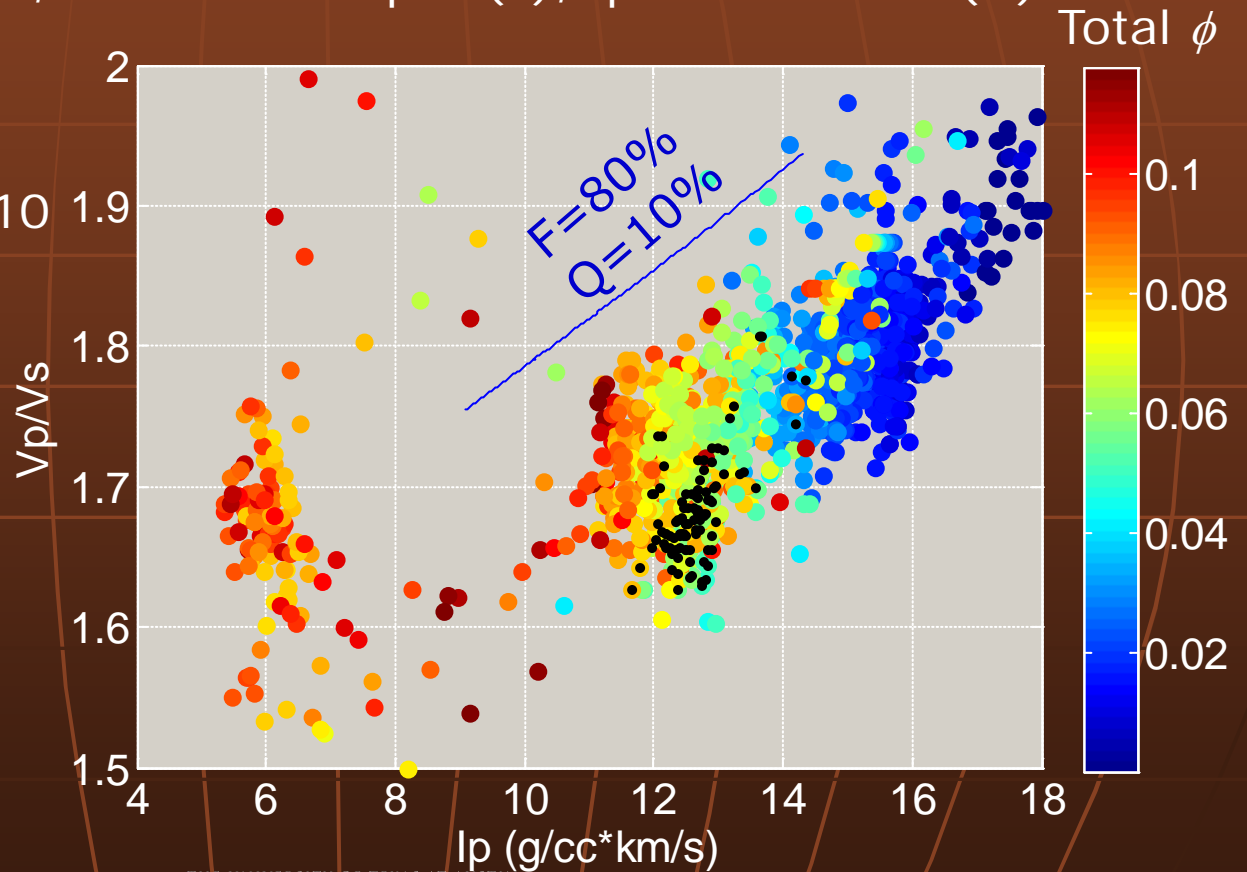
Mineralogy: Clay = 10%, variable feldspar (F), quartz content (Q)

Porosity: 3 to 20%

Pressure: 30 MPa

Critical porosity: 0.4

Coordination number: 10





# Rock physics model

Contact theory model for a stiff rock

## Parameters

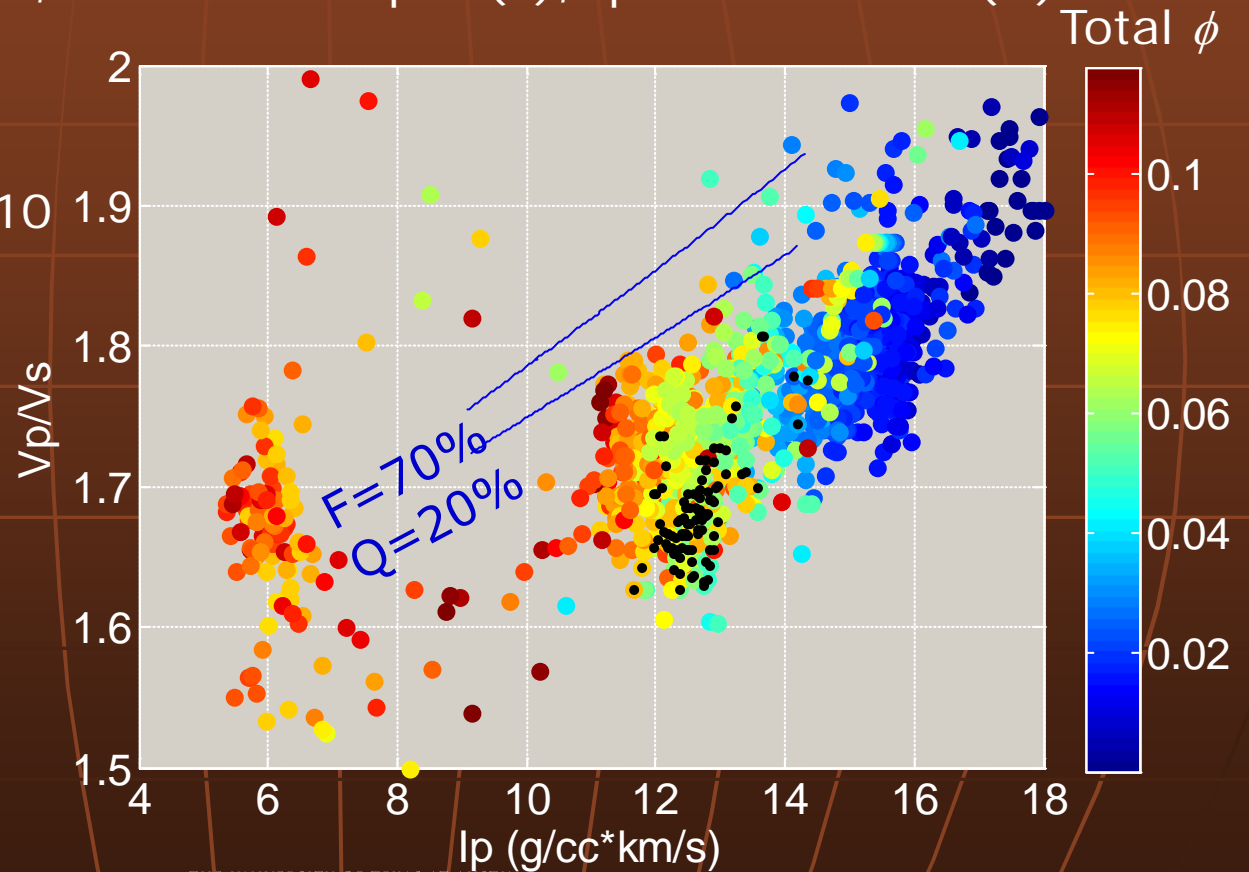
Mineralogy: Clay = 10%, variable feldspar (F), quartz content (Q)

Porosity: 3 to 20%

Pressure: 30 MPa

Critical porosity: 0.4

Coordination number: 10



# Rock physics model

Contact theory model for a stiff rock

## Parameters

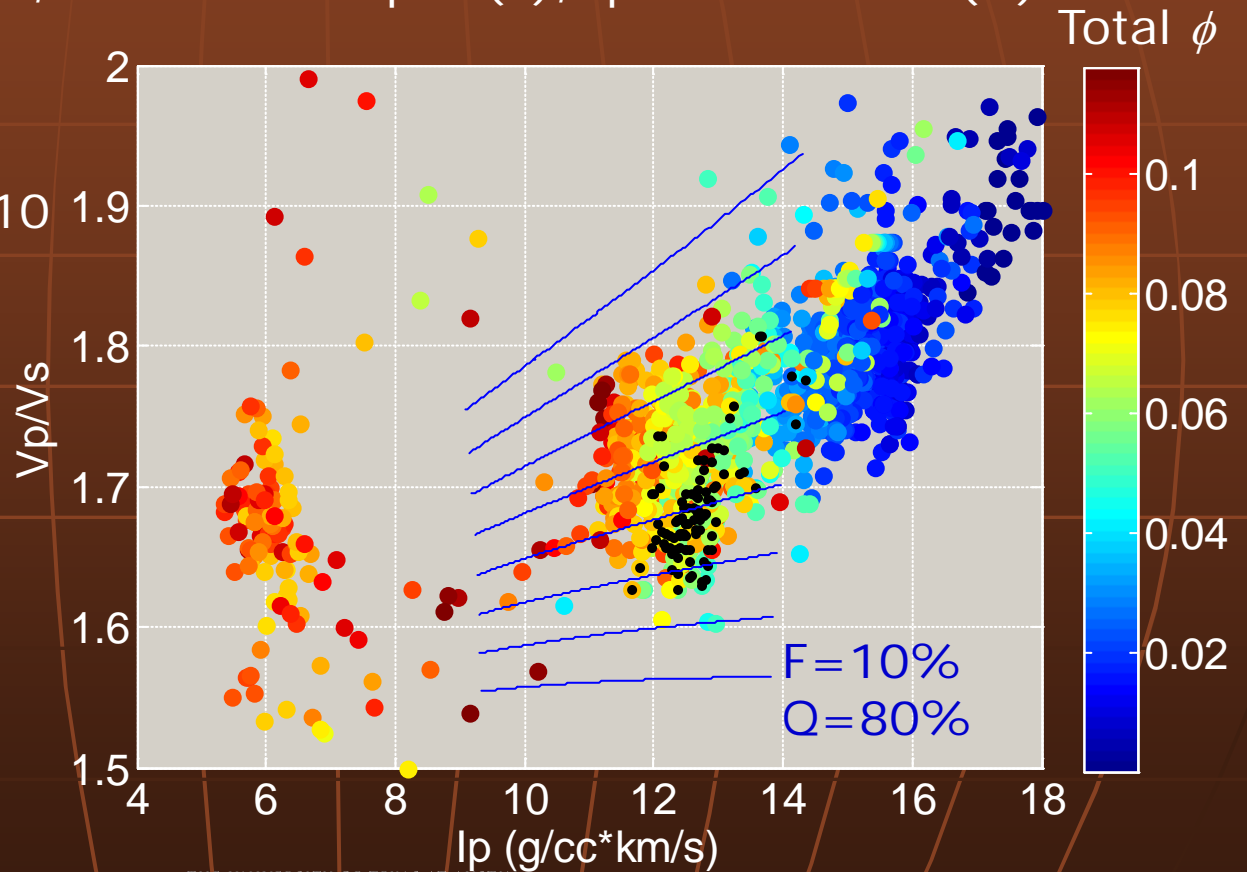
Mineralogy: Clay = 10%, variable feldspar (F), quartz content (Q)

Porosity: 3 to 20%

Pressure: 30 MPa

Critical porosity: 0.4

Coordination number: 10



# Rock physics model

Contact theory model for a stiff rock

## Parameters

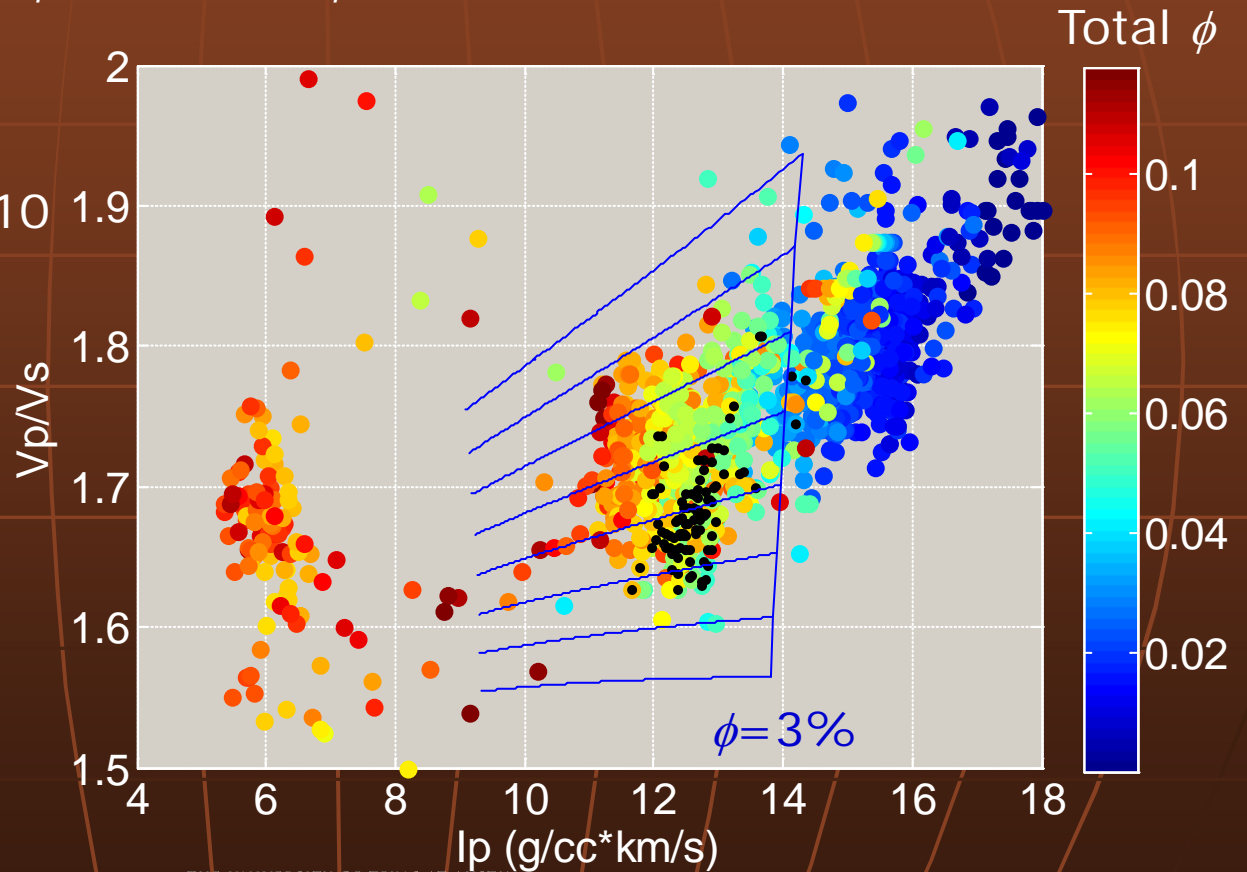
Mineralogy: Clay = 10%, F=10-80%, Q =80-10%

Porosity: 3%

Pressure: 30 MPa

Critical porosity: 0.4

Coordination number: 10



# Rock physics model

Contact theory model for a stiff rock

## Parameters

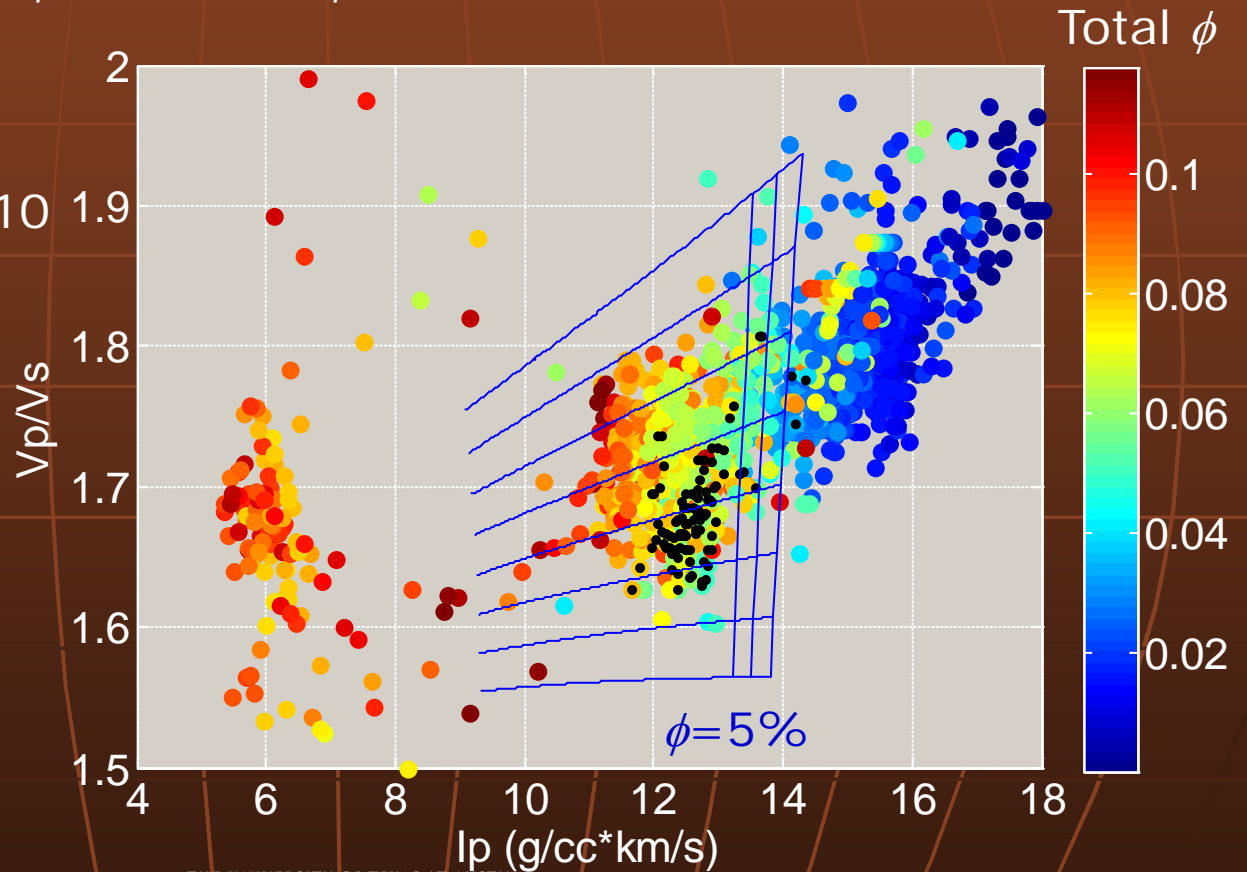
Mineralogy: Clay = 10%, F=10-80%, Q = 80-10%

Porosity: 5%

Pressure: 30 MPa

Critical porosity: 0.4

Coordination number: 10



# Rock physics model

Contact theory model for a stiff rock

## Parameters

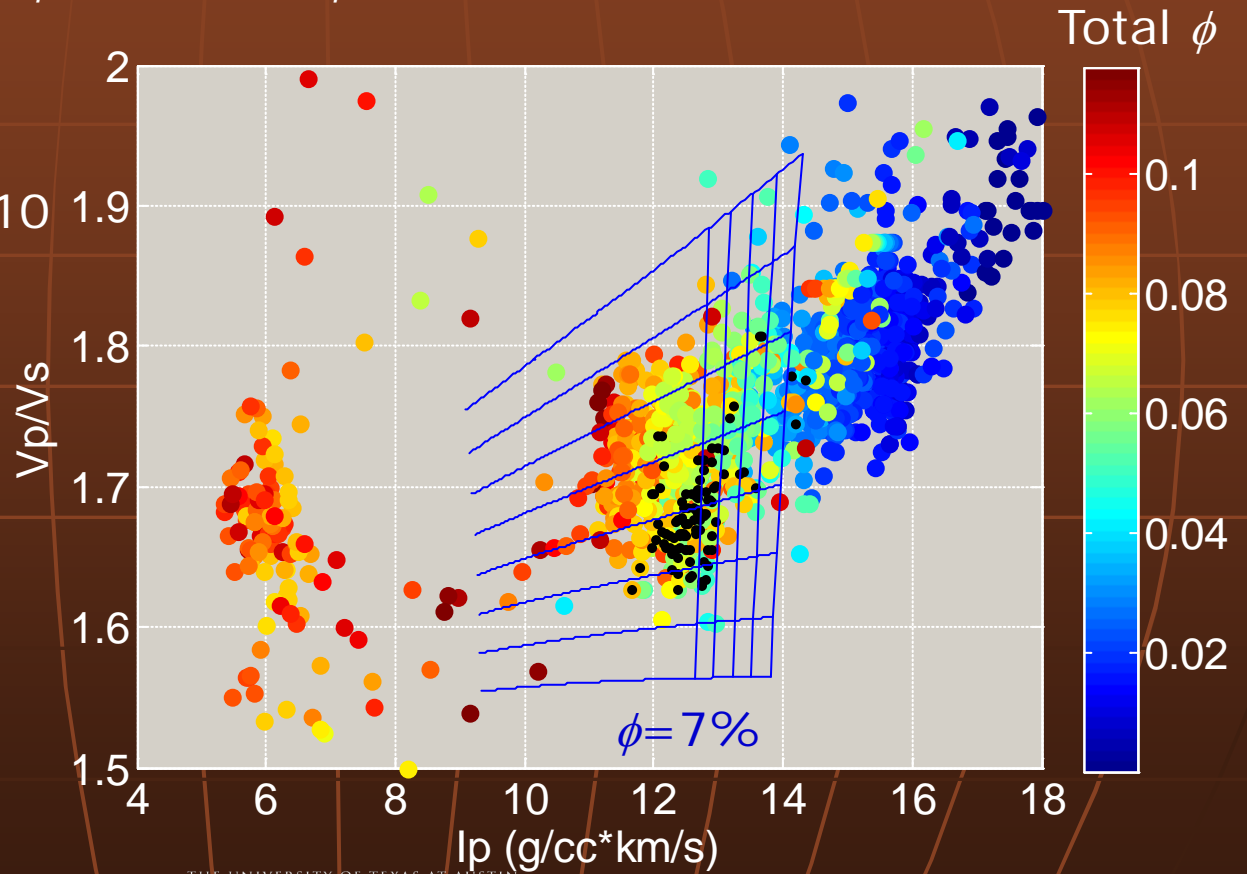
Mineralogy: Clay = 10%, F=10-80%, Q = 80-10%

Porosity: 7%

Pressure: 30 MPa

Critical porosity: 0.4

Coordination number: 10



# Rock physics model

Contact theory model for a stiff rock

## Parameters

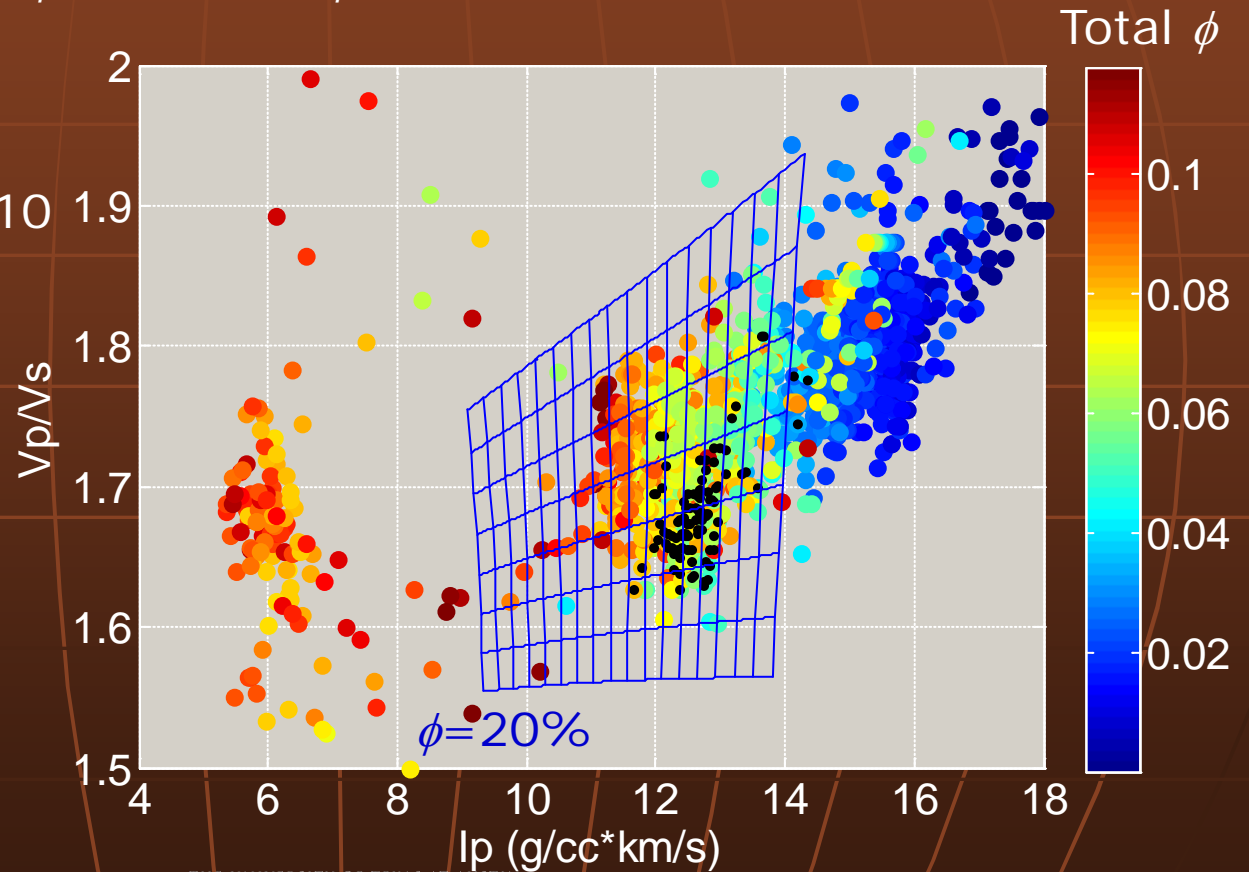
Mineralogy: Clay = 10%, F=10-80%, Q =80-10%

Porosity: 20%

Pressure: 30 MPa

Critical porosity: 0.4

Coordination number: 10



# Areas of future work

- Can model mineralogy and porosity to account for some data scatter
- Need better control on both for fluid sub.
- Need to understand better the effects of pore shape, pore stiffness, and pore fluids on  $V_p$
- For the Middle Bakken, somewhat conventional analysis can be used to an extent
- Must analyze the more subtle parameters that affect the elastic properties
- More work to be done to understand the Upper and Lower Bakken Shales
- Possible that all three intervals will need to be assessed simultaneously to understand the lateral heterogeneity
- Can some of these parameters be included in a seismic inversion for rock properties?

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