# *Pressure and Compaction in the Rock Physics Space*

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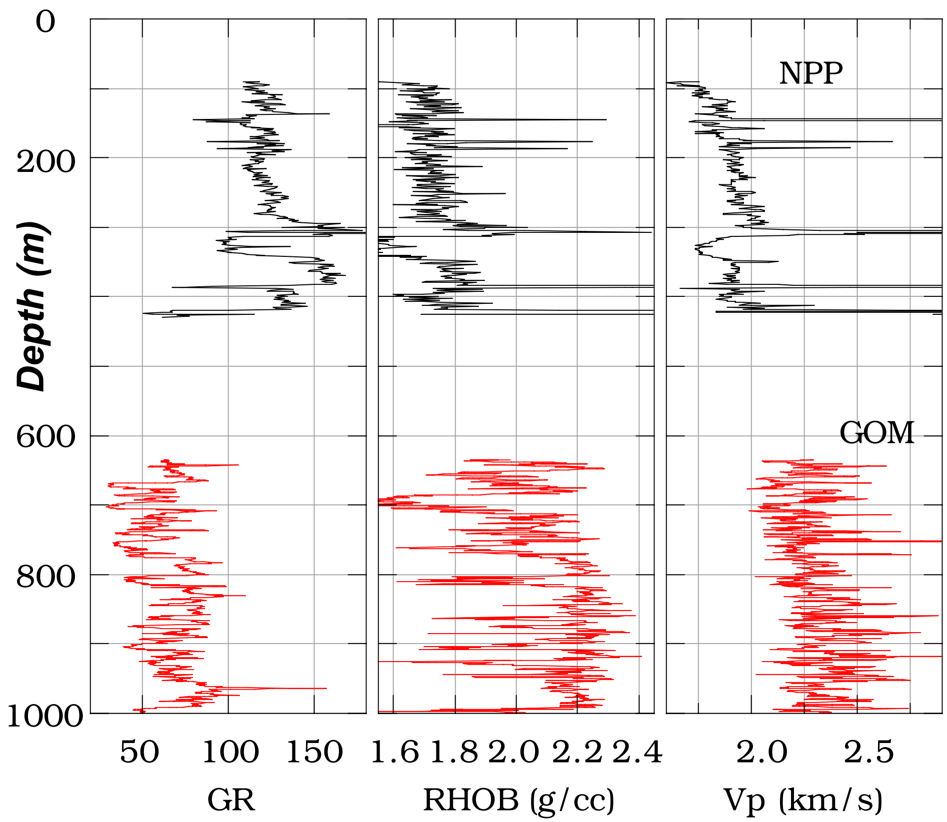
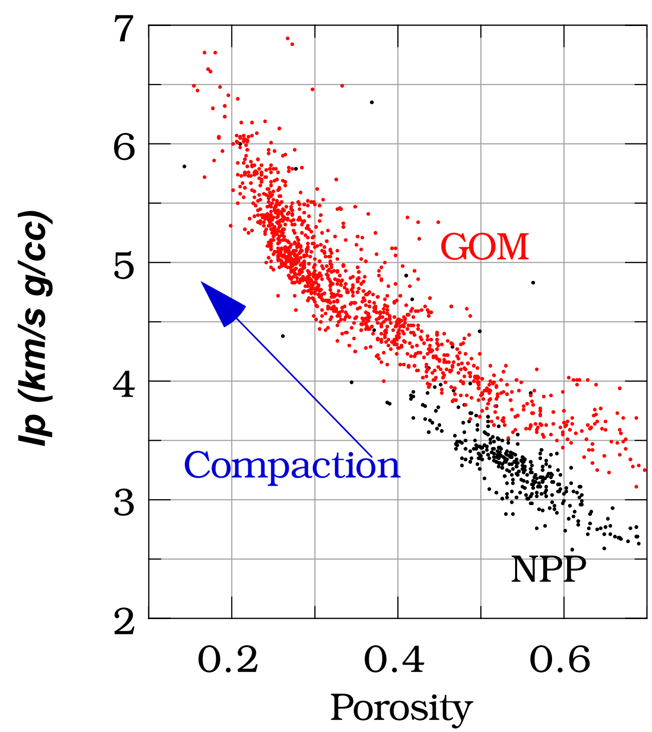
# Compaction of Shales

***Freshly deposited shales and clays may have enormous porosity of ~ 80%. The speed of sound is close to that in water ~ 1500 m/s. The S-wave velocity is small but not negligible. As a result, Poisson's ratio approaches 0.5.***

***As the overburden increases, the shale compacts. Porosity decreases and velocity increases.***



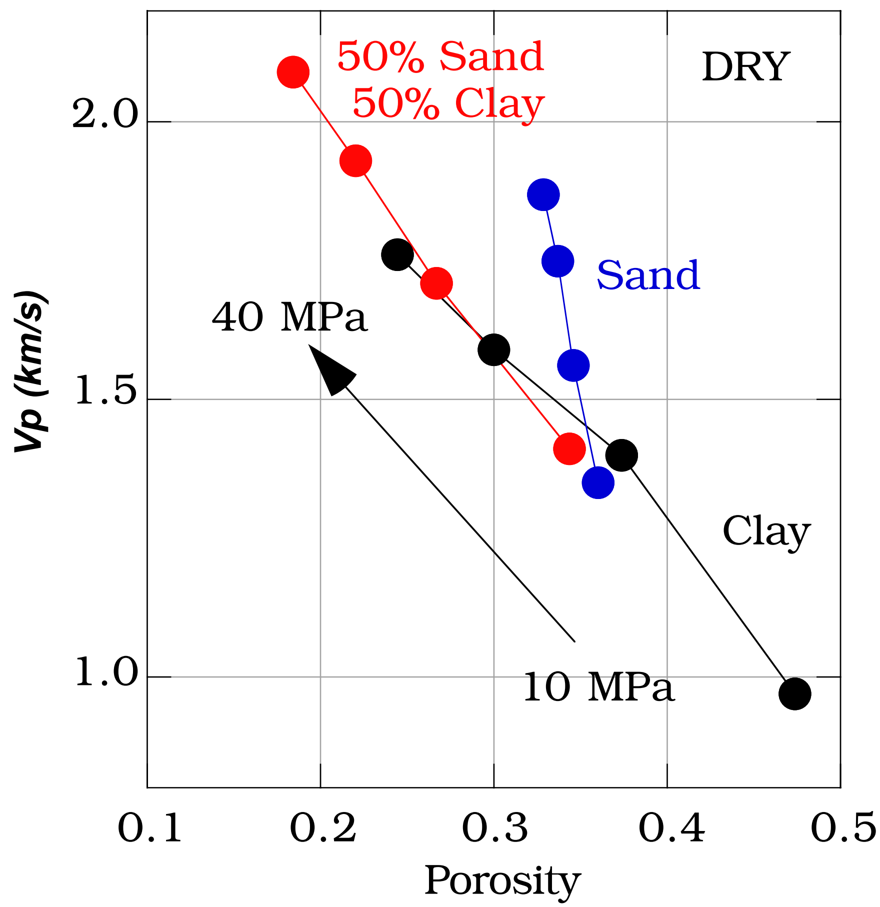

**Compaction in on-shore shale and in GOM.**



# Difference in Compaction of Shales and Sands

***Sands are much less compactable than shales (unless the grains break or diagenesis sets in).***

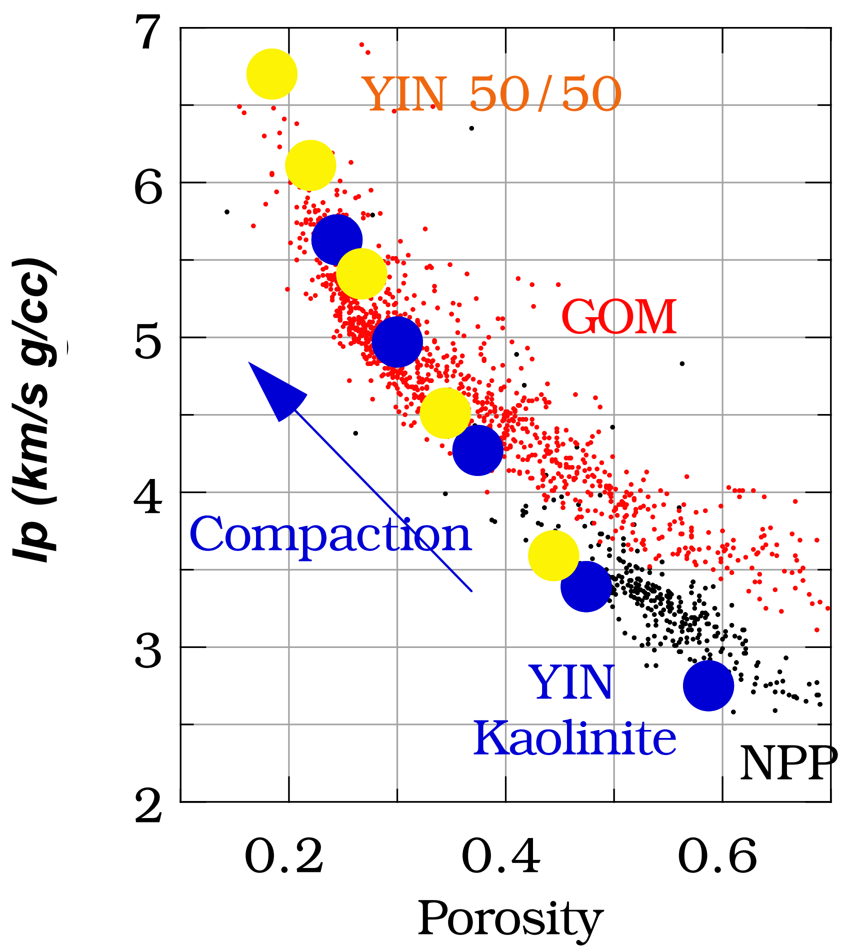
***Compaction in dry kaolinite, Ottawa sand, and a 50/50 mixture thereof (Yin, 1992).***



# Compaction of Shales

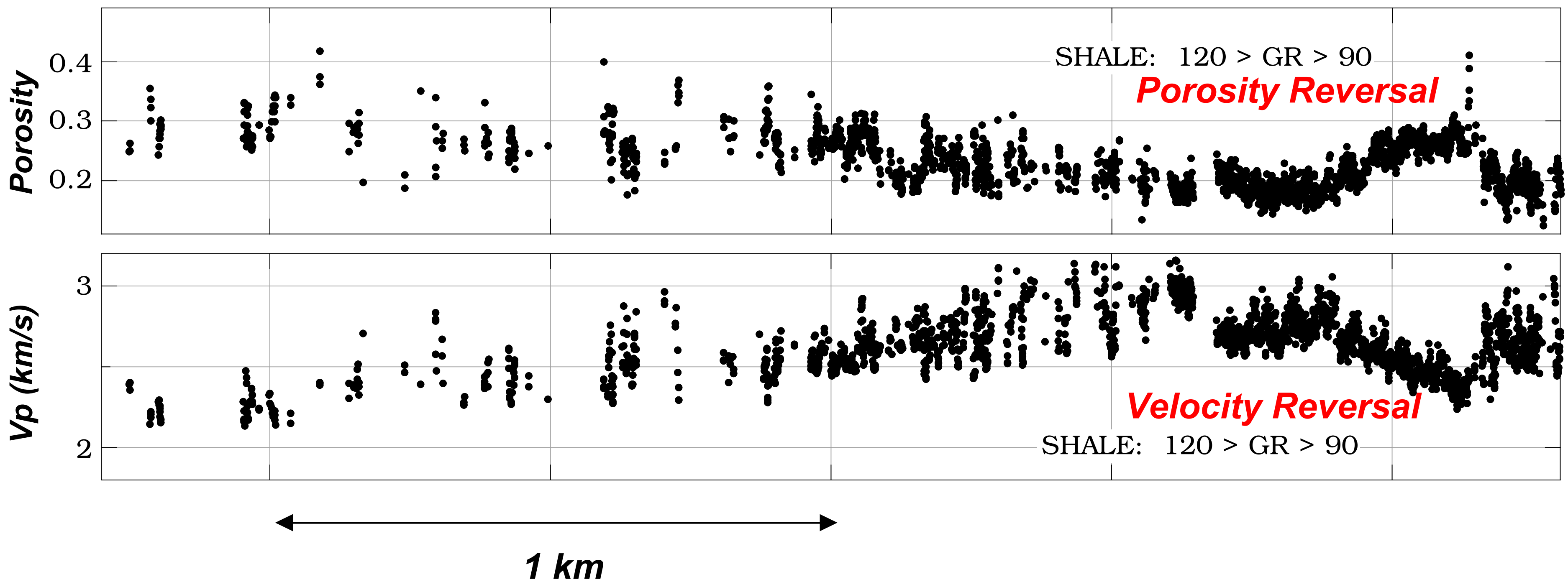
***As long as shale is load-bearing, the compaction trend in the impedance-porosity space seems to be universal among wells logs and lab data.***

***Compaction in on-shore shale and in GOM + Yin's clay and sand/clay data.***



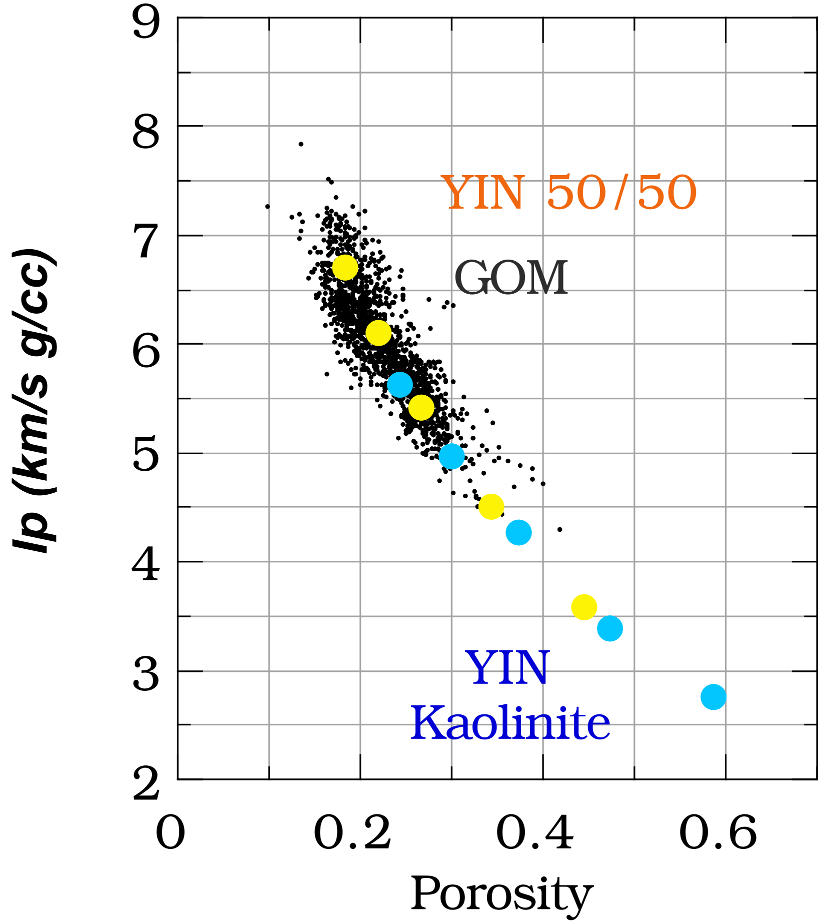
# Compaction and Undercompaction Due to Pore Pressure

**Abnormal pore pressure results in undercompaction and porosity and velocity reversals**



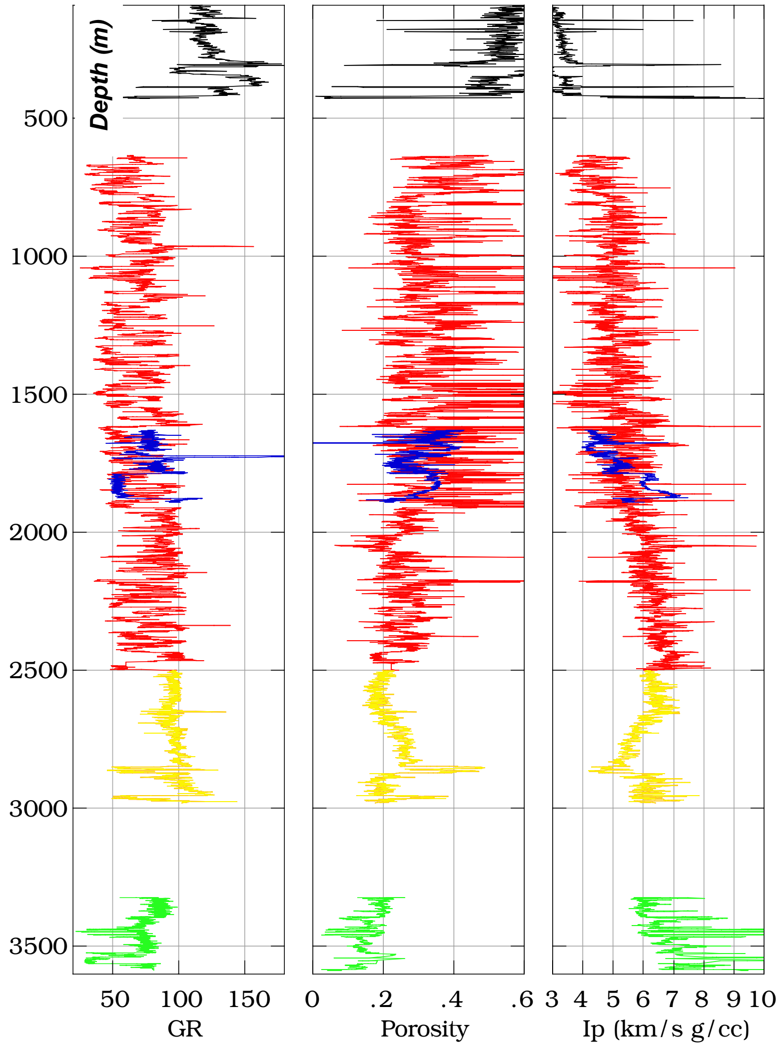
# Compaction and Undercompaction Due to Pore Pressure -- Same Rock Physics Trend

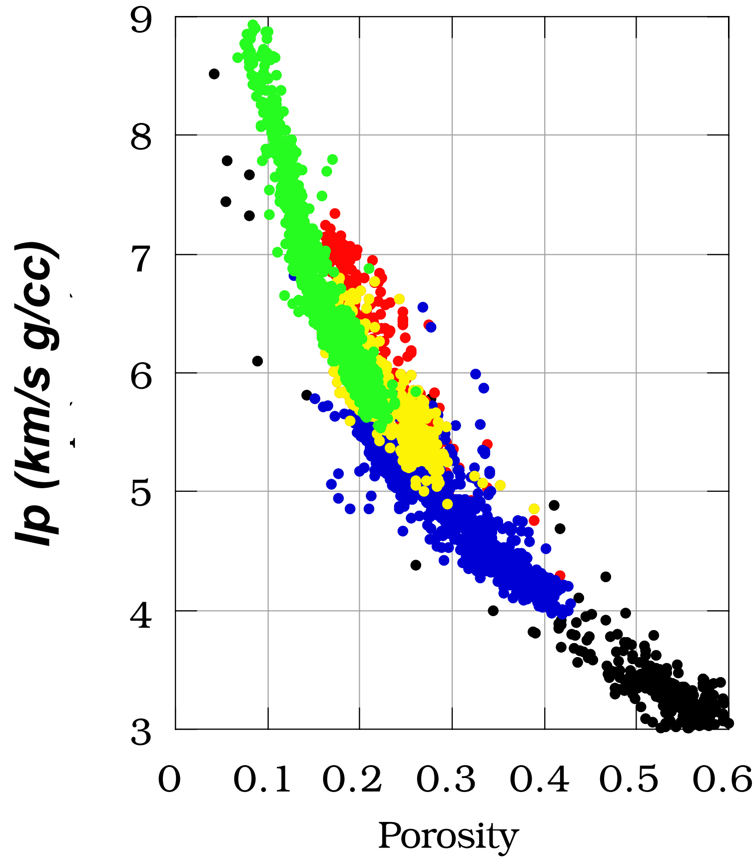
***Normally- and over-pressured parts of the well project onto the same rock physics trend, same as the lab data.***



# Universality of Compaction and Undercompaction in Rock Physics Space

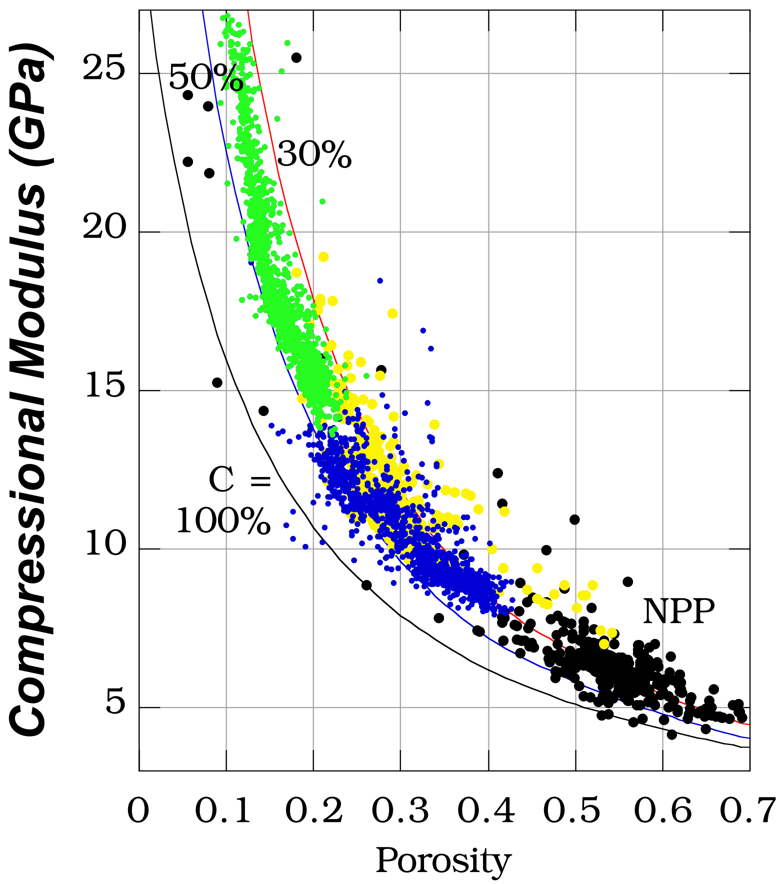
**Moreover, well log data from different wells worldwide fall onto the same Ip-porosity trend. Different color means different well.**

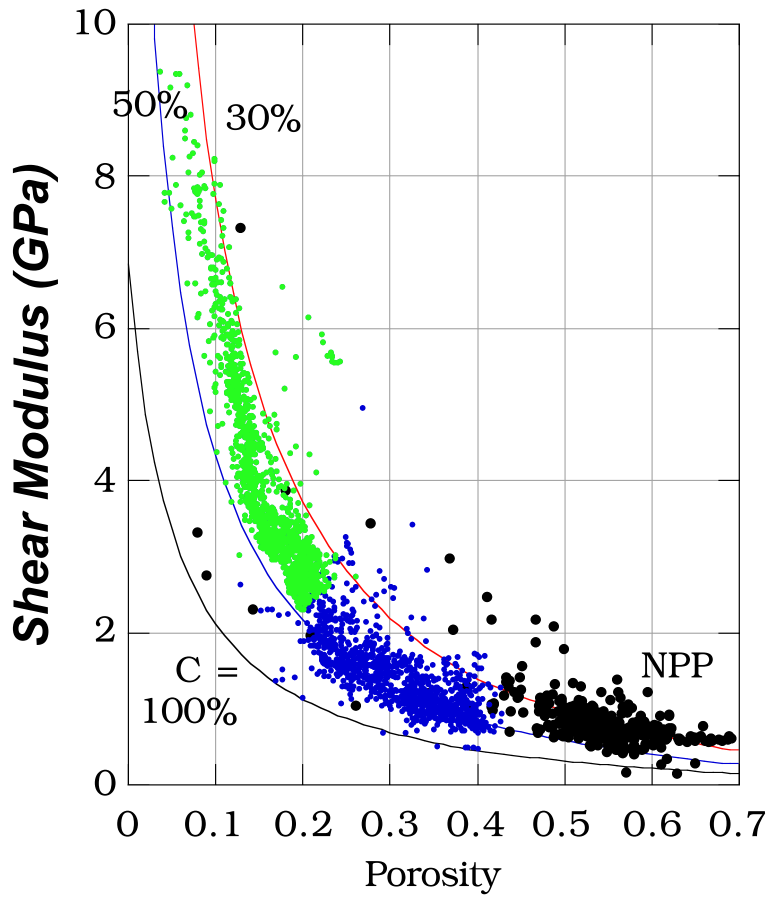


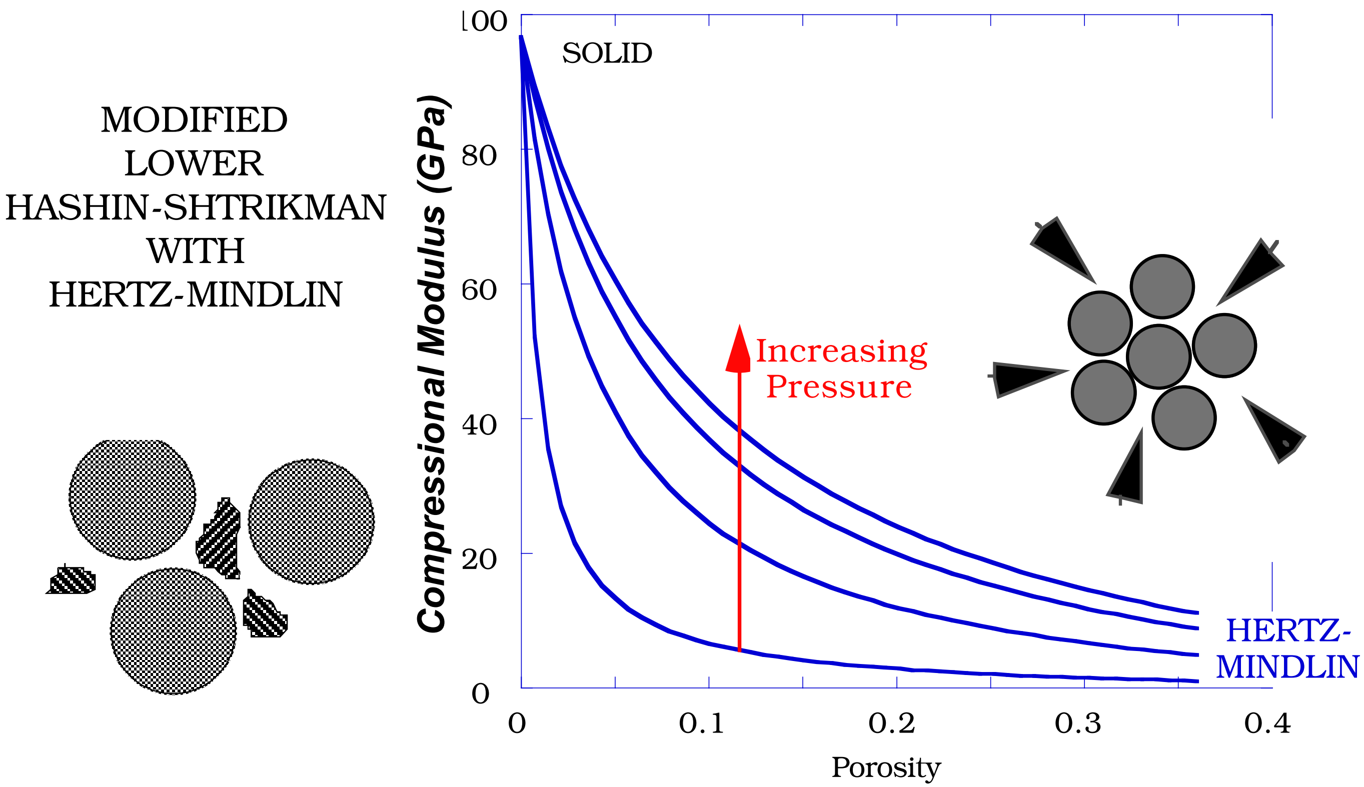
# Universality of Compaction and Undercompaction in Rock Physics Space

**The curves are from "unconsolidated sediment" model that relates elastic properties to porosity, lithology, and pore fluid compressibility.**



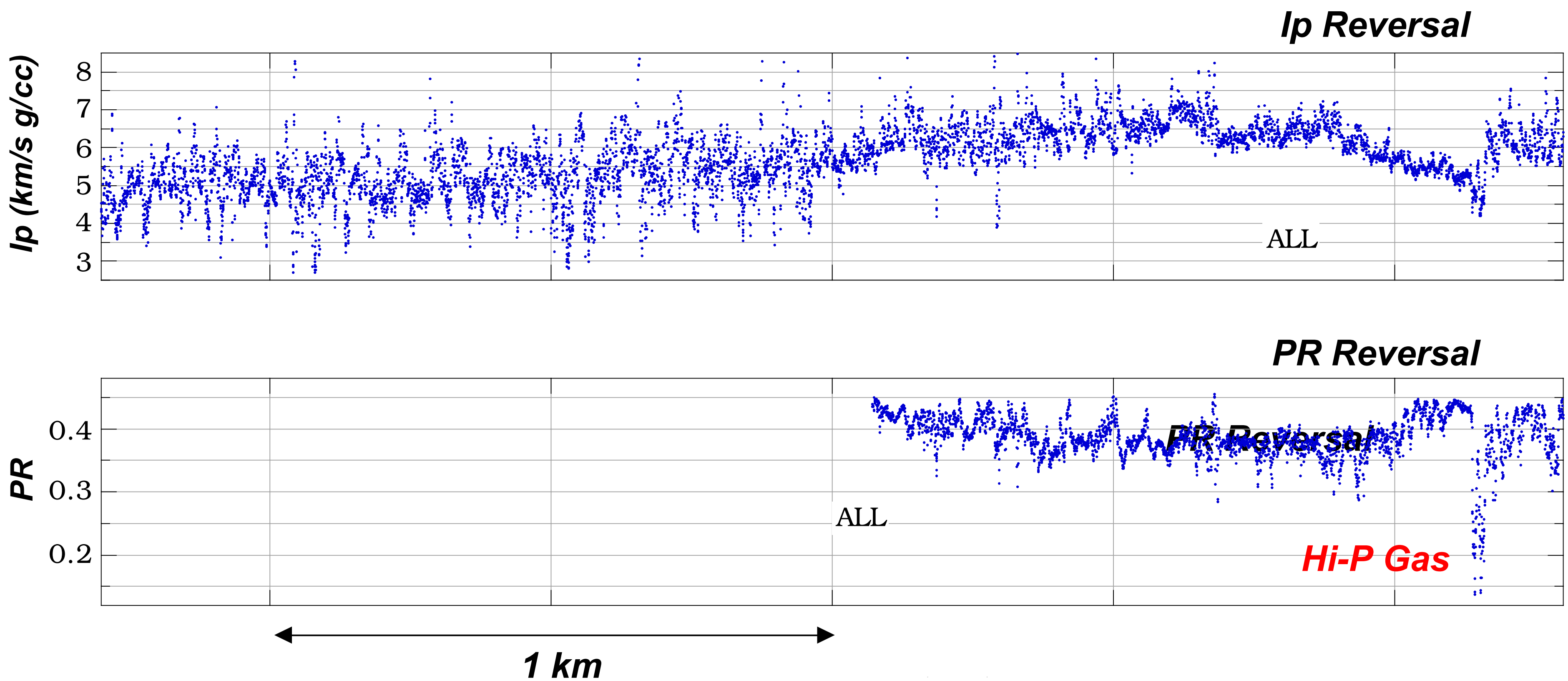
# Rational Effective-Medium Model
# Uncemented Particles
## Hertz-Mindlin Theory + Modified Lower Hashin-Shtrikman




***Hertz-Mindlin theory provides expressions for the contact stiffness between two elastic particles. Based on these expressions, we can derive the elastic moduli for uncemented sediment at critical porosity depending on pressure and pore fluid.***

# Compaction and Undercompaction Due to Pore Pressure in AI-EI Space

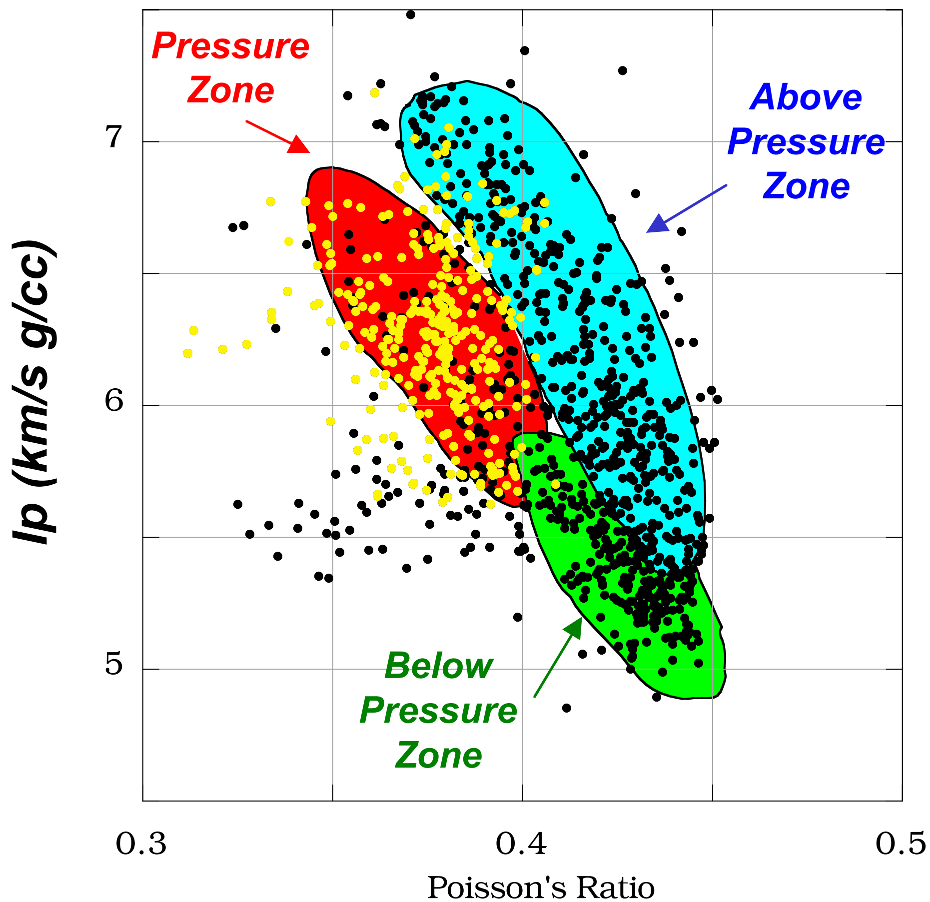
## Abnormal pore pressure also results in AI and Poisson's ratio reversals



# Compaction and Undercompaction Due to Pore Pressure in AI-EI Space

**PR is very sensitive to mineralogy. We may want to use it to detect mineralogical changes associated with onset of overpressure. May help resolve the non-uniqueness of universality of Ip-ϕ trends**

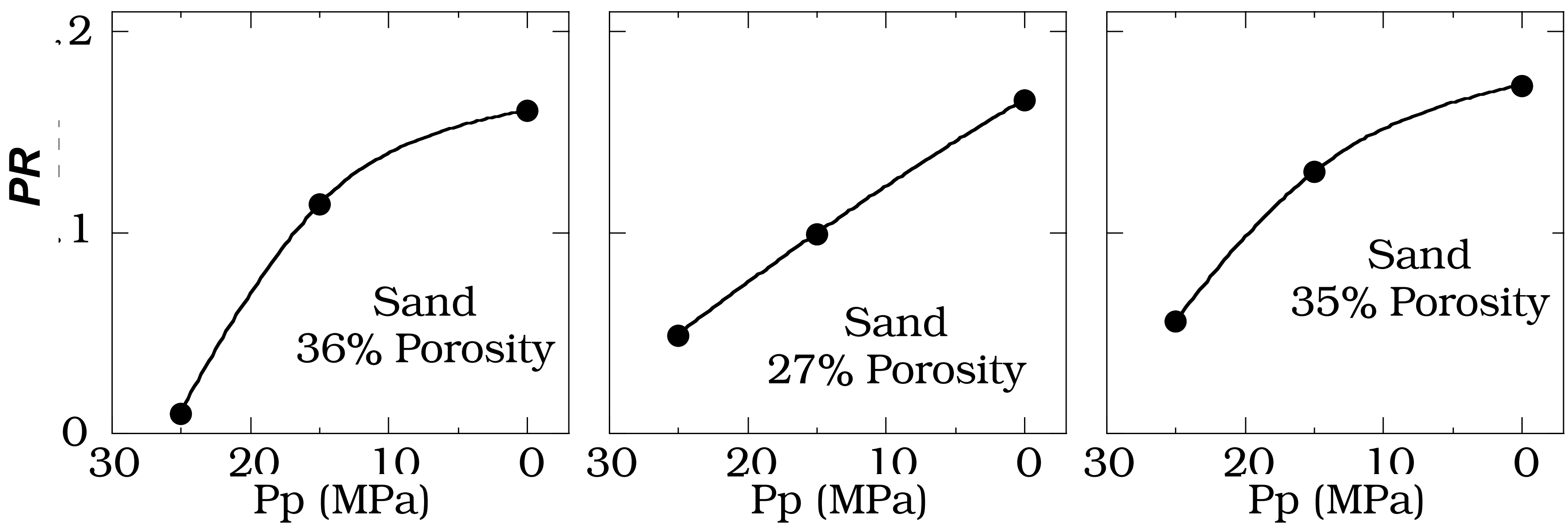
**Just Shales**



# High Pressure in Gas Sands

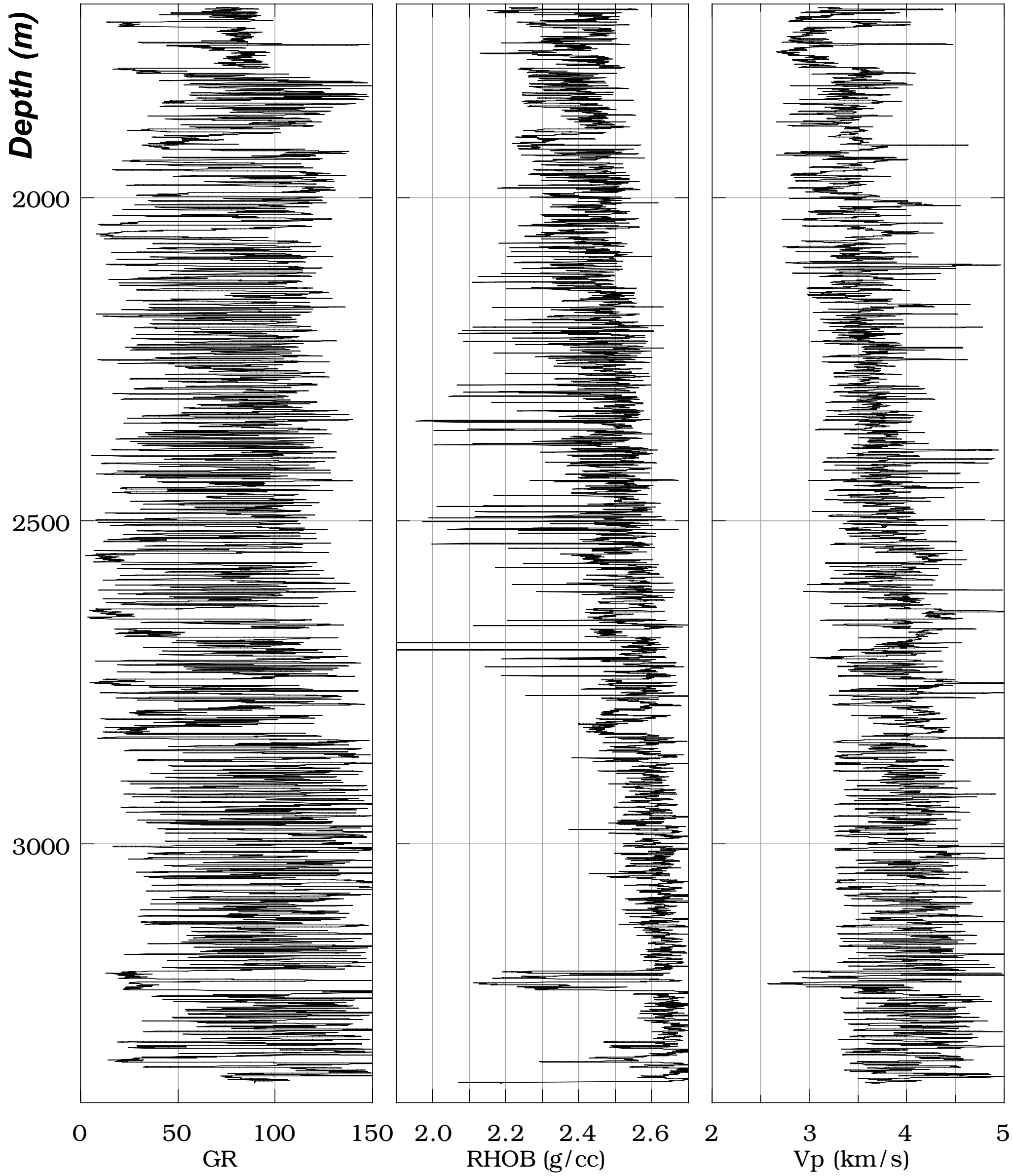
**High pore pressure in rock with gas results in smaller Poisson's ratio. Velocity may vary a lot among rocks but PR behavior is universal.**

**Plots based on lab data.**



# Normal Compaction in Shales

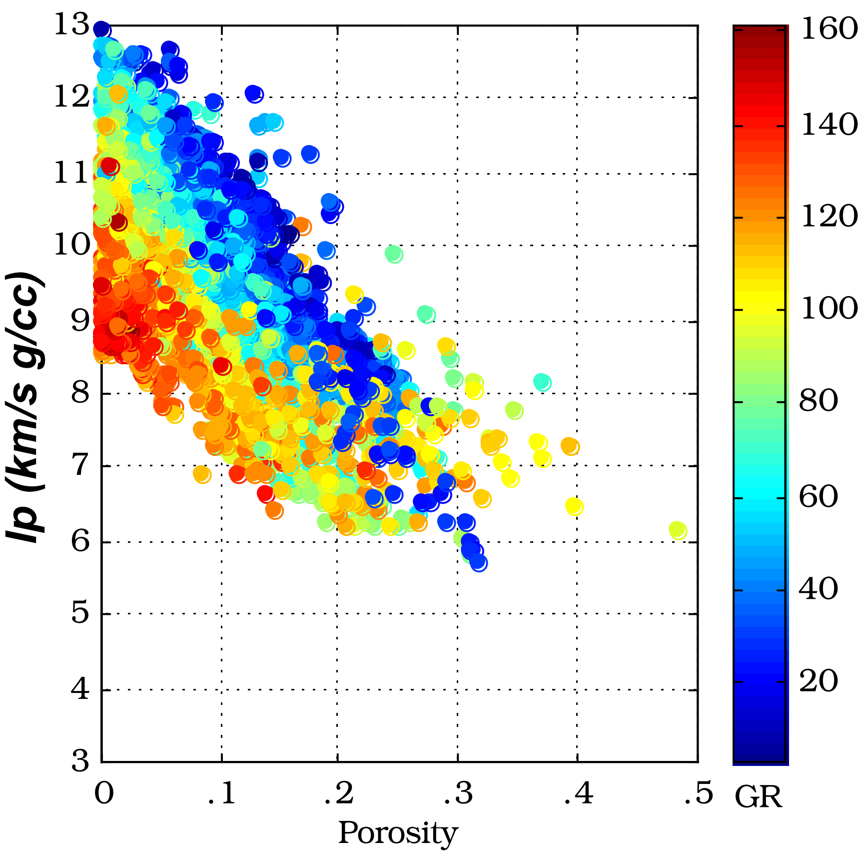
## Log data show monotonic compaction versus depth.

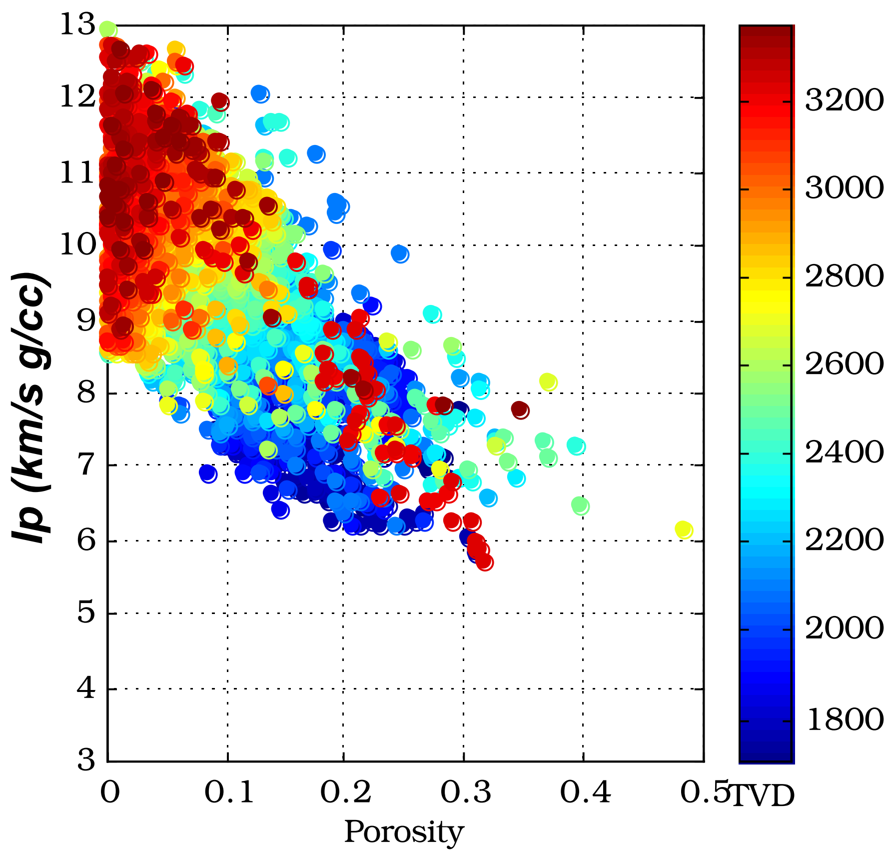


# Normal Compaction in Shales

## Log data show monotonic compaction versus depth.

***Left -- color coding by GR highlights compaction trends for shale and sand.***
***Right -- color coding by depth shows porosity collapse and impedance increase.***

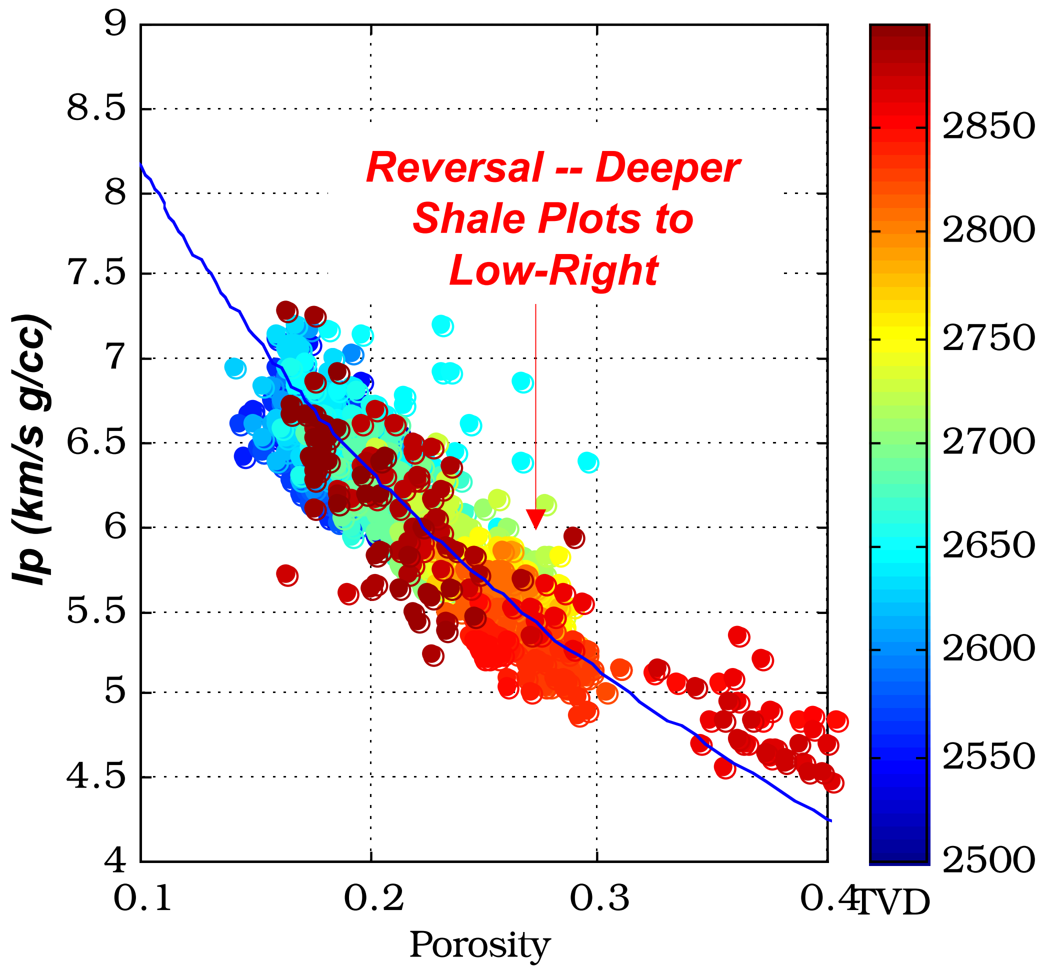


# Undercompaction in Shales

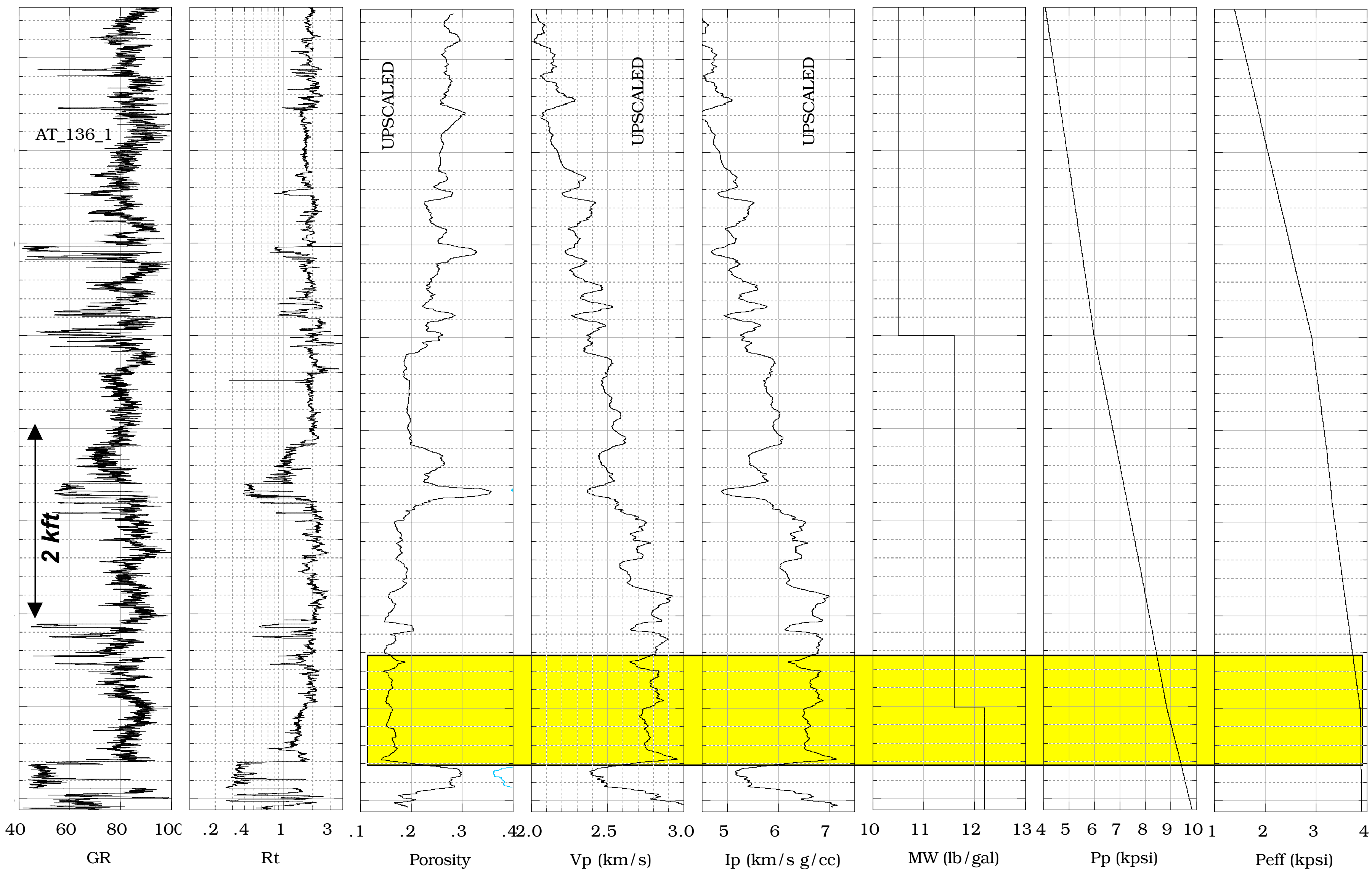
## Log data show reverse compaction versus depth.

***Color coding by depth shows porosity and impedance reversal. Overpressured shales stay on the same rock physics trend as normally pressured shales.***



# Undercompaction in Shales -- Example 2

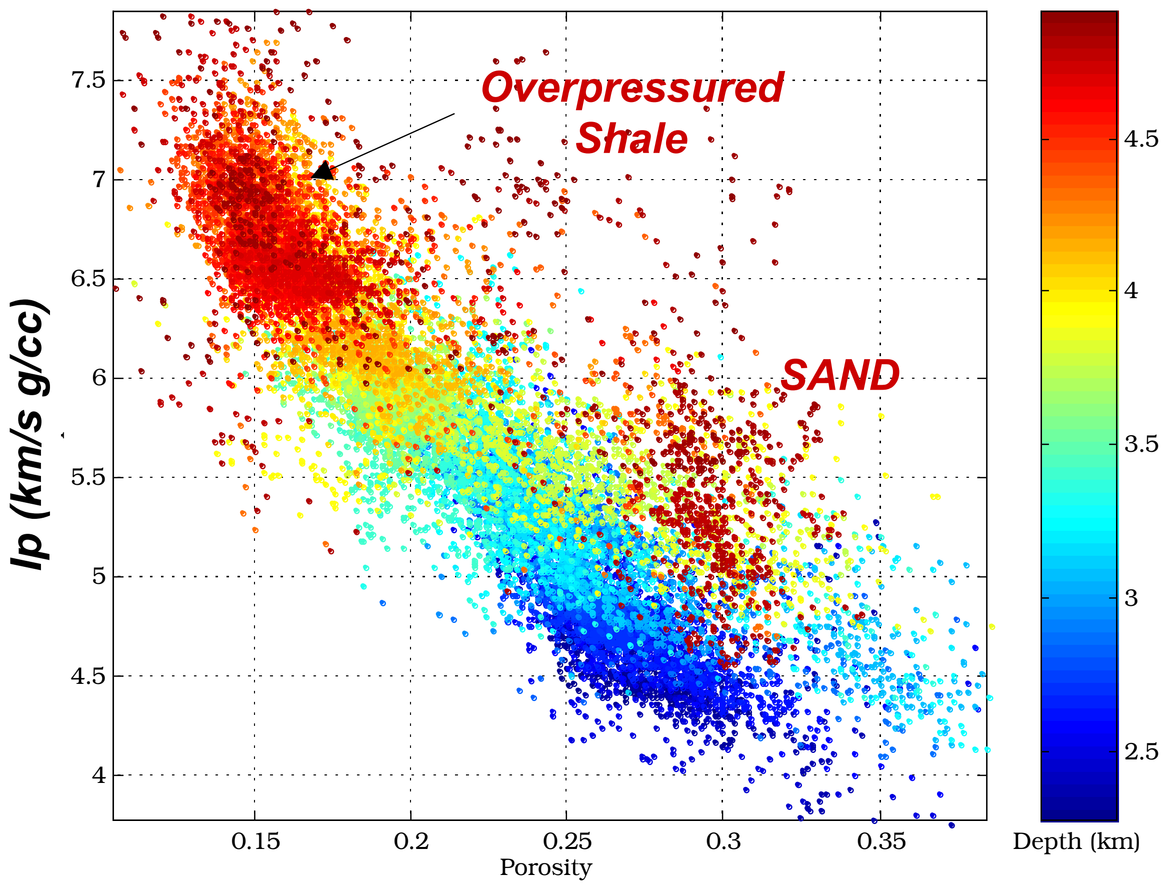
## Mudweight Steps Approximately Match Porosity and Velocity Flattening



# Undercompaction in Shales -- Example 2

***Overpressured shales stay on the same rock physics trend as normally pressured shales.***

**Color-Coded by Depth**



# Undercompaction and Vp/Vs Ratio

***In overpressured (softer) sediments, the Vp/Vs ratio is high and deviates from the established Vp/Vs relations.***

***In overpressured gas sands the opposite is true -- the Vp/Vs ratio is small.***

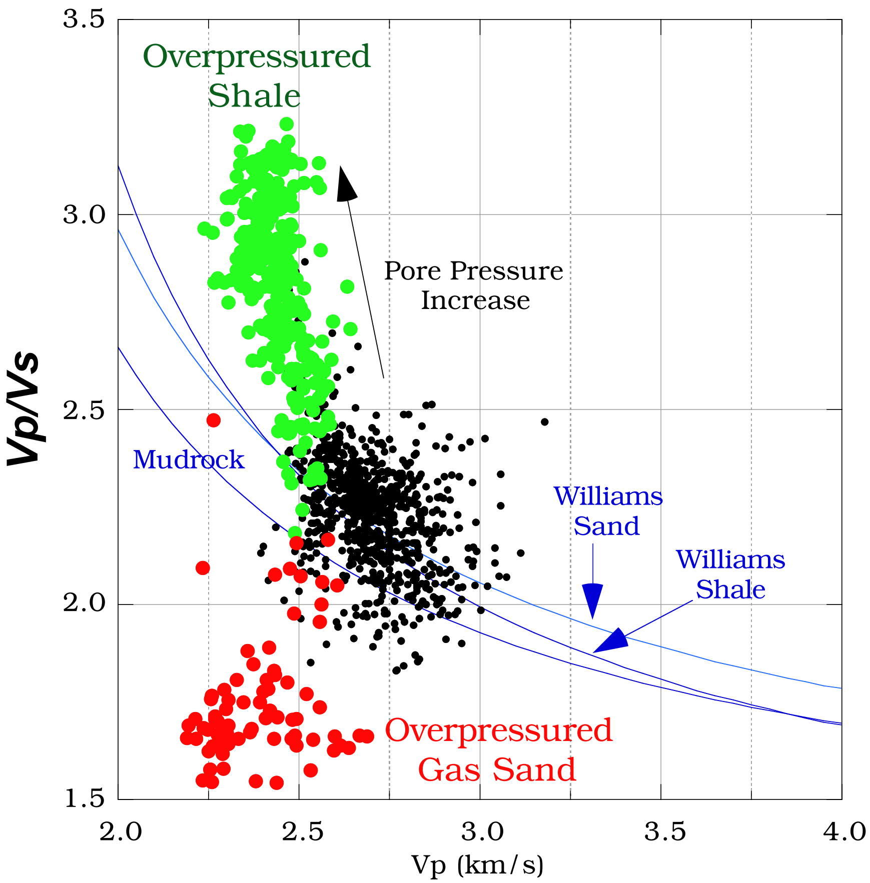
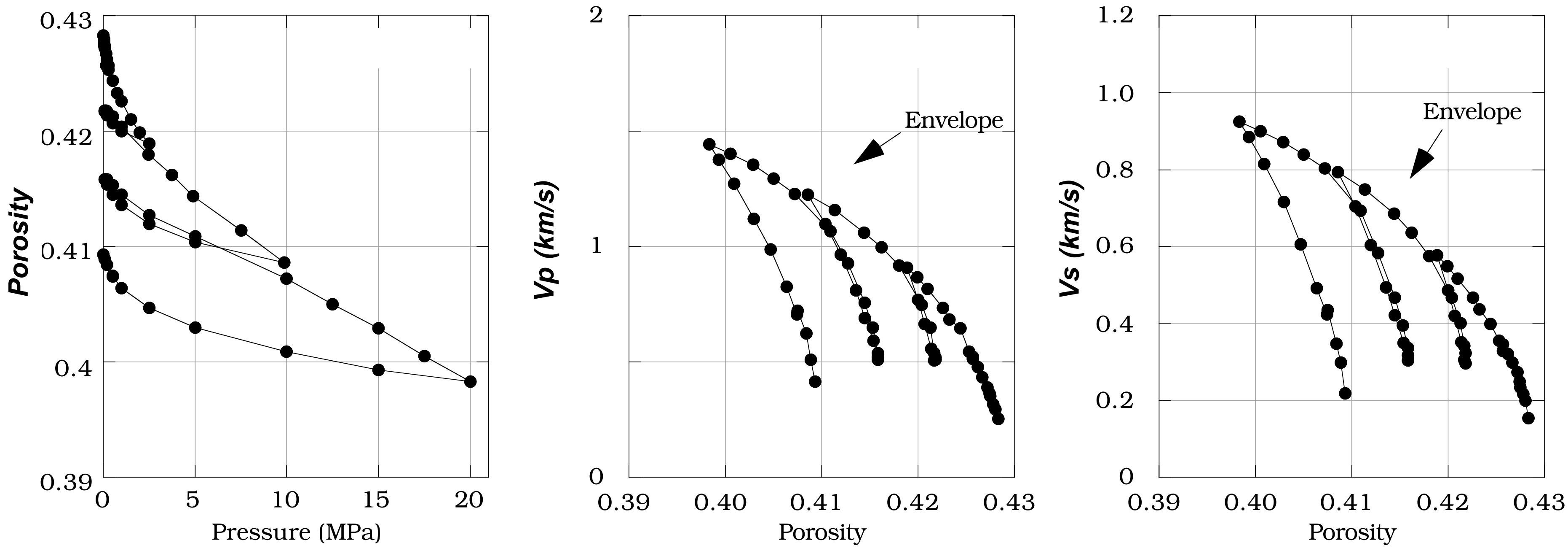



***Figure shows a Vp/Vs versus Vp plot for a well with an overpressured shale section (green) and overpressured gas sand (red). Black symbols are for normally pressured shales. Blue curves show established relations for water-saturated sediment.***

# Compaction and Unloading in Sands

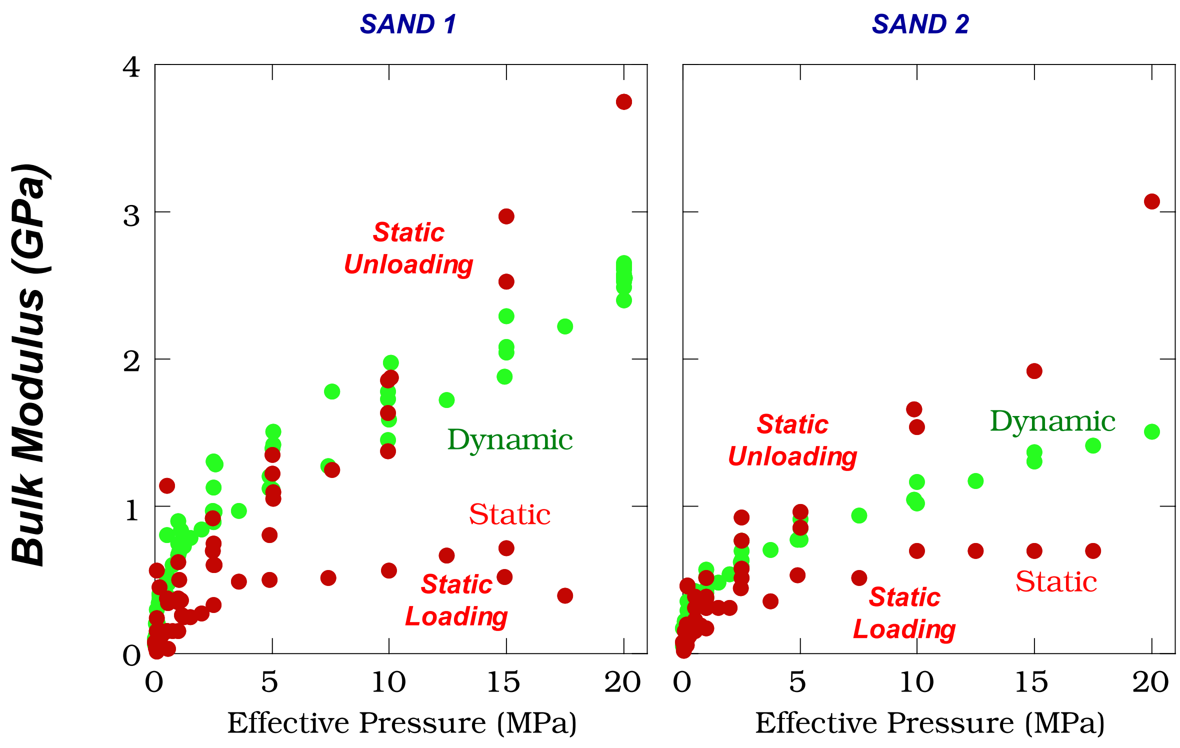
## Loading and unloading produce different strain paths in sand

### Compaction and elastic unloading in a sand.



# Compaction and Unloading in Sands

## Static and Dynamic Moduli



## *Conclusion*

***The projection of compaction (loading) process into the impedance-porosity plane produces a universal trend typical for many soft shales and independent of depth.***

***AI/EI technique may help detect pressure-associated lithology changes in shales. But what to do in frontier areas where impedance inversion is difficult?***

***Unloading (uplift) is different from loading (compaction) and will produce a different trend because of irreversible porosity reduction.***

# Pore Fluid and Pressure Diagnostic from AI and EI

***The softer the rock with liquid the larger the Poisson's Ratio. The softer the rock with gas the smaller the Poisson's ratio.***