# HETEROGENEITY AND SCALING IN GEOLOGIC MEDIA: APPLICATIONS TO TRANSPORT IN THE VADOSE AND SATURATED ZONES

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**New England Research**

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# Hypothesis

Both fracture and matrix properties have many juxtaposed scales and processes.

For sedimentary materials the scales are:

- pore scale (irregularities in grain surface roughness and cementation)
- grain packing faults (and the resulting correlated porosity structures)
- scale dominated by sorting or winnowing due to depositional processes
- scale of geomorphology at the time of deposition.

Studies of heterogeneity and scaling will cross one or more of these boundaries and some means must be devised to recognize and separate them in the description, then re-integrate them in building useful models.

To understand the properties at one scale we must understand the magnitude of influences at the next smaller scale. This process can range from simply assigning an average value to homogeneous sub-units to building a scaling geometry of the whole from the description of heterogeneity and spatial correlations of the sub-units.

# Proposal

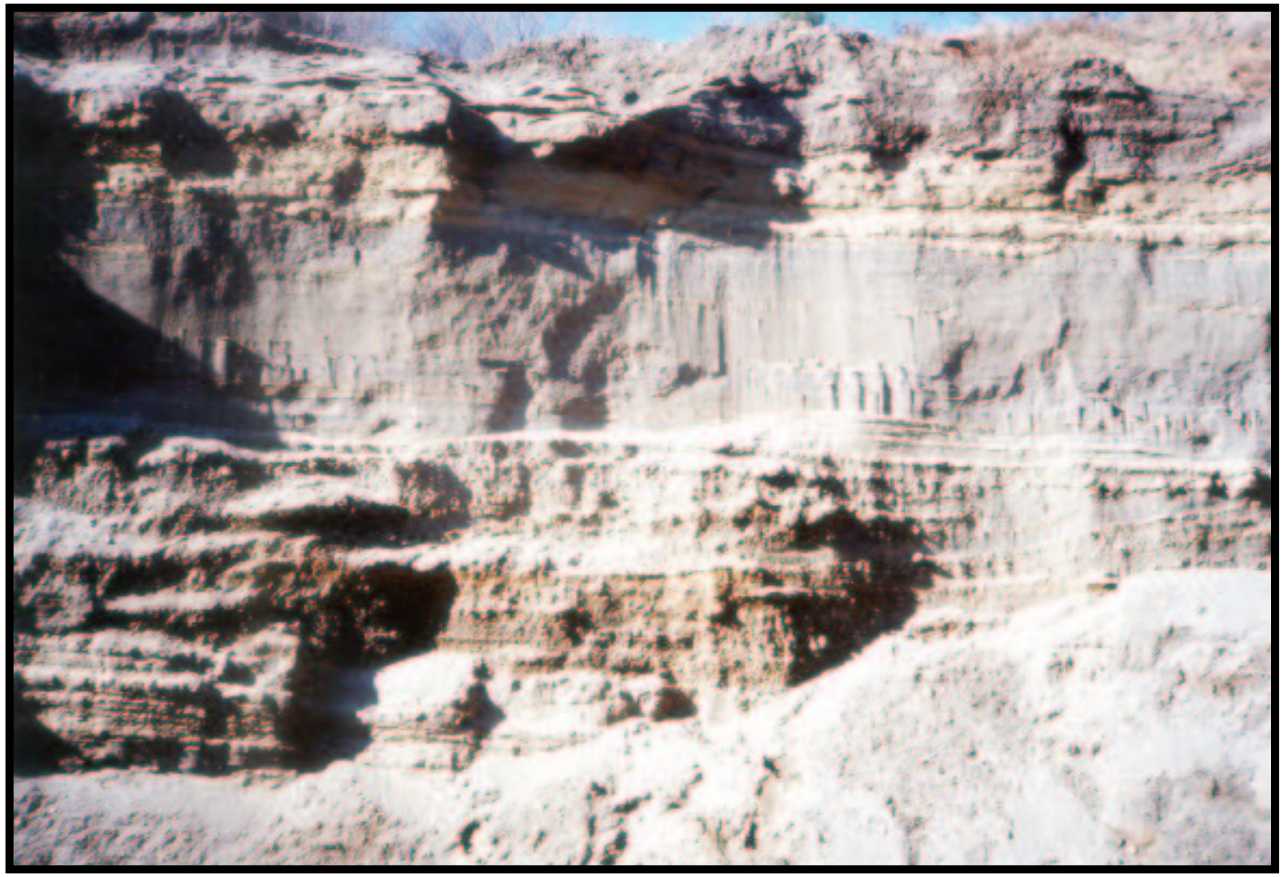
We propose a study of heterogeneity and anisotropy in geometry, permeability, and geophysical response from the sub-millimeter (pore) scale to the meter scale in geologic media.

Upon analysis of these data our goal is to develop useful models of the flow-related properties of geologic materials in the vadose and saturated zones. We define a *useful* model as one that reproduces key features such as degree, scale, and variability of channeling, with particular emphasis on supporting numerical modeling of flow and transport.

To accomplish these goals, we propose the following tasks:

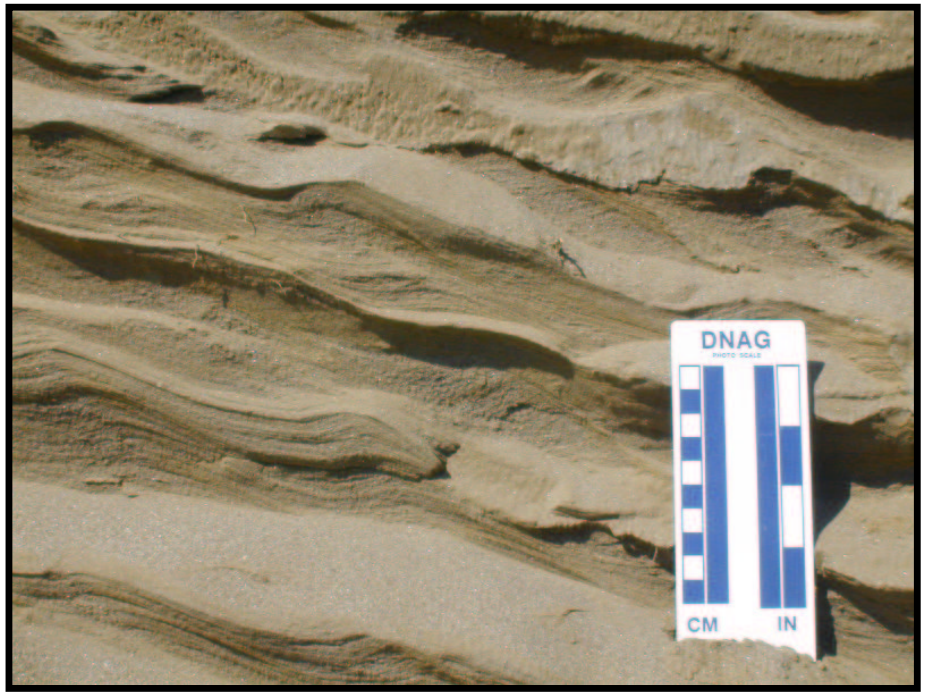
- Multi-scale measurements of heterogeneity and scaling of physical properties at the pore (microscopic), laboratory (mesoscopic), and backyard field (macroscopic) scales.
- Description and synthesis of these data and development of mathematical models.
- Parameter studies to explore these models in the context of transport in the vadose and saturated zones.

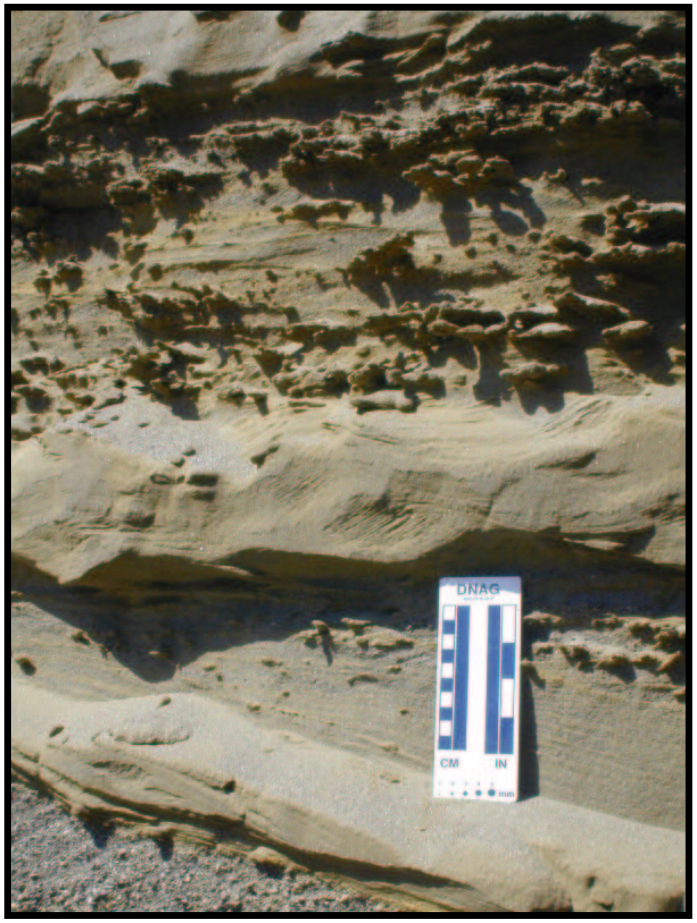
# Field Site: Scotty's Gravel Quarry



- Glacial Kame Terrace
  - fluvial origin
  - unconsolidated sands, clays, and gravels; incipient lithification
  - variety of sedimentary structures at multiple length scales
  - joints and faults

# Field Site: Heterogeneity



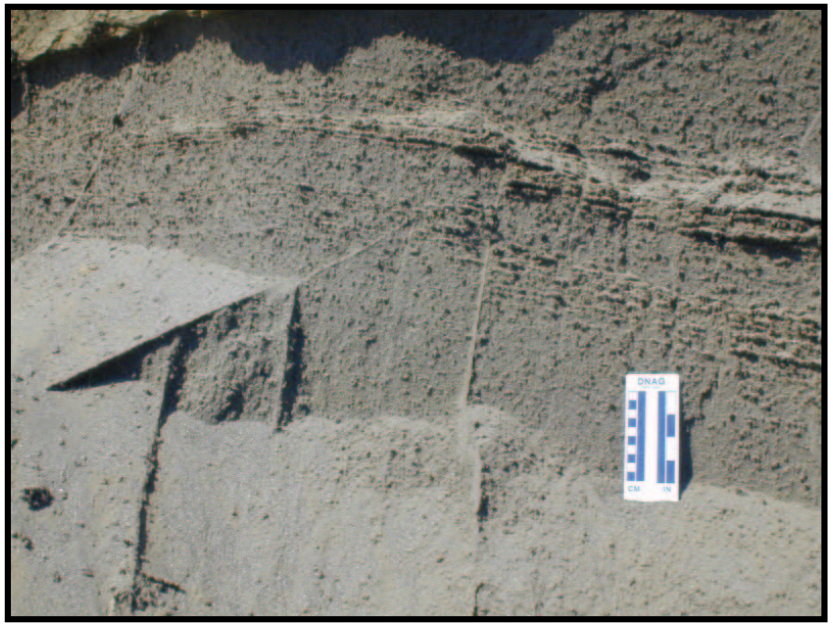



***sedimentary structures***

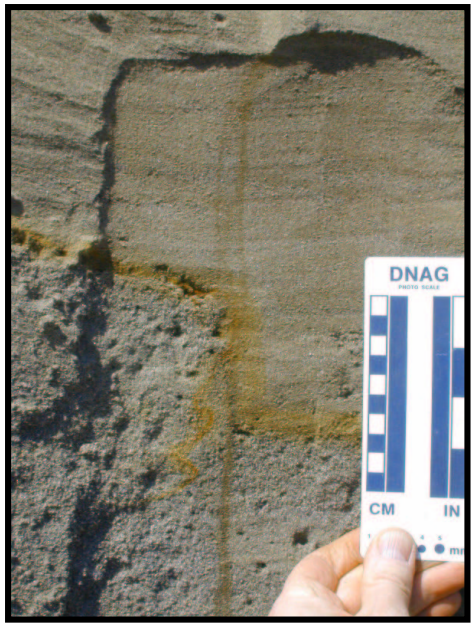
***and***

***incipient lithification***

# Field Site: Heterogeneity



***joints and faults***



# Field Site: Sampling

***obtaining undisturbed samples for laboratory study***

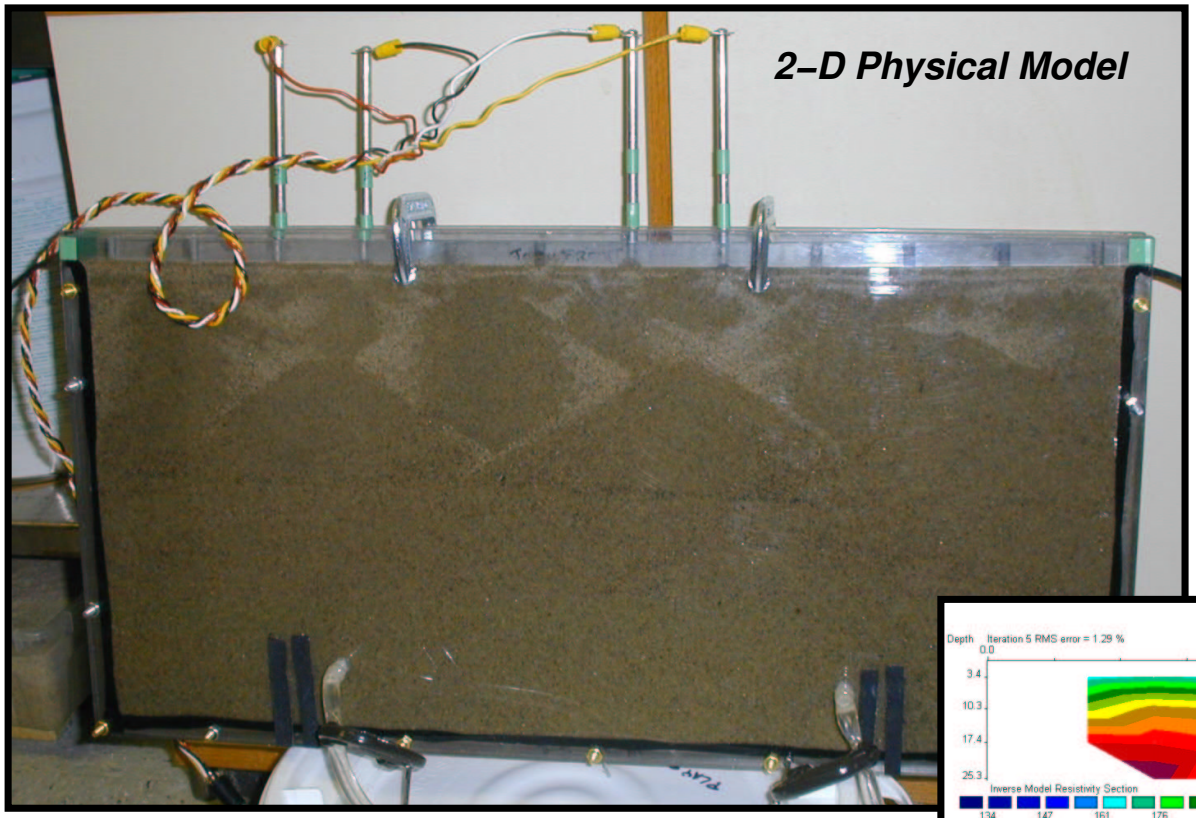
# Field Studies: Equipment

***Field measurement of permeability distributions***

***using***

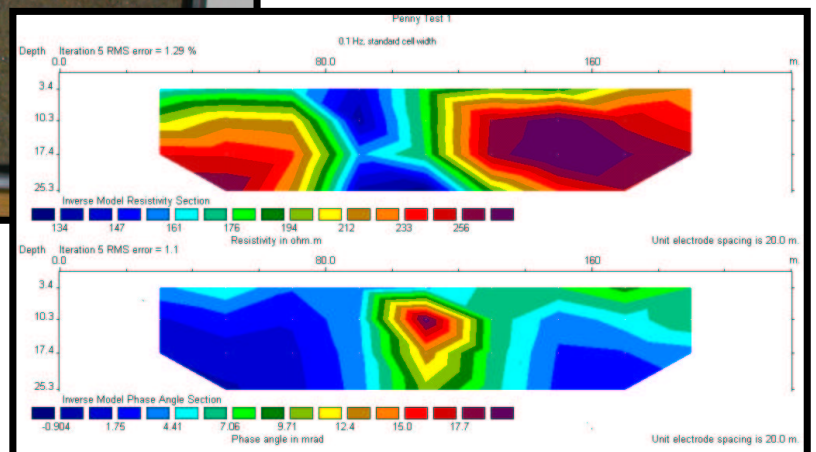
***TinyPerm II: portable syringe air permeameter***

# Evaluation of Methods




## Ant Farm

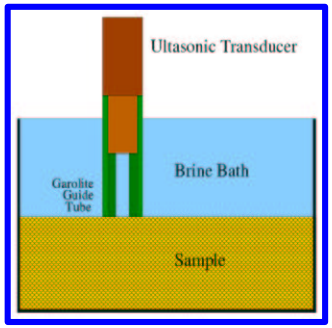
***Studying the resolving power of field resistivity and IP methods for description of heterogeneity***



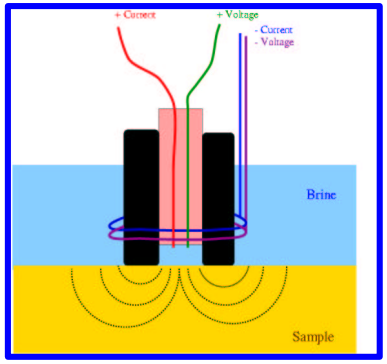

***Resistivity and IP Inversion***

# *Autoscan*

## Current Probes



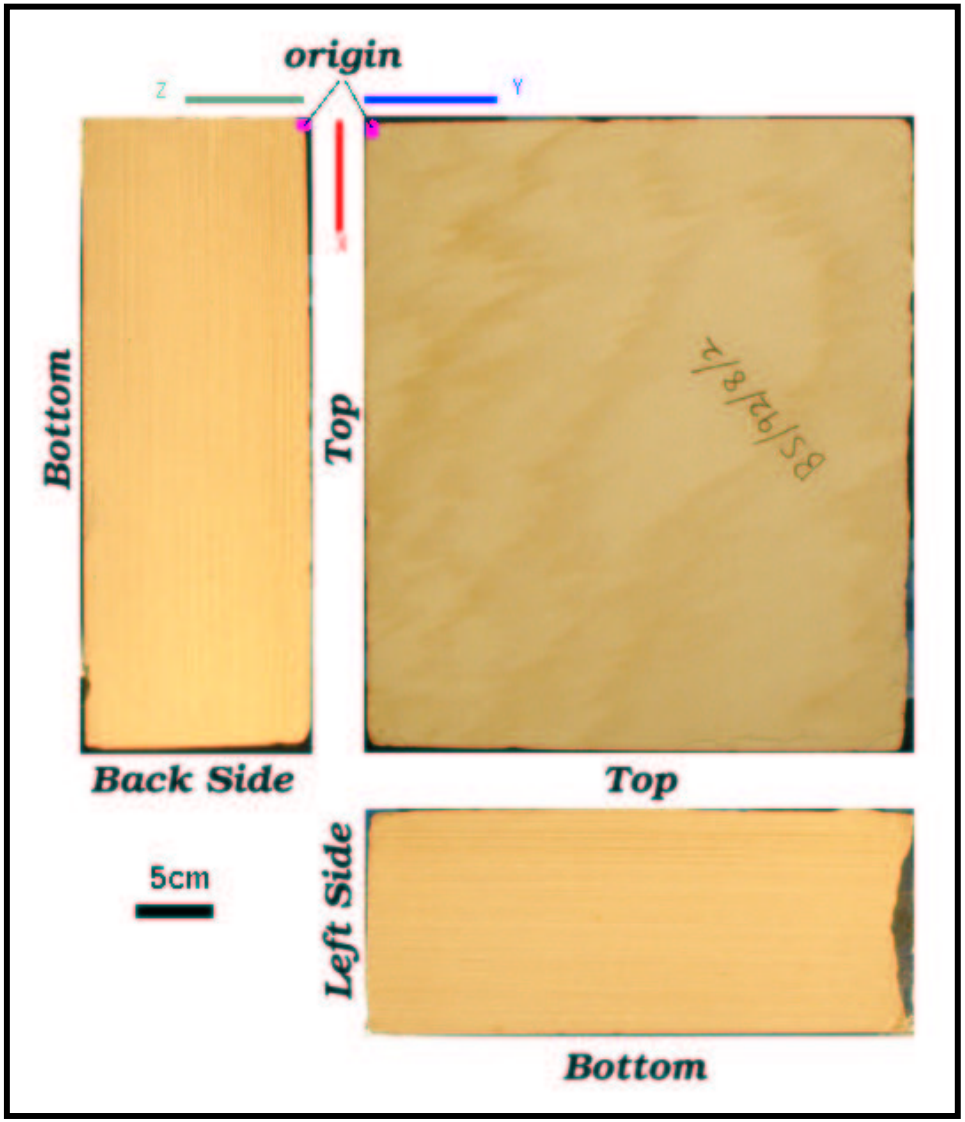

Acoustic Impedance and Permeability



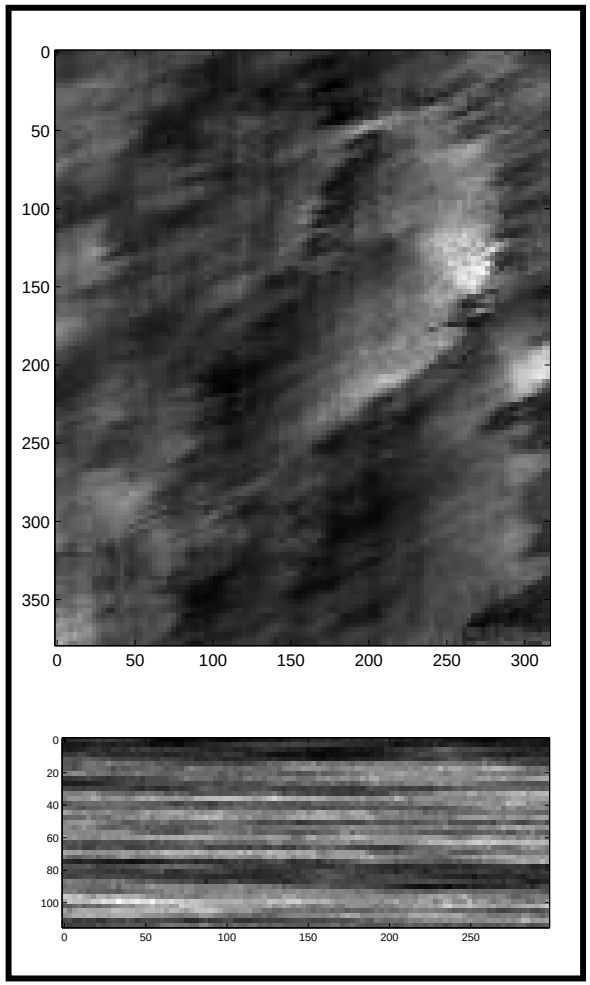

Complex Electrical Impedance

Permeability and Ultrasonic Velocity

# Baseline Study: Berea Sandstone

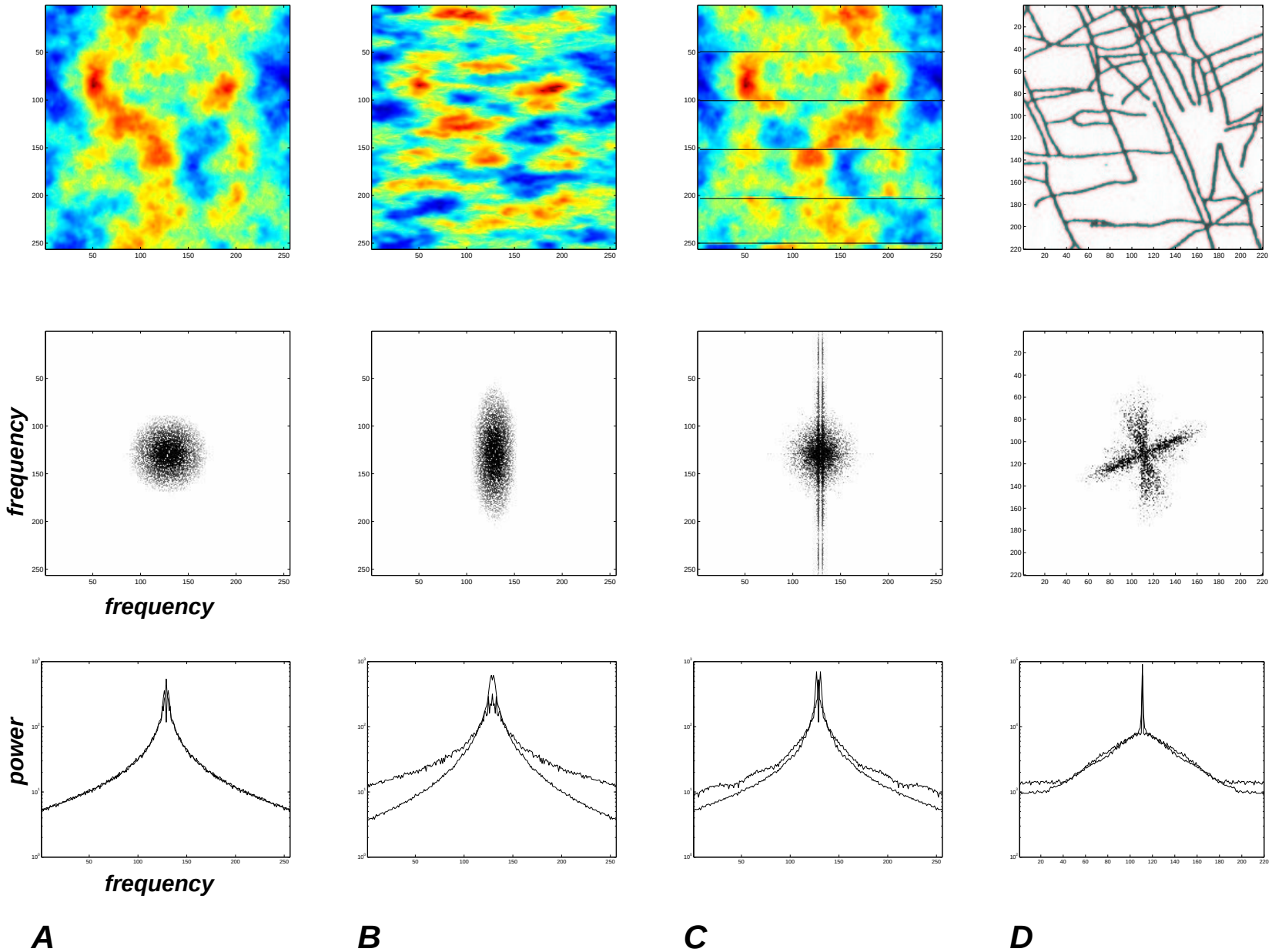



*photograph of sample*

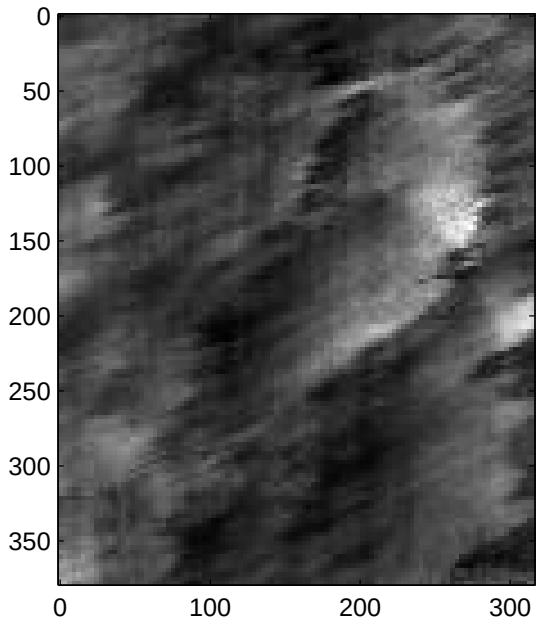


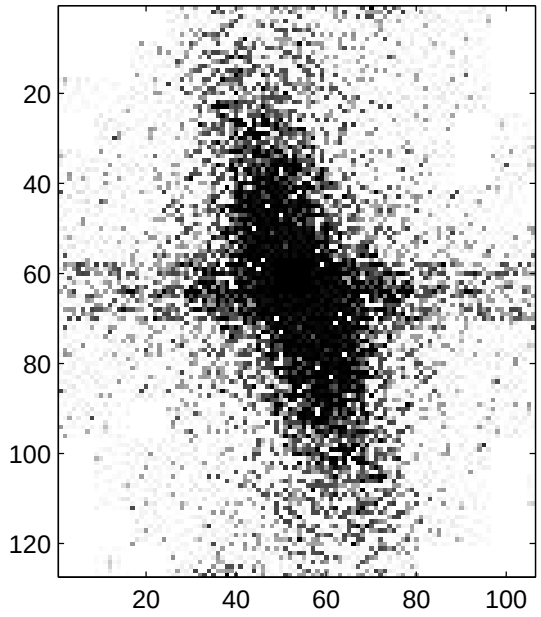

*air permeability*

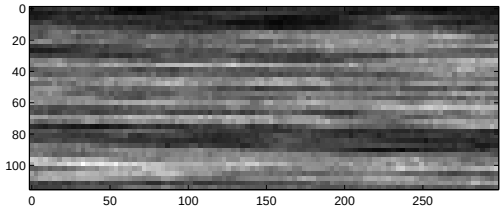
# Data analysis: scaling, heterogeneity, anisotropy

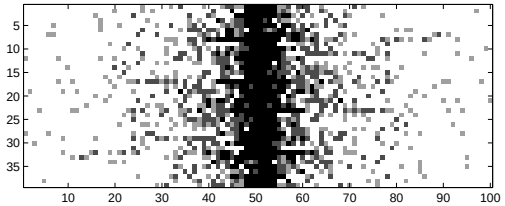


# Baseline Study: Data Analysis



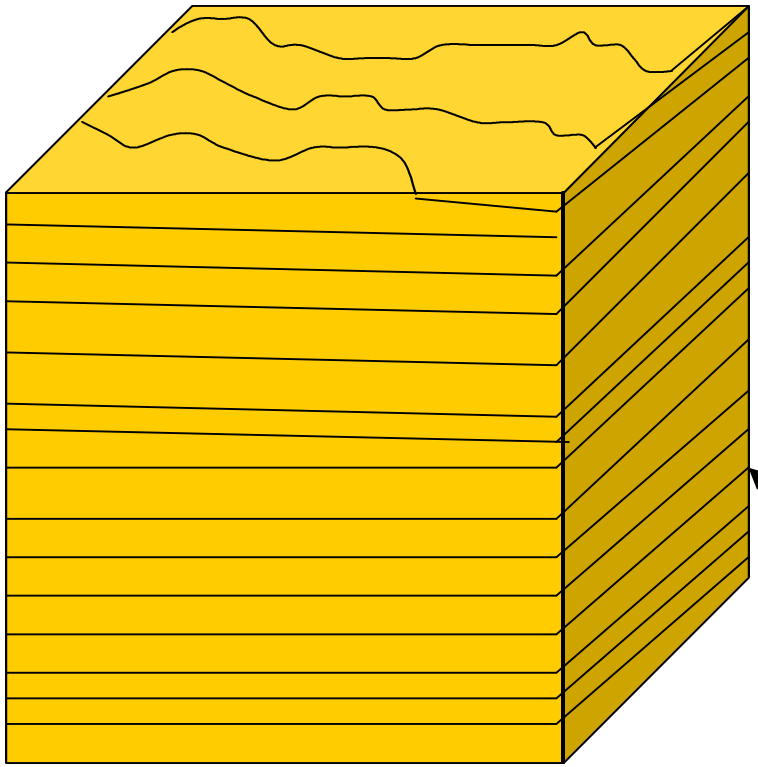




***natural and induced anisotropic permeability structures***

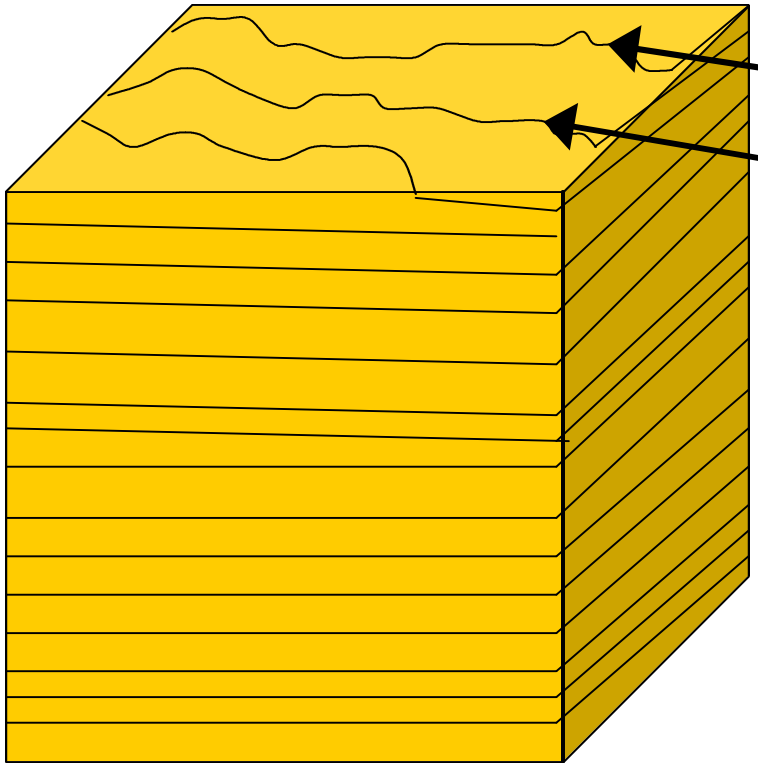
# Berea Sandstone

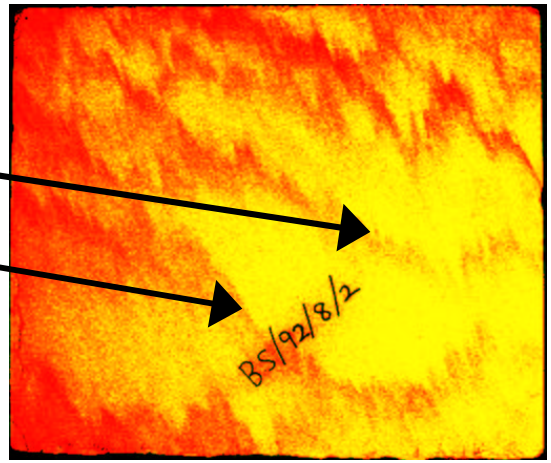


**Enhanced Image**

**Fine Bedding at the sub mm scale**

# Berea :
# Top View

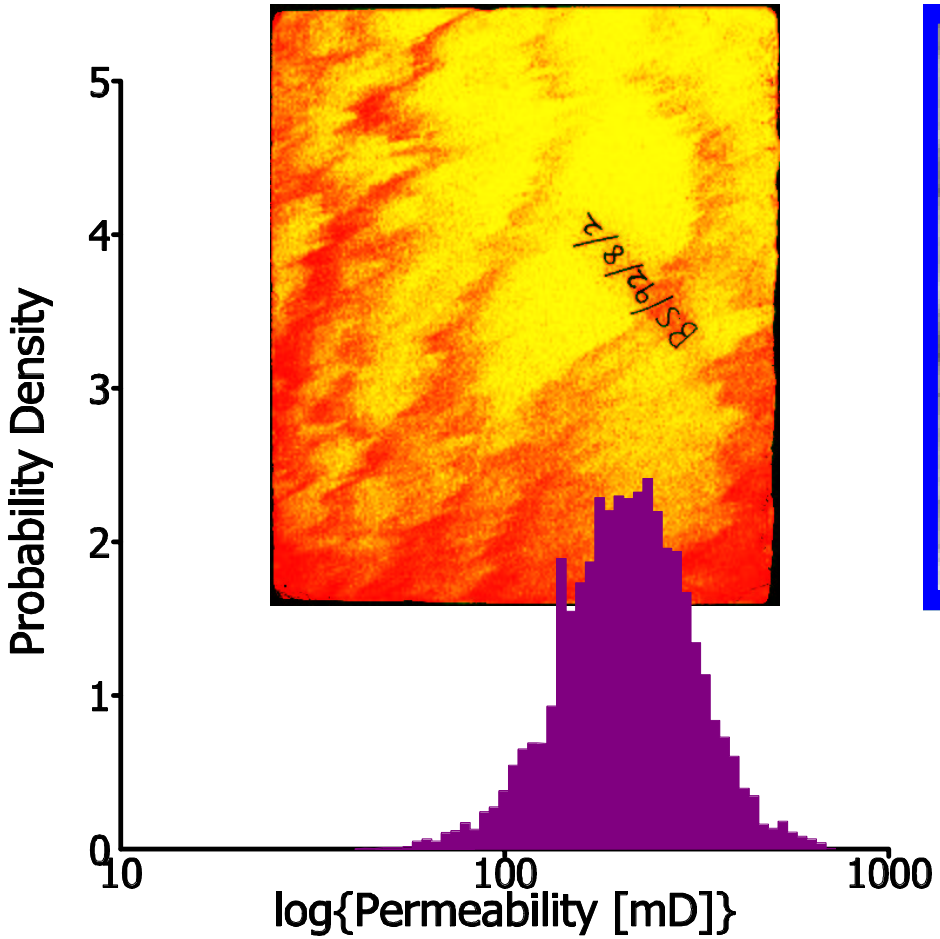


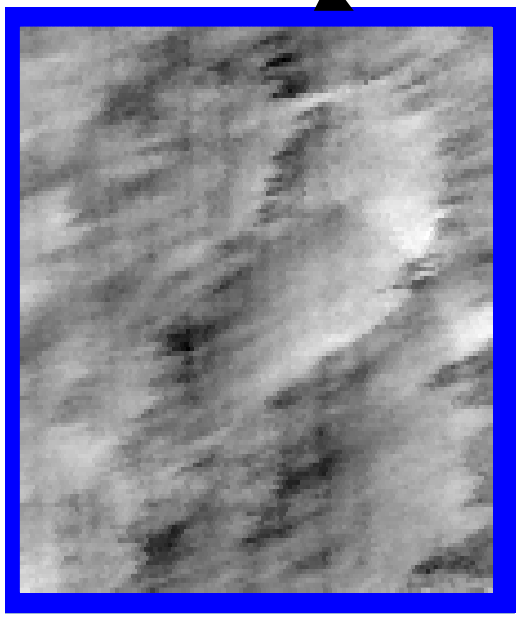



**Enhanced Image**

**Slight dip and/or topography causes outcropping of dark streaks.**

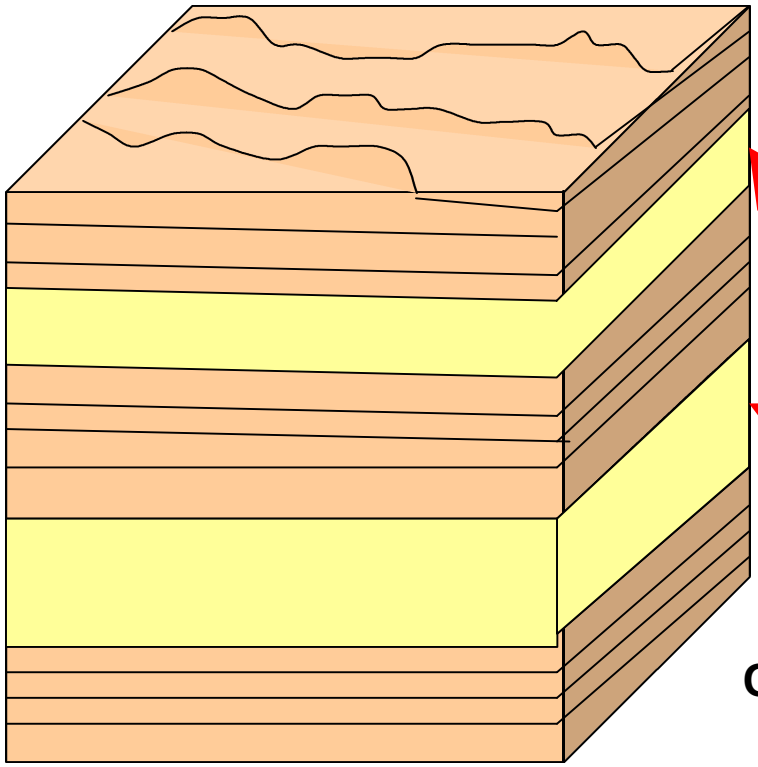
# Permeability Map : 3 mm probe tip



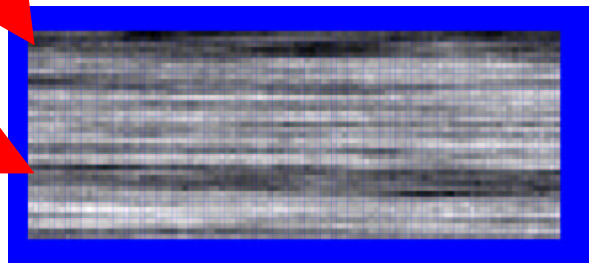



Dark streaks are associated with low permeability, and the permeability distribution within a few beds is log-normal

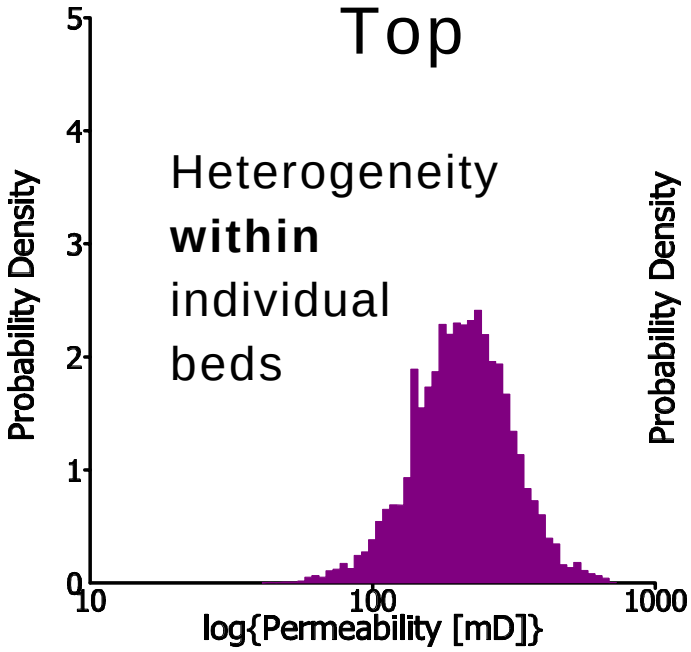
# Berea Permeability : Side View

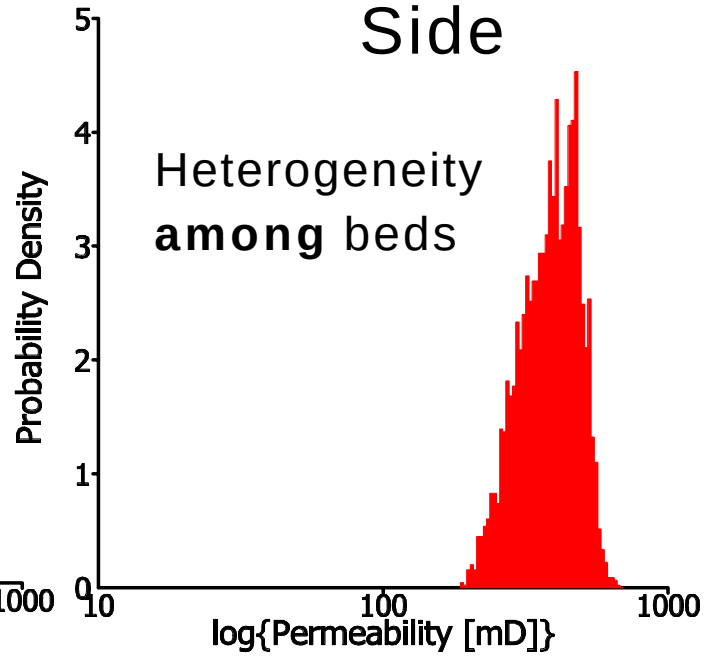


Permeability : 3 mm probe



Correlated groups of beds form heterogeneity at the cm scale



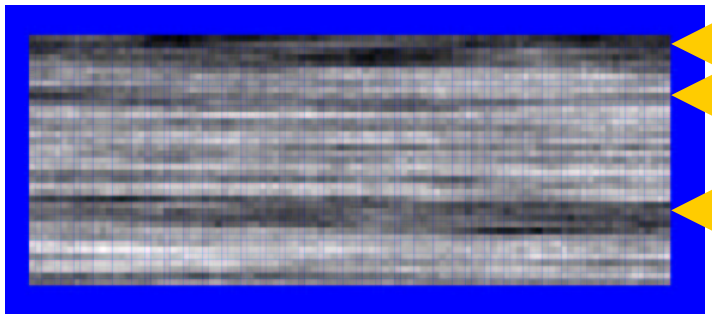

Predicted Anisotropy

$K_H / K_A = 1.20$

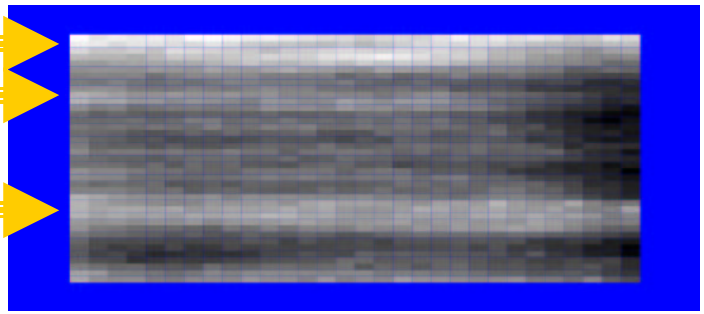
$K_H / K_A = 1.06$

**Berea Sandstone:**
**Joint interpretation of multiple properties**

Permeability



Velocity



In the plane of bedding, low permeability correlates with high velocity. This is an indicator of porosity variation.