PENNSTATE

Influence of Stress on the Ability of Coal to Sequester CO_2

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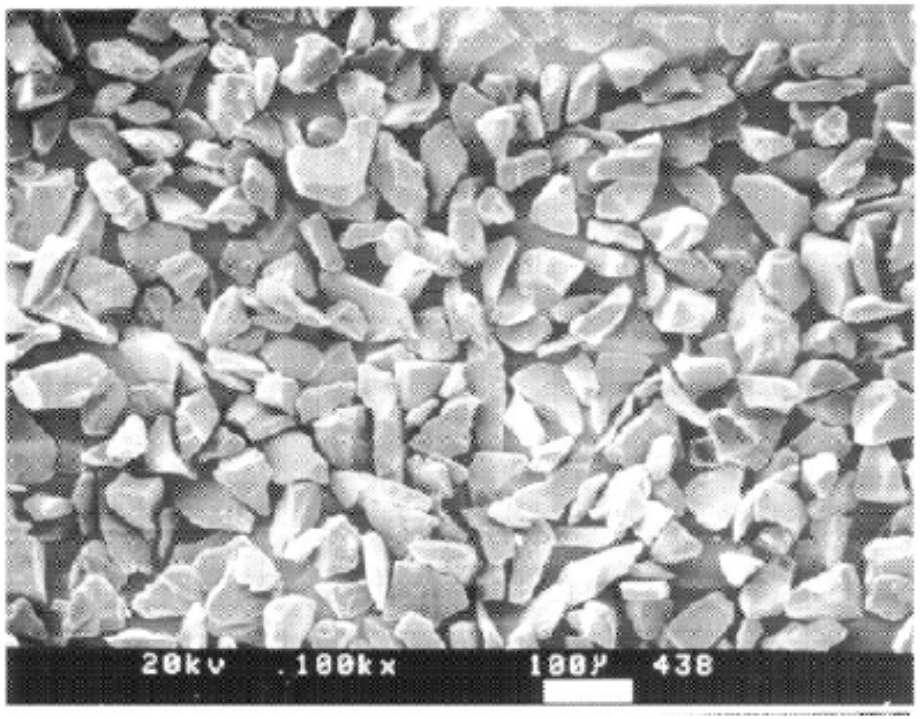
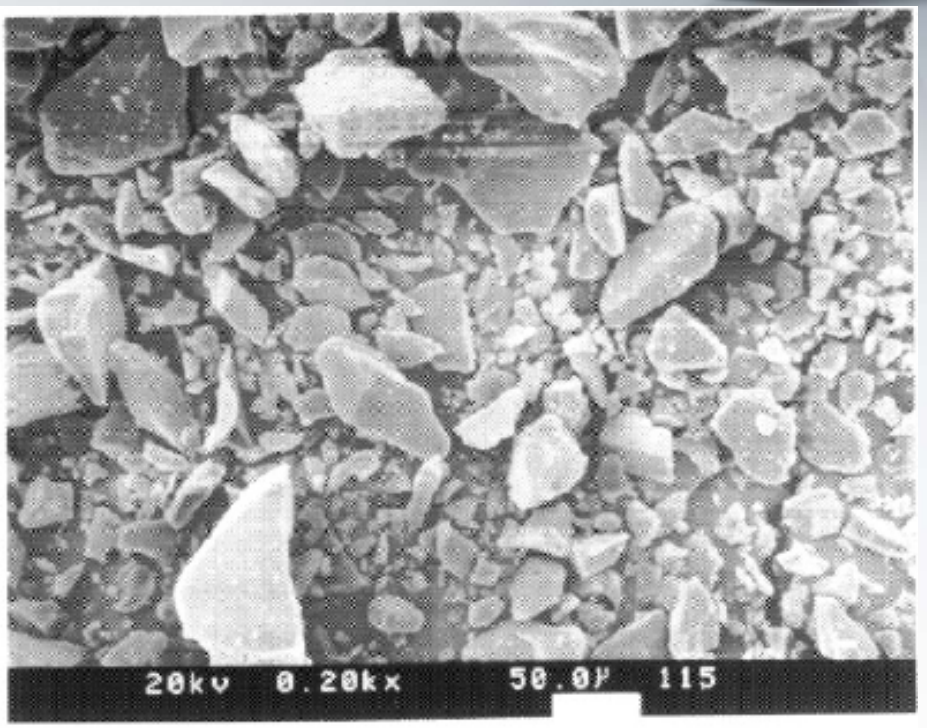
Why Intact Coal; Why Include Stress?

- Most coal research is on pulverized coal
  - By necessity (diversity within coal seams)
- Visible coal bands (lithotypes) behave differently
- CO_2 causes coal to swell
- Stress may limit swelling thus *reducing capacity?*
  - Pulverized coal experiments don't include stress
- Stress also reduces movement of gases

Pulverized Coal





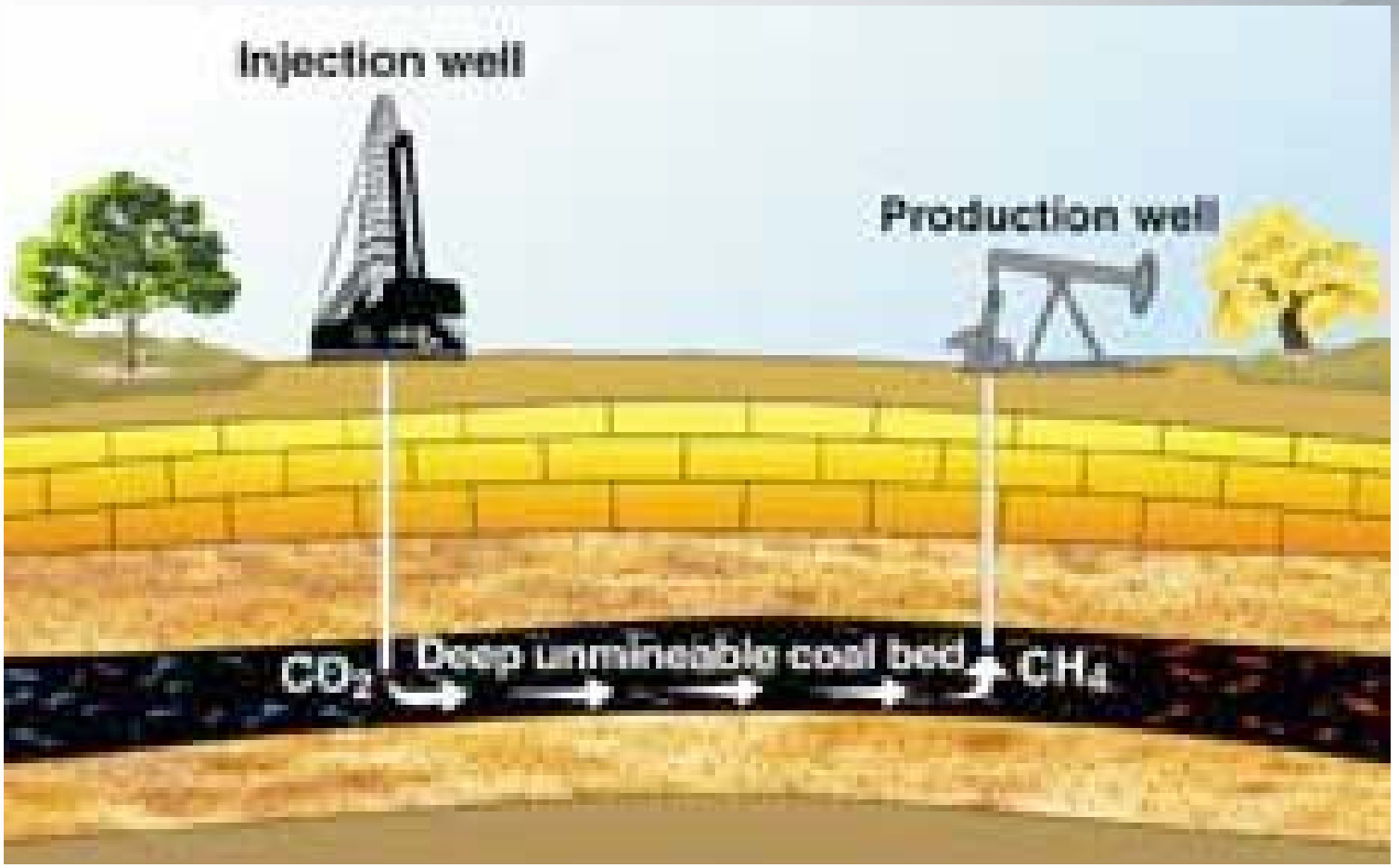
Wet Sieved size cut (very uncommon)

Dry Sieved cut

Considerable effort goes into ensuring the coal sample is representative of the seam (see Argonne or Penn State Coal Sample Bank)

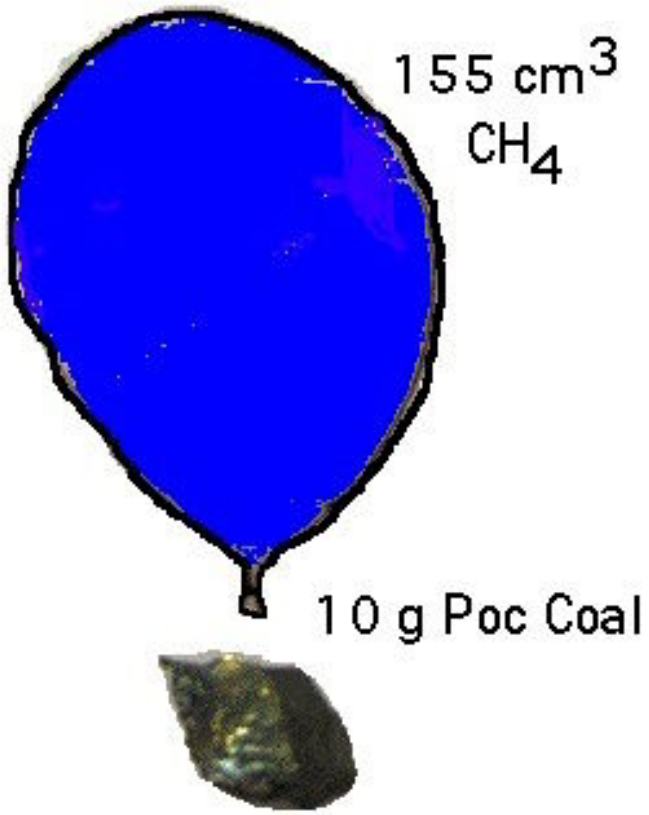
Scanning Electron Microscope Images

Sequestration with Coalbed Methane Production



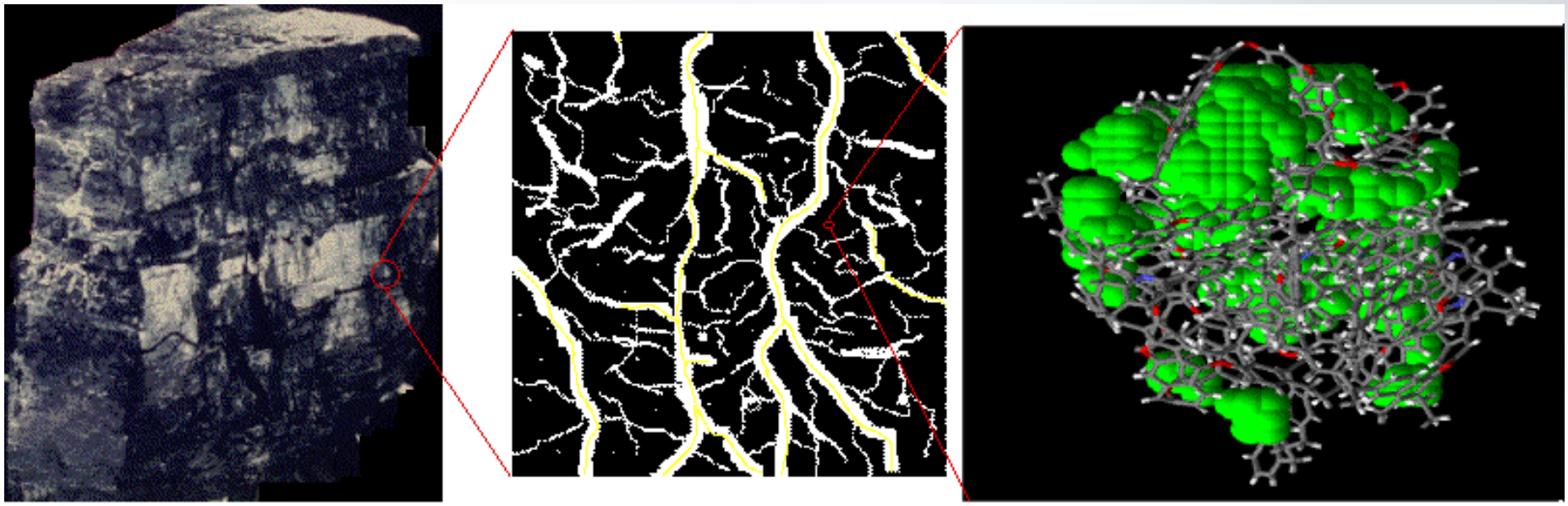
Source: Oak Ridge Nation Laboratory

Methane from Coal

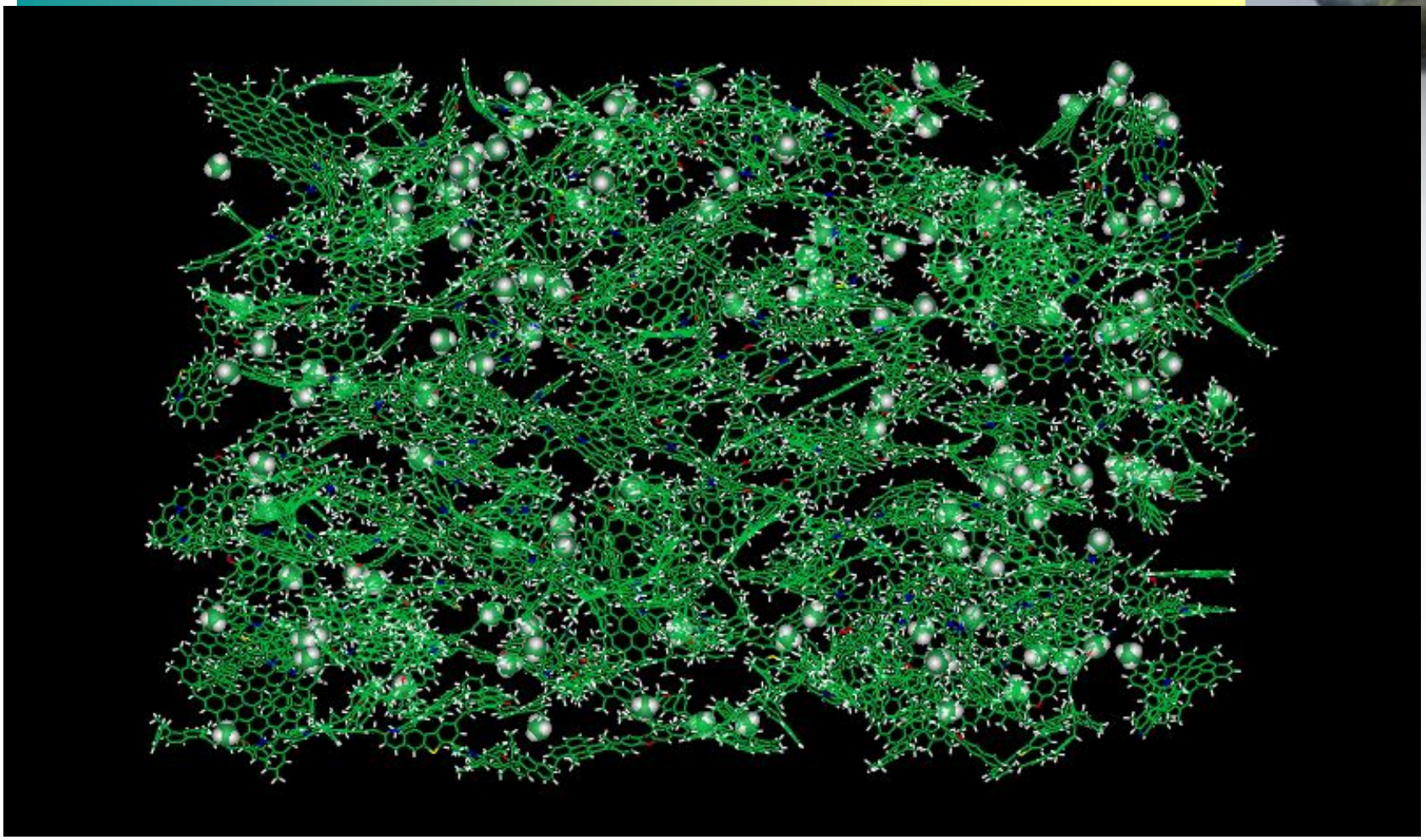


- Coal can contain significant quantities of (mostly) methane.
- High rank coal throughout its history generates more methane than it can store

A Question of Scale



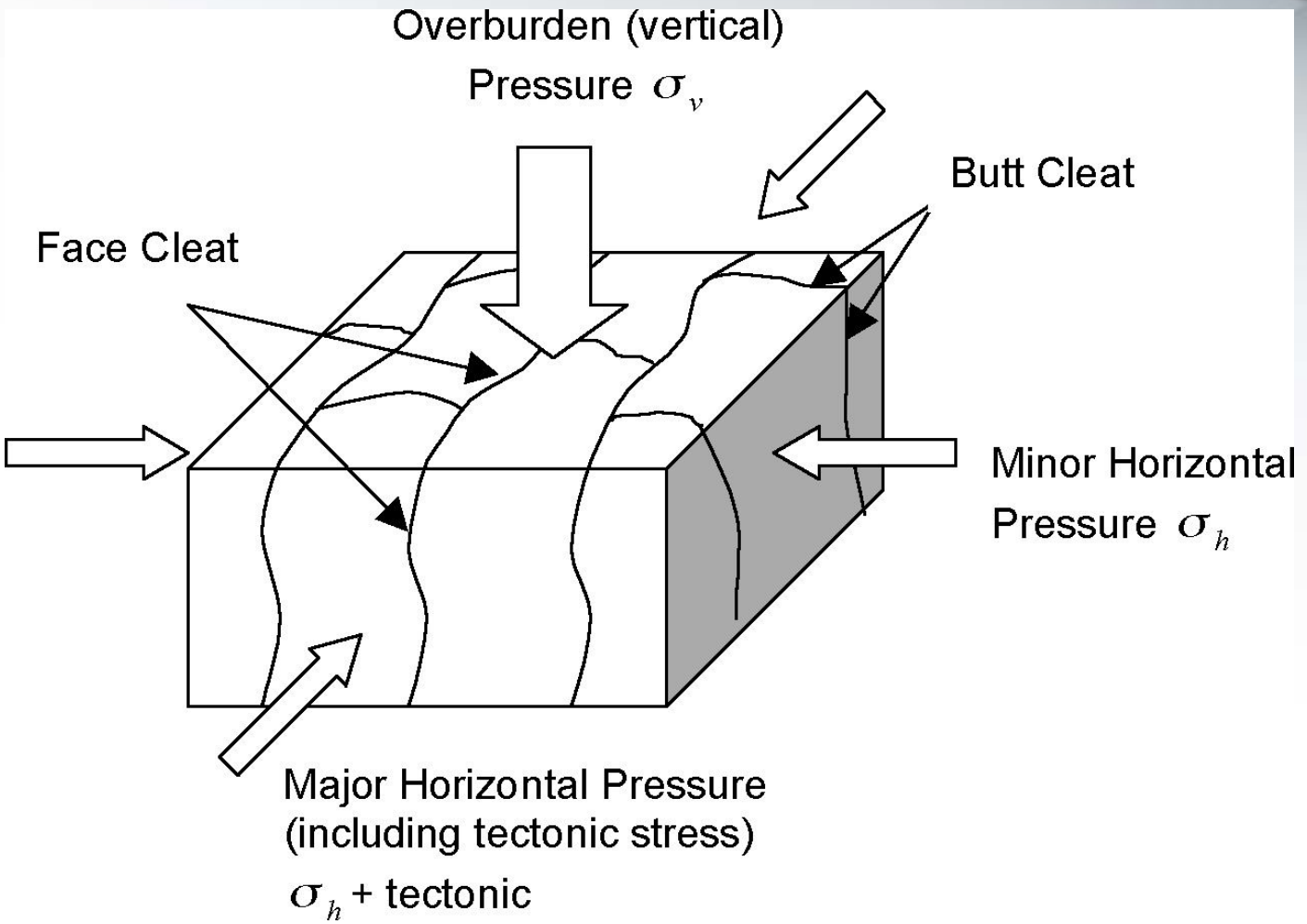
Methane in Coal



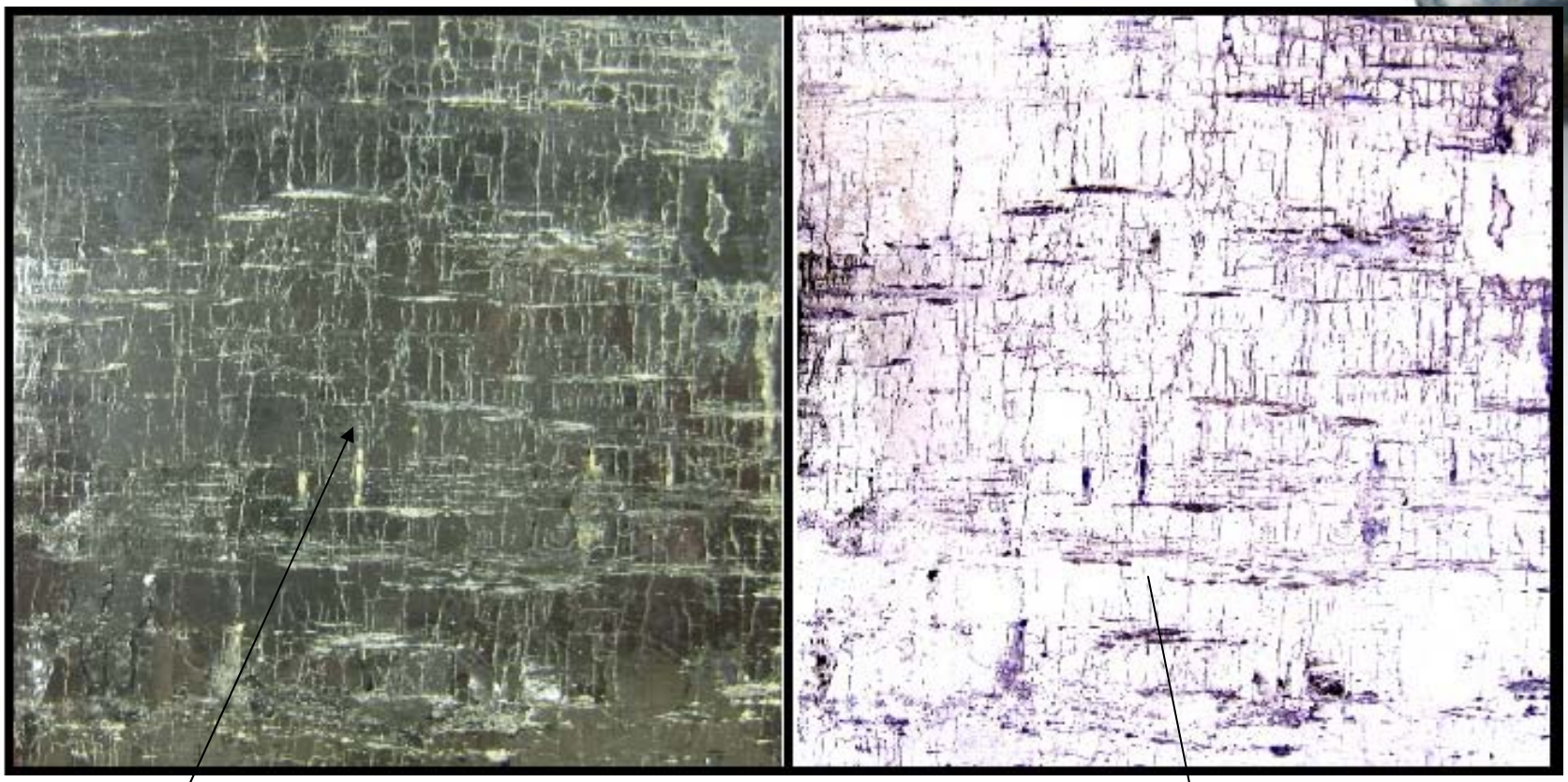
- Methane content: 470 Scf/ton (Pocahontas No. 3)

Source: Narkiewicz & Mathews

Stresses Acting In Situ



Cleats (natural fractures in coal)

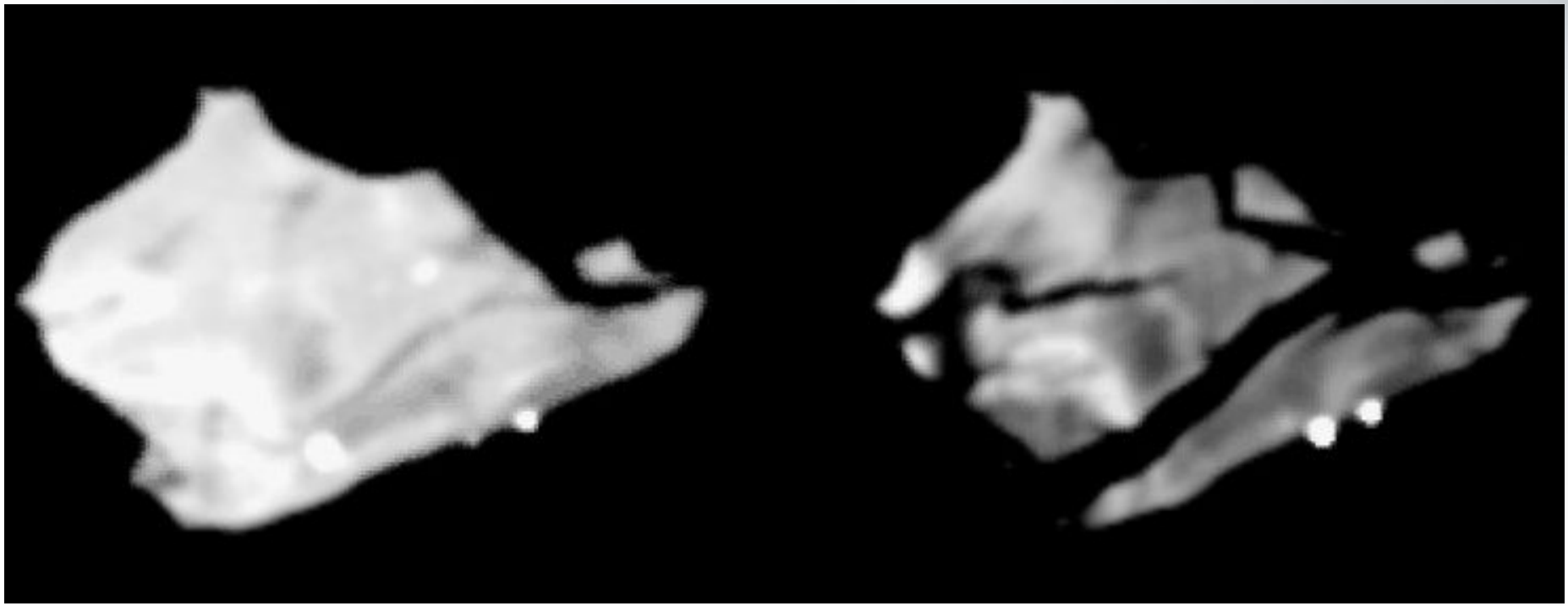


Highly cleated sample, cleats are mineral filled. Negative image of the coal

Highly banded, no cleats
(all samples about 6 inches length)

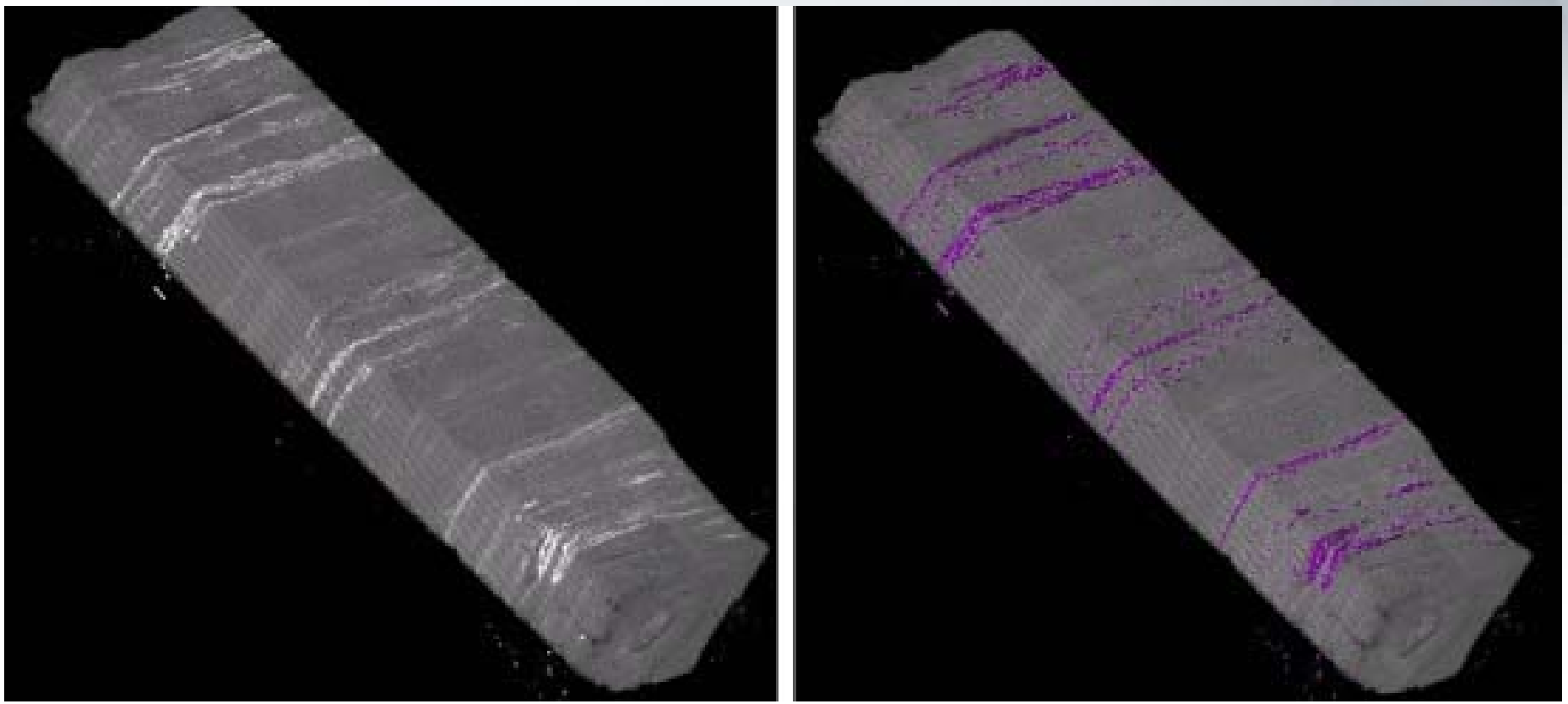
Stress can close the cleats
reducing permeability

Wet vs. Dry Lignite CT



The as-received moisture was 35 % by weight major shrinkage/cracking occurs for the lignite coals

Mineral Bands and Discrete Minerals

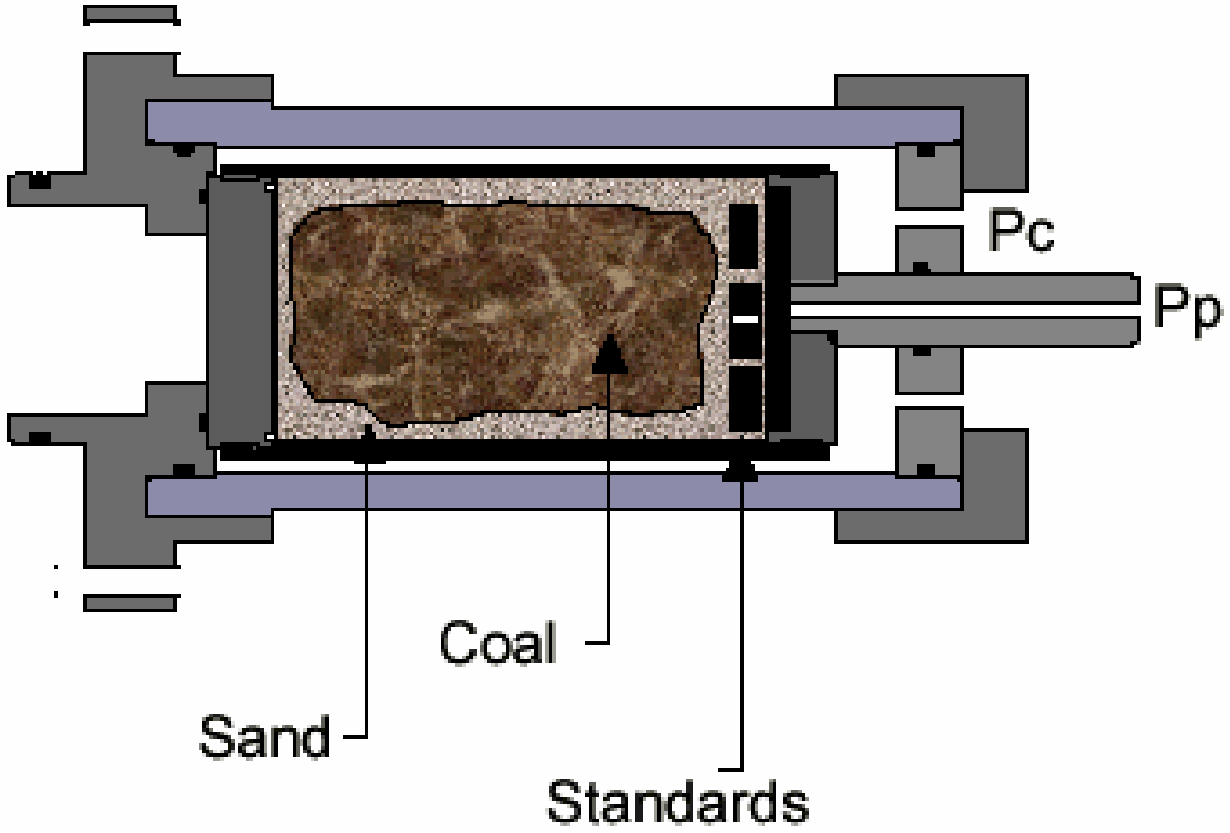


X-ray CT reconstructed image. Higher density (minerals are white in the image on the left and pink (dark) in the image on the right).

Objectives

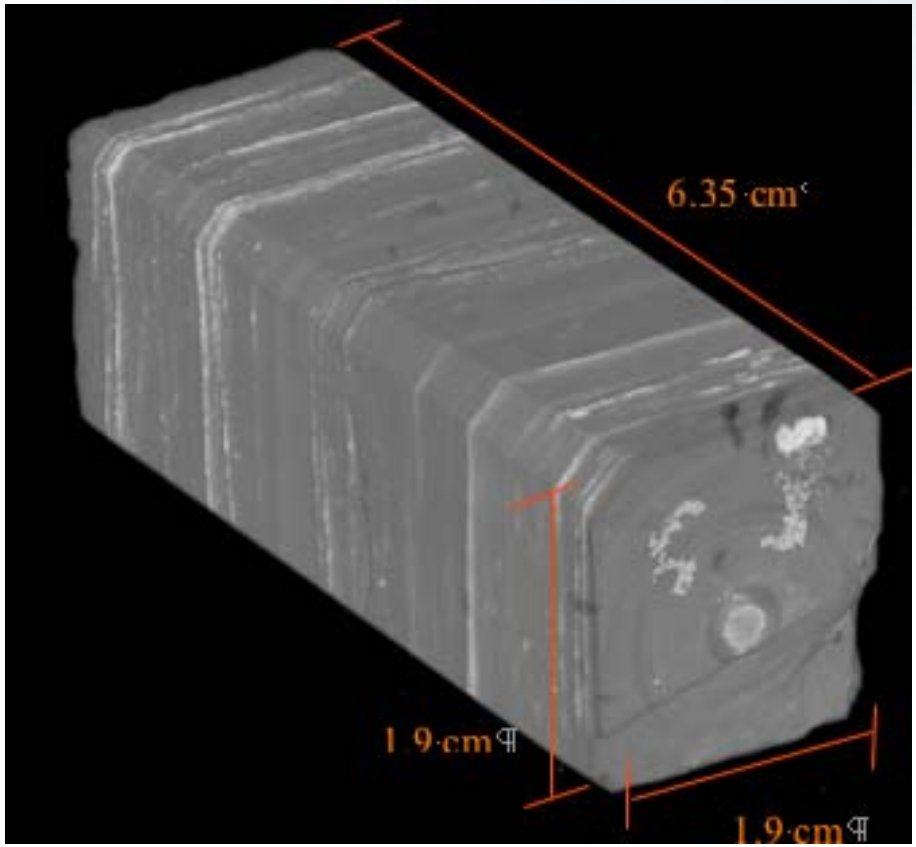
- CO_2 capacity comparison between pulverized coal and intact coal (core)
- Effect of overburden stress on capacity
- Rate of sorption
- Correlation of sorption capacity with lithotypes

“Realistic” Conditions



- Coal is subjected to overburden pressure
- May influence coal swelling
- Sorption capacity
- Uptake kinetics

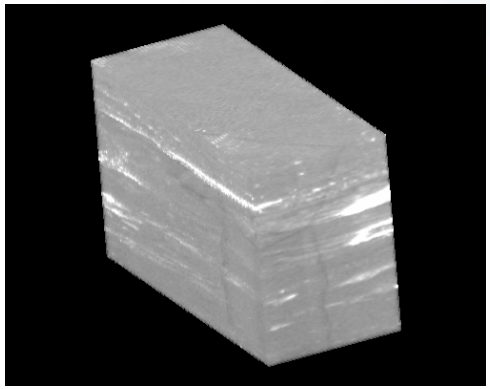
Experimental Approach

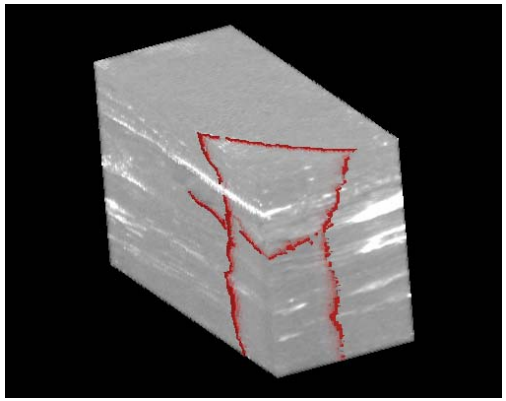


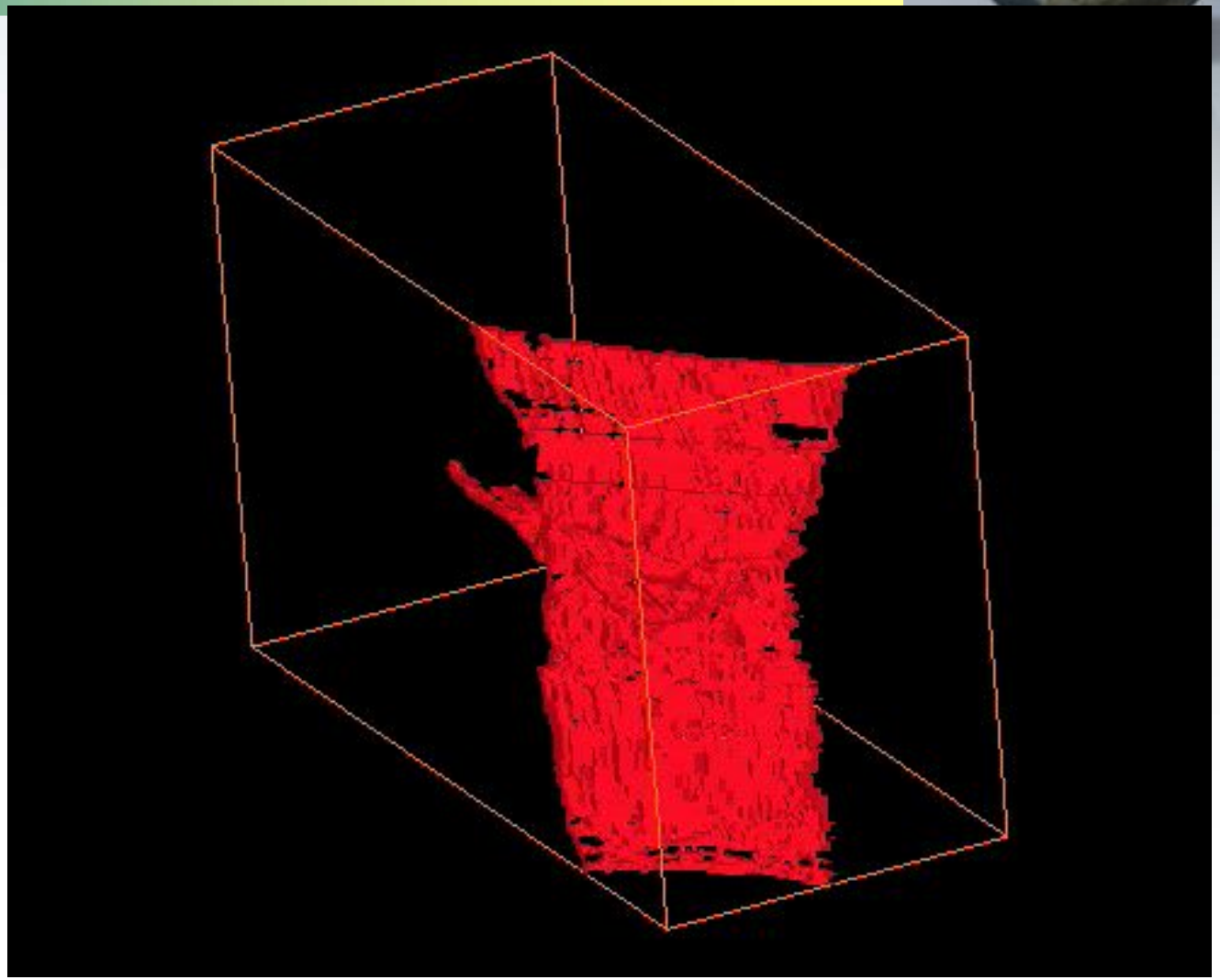
- Obtain 4 sub-samples from a coal core* pulverize one core and use the other 3 for capacity experiments under stress conditions.
  - Image shown is a CT reconstructed image of a sub section of the core.

Our belief is that the coal is altered on swelling and does not necessarily have the same behavior on subsequent exposure/swelling.

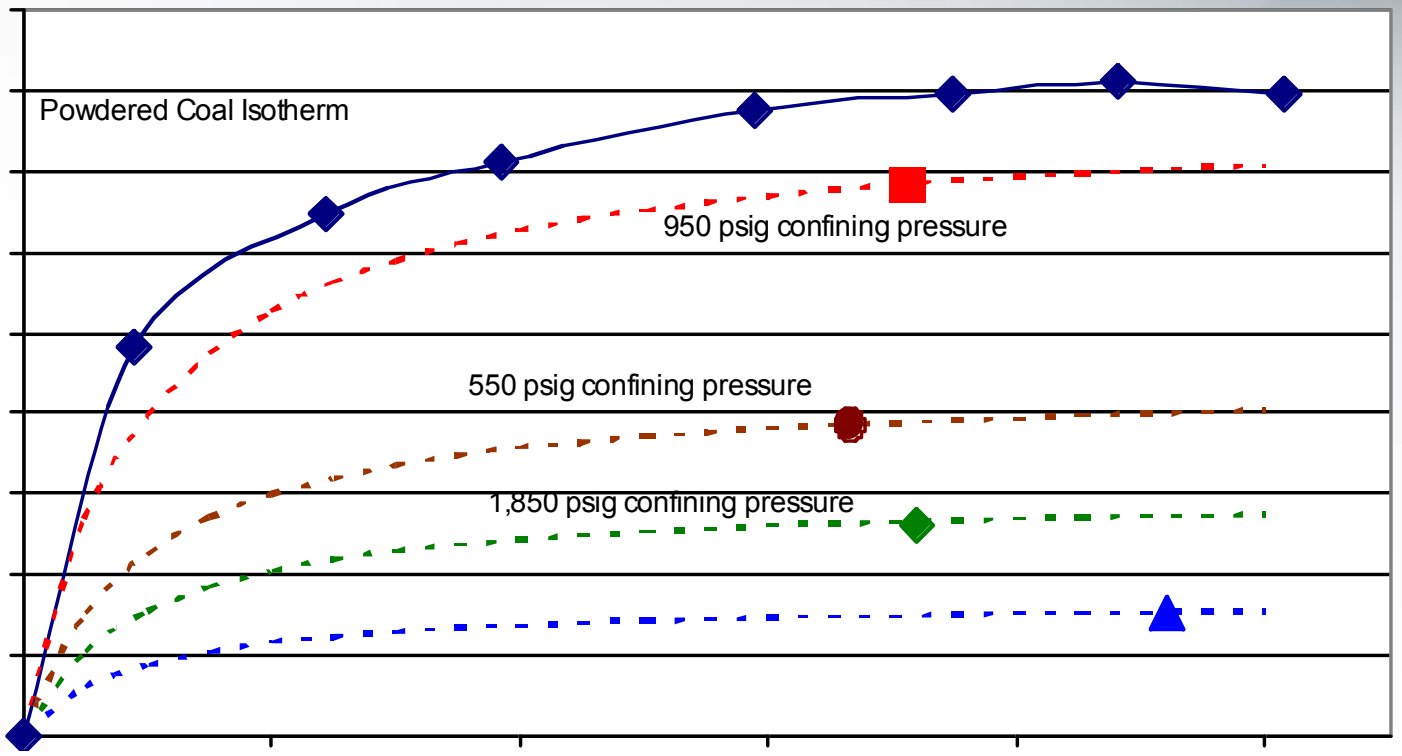
Fracture Image







Powdered Coal vs. Coal Cores With Applied Stress



CO_2 sorption capacity for Pittsburgh-seam coal corrected (CT determined) mineral matter free basis

Coal Swelling because of CO_2

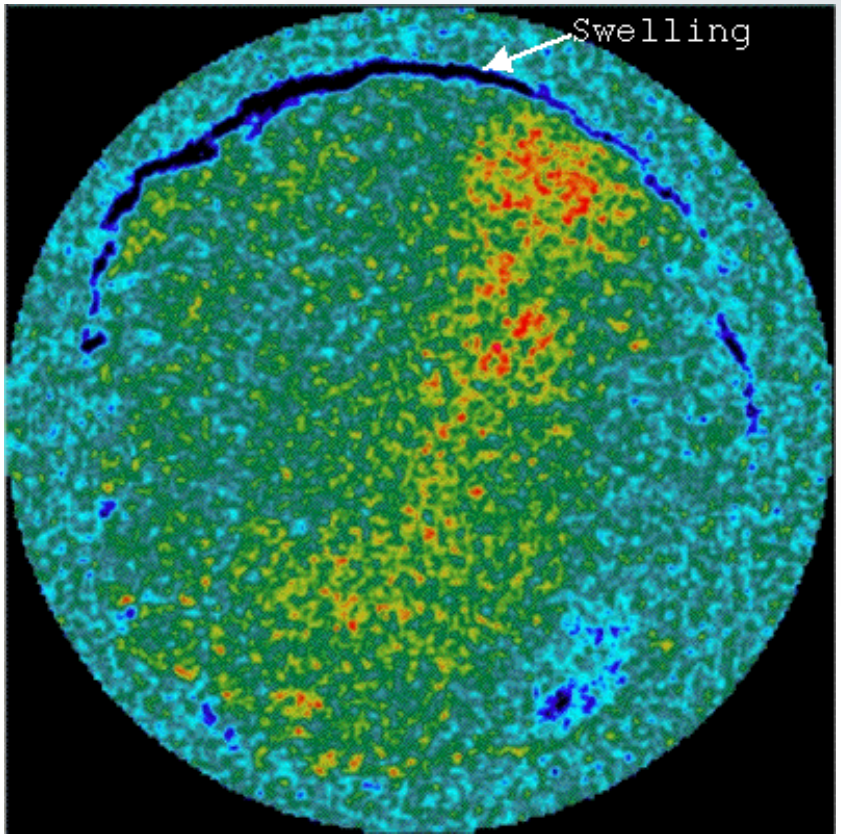
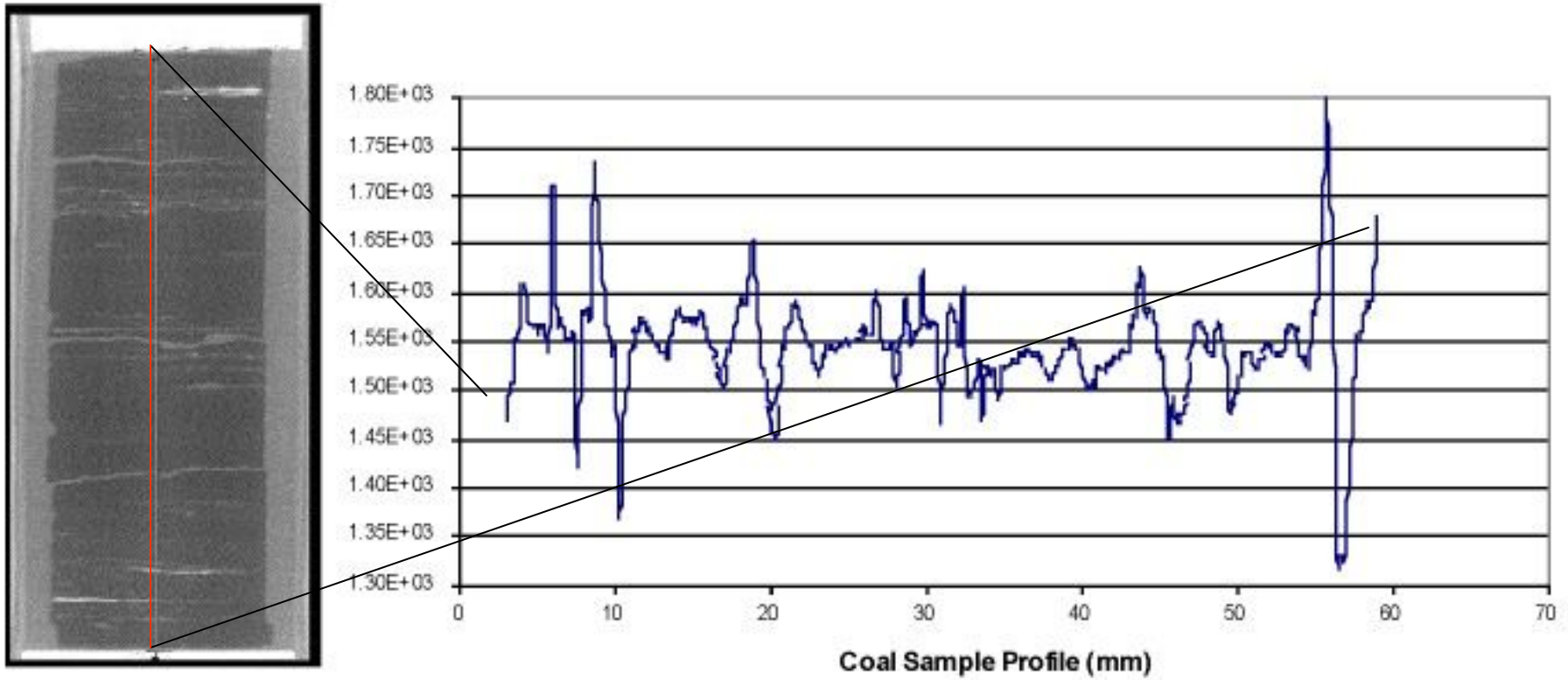


Image is the result of subtracting the CO_2 exposed coal CT data from the unexposed coal CT data. The swelling of the coal displaced the sand surrounding it resulting in a obvious swelling around one side of the coal core. Image was obtained with the medical scanner.

Changes in CT Profile with Swelling/Sorption



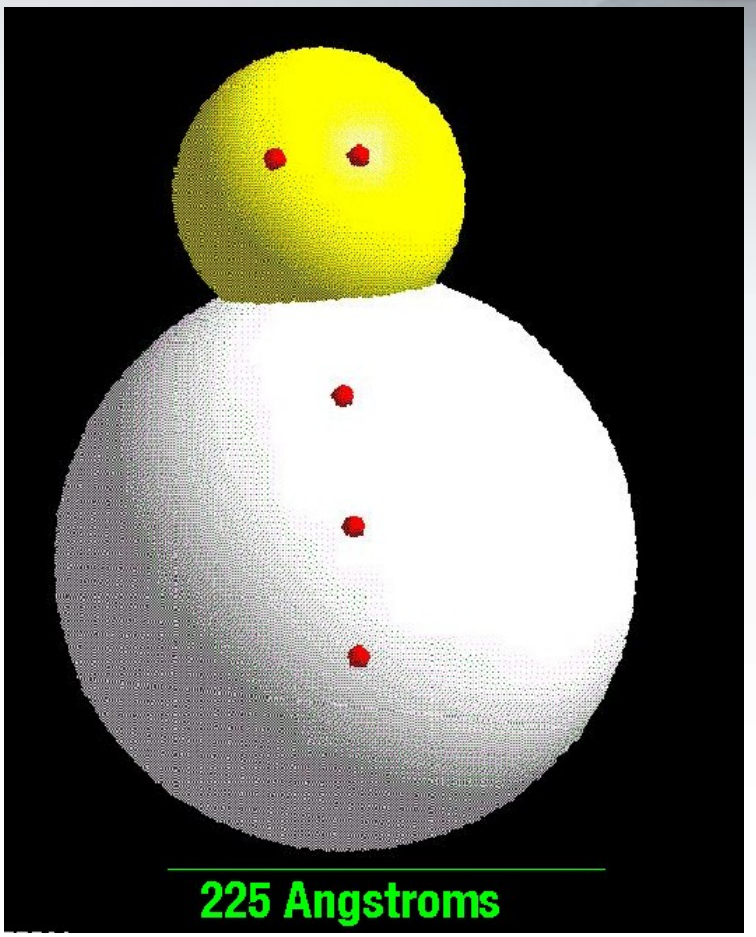
CT numbers change due to swelling (and somewhat the presence of CO_2) higher/lower density lithotypes (and mineral layers) displacing other lithotypes. Plot is created from the subtraction of the site specific CT number post exposure minus pre-exposure. Vitrain bands were evident in high transition regions

Conclusions

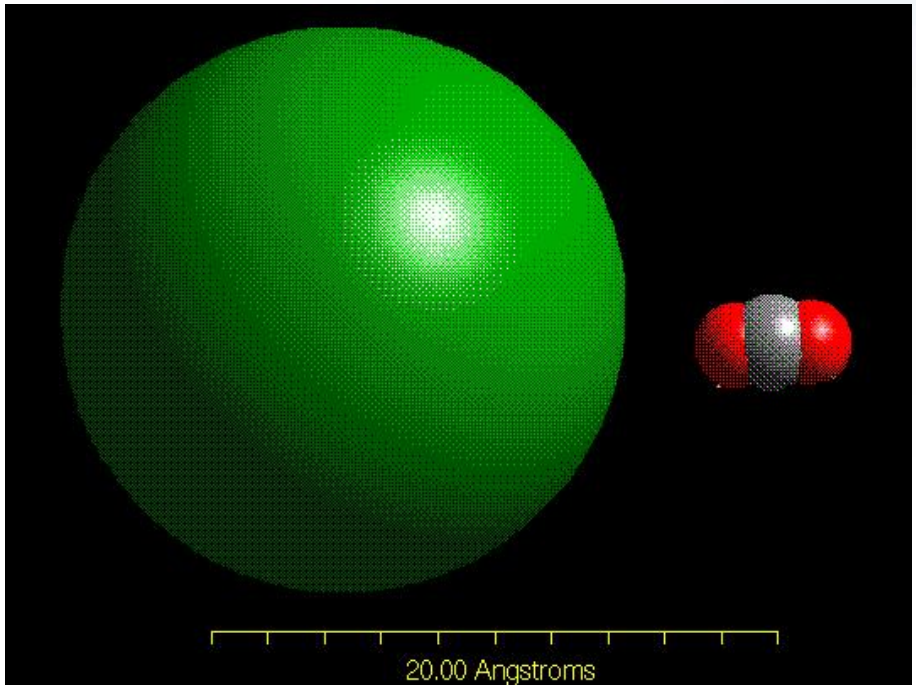
- Applied stress can significantly reduce CO_2 sequestration capacity for dry, evacuated coal.
  - 80% reduction at 2,450 psig
- Lithotype layers swell, some compress other layers.
  - Swelling is not uniform
- Uptake is region specific
- Much, much more to do!

Pores in coal

- Macro
- Meso (transitional)
- Micro
- Bituminous coals are mostly microporous
- Macerals have varying porosity
- Pore frequency, distribution, and interconnectivity are important

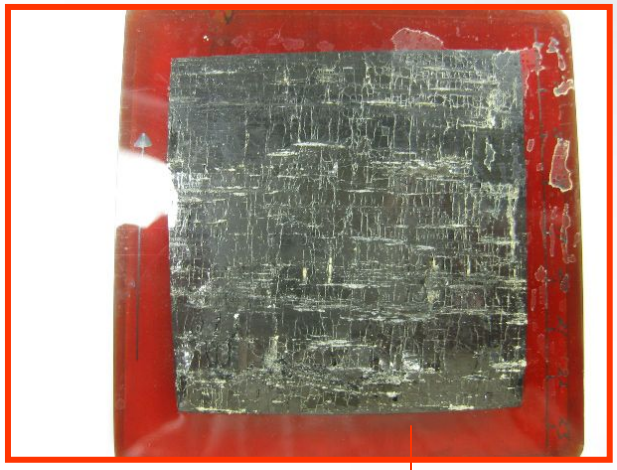


What is the Scale of things?



- Shape
- Molecular Sieving
- Interaction with surfaces
- Size

Cleats in Coal



High Resolution Scanner