Assessing the Geological Sequestration potential in the Illinois Basin – Successes and Challenges

John A. Rupp
Indiana Geological Survey

Center for Coal Technology Research
March 6, 2008

Objectives

1) Assess what it is going to take from a technical standpoint to make geological sequestration of CO_2 in our region possible.
   - *exclusive of political, regulatory, legal and economic context/concerns*

2) Define and discuss the four fundamental factors required for successful sequestration.

The sequestration challenge:

- Use the subsurface geological environment to securely store very large volumes of CO_2 for a very long time

- Need to have:
  - 1) volume, 2) mode,
  - 3) confinement and 4) security

Volume

- How much volume is needed?
- Indiana produces ~ 250 Million metric tonnes of CO_2/year
  - About half (125 MM) comes from point sources
  - Most are from coal-fired generation plants
    - e.g. Gibson Station emits ~20 mm tonnes/3100 Mw/year
    - e.g. Edwardsport will make ~ 4.5 mm tonnes/630 Mw/year

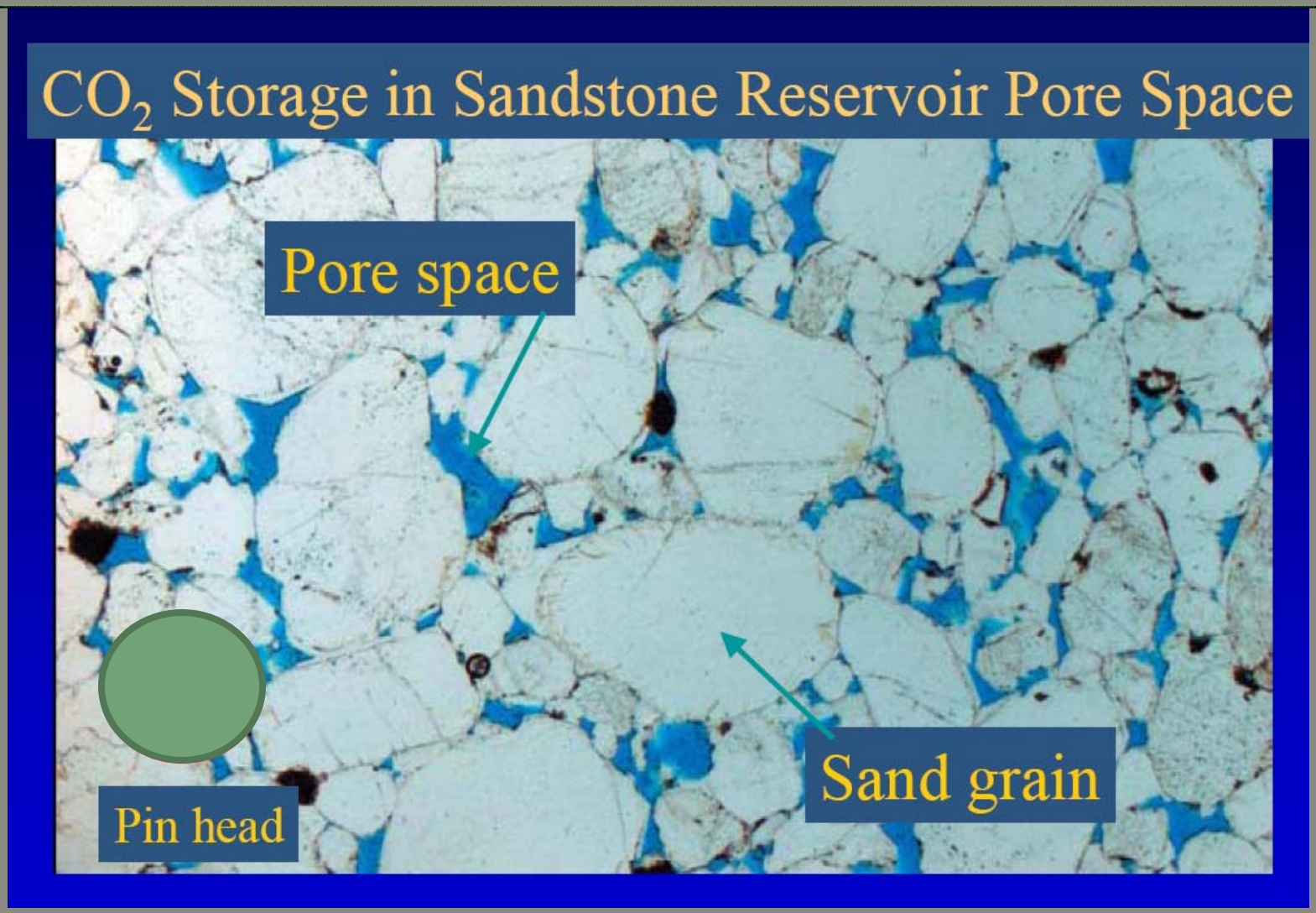
Volume – how much for CCS?

- If half of the CO_2 emissions are to be captured and stored,
  - ~125 million tonnes/year reservoir capacity required.
  - To date, the largest CCS projects store 1-1.5 MM/year
    - Sleipner, Snøhvit, Weyburn, and In Salah
- If 10% (25 mm/yr) of the emissions are to be stored,
  - Will require ten 2.5 MM tonne/year projects

Volume – potential storage

- Mount Simon Sandstone in Indiana:
  - ~15 to 30 billion tonnes
- Mature oil fields and coal seams:
  - ~<1billion tonnes
- Organic shales??
  - ~~ 5 billion tonnes

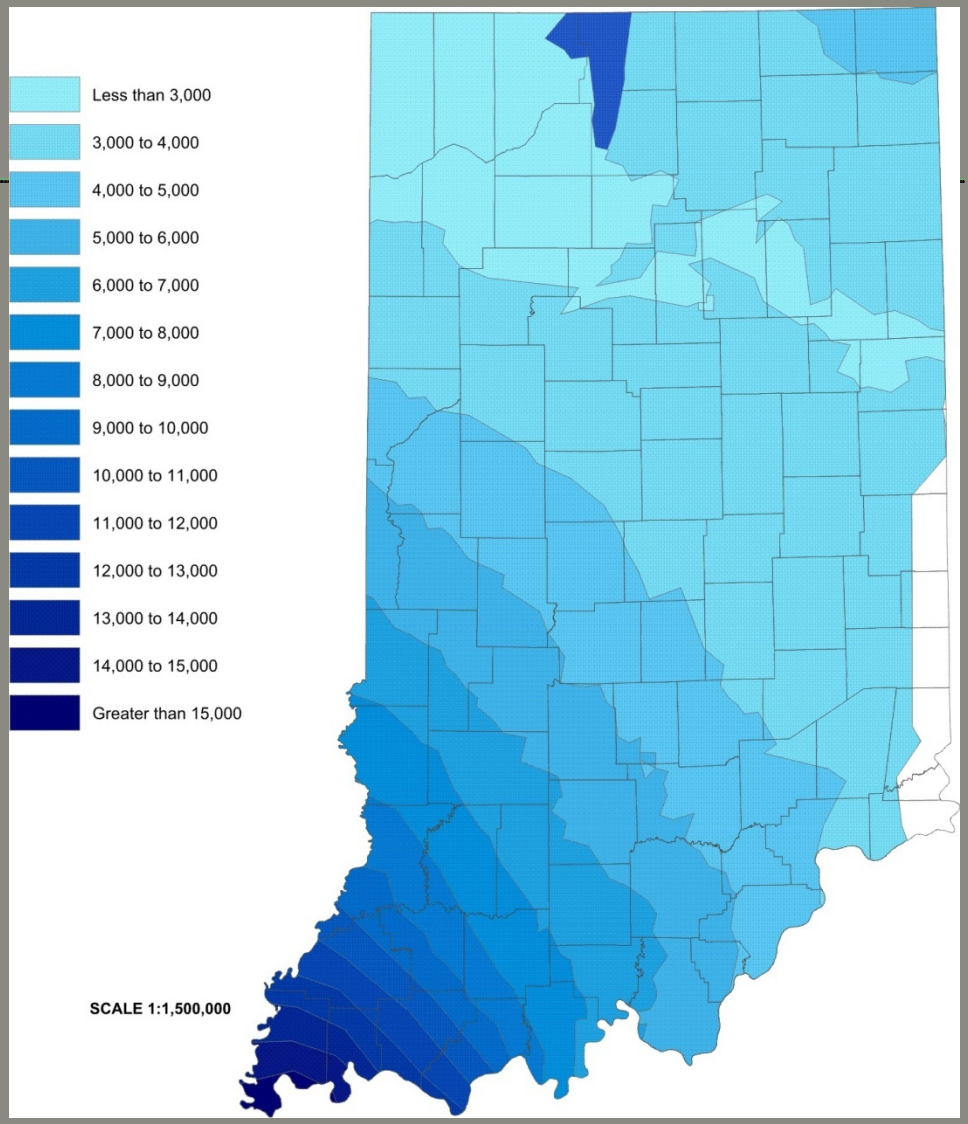
Storage volume = pore volume



Volumetric calculations -initial

10% of average (14%) pore volume

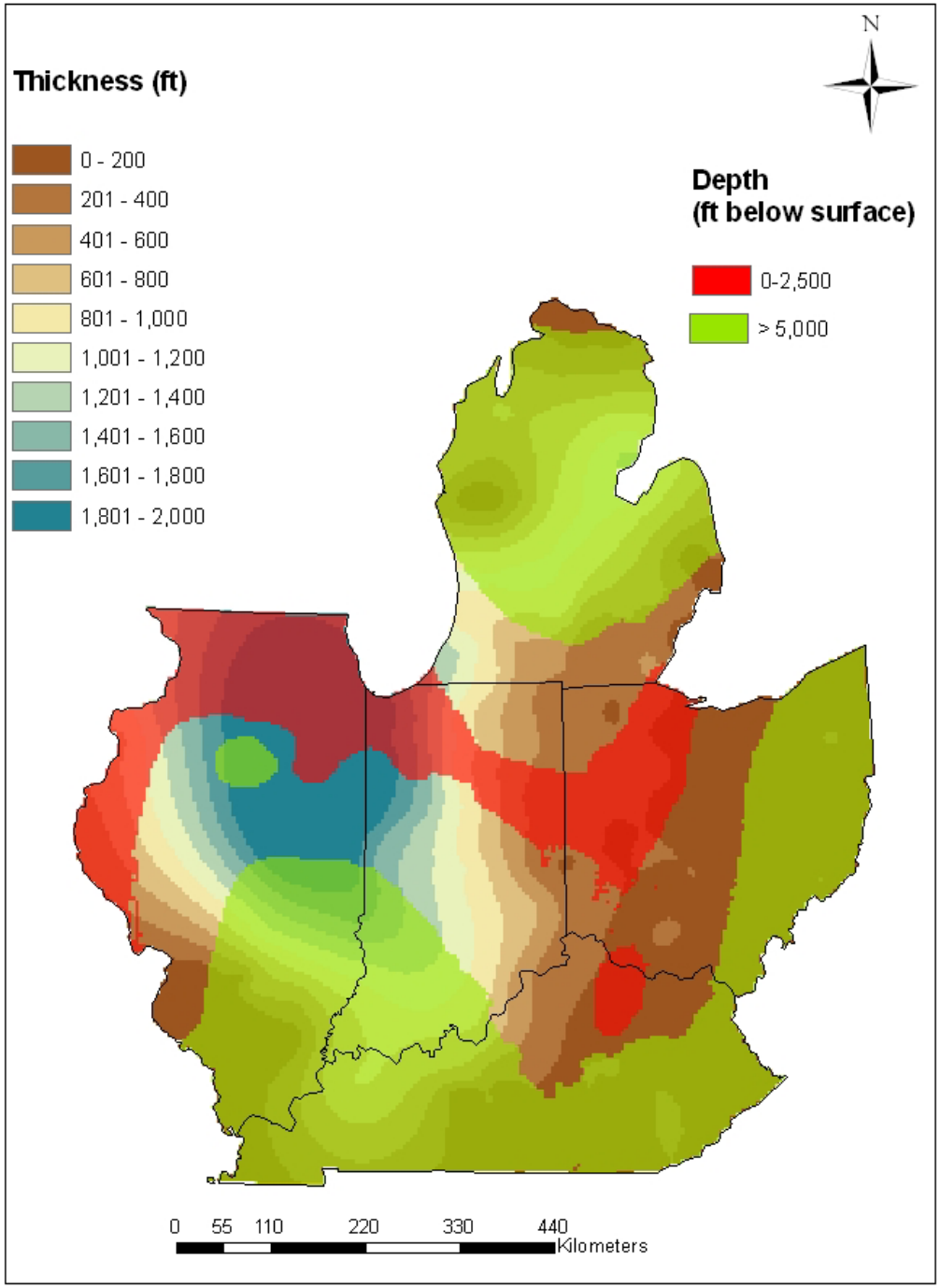
greater than 2,500' depth



Volumetric considerations -revised

~8% = <5,000 feet
~5% = <7,500 feet

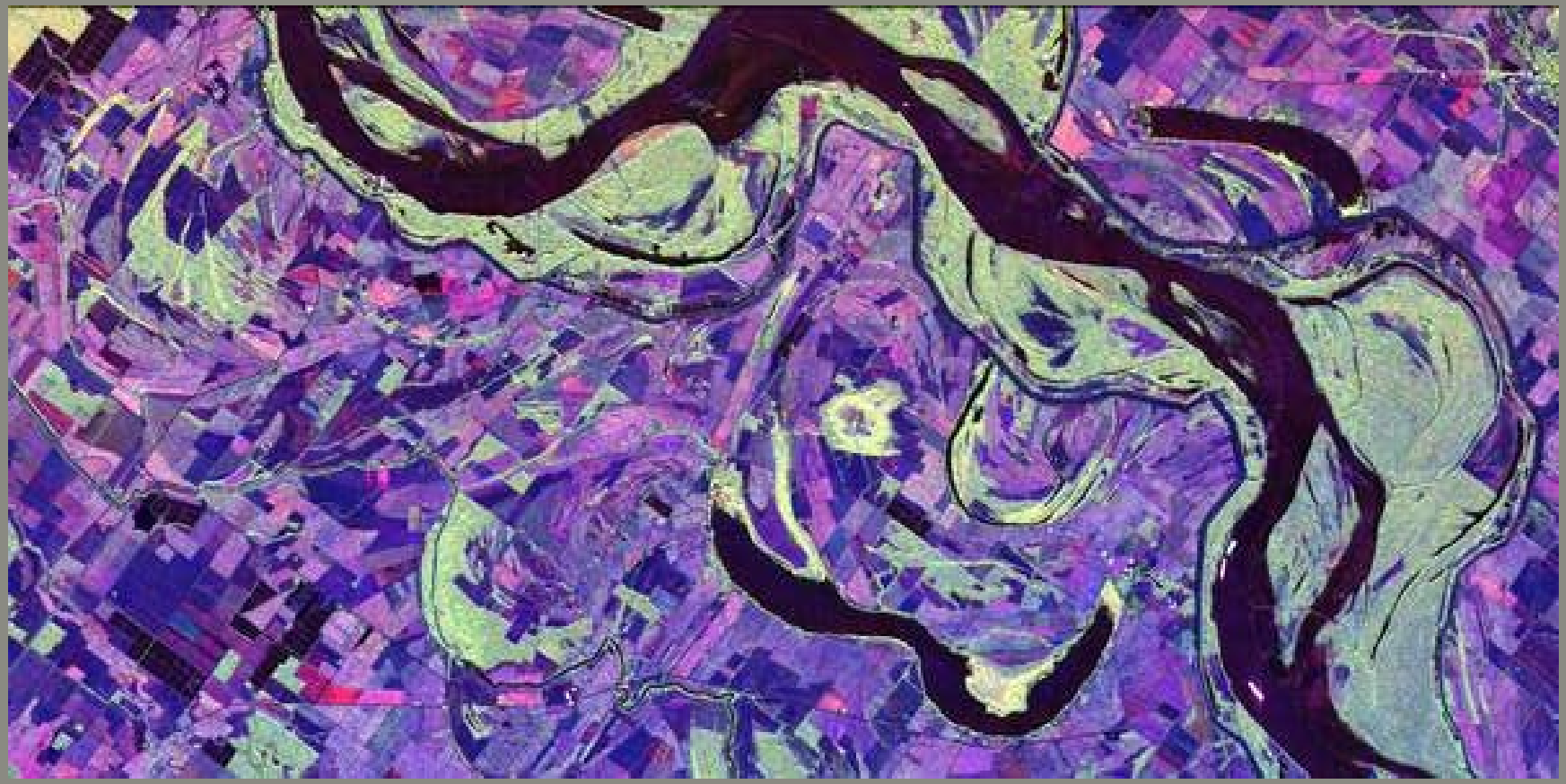
New NETL capacity calculations:
"1-4 % of available pore space present is useable"



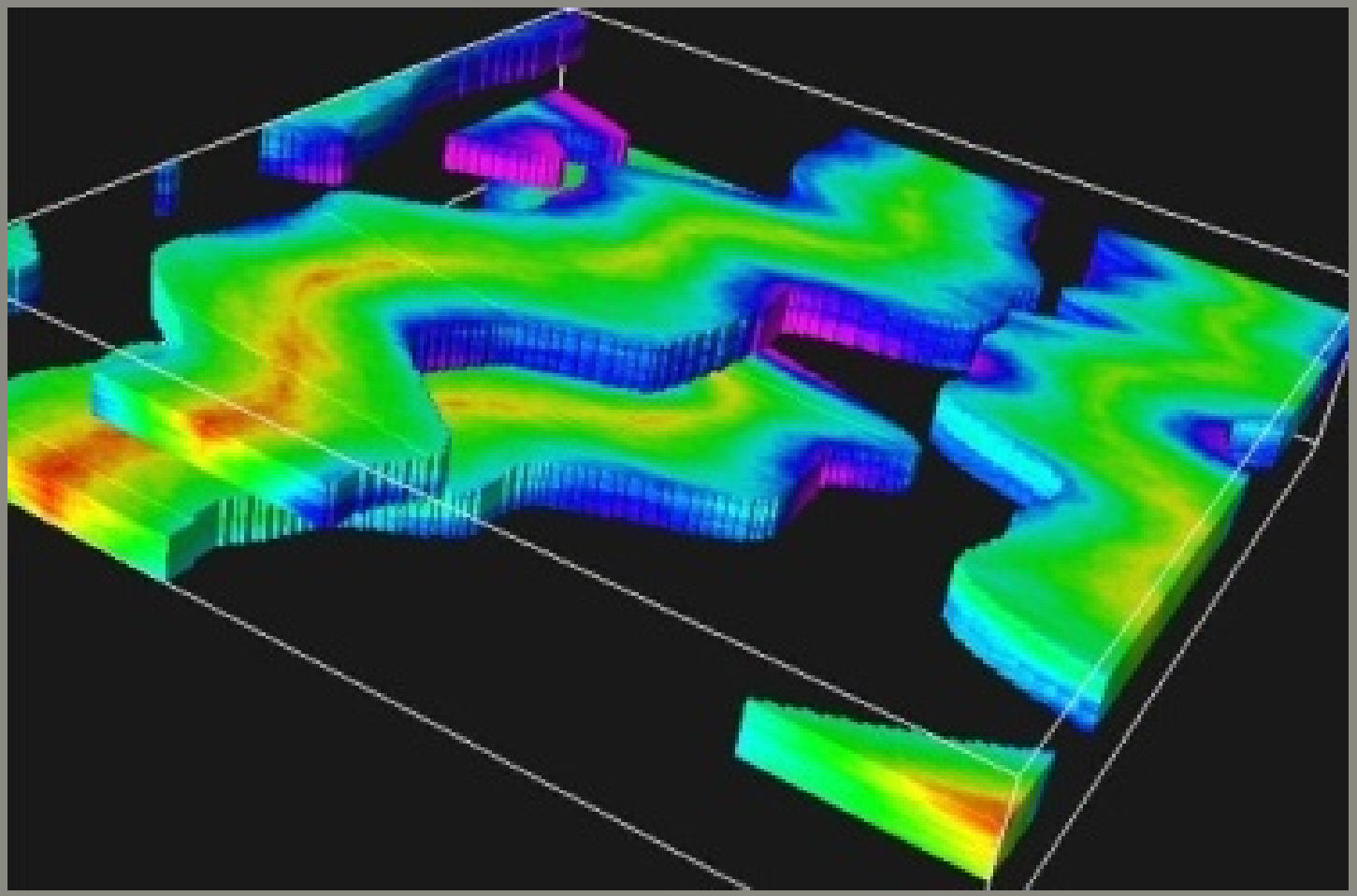
Volume – accessing pore space

- To emplace the injected CO_2 into the pore volume, need to access it.
- Assume all CO_2 exists as super critical fluid that is efficiently displacing the existing pore water.
- Challenge of managing the reservoir:
  - Well fields or "arrays"
  - Horizontal vs. vertical wells
  - Reservoir heterogeneity (porosity and permeability)

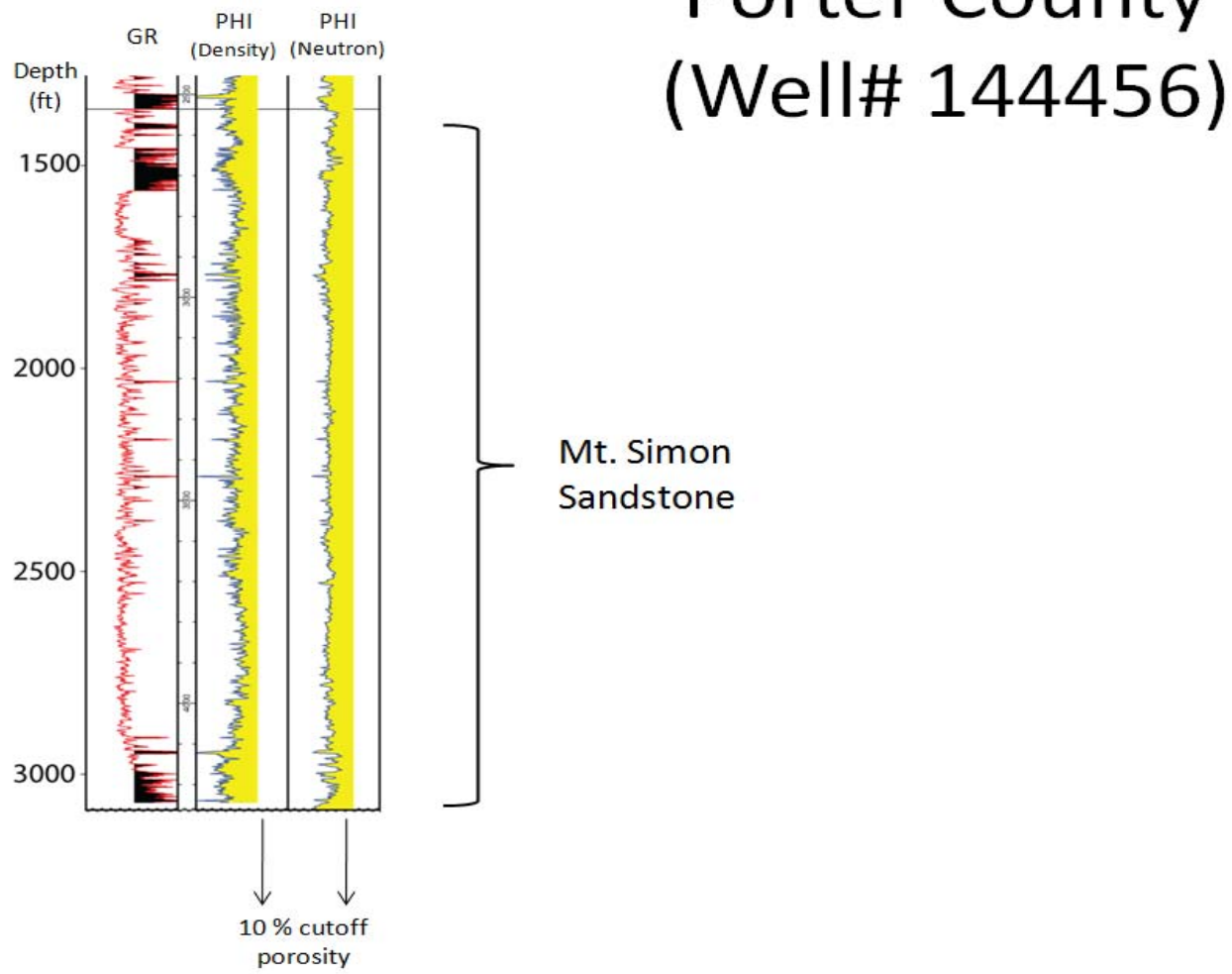
Irregularly distributed porosity and permeability in a sandstone



Irregular flow pathways in a heterogeneous reservoir



Reservoir heterogeneity



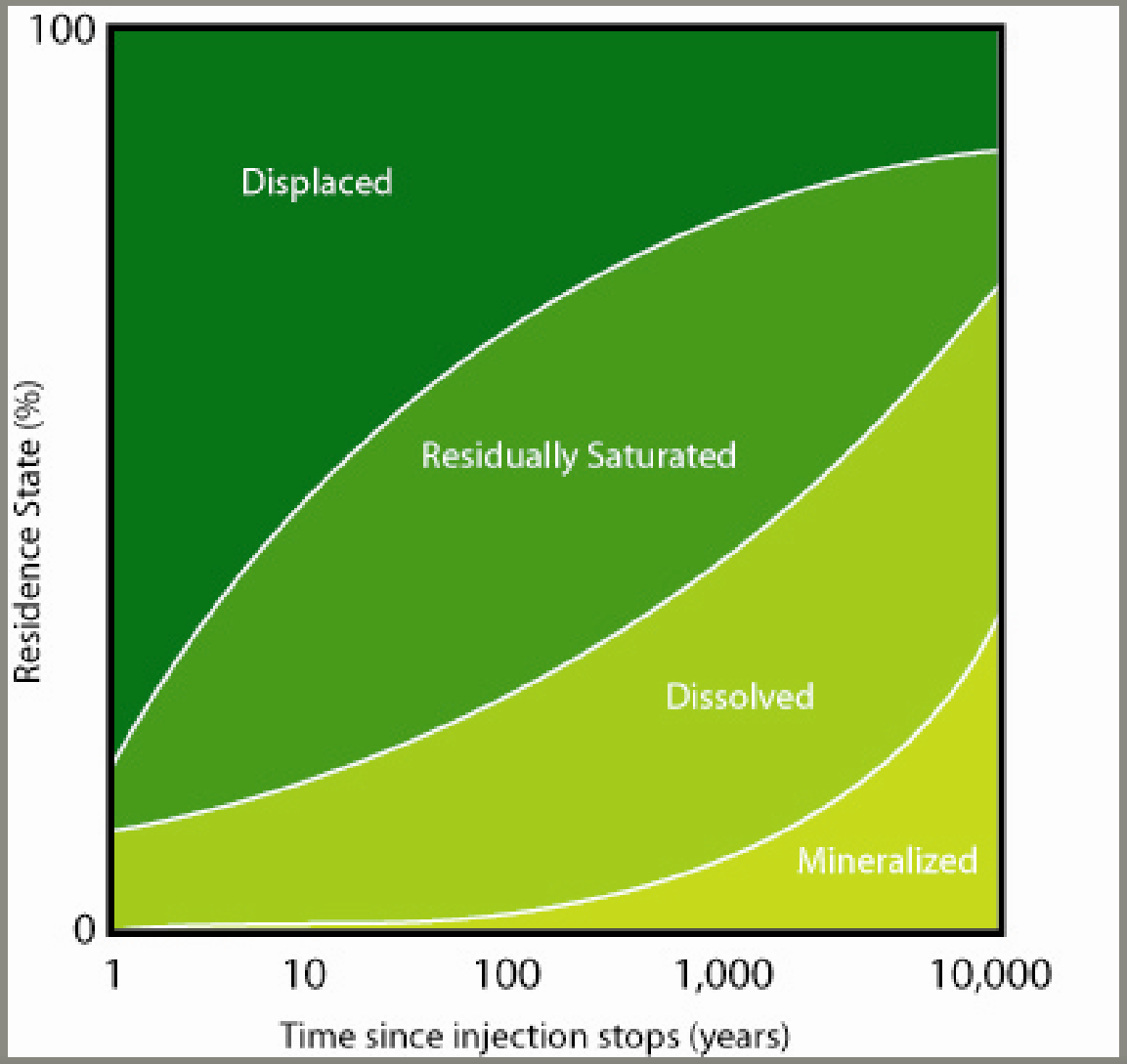
Volume - what is needed for a project?

- Measurements of porosity and permeability (borehole sourced, whole core derived, laboratory measured, and office interpreted)
- Geometry and composition of the pore system (as above)
- Reservoir Volume (3D extrapolation of above information; with seismic data and other boreholes)

Storage Modes – in reservoirs

- CO_2 can exist in the reservoir in four ways:
  - Displacement of brine in pore spaces
  - Dissolution into the brine
  - Saturate the capillary spaces as an Irreducible fluid
  - Precipitation as Mineral phases

Modes of ‘residence”

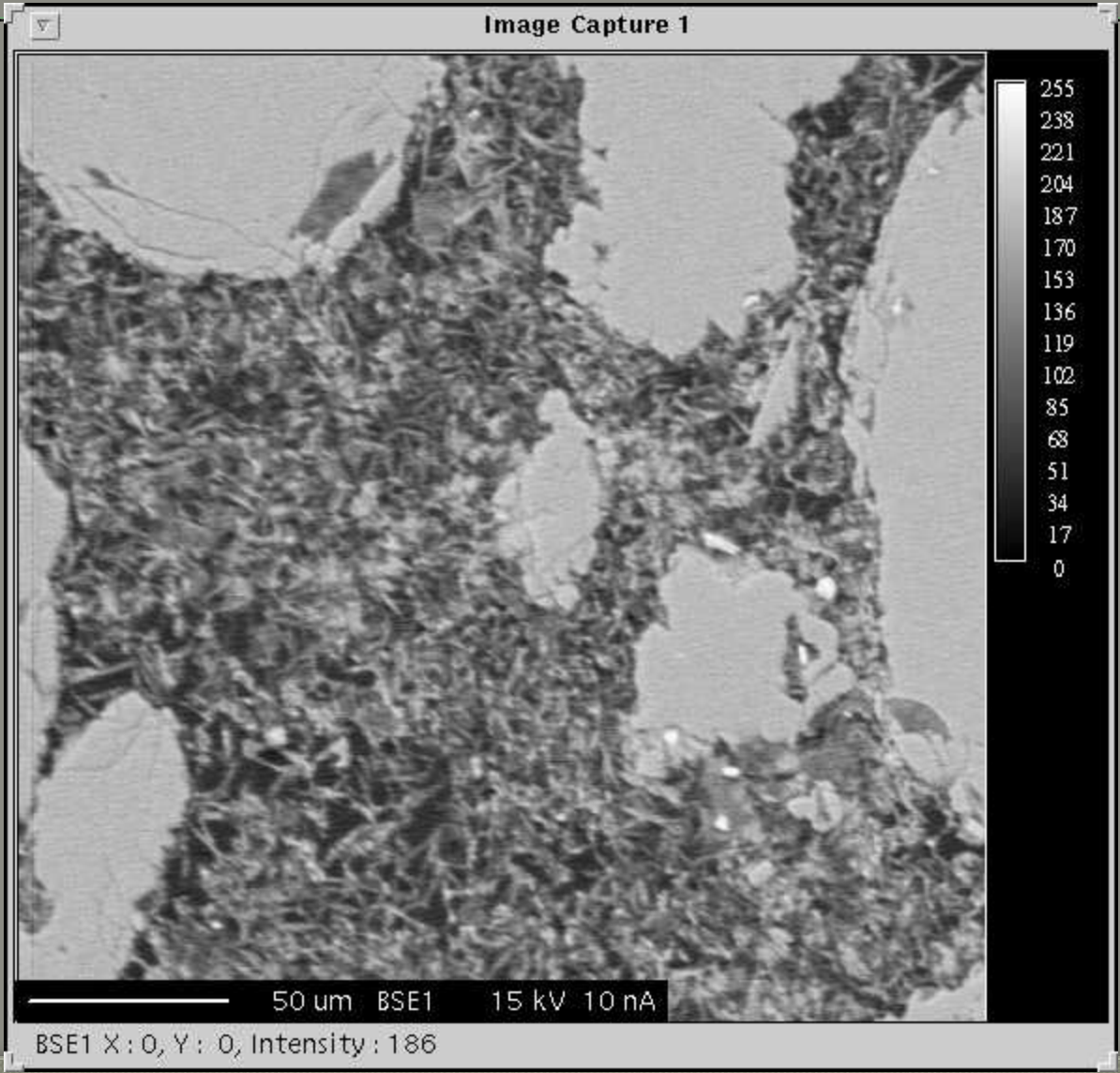


Storage modes

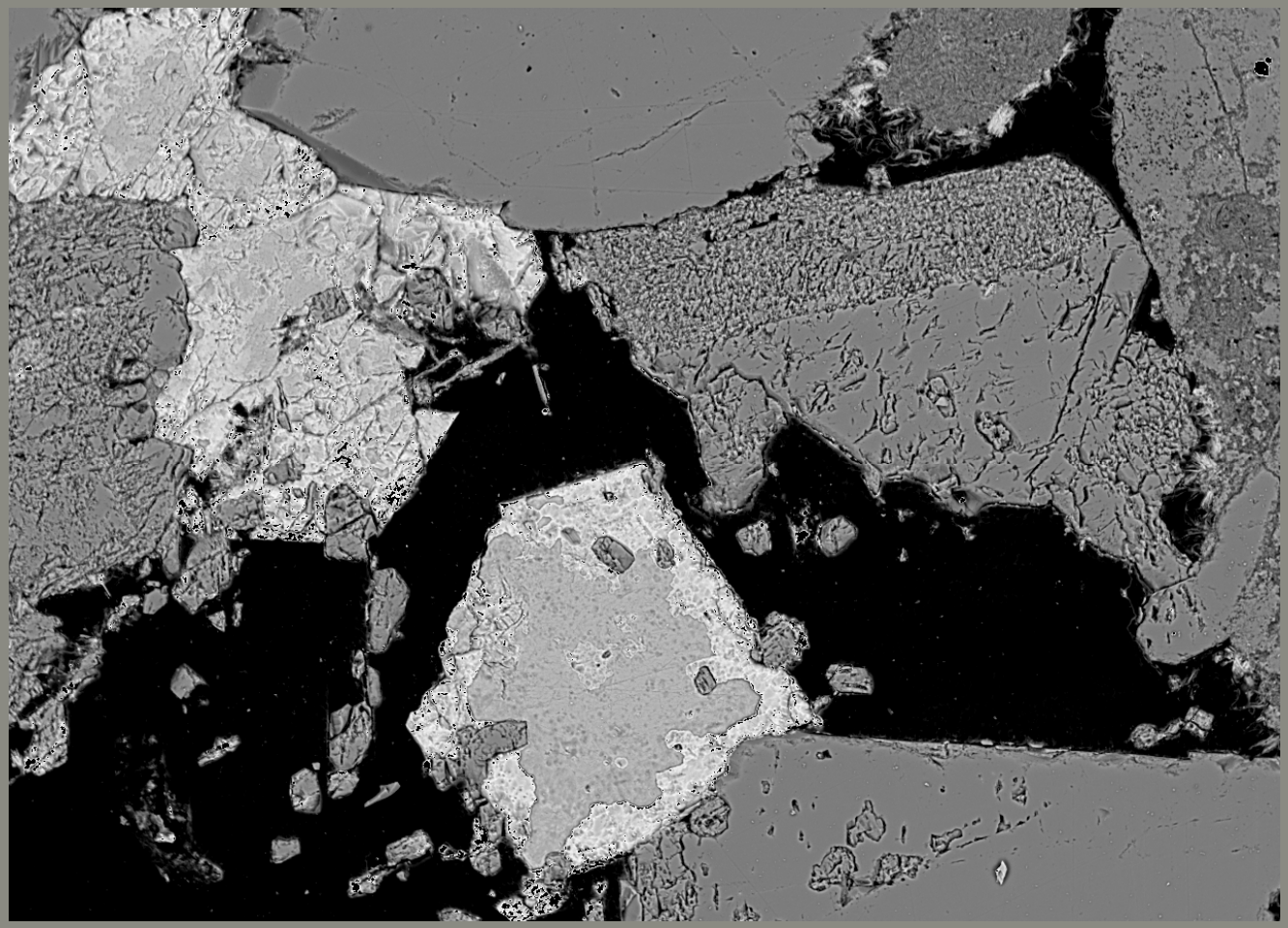
- Directly relates to efficiency of emplacement, migration and ultimately secure confinement.
- Could be positive or negative effects
  - e.g. mineral precipitation chocks pore throats and inhibits emplacement

    or
  - Fixes CO_2 as mineral phase after emplaced enhancing security of confinement

Reservoir mineralogy -interactions



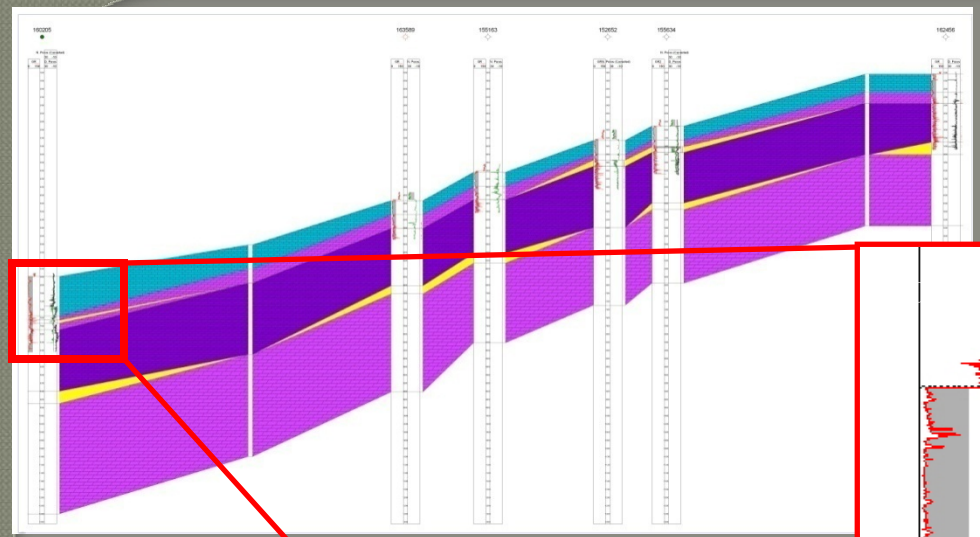
Complexity of interaction of these processes in both time and space is not known

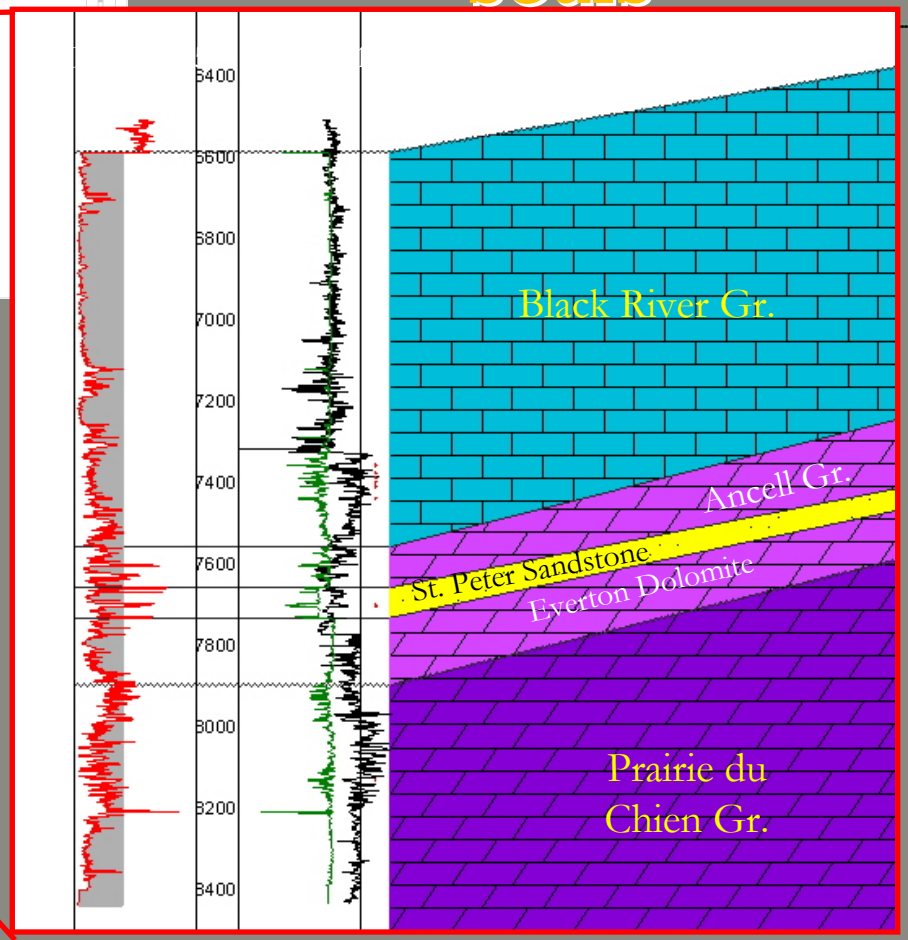


Confinement

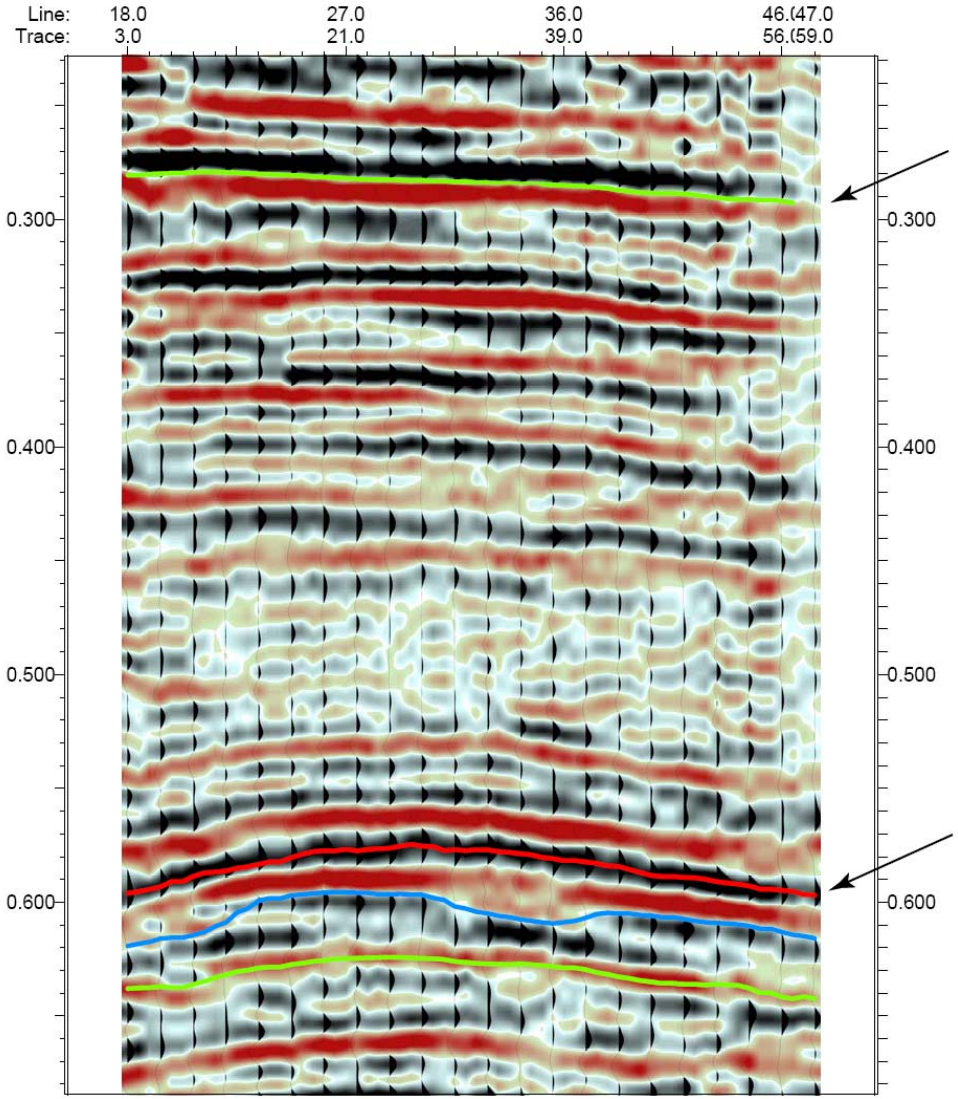
- For CO_2 that is displacing brine, acts as a buoyant fluid:
  - Vertical migration barriers – "seals"
  - Lateral migration barriers – "traps"
  - Seal + Trap = Confinement
- Seal integrity can be compromised by:
  - Reactivity
  - Unplugged boreholes
  - Borehole cement degradation

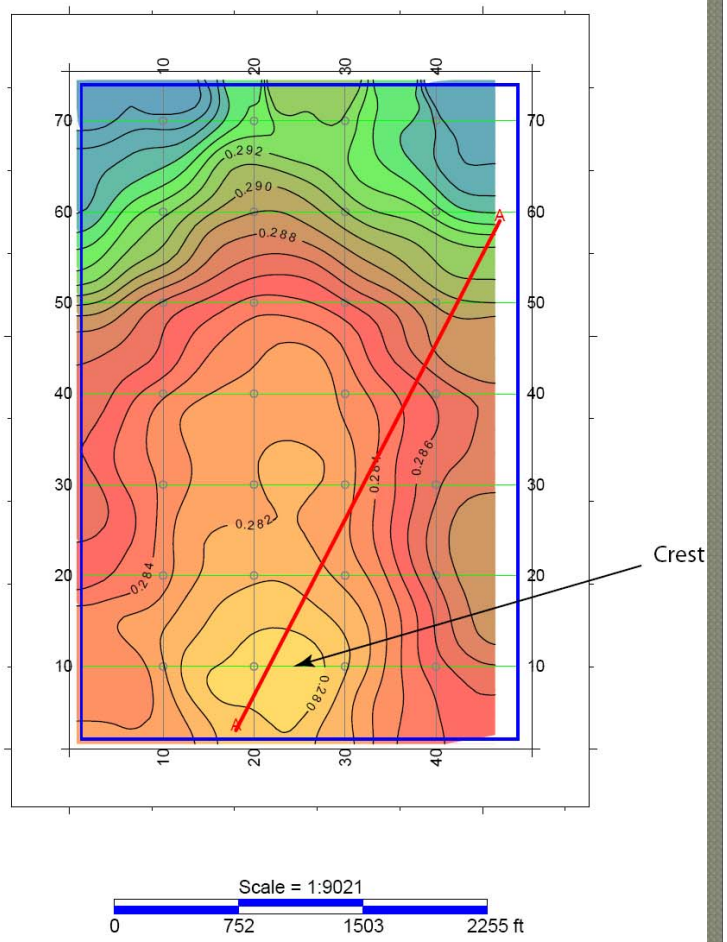
Regional reservoir seals





Local trap formed by a structural dome





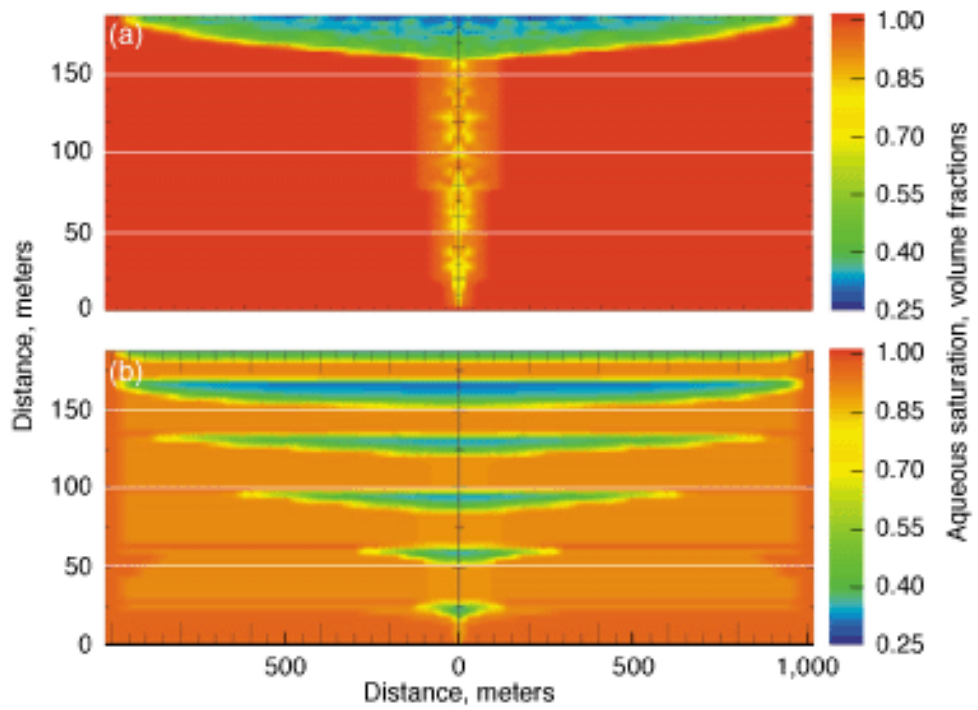
Security

- MMV techniques:
  - Monitoring the reservoirs and other aspects of the subsurface and surface
  - Measurement of how much CO_2 is moving and where
  - Verifying that the vast majority of the stored CO_2 is where it should be

Security

- MMV tools to assure long term security include:
  - Monitoring wells
  - Shallow and surface sensors
  - Tracer surveys
  - Reservoir fluid flow models

Long Term integrity of sequestration



Sequestration performance depends on the geology of the proposed sequestration site. (a) In an aquifer with no shale layers, the CO_2 plume rises quickly to the aquifer caprock, where it migrates laterally beneath this impermeable seal. (b) When shale units are present, they effectively retard the plume's vertical migration while promoting its lateral extension, thus enhancing the effects of solubility and mineral trapping.

- Modeling results – lateral migration of CO_2

Security challenges

- Slow leakage across seals
- Displacement of saline waters into oil or fresh drinking water reservoirs
- Loss of injectivity; pressure buildup; fracturing…leakage

Summary

- Large storage volumes required
- Storage mode in reservoirs needs to be considered
- Effective confinement needed
  - Sealing and entrapment
- Long term, secure storage required
  - Protection of health and human welfare + resources