Stanford University

GCEP Global Climate & Energy Project

CSLF Panel on
Technology Perspectives
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Geologic Storage of Carbon Dioxide

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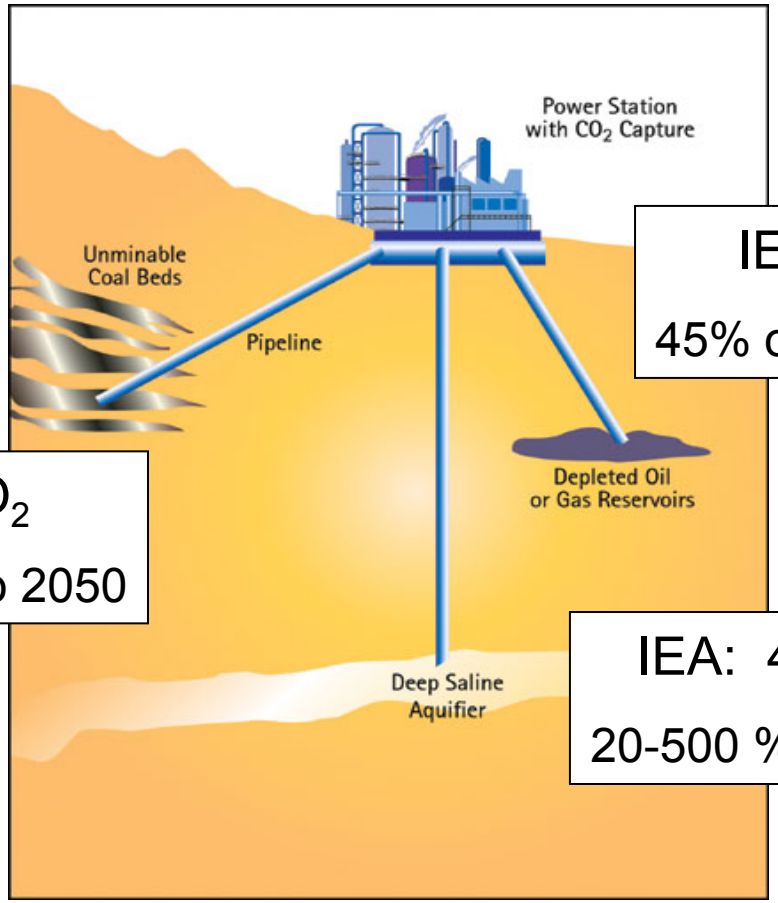
Geological Storage Potential



IEA: 40 Gt CO_2

<2% of Emissions to 2050

Parson & Keith:
370-1100 Gt CO_2

IEA: 920 Gt CO_2

45% of Emissions to 2050

Parson & Keith:
740-1850 Gt CO_2

IEA: 400-10 000 Gt CO_2

20-500 % of Emissions to 2050

Parson & Keith:
370-3700 Gt CO_2

Source: Freund, IEA - Comparative potentials at storage costs of up to \$20/t CO_2

Source: Parson & Keith, Science 282, 1053-1054, 1998

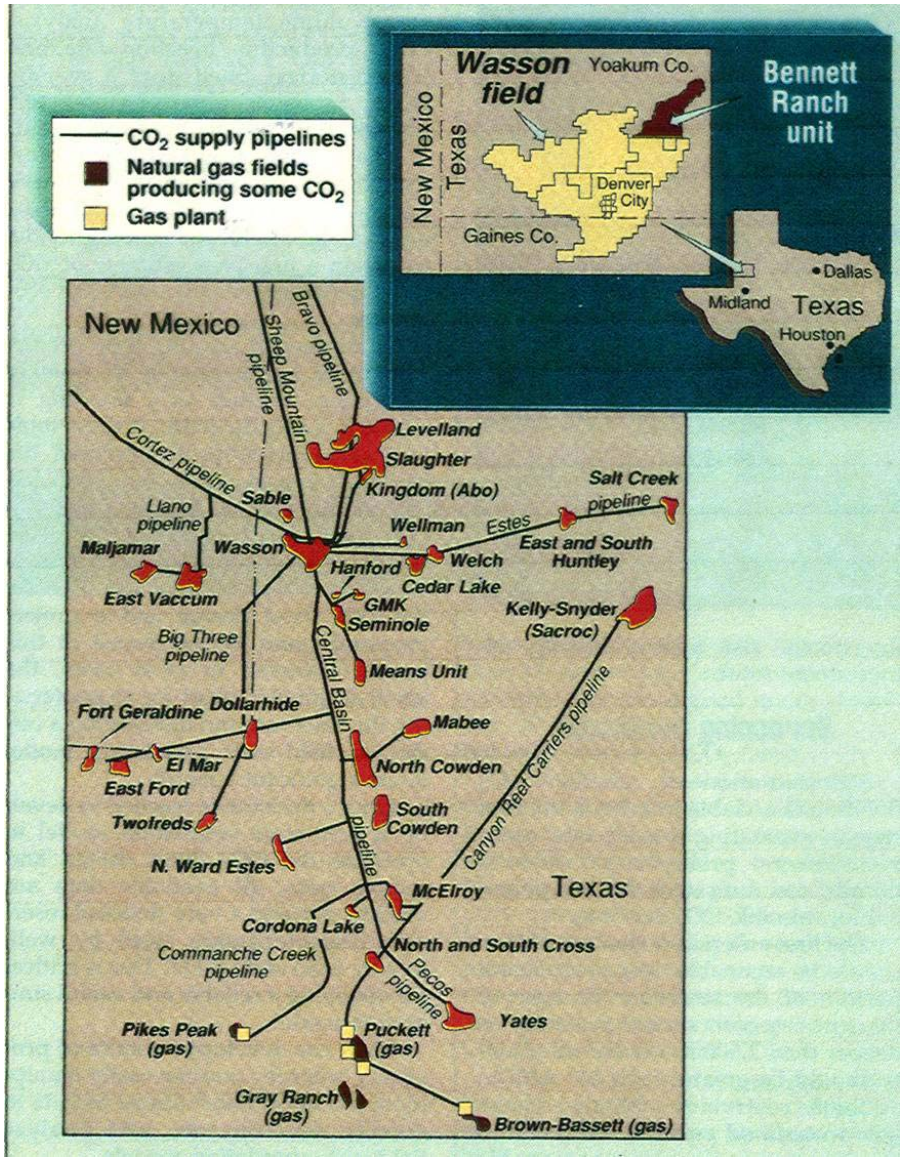
Is the required technology available to do this at large scale?

- Oil reservoirs – known geologic trap, good experience, but lots of places with no oil reservoirs.
- Gas reservoirs – potential, but not much experience so far.
- Aquifers – wide geographic distribution, opportunities to select sites with multiple barriers to flow to contain CO_2, less information available about flow properties.
- Deep, unmineable coal beds – adsorption mechanism is favorable, details least well understood of the four options.

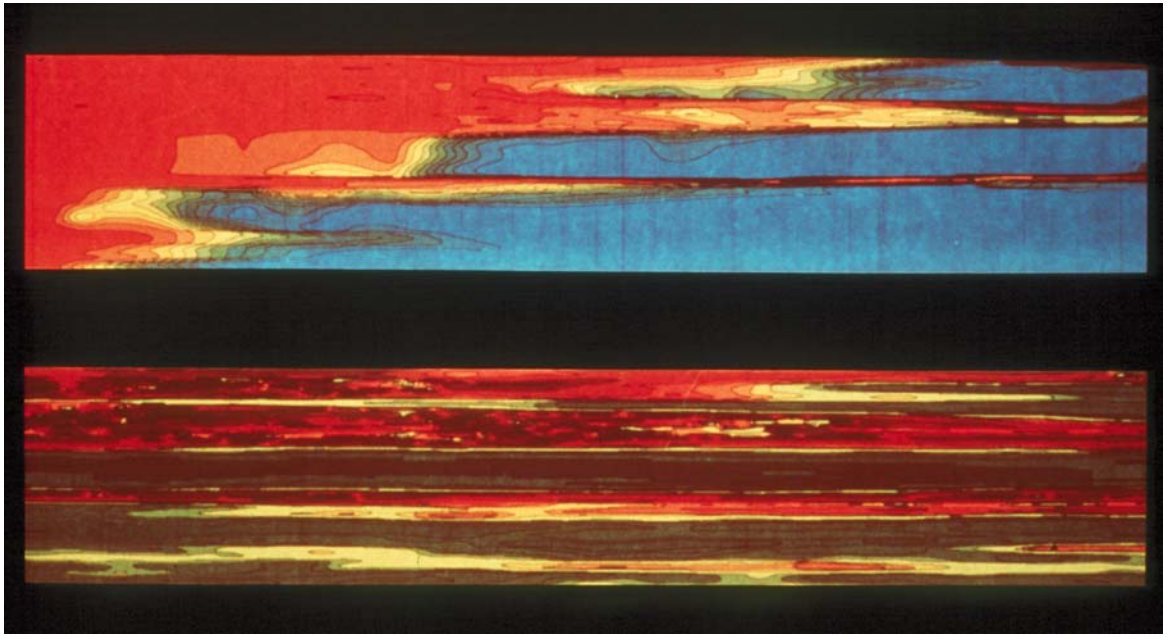
Answer: Yes, but there is more to do …

CO_2 for EOR

- Proven technology – 66 projects in US
- Use of CO_2 for oil recovery is limited by gas supply
- 1998 production ~ 180,000 B/D
- 1998 CO_2 injection (natural CO_2) ~ 7.5 million t/yr C ~ 0.6% of fossil fuel emission

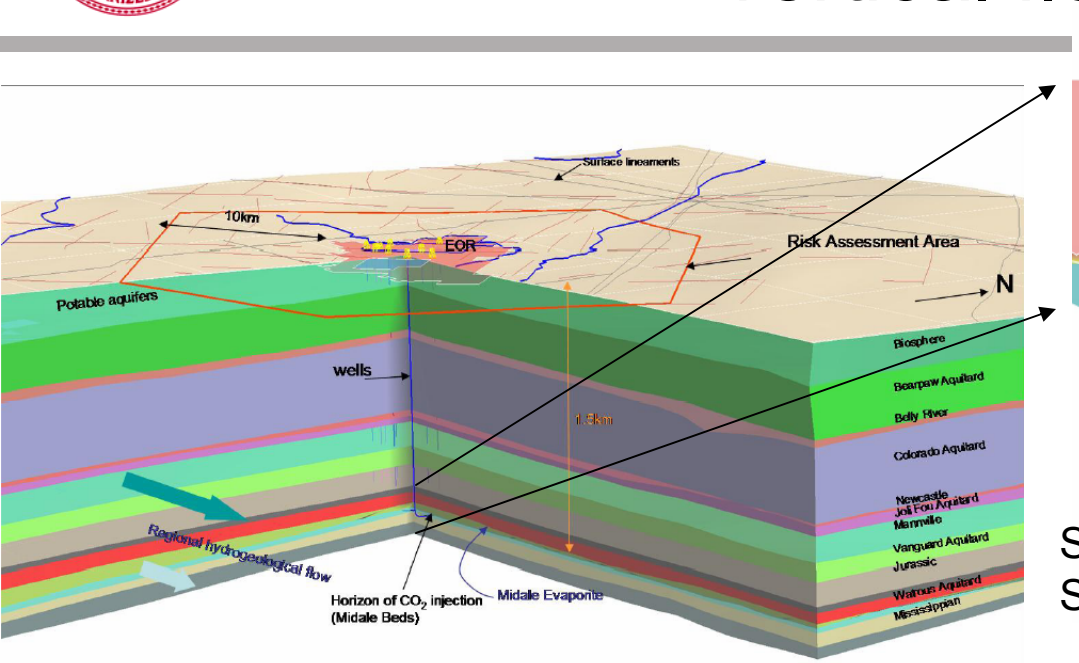


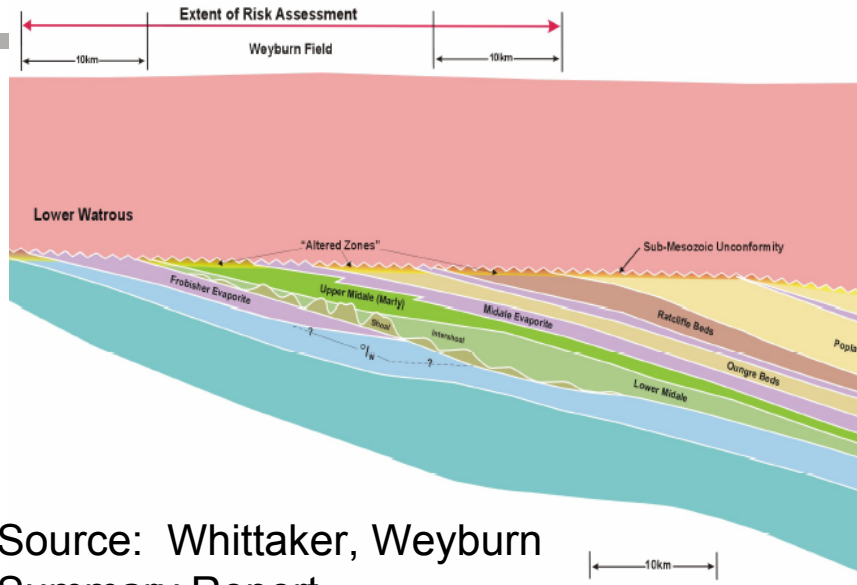
Flow in the subsurface is dominated by the variable flow properties of the rocks



- In deep, saline aquifers, this is actually an advantage – heterogeneity distributes CO_2, making it easier for it to dissolve. Once it is dissolved in the water, there is no driving force for upward migration.
- Capillary forces can also trap CO_2, limiting its flow.
- Seek sites with multiple low-permeability layers above that limit flow.

Weyburn: multiple barriers to vertical flow

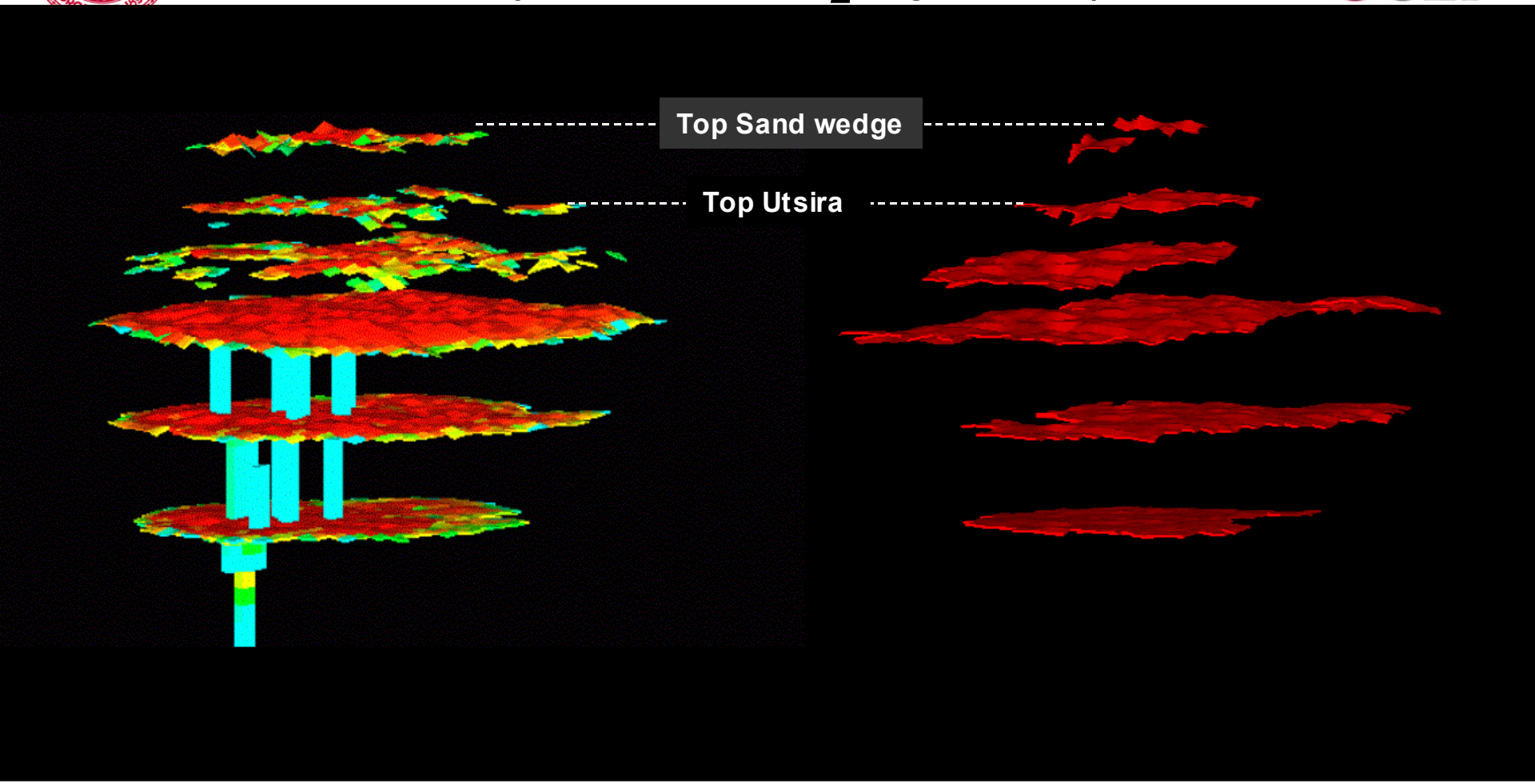




Source: Whittaker, Weyburn Summary Report

- Even if the oil were not present at Weyburn, it would be a good place to store CO_2. But the oil indicates that there is a trap with a good seal.
- The deep formations containing salt water are separated from shallow aquifers by multiple, thick, low permeability formations.

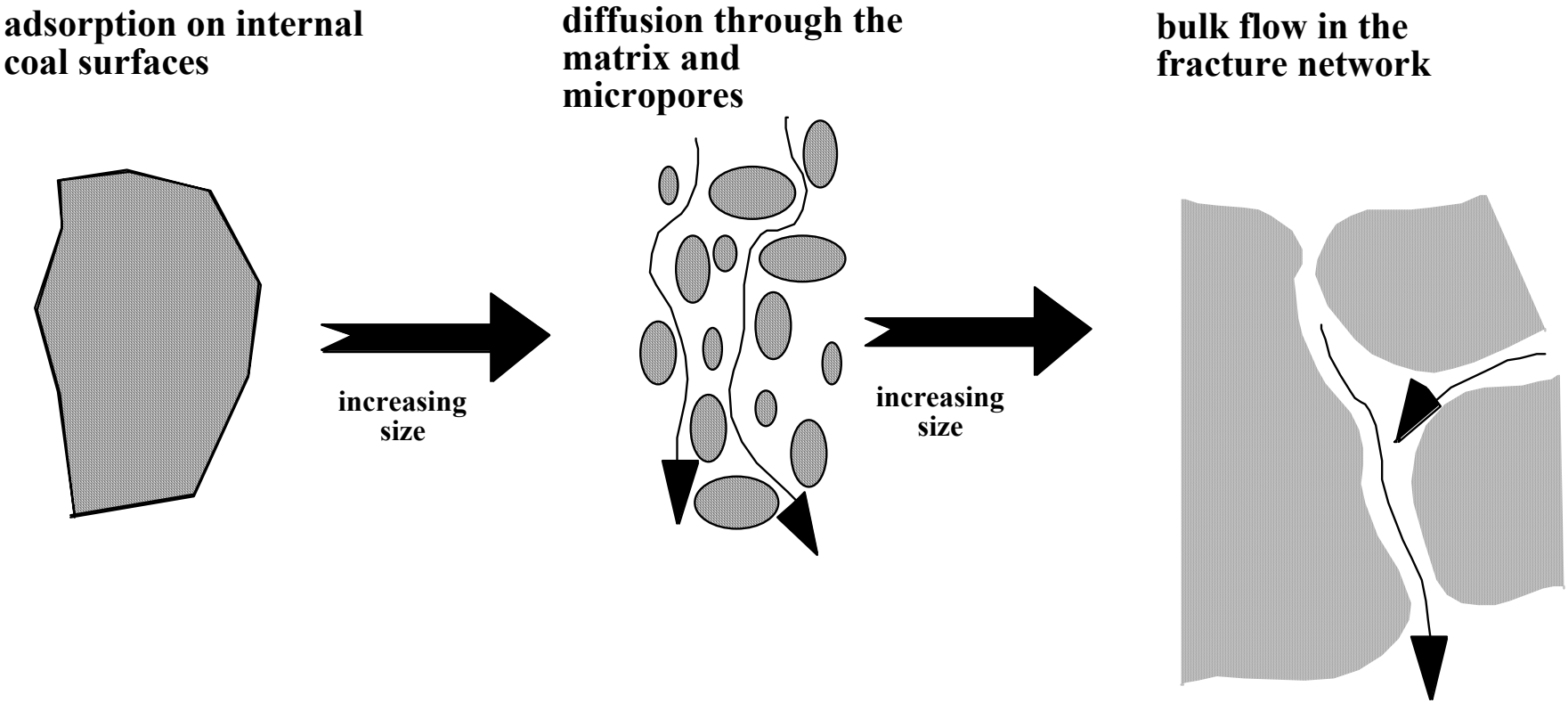
Simulation vs seismic observations (after five years of CO_2 injection)



Gravity segregation with flow under shales strongly influences the distribution of injected CO_2.

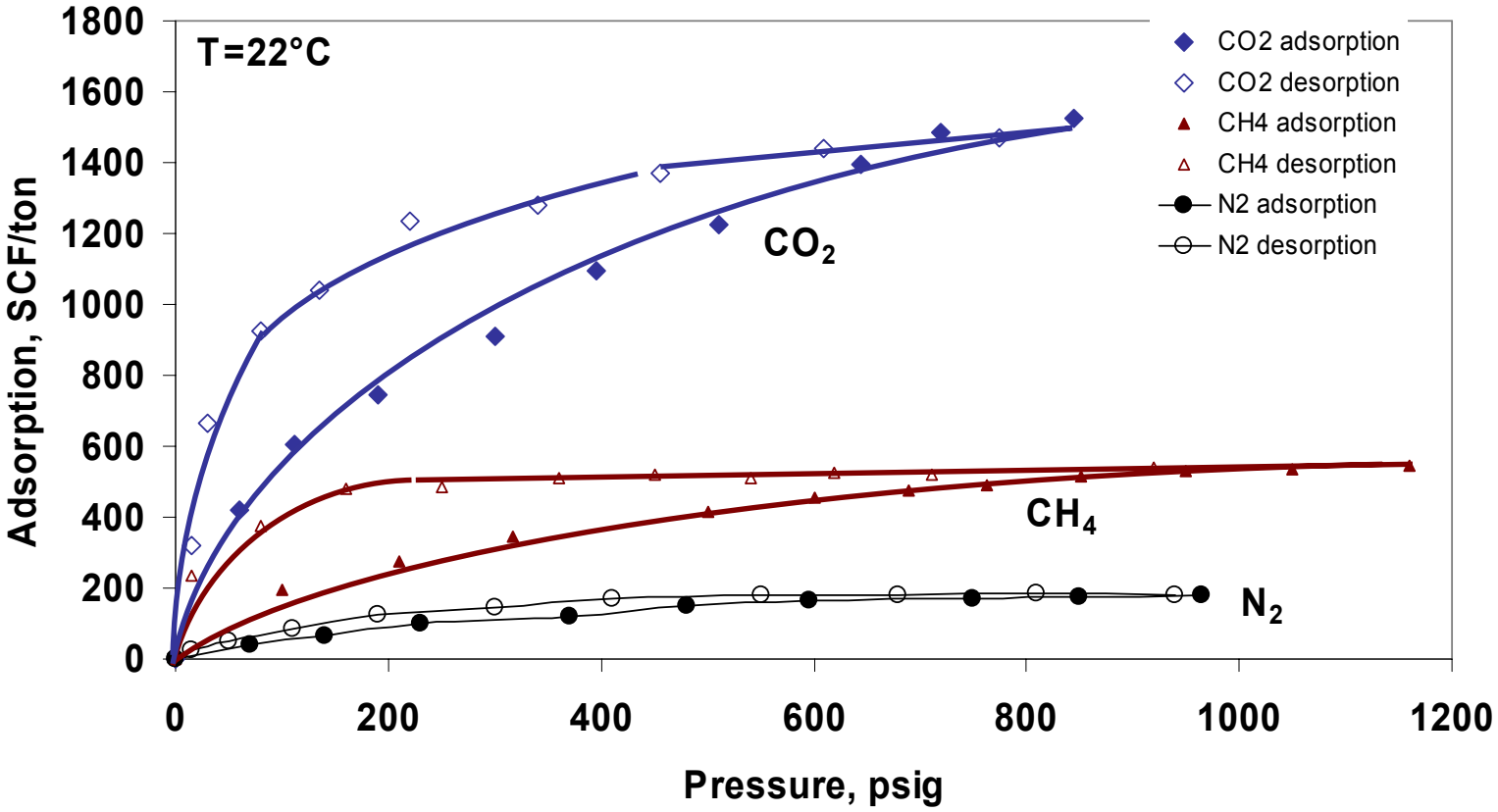
Source: Lindeberg, SACS Best Practices Report

Adsorption/Desorption/Transport in Fractured Coal



In many coal beds, methane is adsorbed on coal surfaces. When CO_2 is injected, it replaces the methane, which can then be recovered.

Adsorption Behavior



Substantially more CO_2 adsorbs on coal particle surfaces than does CH_4 or N_2. Once the CO_2 is adsorbed, it will stay adsorbed even if pressure is reduced signficantly.

Source: Kovscek, Stanford University

Observations

- CO_2 storage will be very site specific. For each site, we will need to:
  - Predict where the CO_2 will go
  - Measure where it went
  - Understand seal integrity and barriers to leakage
- Experience with EOR indicates that this can be done safely with:
  - Careful design for each site
  - Careful attention to safe operations
- Good communication with the public will be essential