Sequestration in Coal Seams: An Overview

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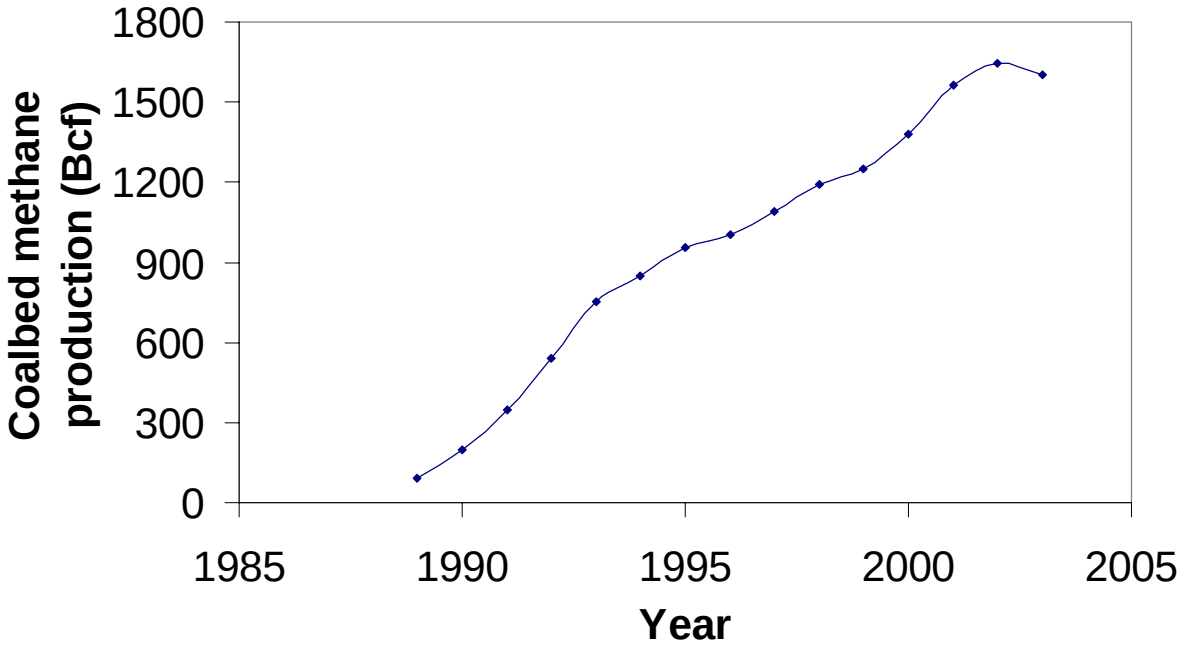
Coalbeds are a major source of natural gas.*

- **3000 to 9000 Tm^3 estimated global resource**
- **8 to 17 Tm^3 estimated U.S. resource**
- **Estimates of between 155 and 185 Billion tonnes of CO_2 storage capacity in North American coals**

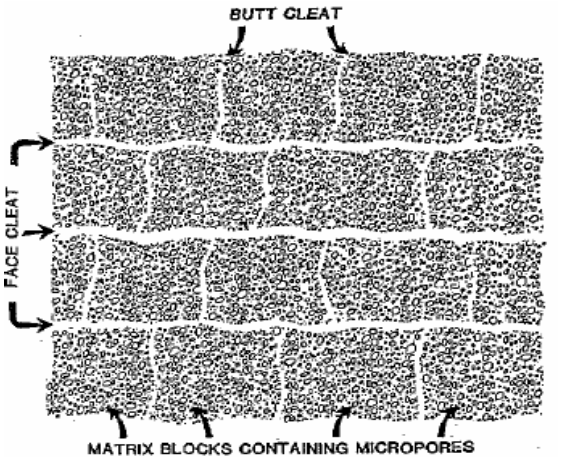


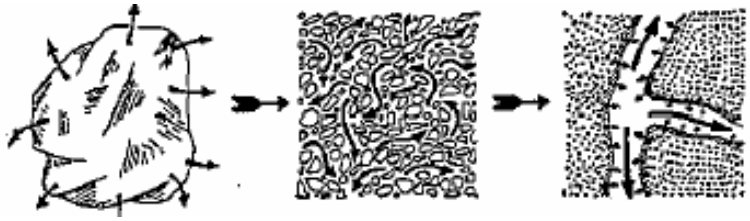
Data from Energy Information Administration. U.S. Crude Oil, Natural Gas, and Natural Gas Liquids Reserves 2003 Annual Report, Table 12.

*C.M. White, D.H. Smith, K.L. Jones, et al,"Sequestration of Carbon Dioxide in Coal with Enhanced Coalbed Methane Recovery--A Review," *Energy & Fuels* 19, 659-724 (2005).

Production from coal can be a complex process.

- Flow through coal is defined in large part by the cleat network.
- Methane sorbed on the coal is released by decreasing pressure.
- Water needs to be moved out of cleats before gas can flow.
- CO_2 injection causes reverse process (adsorption instead of desorption.

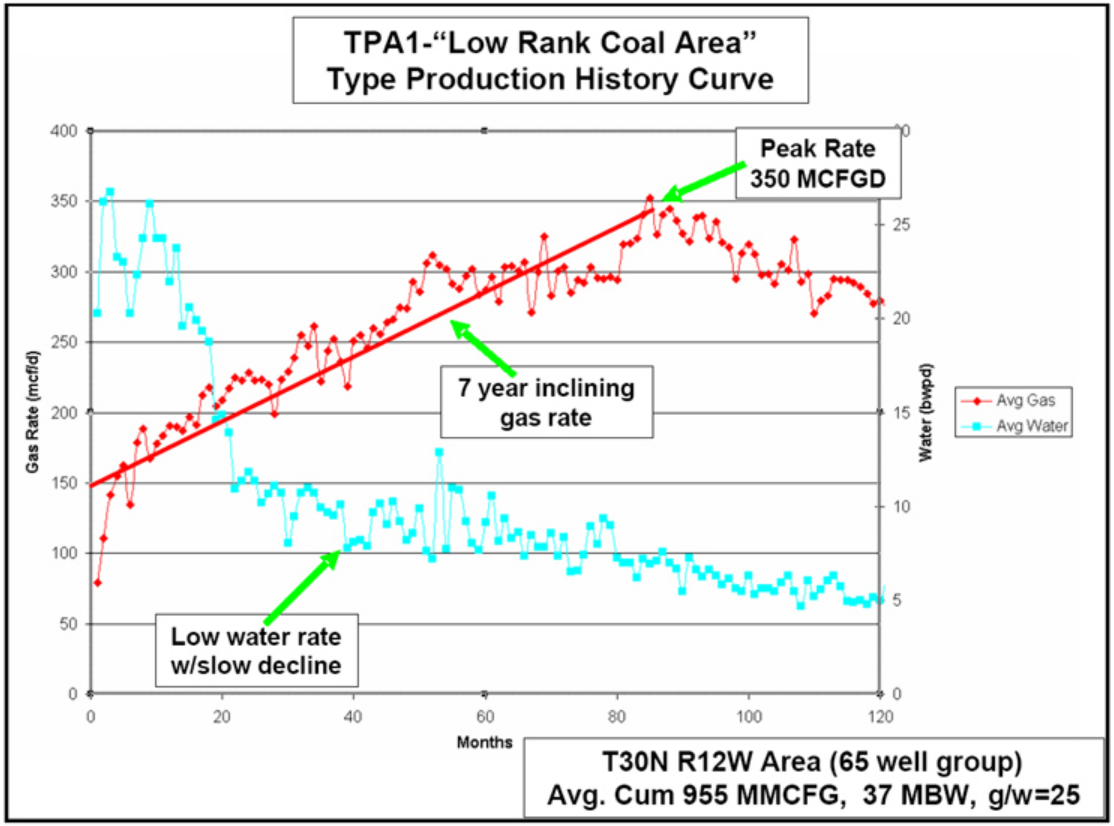




SORPTION DIFFUSION ADVECTION

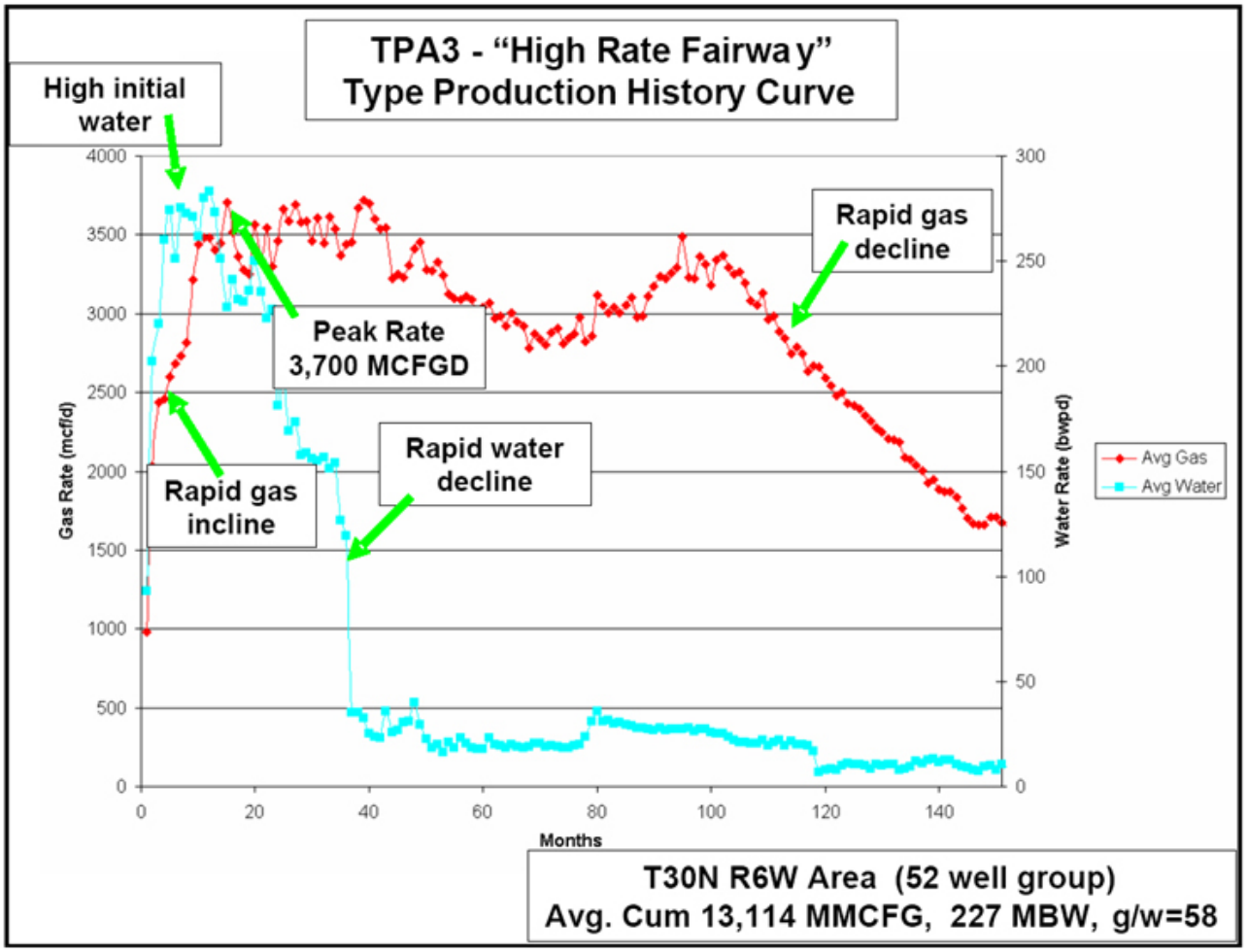
Often, gas production is inhibited by initial water production.

- Relative permeability in the cleats affects flow of gas.
- Most of the water around the injection area should be removed before CO_2 is injected.



Meek and Levine, 2006

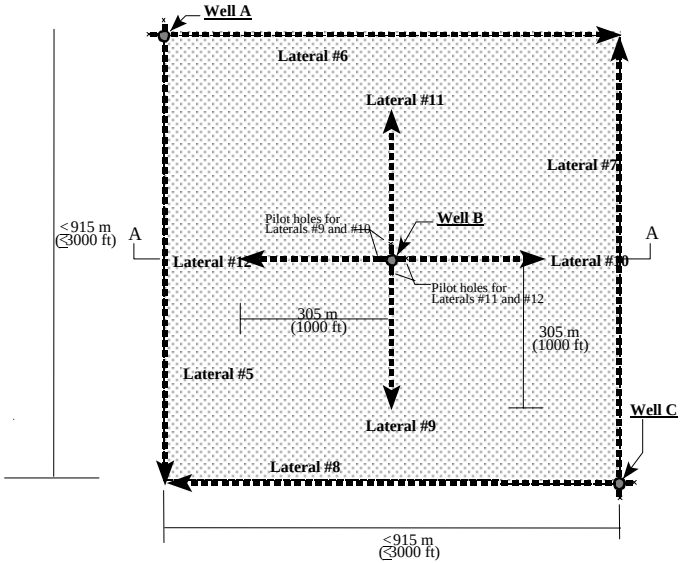
However, sometimes water has short or little effect.

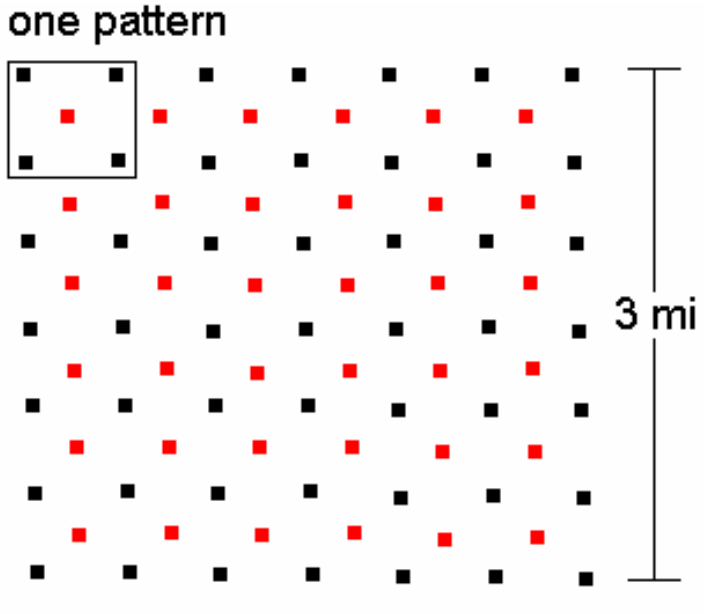


Meek and Levine, 2006

CO_2 sequestration in coal will occur with ECBM.

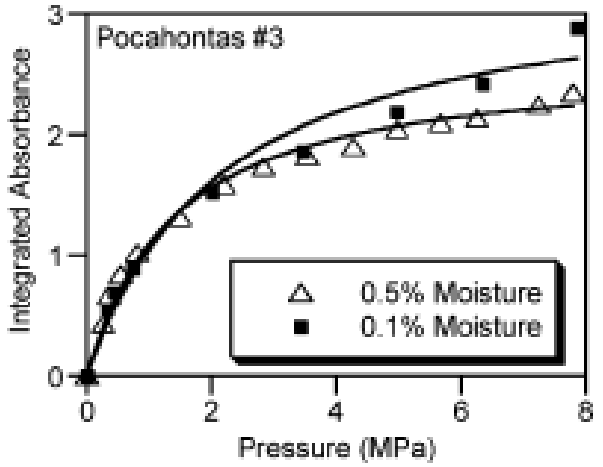
- Five-spot pattern for thick coals (San Juan Basin)
- For thinner seams, horizontal wells may be used.

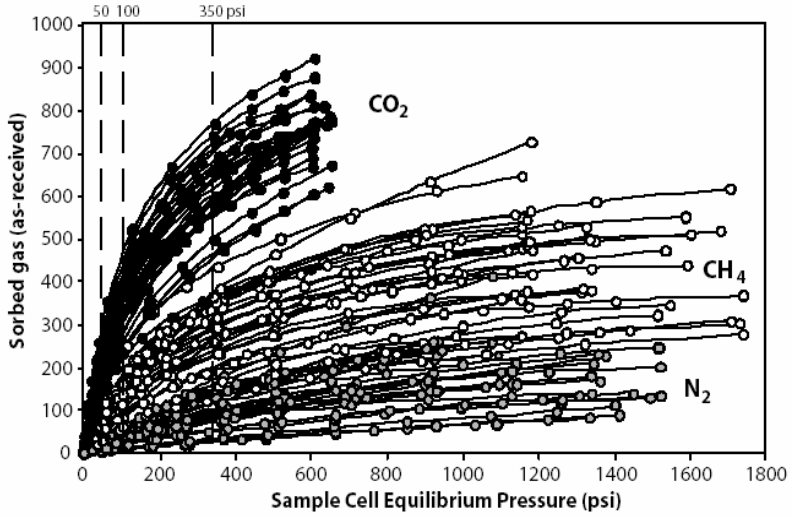




How much CO_2 can be stored (and methane removed)?

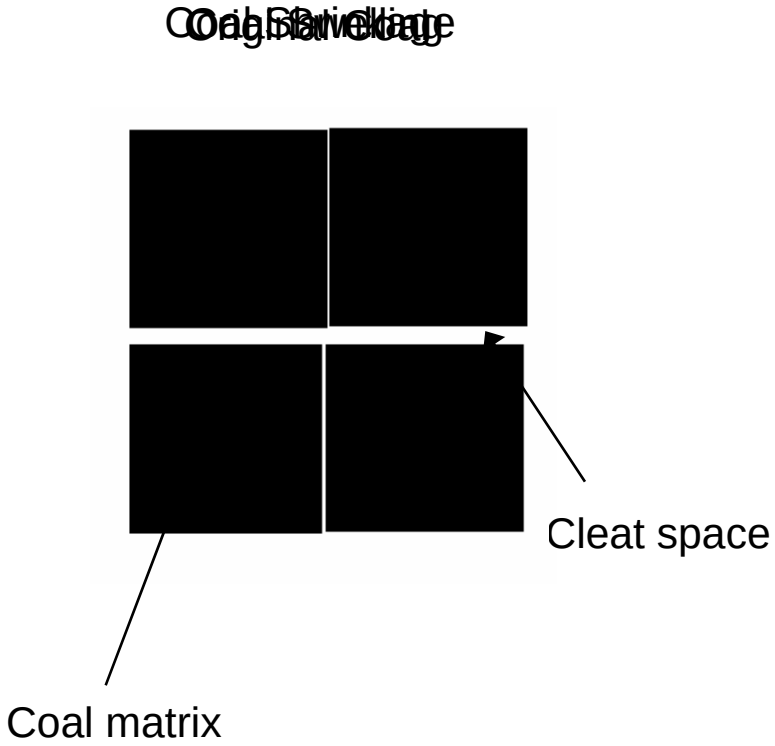
- Sorption is typically considered to follow a Langmuir isotherm.
- The gas pressure in the coal seam determines how much is sorbed to the coal.
- CO_2 is preferentially sorbed to coal, compared to methane.



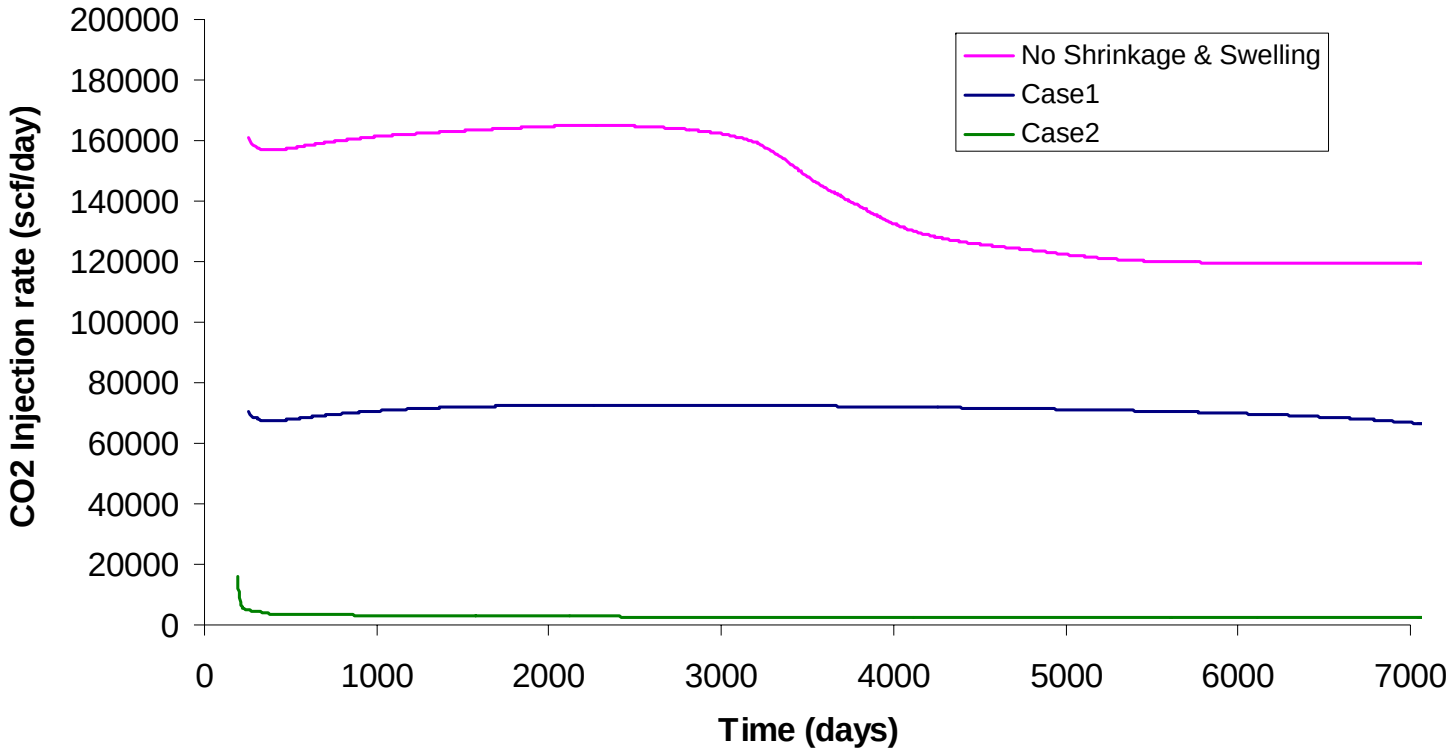


Coal shrinkage and swelling can have significant impact of cleat permeability.

- **Based on the Palmer-Mansoori model**
- **Most important effect is on permeability**
- **Most important coal properties for shrinkage and swelling:**
  - Porosity (ϕ)
  - Young's modulus (E)
  - Poisson's ratio (ν)



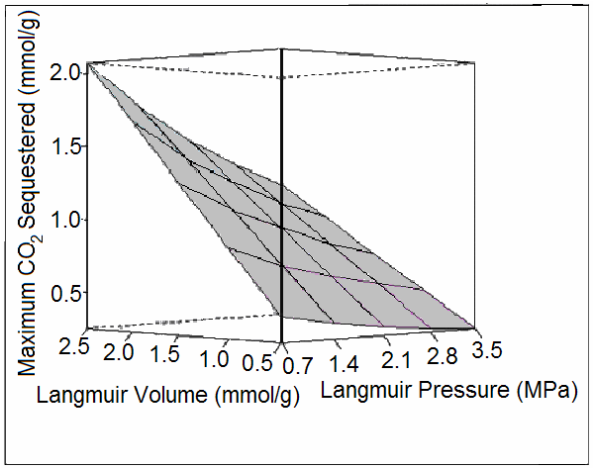
Swelling may significantly reduce cleat permeability and therefore injectivity.

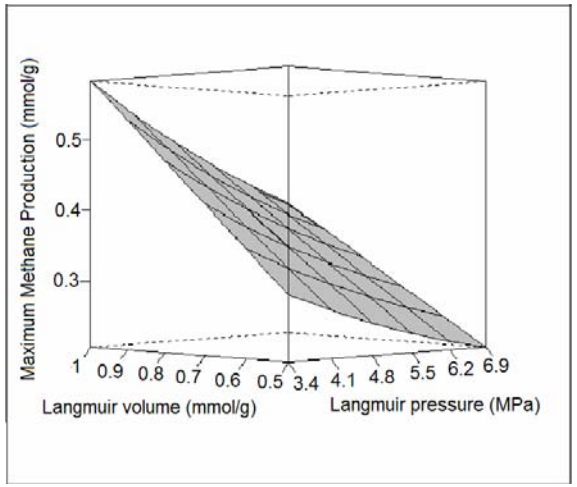


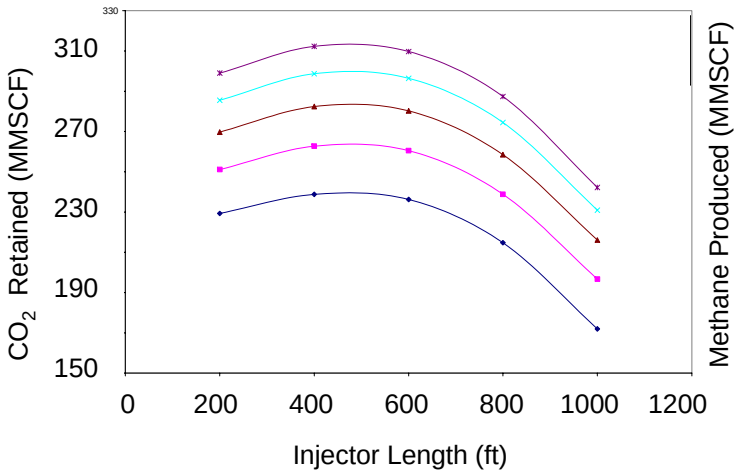
Concluding Statements

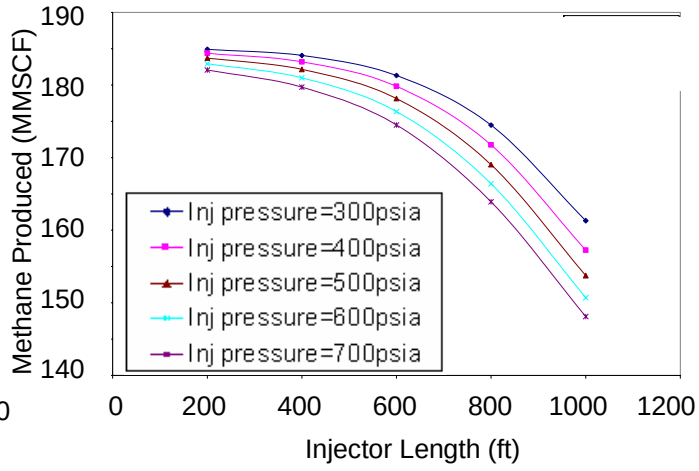
- We have a couple of decades of experience in CBM production.
- CO_2-ECBM is still in its infancy and much is being learned.
- A lot of capacity may be available.
- Swelling could prove to be a big issue.

We found optimum engineering designs for many different values of the coal properties.



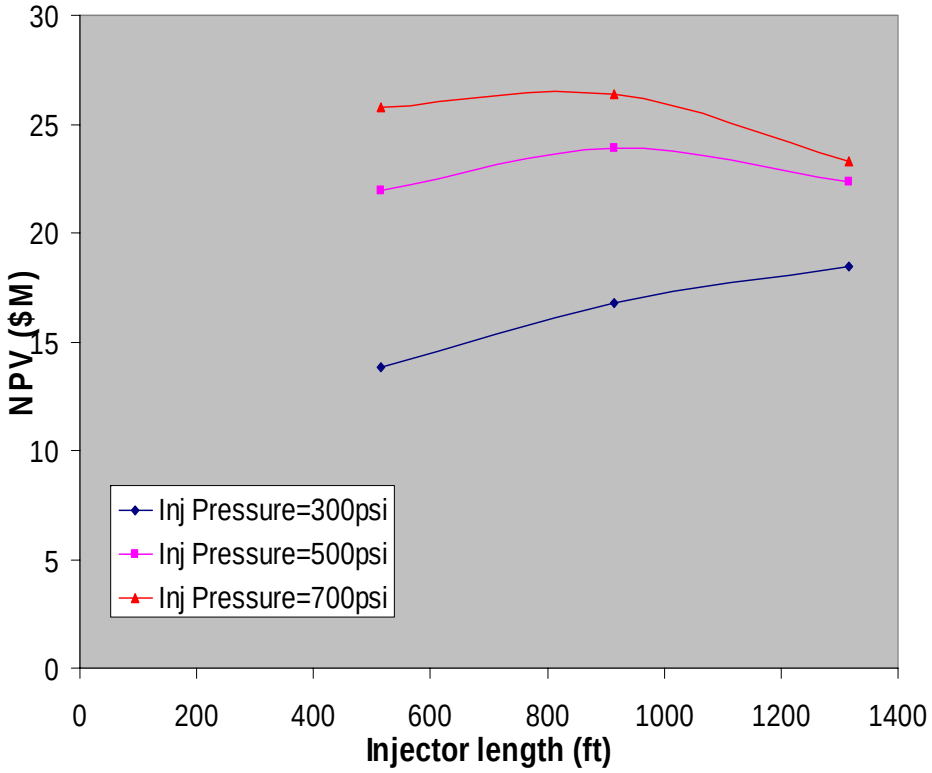






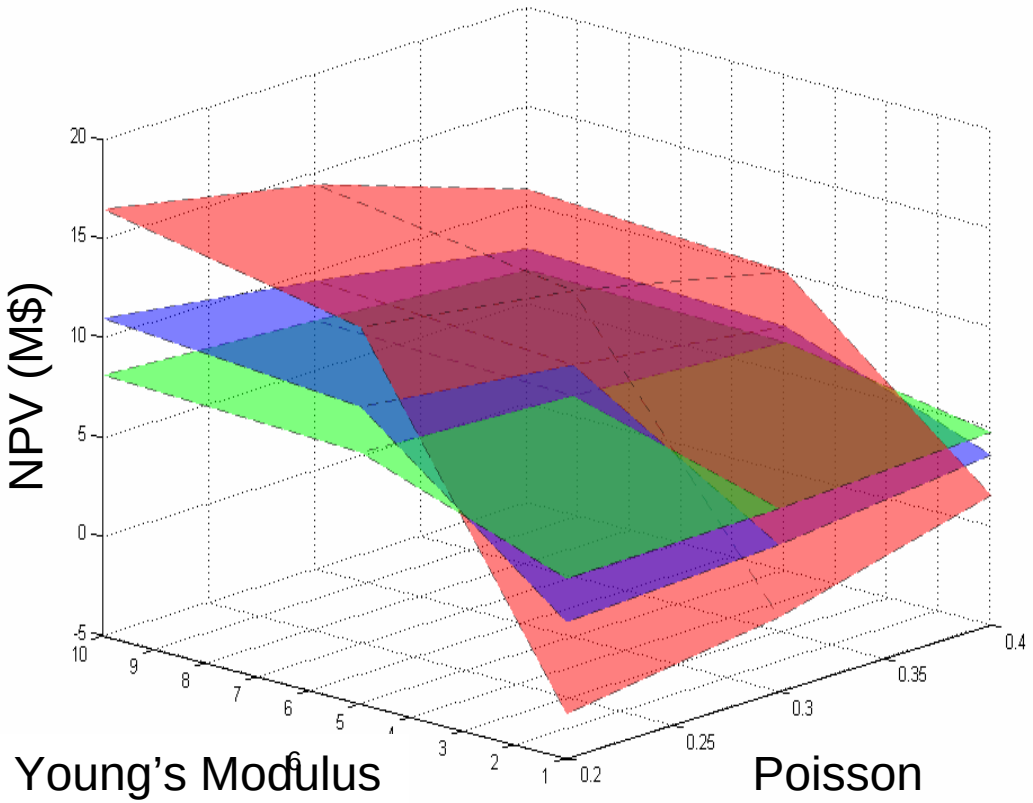
We found which physical parameters are most important for sequestration economics.

- **Vertical wells.**
- **DOE horizontal well project:**
  - Shorter injectors better for enhanced gas production, but not for sequestration.
  - Natural gas price important for profitability, but for the cases studied, had little effect on optimal design.
  - CO_2 price/credit determines optimized design.
- **Initiated discussions for possible addition to IECM.**



For the Technology Opportunity "modeling studies of swelling," we predicted which petrophysical parameters are economically important.*

- Young's modulus generally more important than Poisson's ratio.
- Preferred cleat porosity depends on Young's modulus.



*Sequestration Technology Roadmap

Our simulations and experiments are mutually supportive.

- CT imaging of coal cores: before, during, after injection
- Petrography
- Gas sorption and uptake rates, <u>at lithostatic pressures</u>
- Young's modulus, etc.
- DEMONSTRATED THAT SORPTION ISOTHERMS ARE NEEDED AT LITHOSTATIC PRESSURES.