

Sequestration in Coal Seams: An Overview

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Carbon Sequestration Leadership Forum

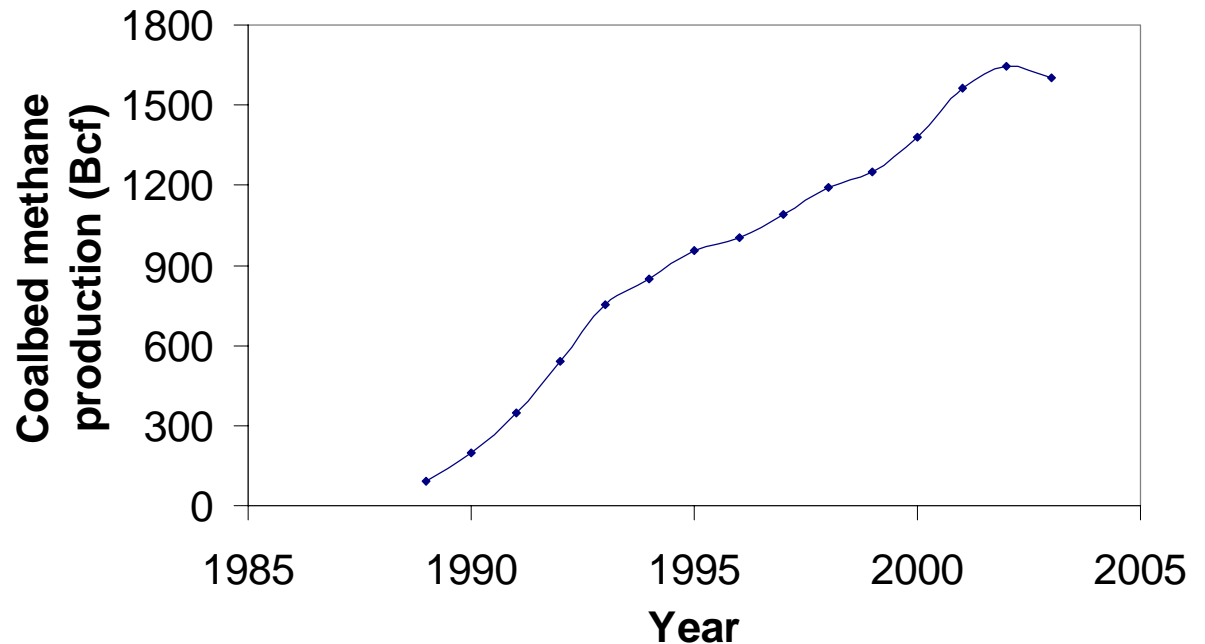
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Coalbeds are a major source of natural gas.*

- 3000 to 9000 Tm³ estimated global resource
- 8 to 17 Tm³ estimated U.S. resource
- Estimates of between 155 and 185 Billion tonnes of CO₂ storage capacity in North American coals



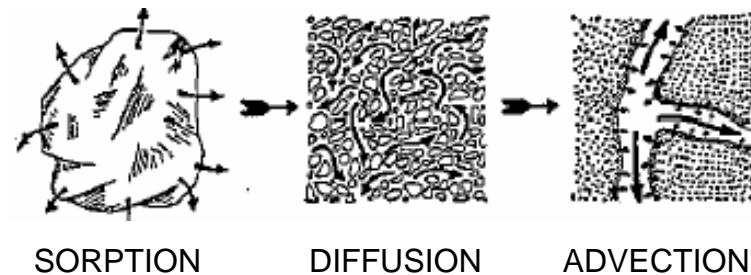
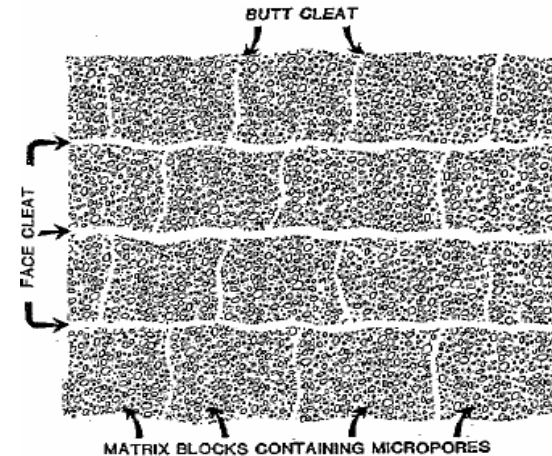
Data from Energy Information Administration. U.S. Crude Oil, Natural Gas, and Natural Gas Liquids Reserves 2003 Annual Report, Table 12.



*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).

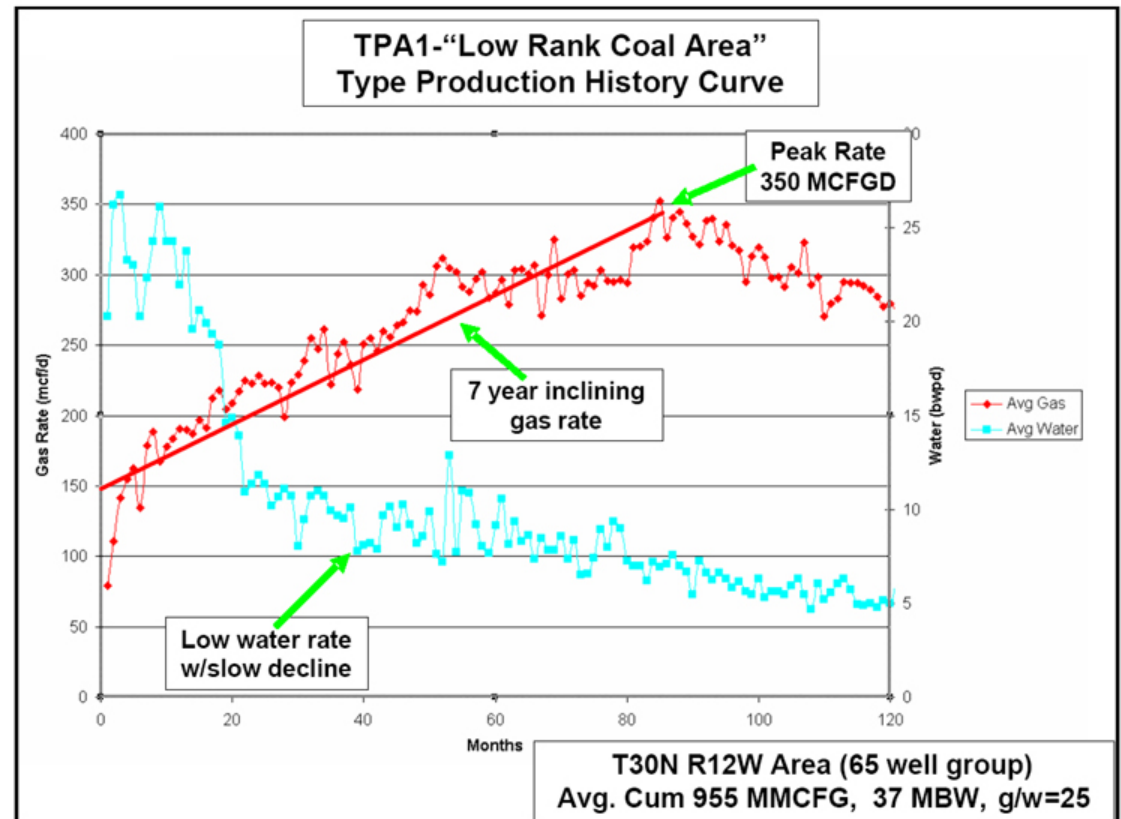
Production from coal can be a complex process.

- 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.
- CO₂ injection causes reverse process (adsorption instead of desorption).



Often, gas production is inhibited by initial water production.

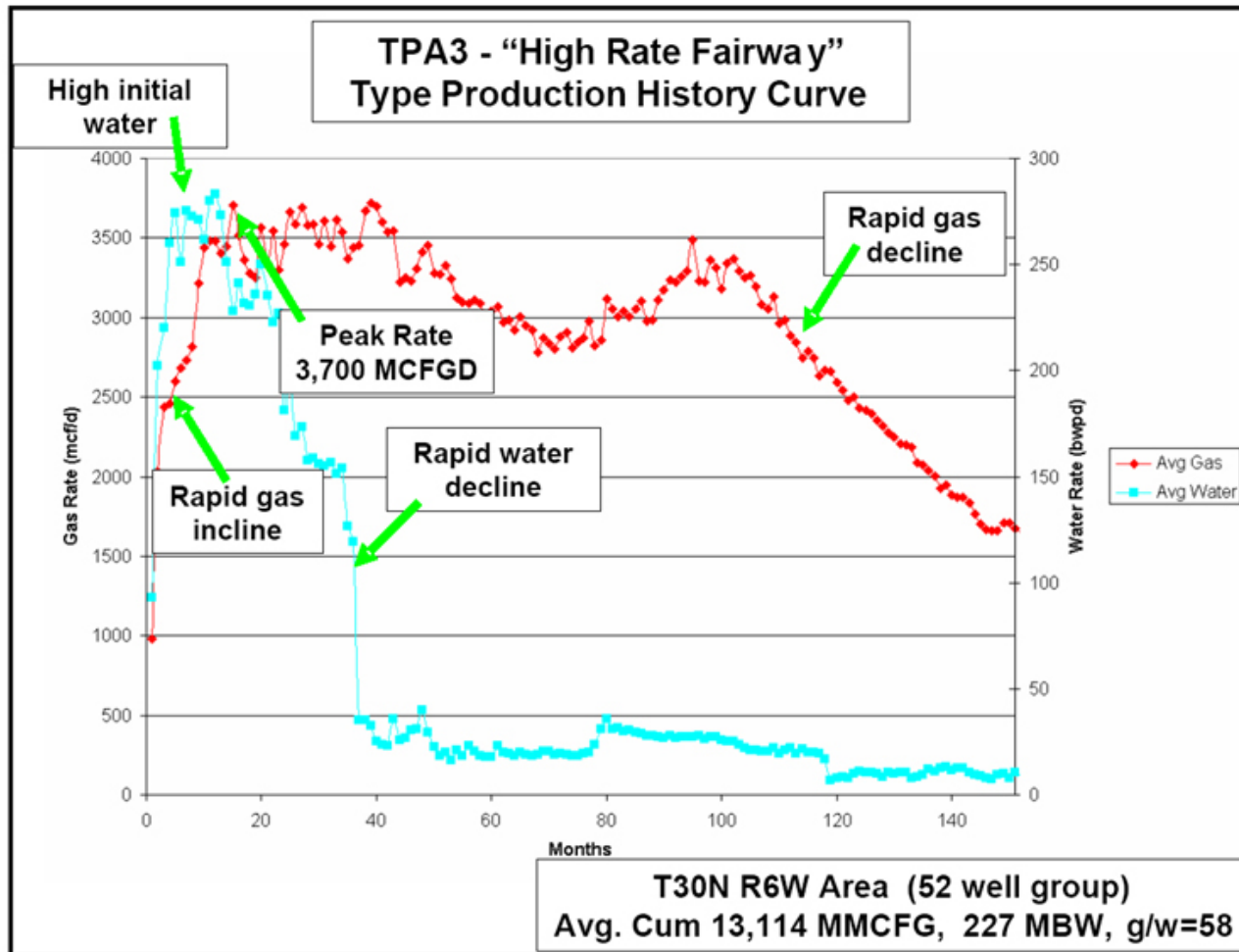
- Relative permeability in the cleats affects flow of gas.
- Most of the water around the injection area should be removed before CO₂ is injected.



Meek and Levine, 2006



However, sometimes water has short or little effect.

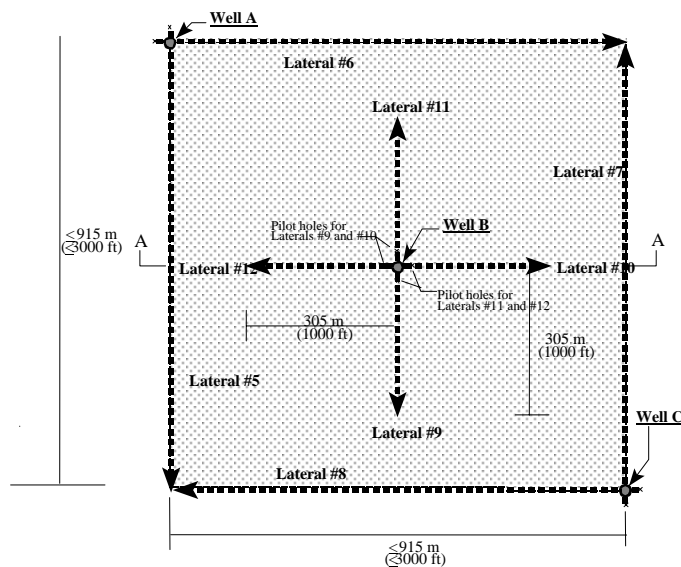


Meek and Levine, 2006

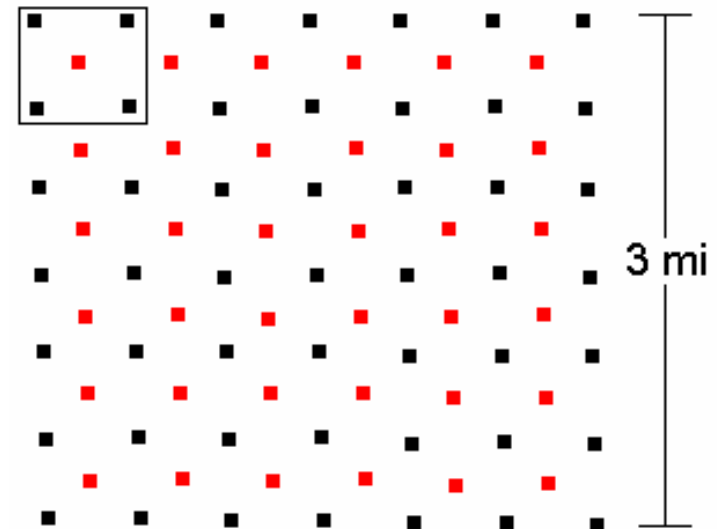


CO₂ sequestration in coal will occur with ECBM.

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

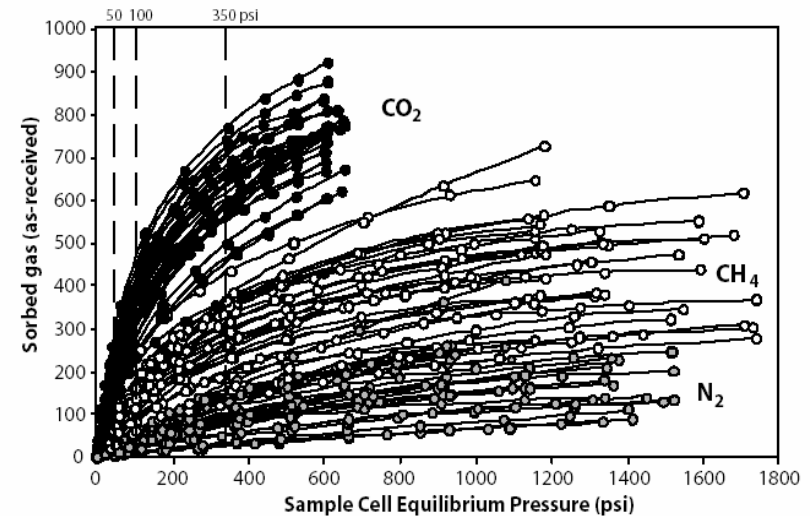
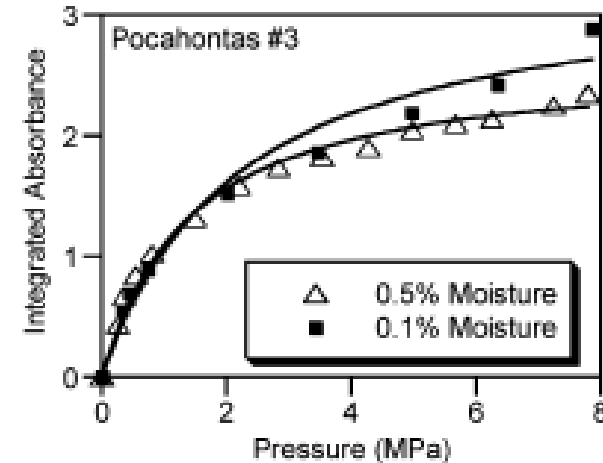


one pattern



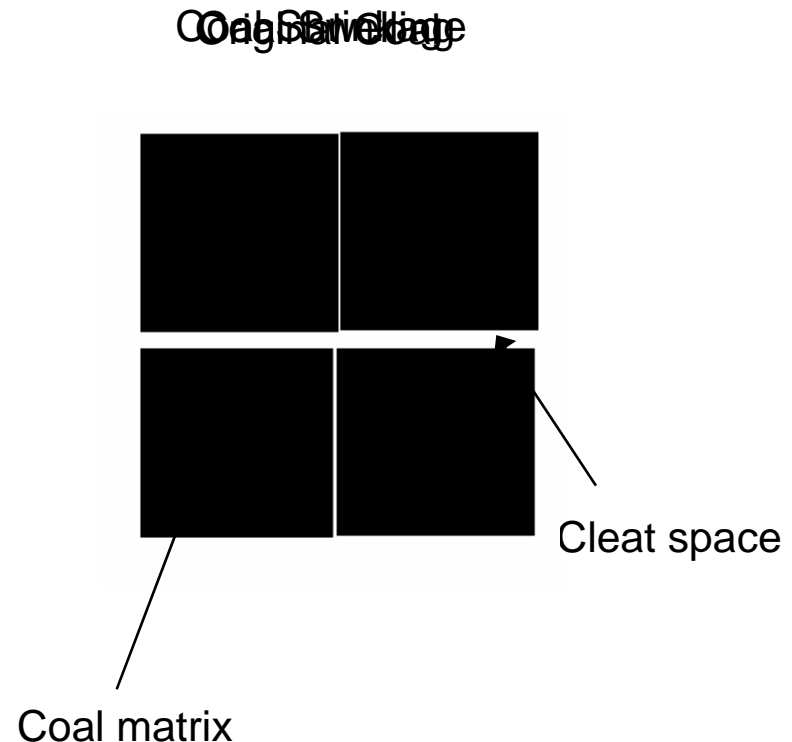
How much CO₂ can be stored (and methane removed)?

- Sorption is typically considered to follow a Langmuir isotherm.
- The gas pressure in the coal seam determines how much is sorbed to the coal.
- CO₂ is preferentially sorbed to coal, compared to methane.

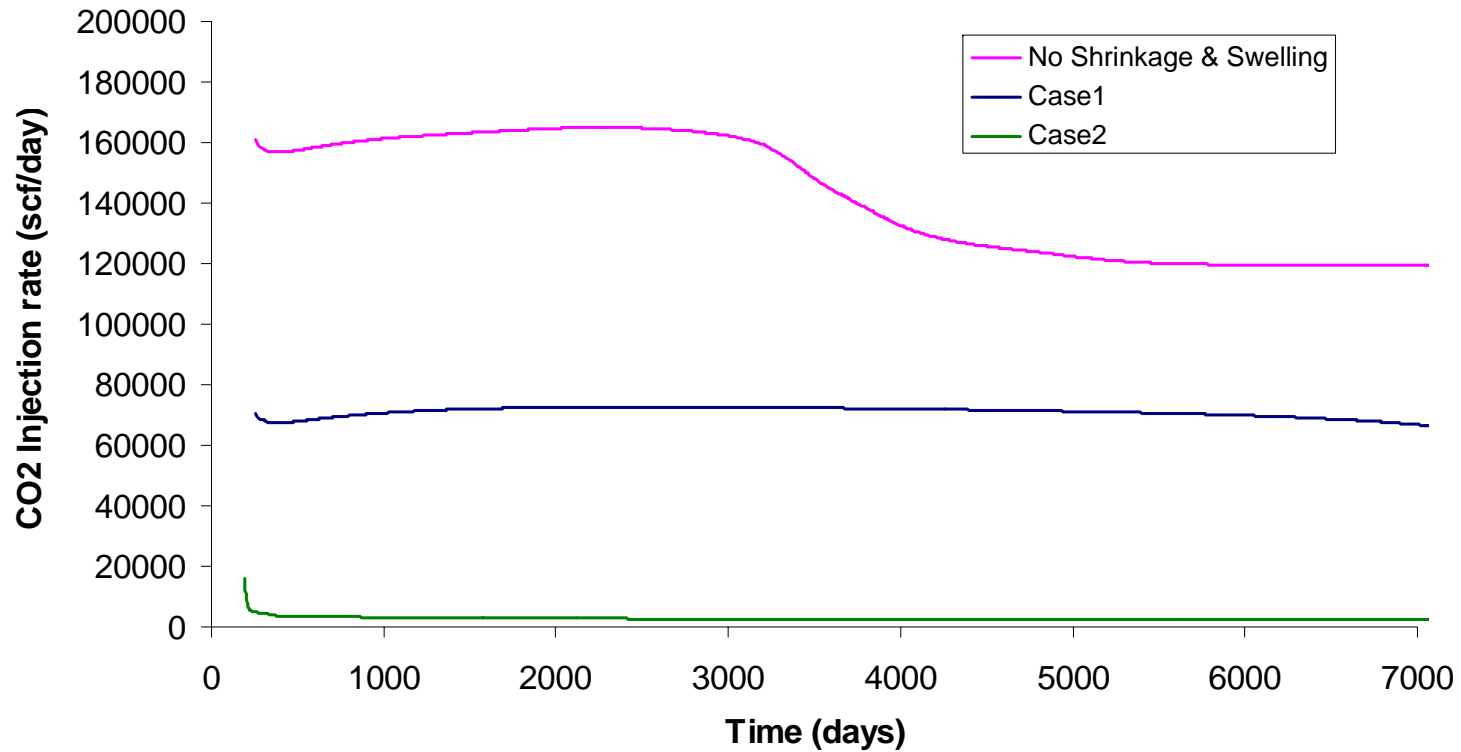


Coal shrinkage and swelling can have significant impact of cleat permeability.

- 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.

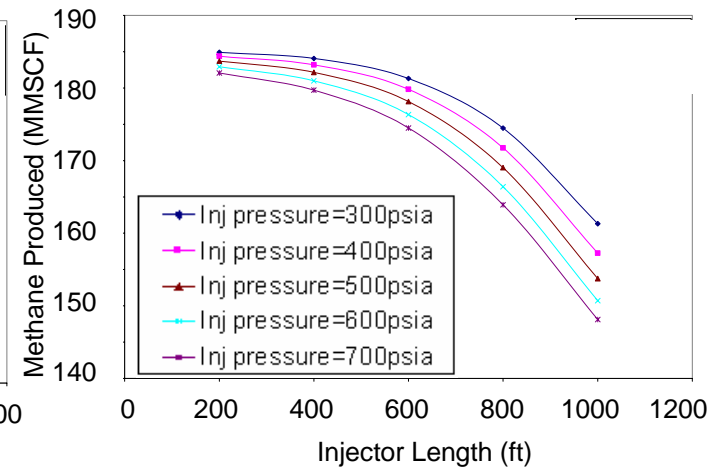
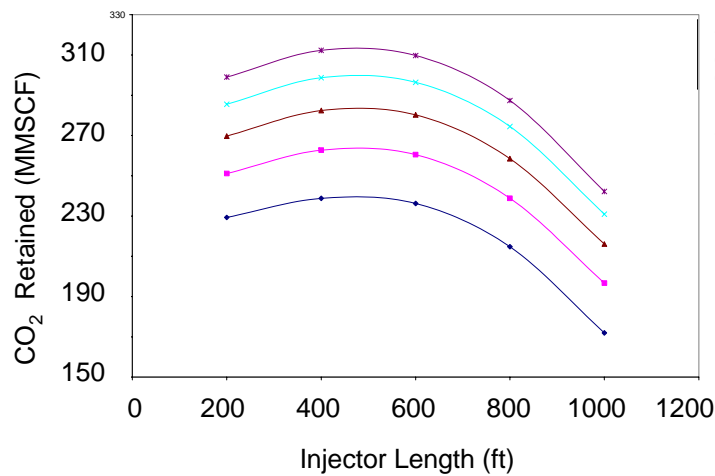
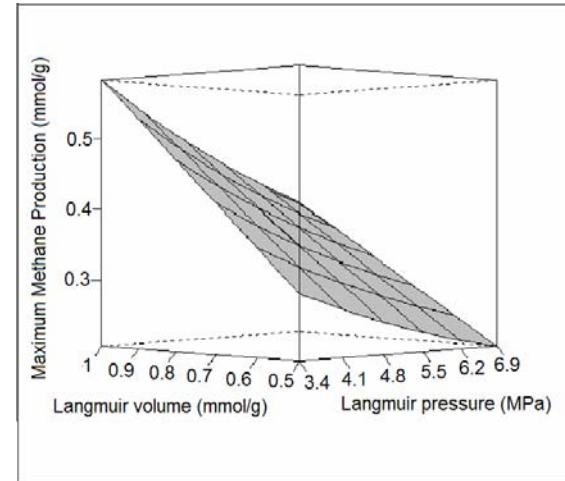
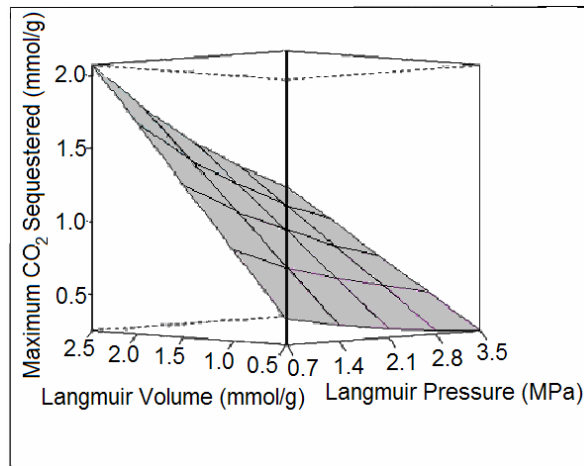


Concluding Statements

- We have a couple of decades of experience in CBM production.
- CO₂-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.

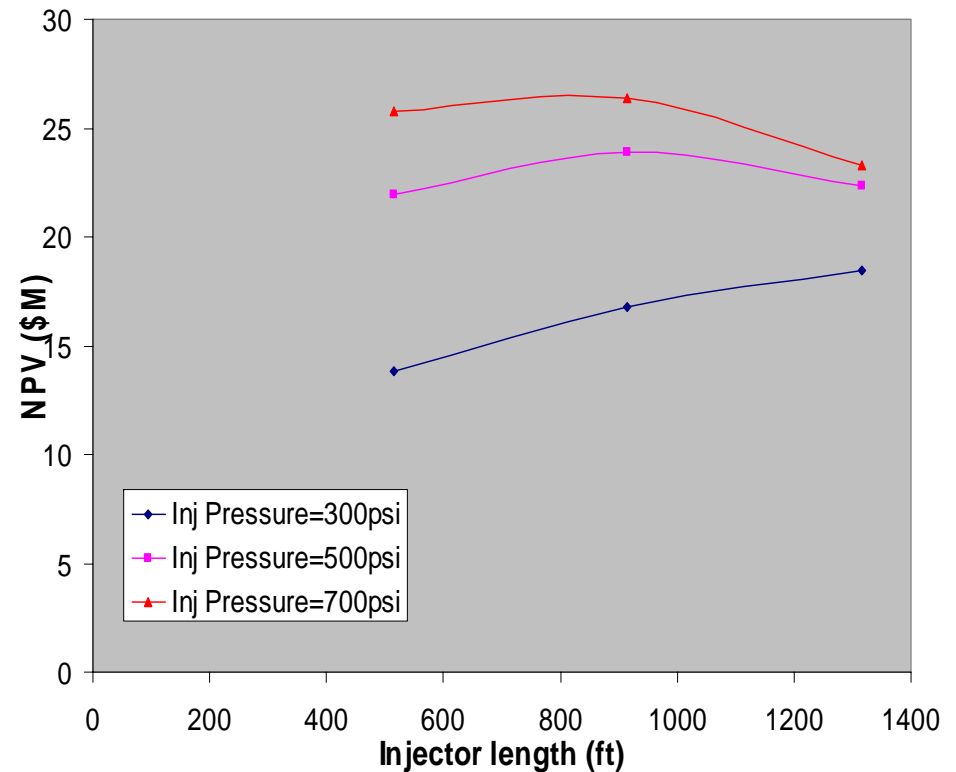


We found optimum engineering designs for many different values of the coal properties.



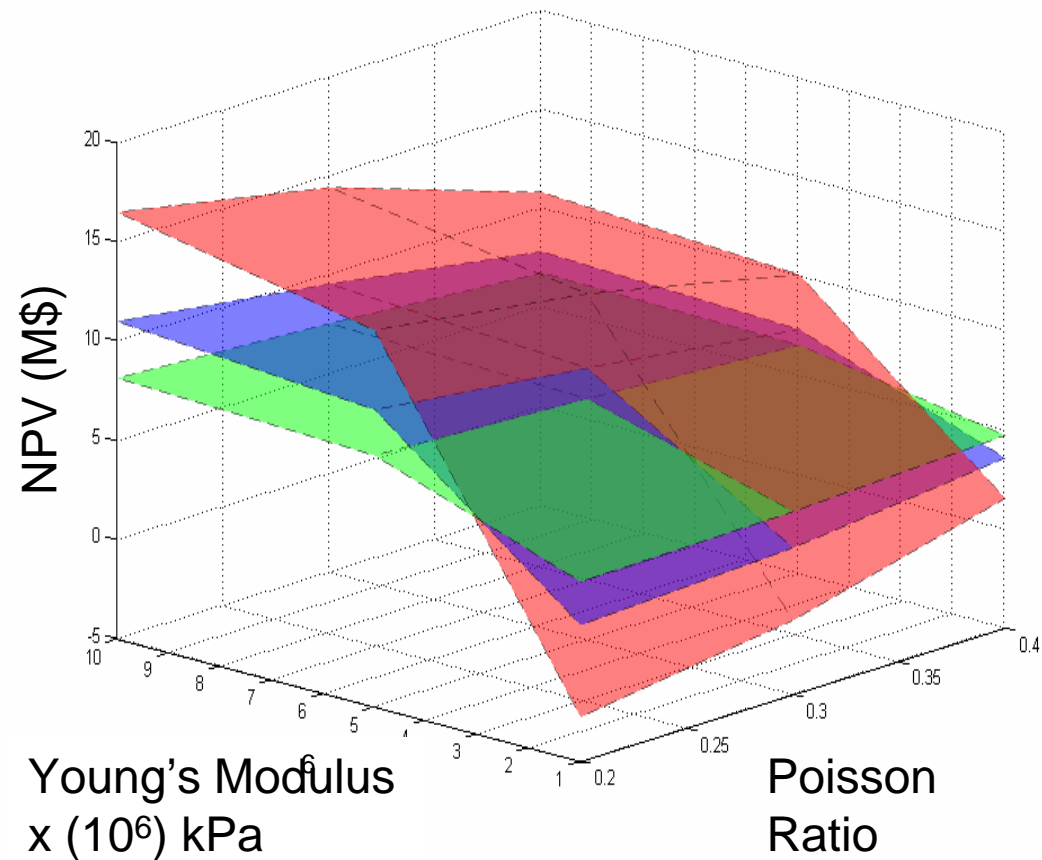
We found which physical parameters are most important for sequestration economics.

- 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.
 - CO₂ 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, at lithostatic pressures
- Young's modulus, etc.
- **DEMONSTRATED THAT SORPTION ISOTHERMS ARE NEEDED AT LITHOSTATIC PRESSURES.**

