

Fourth Annual Conference on Carbon Capture & Sequestration

*Developing Potential Paths Forward Based on the
Knowledge, Science and Experience to Date*

*Geologic – Coal Seams (1)
Session #19*

The Coal-Seq II Consortium: Advancing the Science of CO₂ Sequestration in Deep, Unmineable Coalseams

Paper #82

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Abstract

In 2000, the government-industry collaboration Coal-Seq project was launched. Using a combination of theoretical, laboratory and field studies, over the past four years the project has successfully demonstrated that CO₂ sequestration in coal is not only feasible, but under certain cases profitable. Further, the potential sequestration capacity in the U.S. was assessed at 90 Gt, with an associated ECBM resource of 150 Tcf. However, important challenges were also identified, most notably the occurrence of coal swelling and injectivity reduction with CO₂ injection, which significantly impacts economic performance. This complex behavior is not fully understood nor can it be reliably predicted, most likely due to inadequate underlying theories to predict multi-component sorption, bi-directional diffusion, and CO₂-mixture PVT properties. An improved understanding of these mechanisms is required to enable industry to identify the reservoir environments most suitable for sequestration/ECBM, and the best operating practices for them.

In response to this need, the Coal-Seq II consortium was formed in January, 2005. The \$1.5 million, 3-year consortium is 50% funded by the DOE, and 50% by industry sponsors. The consortium objectives are to perform laboratory experiments and develop analytical models to describe the complex reservoir mechanisms mentioned above. The models will be validated with both laboratory core flood experiments as well as field data. The resulting models will be used to assess geologic and reservoir environments best suited to sequestration/ECBM, and the best operating practices for them. This presentation describes the background, objectives, planned activities and organization of the Coal-Seq II Consortium.



Presentation Outline

- Coal-Seq Project Results
- Technology Needs
- Coal-Seq II Description



Coal-Seq Project Objectives

- Demonstrate Efficacy of Carbon Sequestration in Deep Unmineable Coals by Performing Detailed Field Studies of Existing CO₂/N₂-ECBM Projects (Allison & Tiffany)
- Understand Critical CO₂ Sequestration Reservoir Mechanics (multi-component sorption, coal swelling)
- Demonstrate Utility/Validity of Reservoir Simulation Models
- Develop Techno-Economic Screening Model to Evaluate Potential Coalseam Sequestration Projects
- Identify Geologic Settings Most Amenable to Low-Cost Sequestration
- Assess Capacity for Coalseam Sequestration across U.S.
- Disseminate Results to Industry



Coal-Seq Accomplishments

- CO₂-ECBM/sequestration documented at Allison
 - Breakeven gas price of \$2.60/Mcf
 - Incremental methane recovery of 17-18% OGIP
 - Injectivity reduction observed
- N₂-ECBM documented at Tiffany
 - Breakeven gas price of \$2.40/Mcf
 - Incremental methane recovery of 10-20% OGIP.
- Prepared field practices manual
- Demonstrated utility of existing reservoir models, and made improvements to coal swelling formulation
 - Established differential swelling factor
- Identified critical gaps in our understanding of reservoir mechanics
 - Multi-component sorption, bi-directional diffusion, CO₂-mixture PVT behavior
 - Established public database of CH₄, CO₂ and N₂ isotherm data

**Massive leveraging
of prior industry
investment.**



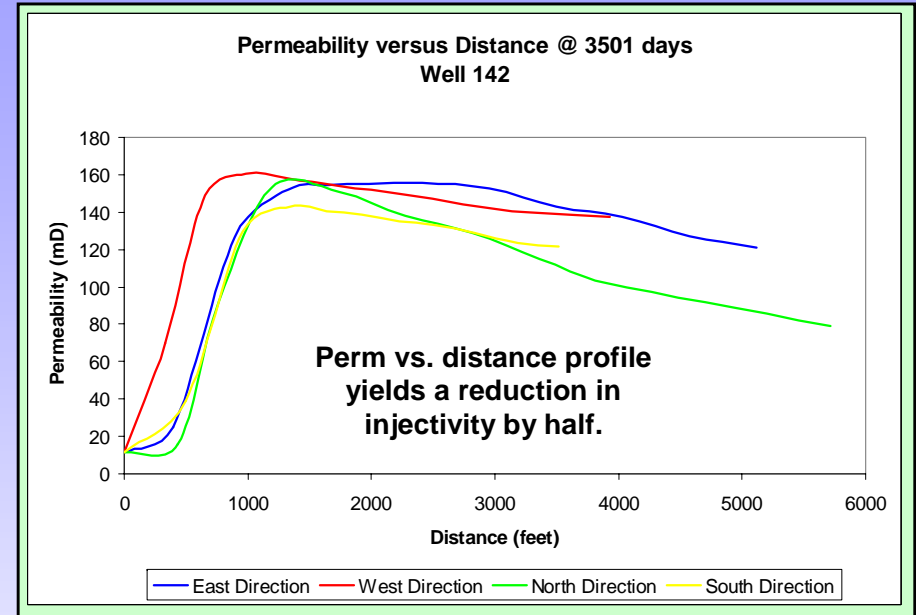
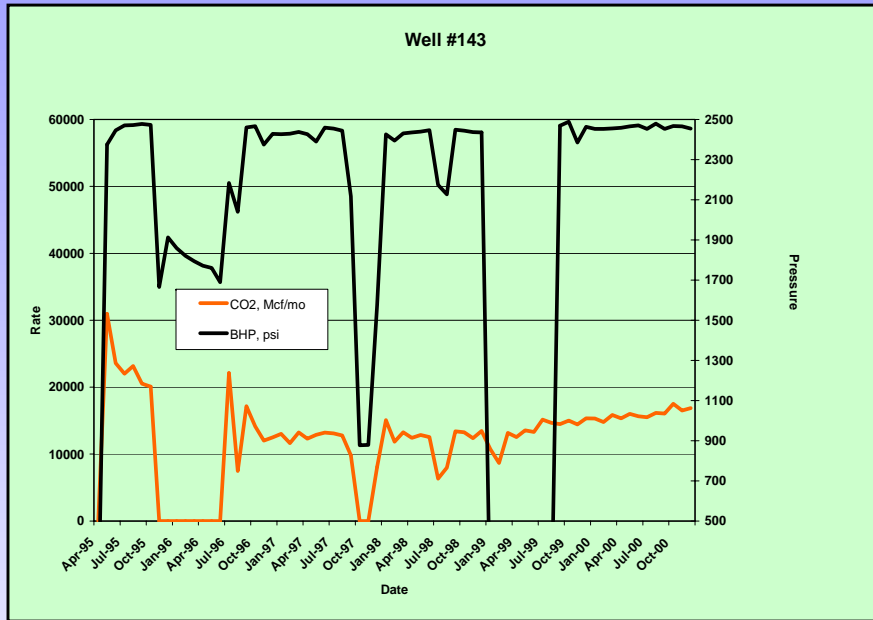
Coal-Seq Accomplishments (continued)

- Created techno-economic project screening model
 - >100 copies requested and distributed internationally
- Performed technical/economic sensitivity of CO₂ sequestration in coal
 - Best areas are deep, low-permeability, high-rank coals previously undeveloped for conventional CBM
- Assessed U.S. potential for CO₂-ECBM/sequestration
 - 90 Gt CO₂
 - 150 Tcf ECBM
- Implemented successful technology transfer program
- Achieved integration and coordination with other projects: government, academia, industry, international
- Developed broad perspective on technology development
- Established Coal-Seq as the leading worldwide program in the area of carbon sequestration in deep, unmineable coal

To be continued in
Coal-Seq II



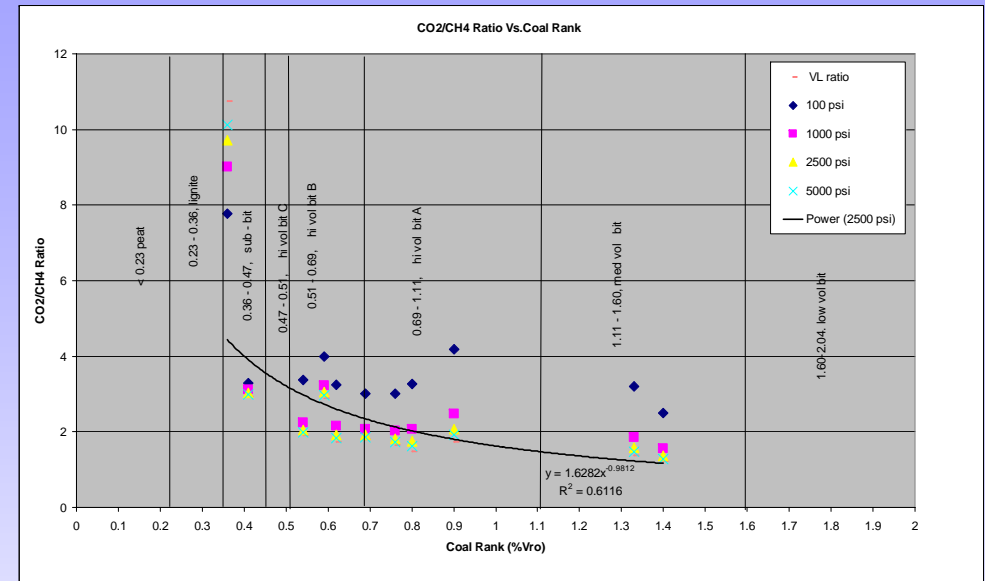
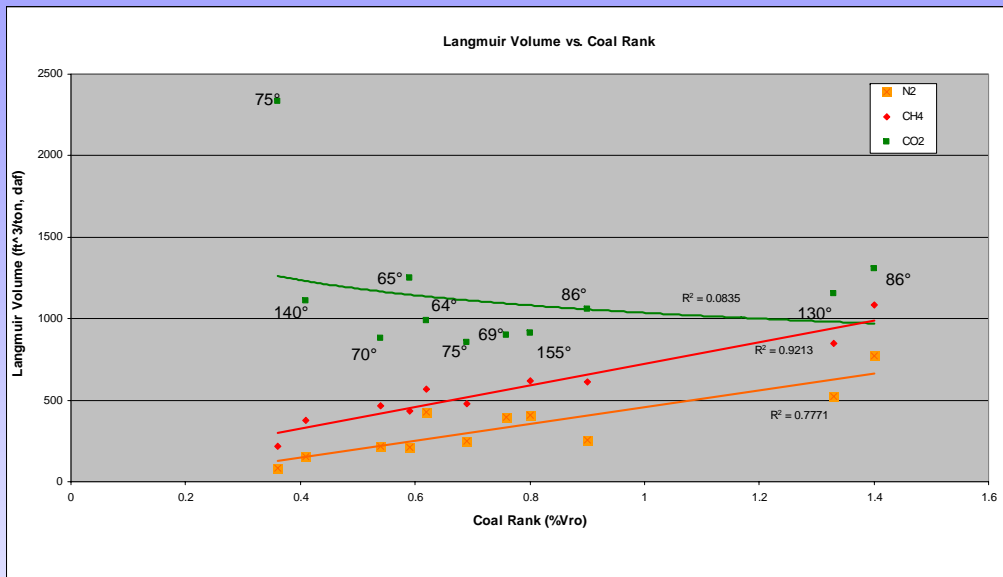
Injectivity Reduction Problem



Financial Parameter	Same Injection Rate		Injection Rate X 4	
Net Present Value:	<u>\$ 2.20/MMBTU</u> (\$0.6 million)	<u>\$4.00/MMBTU</u> \$2.6 million	<u>\$2.20/MMBTU</u> \$3.6 million	<u>\$4.00/MMBTU</u> \$15.0 million
Breakeven Gas Price:	\$2.57/MMBTU	\$2.57/MMBTU	\$1.63/MMBTU	\$1.63/MMBTU
Breakeven CO ₂ Cost:	\$0.12/Mcf (\$2/ton)	\$1.06/Mcf (\$18/ton)	\$5.65 (\$98/ton)	\$19.38 (\$335/ton)
Sequestration Cost:	\$2.17/ton	(\$9.39/ton)	(\$13.00/ton)	(\$34.15/ton)



Favorable Geologic Environments



- Deep Coals
 - High rank
 - Low permeability
- High Rank Coals
 - Similar CO₂ storage capacity
 - More methane recovery
 - Less net coal swelling
- Low Permeability
 - Undeveloped for CBM
 - High pressure injection to expand cleats
- Undeveloped Coals
 - More methane recovery



Technology Transfer

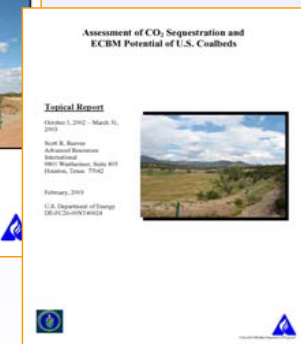
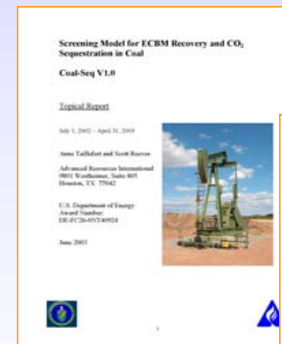
- Publications

- Topical Reports
- Technical Articles
- Presentations
- Etc.

- Coal-Seq forums

- Coal-Seq I, March, '02, Houston
- Coal-Seq II, March, '03, Washington
- Coal-Seq III, March, '04, Baltimore

- www.coal-seq.com

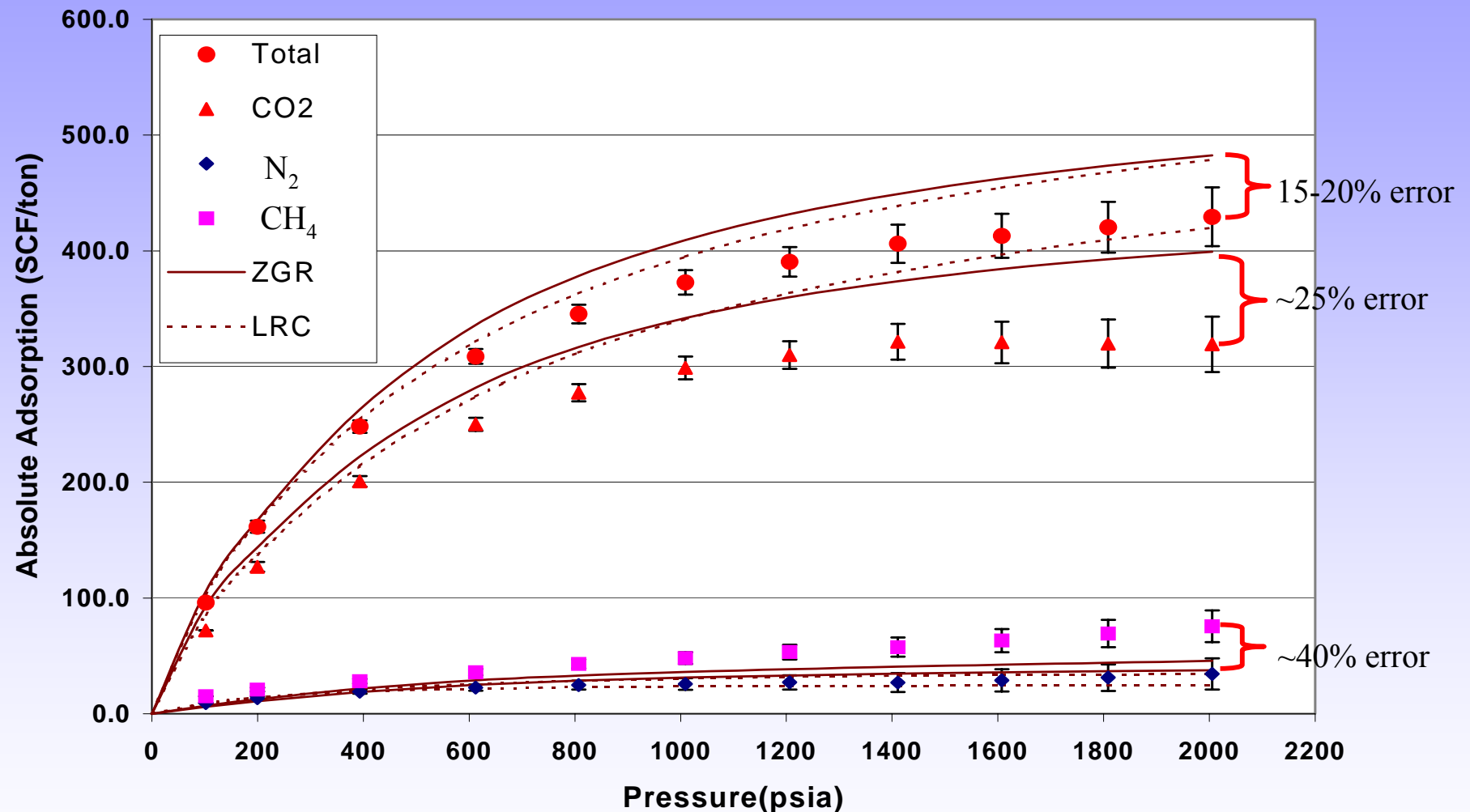


Critical Technology Gaps

- Accurate performance predictions:
 - Multi-component isotherm behavior
 - Bi-directional diffusion
 - CO₂ - mixture PVT behavior
 - and, as a result, coal-swelling and injectivity loss
- CO₂- injectivity is a critical factor influencing economic performance
- Being unable to reliably *predict* CO₂-injectivity loss is an important prerequisite to large-scale project investment
- CBM modeling analog (GRI experience)

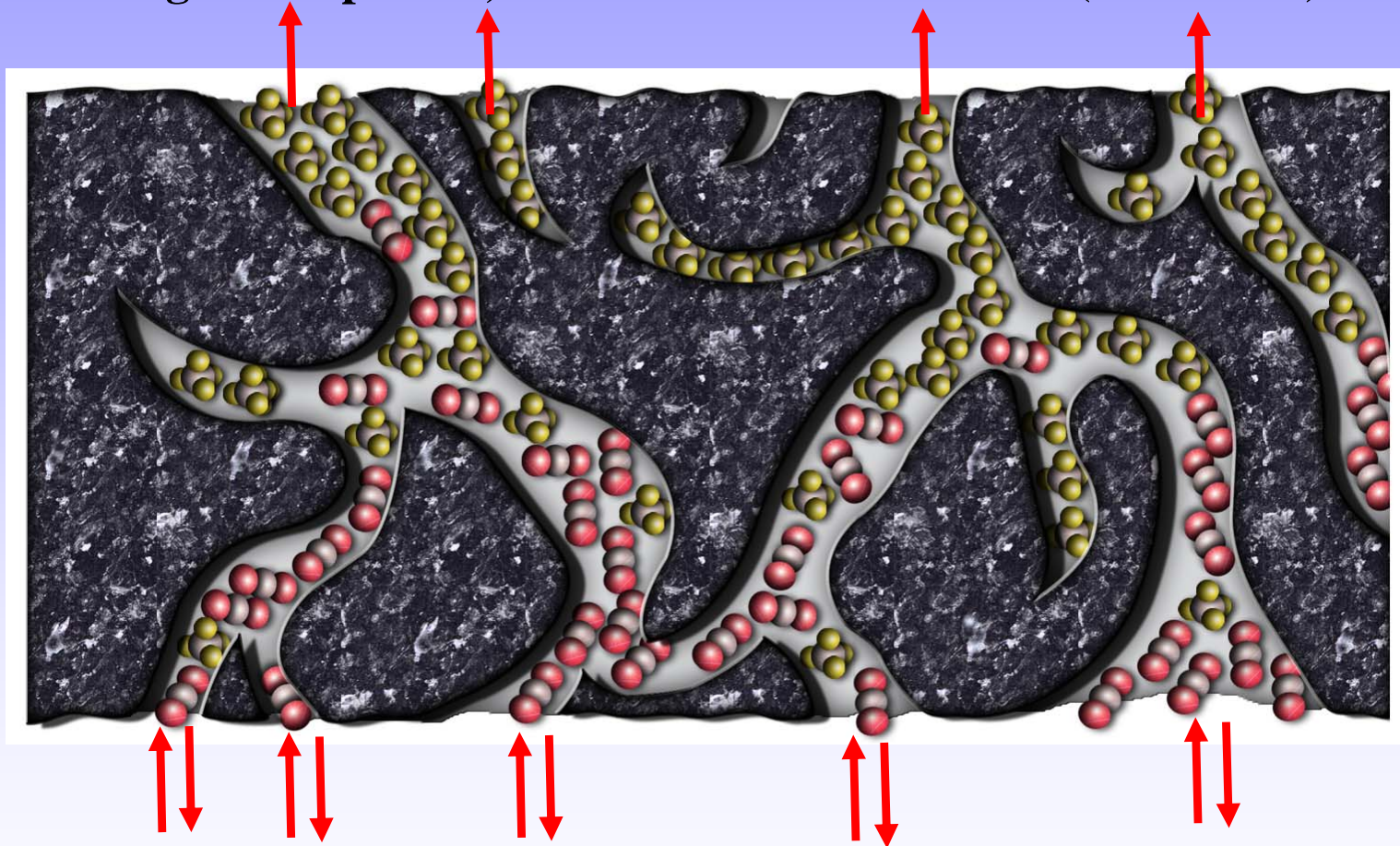


Multi-Component Isotherm Modeling



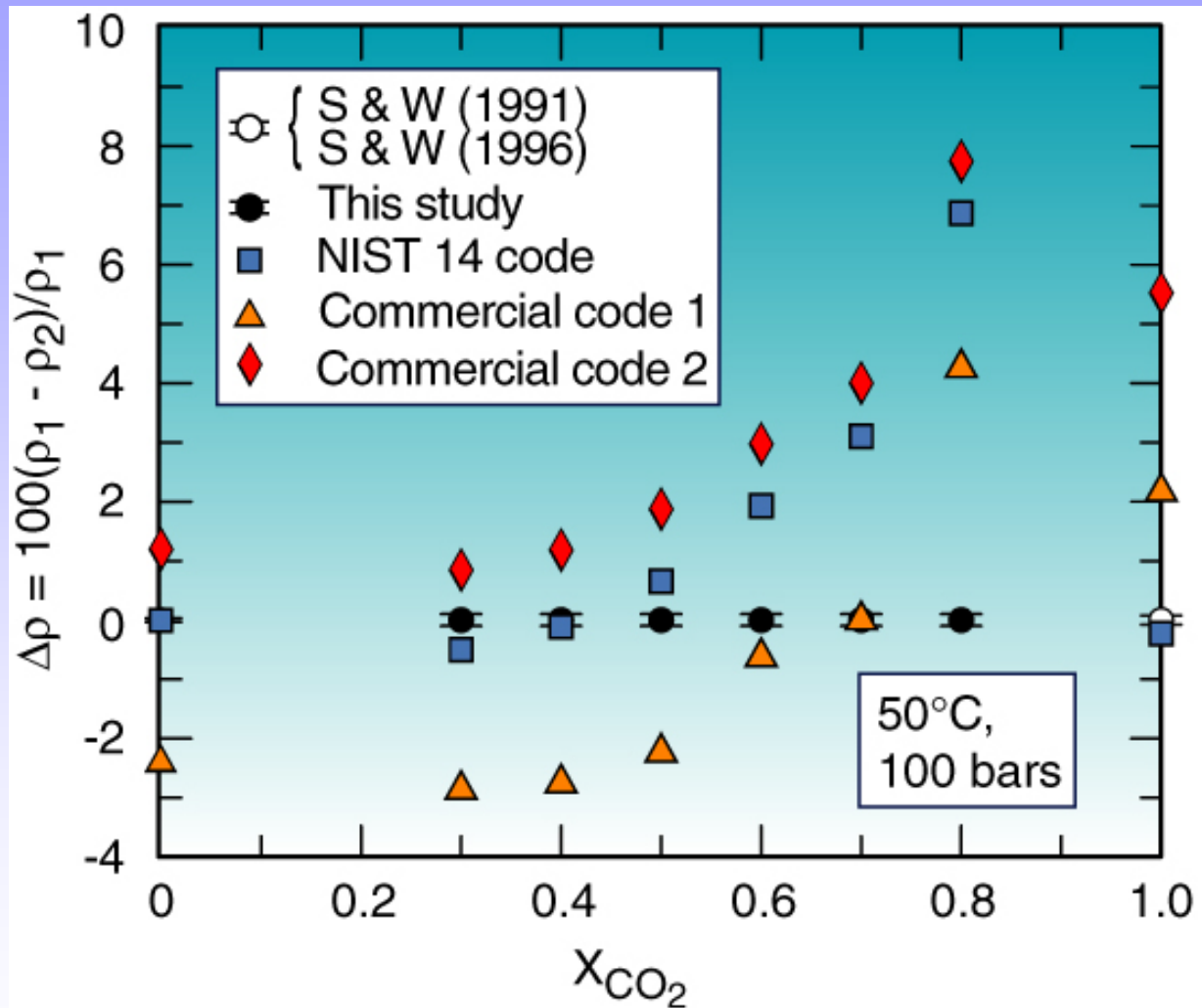
Bi-Directional Diffusion

Single-Component, Uni-Directional Diffusion (Ficks Law)



Multi-Component, Bi-Directional Diffusion

CH₄-Mixture PVT Behavior



Coal-Seq II Consortium Objectives

- Develop new, advanced predictive models for:
 - Multi-component sorption
 - Bi-directional diffusion
 - CO₂-mixture PVT behavior
- Couple with permeability model
- Incorporate into dynamic flow simulator (COMET3)
- Validate against laboratory flow experiments
- Validate against field data (Allison, Tiffany, RECOPOL)
- Perform sensitivity analysis to identify best geologic/reservoir environments and development strategies
- Maintain established relationships with other R&D and demonstration projects
- Provide single-source on global activities on CO₂ sequestration in deep, unmineable coals to membership



Coal-Seq II Organization

**Current
Industry Sponsors
(\$750,000)**

CO₂-CRC
(Australia)



*Illinois Clean
Coal Institute*
(USA)



*Japan Coal
Energy Center*
(Japan)



*Shell International
Exploration &
Production*
(Netherlands)





*Advanced
Resources
International*



**Government Sponsor
(\$750,000)**


*U.S. DOE – NETL
Carbon Sequestration Program*



*Oklahoma
State
University*



*Electrochemical
Systems*



*Southern
Illinois
University*



Project Roles

Advanced Resources International (Scott Reeves)

- Project management
- Simulation & modeling

Oklahoma State University (Dr. Khaled Gasem)

- Multi-component isotherm experiments & modeling

Electrochemical Systems (Dr. Simon Marshall & Dr. Jim Blencoe)

- Bi-directional diffusion modeling
- CO₂-mixture PVT experiments & modeling

Southern Illinois University (Dr. Satya Harpalani)

- Core-flood experiments



Current Sponsor Status

- \$1.5 million required; \$1.05 million committed (70% subscribed)
- Still seeking six industry sponsors to reach full subscription:
 - \$75,000 per member
 - \$25,000 per year for 3 years
- Benefits of membership
 - Access to project results – ability to high-grade early opportunities for ECBM/sequestration
 - Single source of information on global R&D and demonstration activity



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