

Geologic Storage of CO₂ in Coal Beds

Investigators: Jerry M. Harris and Mark D. Zoback, Professors, Department of Geophysics; Anthony R. Kavscek, Associate Professor, and Franklin M. Orr, Jr., Professor, Department of Petroleum Engineering, Stanford University

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Objective: It has been shown that the storage of CO₂ in deep coal beds is an option for greenhouse gas mitigation. However, many of the fundamental processes associated with CO₂ emplacement and containment in coal are poorly understood. The researchers propose to investigate the chemistry and geomechanics of CO₂ injected into a deep coal bed through a combination of experiments and simulations. The resulting greater understanding of CO₂ behavior in coal beds may result in new injection strategies that increase the size of available storage and reduce uncertainties surrounding the safe and effective management of a storage site.

Background: Deep, unmineable coal beds may provide a stable storage reservoir for the CO₂ resulting from the conversion of carbon-based fuels. Unlike storage in oil and gas reservoirs, where a persistent buoyant mass of CO₂ adds uncertainty to the long-term efficacy of the storage project, it has been shown that CO₂ adsorbs to the surfaces of the coal bed structures and is therefore less likely to flow to the surface. However, a greater knowledge of coal properties and flow dynamics as well as methods to monitor the injection progress are required before this option can be deployed.

Flow of CO₂ in coal beds takes place in a multiscale system of fractures and material matrices. The interplay of the high permeability of the cleat system (the macroscopic fracture network) and the low permeability of the matrix with adsorption and desorption in coals needs to be well understood in order to allow for appropriate management of injection and production processes. The permeability of the fracture system depends in part on the species and density of the adsorbed gas. In principle, CO₂ can be injected into a coal bed and adsorbed preferentially in place of CH₄, but the CO₂ adsorbs at a greater density and decreases permeability. Moreover, fracture systems in coal beds often contain water. It is necessary to determine how high water saturation influences the exchange of CO₂ and CH₄ under stress conditions typical of deep coal beds.

Another area of exploration that might benefit the practicality of coal bed storage is the potential for storage of components produced in coal gasification operations (sulfur oxides and H₂S). Design and prediction of such processes requires significantly better understanding of multicomponent adsorption and the flow of injected gas in coal fracture networks containing water. Also, the geomechanics of coal beds must be described more accurately if the potential for using induced fractures to manage emplacement of gas and subsequent flow is to be evaluated.

An additional benefit accompanying the ability to predict and manage flow of CO₂ in coal fracture networks might be the development of methods to control and extinguish coal bed fires. These underground fires currently emit substantial quantities of CO₂ and other combustion products to the atmosphere. It may be possible to use injected CO₂ to disrupt the pressure gradients supplying oxygen to the combustion zone by CO₂ injection in unburned coal adjacent to the reaction zone.

Finally, appropriate methods for monitoring gas flow and adsorption in coal beds are needed. Monitoring is necessary to follow the progress of the injection and confirm understanding of the flow and geomechanics.

Approach: An interdisciplinary, laboratory-scale, experimental program is being undertaken to provide quantitative tests of fluid flow through coal beds and requisite input parameters for numerical simulation of CO₂ sequestration at field scale. Experiments are planned that probe: (i) the interplay of gas sorption, matrix shrinkage or swelling, and gas transport through coal, (ii) the geomechanical, transport, and acoustic properties of coal under various conditions of stress, loading of coal surfaces in the presence of multiple gas components, and water saturation, and (iii) the nature of cleat to matrix gas transfer at stress states relevant to deep, unmineable coal beds.

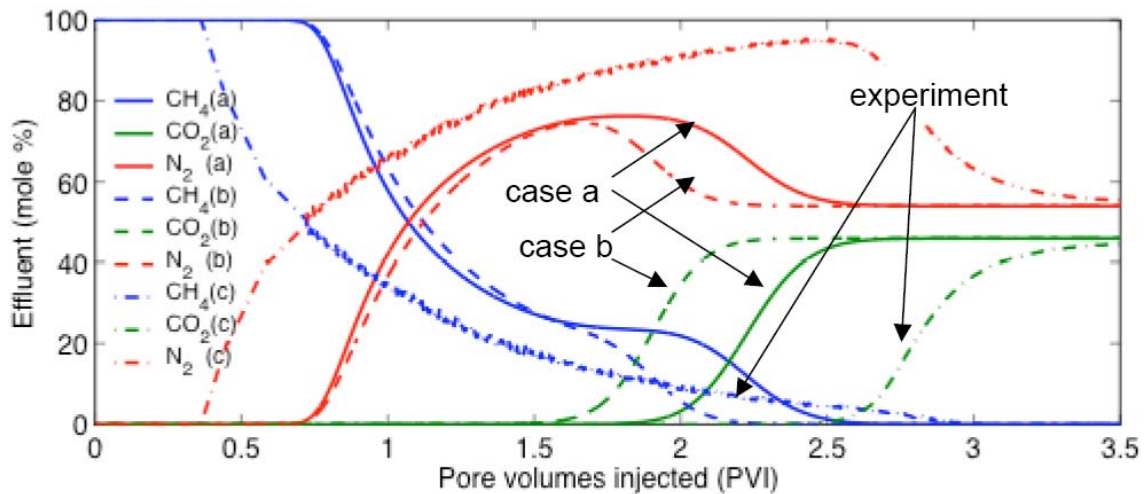


Figure 1: Effluent composition profiles resulting from the injection of 46/54 by mole CO₂/N₂. Combinations of simulations and in-situ condition experiments such as this will aid in understanding the underlying science of multi-component interactions in coal beds.

A comprehensive suite of simulations for coal bed sequestration is under development that expands the knowledge base for coal bed CO₂ sequestration by providing global screening metrics for the suitability of sub-bituminous coals. These metrics consider cleat and matrix permeability, adsorption/desorption isotherms, coal bed swelling/shrinkage and other geomechanical constraints. These simulations also provide a test bed of synthetic data for simulations of monitoring at field scale.

The feasibility of the streamline simulation approach as an efficient tool for predicting storage performance is under investigation for systems that equilibrate on time scales that are short with respect to flow time scales. Comparison on both coarse and fine grids is required to show that the physics of flow in coal beds is represented accurately within the 3D streamline methodology.

The flow investigation results are useful in exploring the possibility of extinguishing coal bed fires using CO₂ injection. The investigators are conducting a scoping study using a heavy-oil *in situ* combustion simulator to examine whether the flow regime around a combustion zone can be modified sufficiently by CO₂ injection to shut down the reaction.

Finally, a dynamic subsurface monitoring strategy is being developed that exploits the temporal accumulation of measurements, incorporates knowledge regarding the physics of the changes in coals due to injected CO₂, and utilizes prior information and predictions. The goal is to develop a dynamic imaging method that recursively constructs time-lapse subsurface images (or models) whenever new data of any type or source are obtained.

Contacts:

jerry.harris@stanford.edu,
kovscek@pangea.stanford.edu,
fmorr@stanford.edu,
zoback@stanford.edu