R & D **facts**

U.S. DEPARTMENT OF ENERGY
OFFICE OF FOSSIL ENERGY
NATIONAL ENERGY TECHNOLOGY LABORATORY

Sequestration

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# GEOLOGY AND RESERVOIR SIMULATION FOR COAL SEAM SEQUESTRATION

## Background

Unmineable coal seams are an attractive sink for power plant-generated carbon dioxide ($CO_2$), as this utilizes an otherwise uneconomic resource and makes possible the production of natural gas from coal seams. A coal seam sequestration model would help developers answer such questions as how much natural gas could be produced; how much, how fast, and under what operating conditions $CO_2$ could be sequestered; where to place injection and withdraw wells; and how much leakage could be expected.

As a result of past work, NETL currently has a suite of FORTRAN-based codes that generates a reasonable fracture pattern for a gas reservoir, FRACGEN, and solves the material balance for compressible fluid flow in the rock matrix and fractures of the reservoir, NFFLOW. Figure 1 shows a typical gas reservoir fracture pattern. Figure 2 shows the simulated fracture pattern for the same gas field but on a larger size, as generated by FRACGEN. Figure 3 compares NFFLOW's predictions for a well test to measured data.

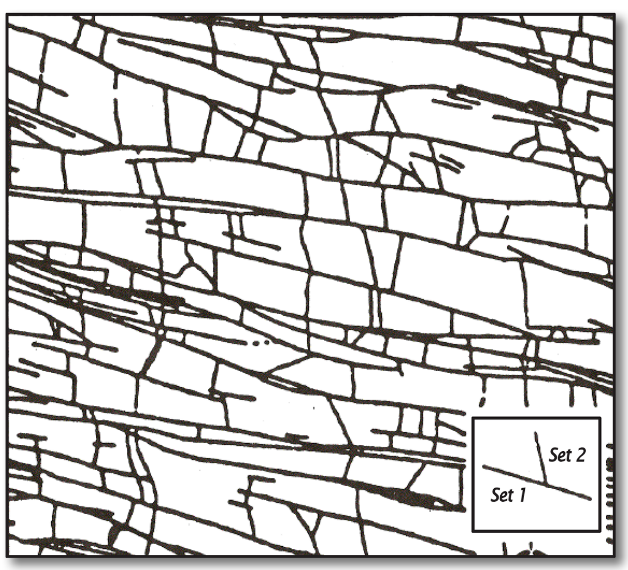


*Figure 1. Typical reservoir fracture pattern, MWX site.*


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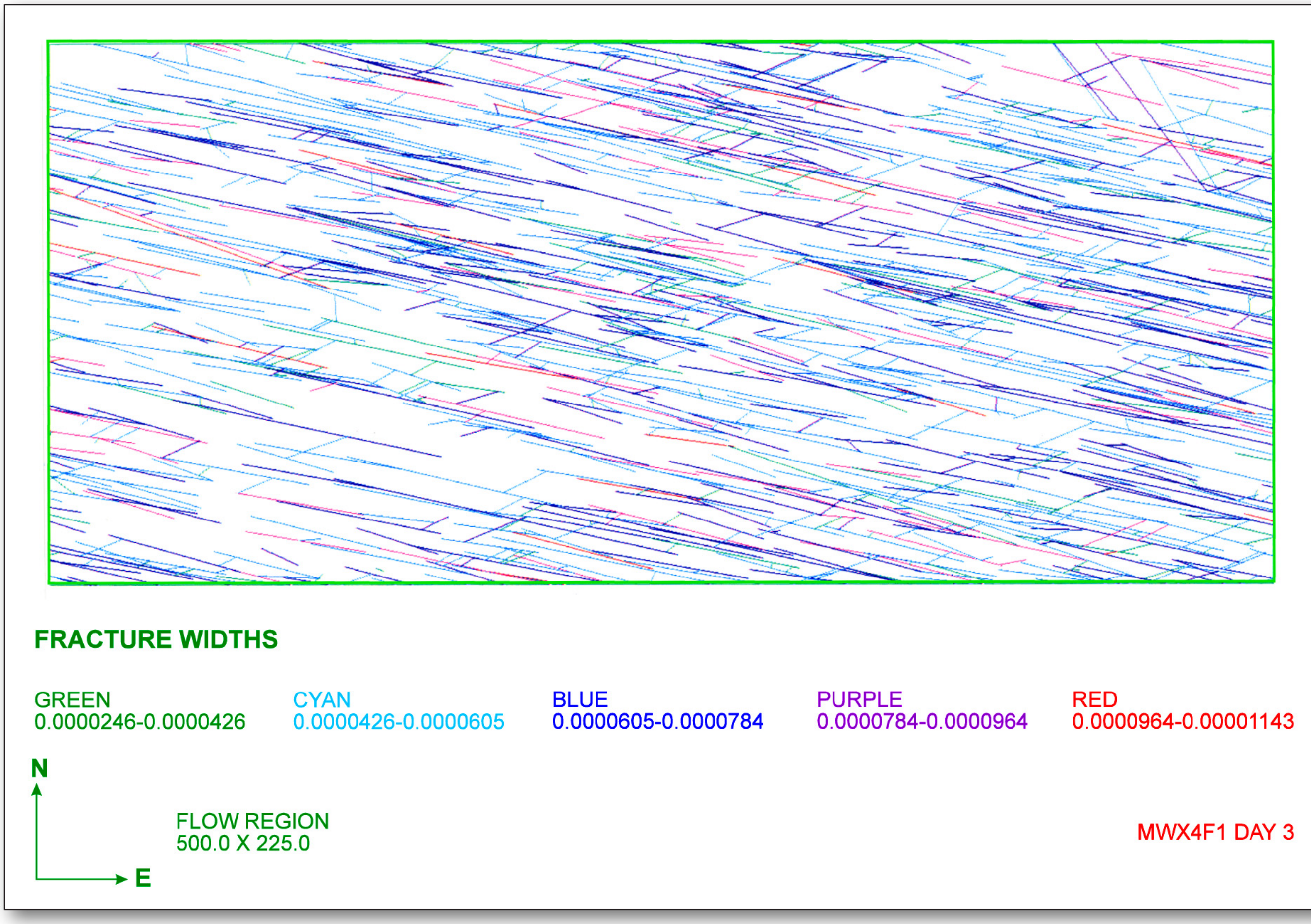


*Figure 2. This multicolored fracture pattern is a realization of NETL's model of the fracture network at the MWX site.The colors represent fracture aperture size.*

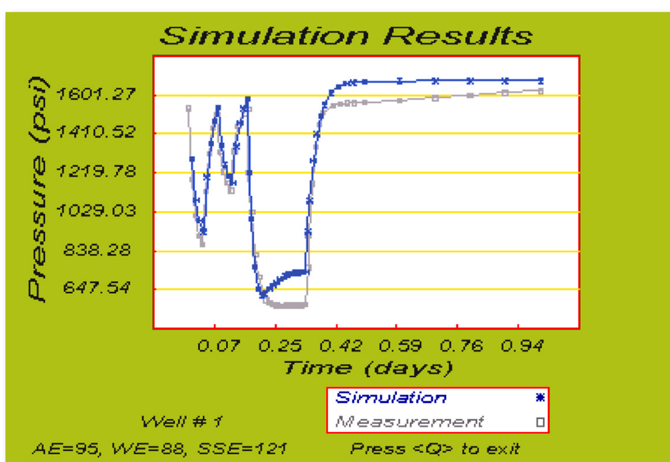


*Figure 3. Measured and simulated wellhead pressure.*

The “Geology and Reservoir Simulation for Coal Seam Sequestration” project undertaken by NETL’s Geosciences Division intends to further advance the existing suite of reservoir simulation codes and adapt them to the problem of coal seam sequestration.

The current reservoir fracture network generator, FRACGEN, implements four Boolean models of increasing complexity through a Monte Carlo process that samples fitted statistical distributions for various network attributes of each fracture set. Termination and intersection frequencies can be controlled either implicitly or explicitly. Three models account for hierarchical relations among fracture sets, and two generate fracture swarming. Of course, the fracture network in a gas reservoir contains fewer but much longer and wider fractures than the system of cleats in a coal seam. FRACGEN will be modified to account for the fracture pattern in a coal seam.

Dual-porosity simulators are ubiquitously used for fractured reservoirs. However, networks and fractures themselves usually present large permeability aniso-tropies and heterogeneities across a range of scales. Thus, the scale of observation and spatial variability become critical issues in every investigation, and simple averaging, as required by conventional models, tends to lose utility. NETL has found that its explicit-fracture simulator, NFFLOW, is able to increase the accuracy and reliability of simulations for highly fractured reservoirs because it directly uses descriptions of such characteristics as fracture length, orientation, and aperture as obtained from well logs, outcrop analyses, and other geological data. In addition, by using the real gas potential for fluids, NFFLOW is able to treat compressible fluids. It has been developed with natural gas in mind, but with the appropriate equation of state, it could be used for flows of $CO_2$.

NFFLOW computes transient flow rates or bottom hole pressures according to user-specified pressure or rate sched-ules. It assumes that the reservoir is isothermal and one layer and that no flow occurs across the upper and lower boundaries of the reservoir. Each fracture is assumed to span the thickness of the reservoir, and the fracture network is assumed to contain no intersections formed by more than two fractures. Gravity effects are ignored, and the flow is single phase. The simulator handles wells that are horizontal or vertical and are either hydrofractured or intersected by natural fractures. All flow toward the well occurs through the fractures, except for drainage from the rock directly contacting the wellbore.

Volumetric flow within the fractures and wellbore is modeled as a linear function of the pressure difference between the recharge points and the fracture intersections. Darcy’s Law is used to model the flow through the rock matrix to the recharge points in the nearby fractures. The resulting material balances at each fracture intersection and recharge point are discretized using finite difference and solved using a Newton-Raphson technique.

To become applicable to $CO_2$ flowing throughout a coal seam, NFFLOW must be modified to account for two-phase flow and to treat the coal matrix geometry realistically.

***NETL has found that its explicit-fracture simulator, NFFLOW, is able to increase the accuracy and reliability of simulations for highly fractured reservoirs***

## PROJECT PARTNERS

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## Primary Project Goal:

The primary goal of this project is to create a tool that will help evaluate the suitability of a coal seam for sequestration and assist in optimum well placement.

## Objectives

The main objective of the project is to adapt existing gas reservoir simulation codes to simulate coal seam $CO_2$ sequestration.

## Accomplishments

- NFFLOW has been modified to account for more than one component in the gas phase.
- NFFLOW has been modified to include $CO_2$ adsorption on coal.

## Benefits

$CO_2$ sequestration in unmineable coal seams utilizes otherwise uneconomic resources, allows for the production of natural gas from the coal seams, and prevents $CO_2$ from entering the atmosphere.