

# CO<sub>2</sub> Injection Performance in the Fruitland Coal Fairway, San Juan Basin: Results of a Field Pilot

SPE 127073

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ConocoPhillips



Schlumberger



# Disclaimer

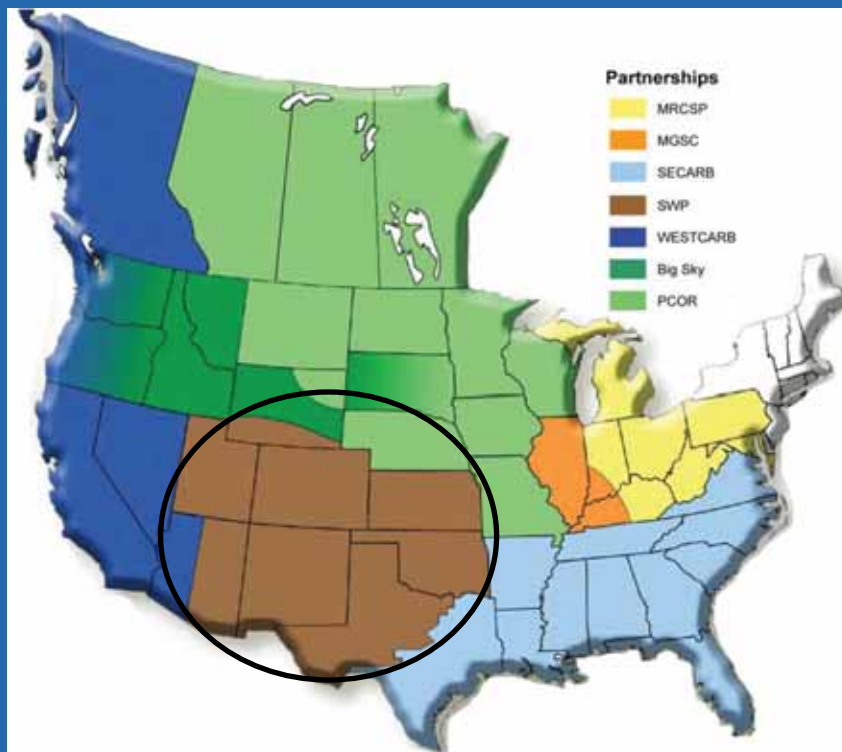
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# Outline

- **Introduction**
- **Permitting and Regulatory**
- **Field Operations**
- **Measurement, Verification and Accounting**
- **Reservoir Characterization**
- **Reservoir Modeling**
- **Conclusions**

# Project Background

- The Southwestern Partnership (SWP) is one of seven regional partnerships sponsored by the U.S. Department of Energy (DOE)



- Phase I - Characterization
- Phase II – Validation ←
  - the SACROC Unit
  - the Aneth oil field
  - the Pump Canyon site : unmineable coalbed methane
- Phase III – Deployment



# Permitting and Regulatory

- **Injector Well**
  - Application for Permit to Drill and for Authorization to Inject
- **Pipeline**
  - Right of way must be obtained
    - Archeological survey
    - Environmental assessment (EA) study
- **Site Access**
  - Work Authorization Agreement (WAA) between the individual SWP contractors and ConocoPhillips
- **National Environmental Policy Act (NEPA)**
  - Environmental questionnaire must be completed
- **National Historic Preservation Act (Section 106)**
  - Any proposed surface disturbances must be reviewed by the State Historic Preservation Office (SHPO) and any Native American tribes
  - After being delayed, Section 106 was approved in April 2008, which allowed field operations to start.

# Field Operations

## Injection Well Construction

- Well drilled just above the upper coal to casing point at about 3,000 ft
- Kirtland shale (overlies the Fruitland coal) was cored
- First logging suite was conducted
- Casing was set
- Well drilled through Fruitland coal with air mist
- Hole under-reamed to 9 ½ "
- Coal cuttings collected through each coal
- Second logging suite and pre-injection VSP were run
- Well couldn't be stimulated due to low pressure

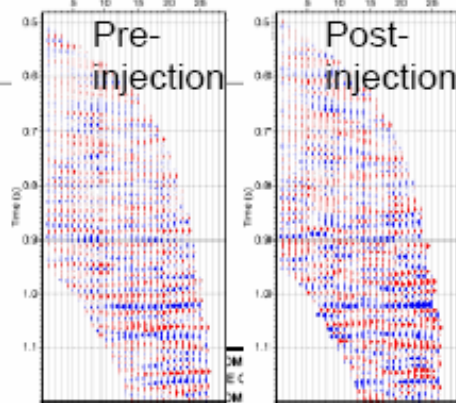
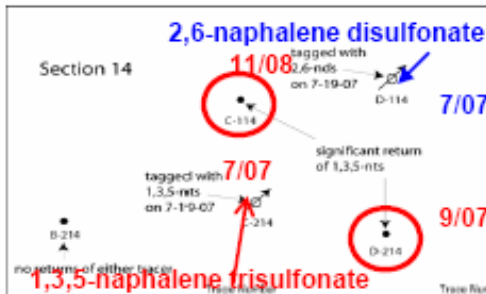
# **Field Operations Pipeline Construction**

- **4-inch diameter, 2.6-mile pipeline tied to the Kinder-Morgan operated Cortez pipeline**
- **Trenching started in January 2008 but was halted over State lands while waiting for the Section 106 consultation process to be completed**
- **Line is being turned over to move produced water from the site**

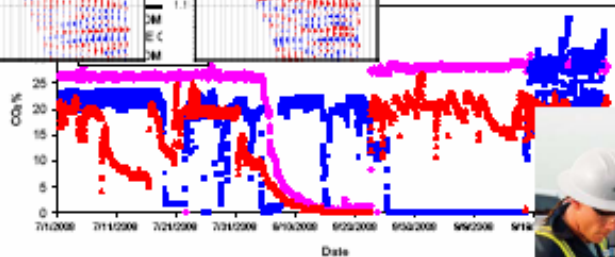
# Monitoring, Verification and Accounting

## Distribution/Movement of CO2 in Reservoir

Tracers (Perfluorocarbons-gas, naphalene sulfonates – H2O)



Time lapse VSP (Vertical Seismic Profiling)



Produced Fluids (fluid chemistry and [CO2])



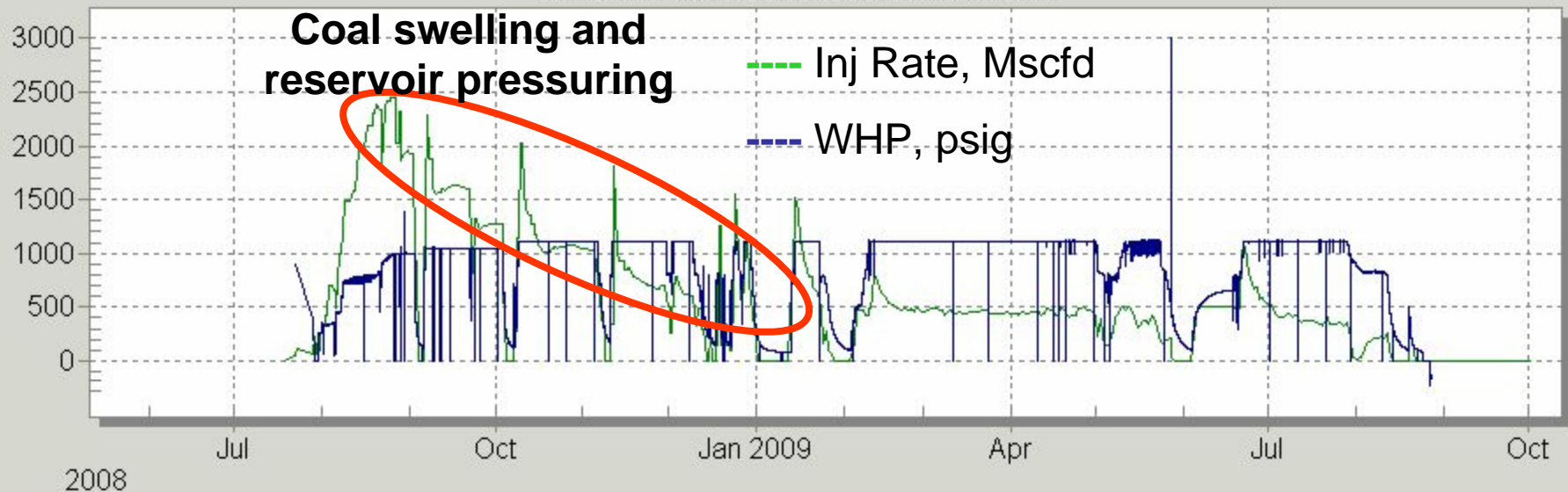
Tiltmeters + InSAR (Ground swell)

# Injection Well

- Continuous surface measurements of CO<sub>2</sub> injection volumes, pressures and temperatures
- Downhole measurements of injection pressure and temperature
- Injection started on July 30<sup>th</sup>, 2008 and ended on July 29<sup>th</sup>, 2009
- Injection rate maximized at 1,100 psig

# Injection Profile

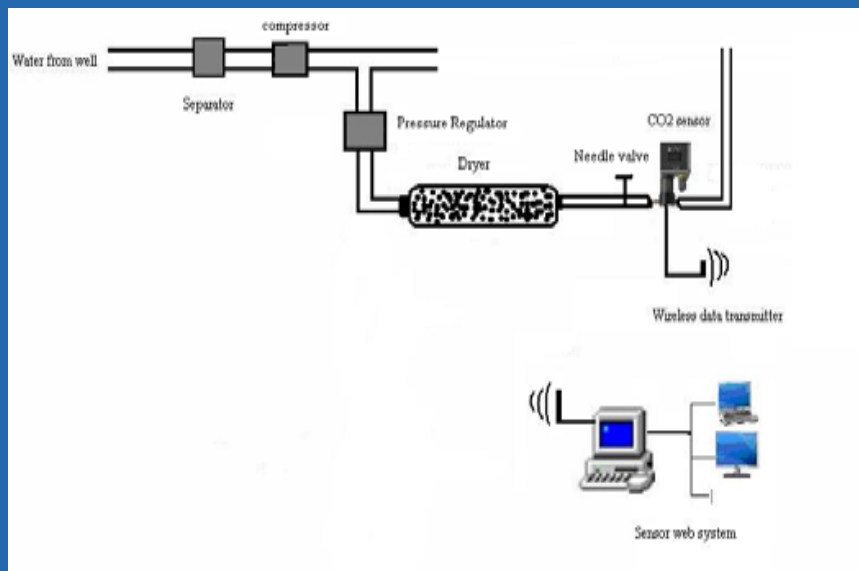
- Planning was to inject CO<sub>2</sub> in stages from bottom to top to minimize breakthrough
- Due to delays in permitting, CO<sub>2</sub> was injected simultaneously in the three layers



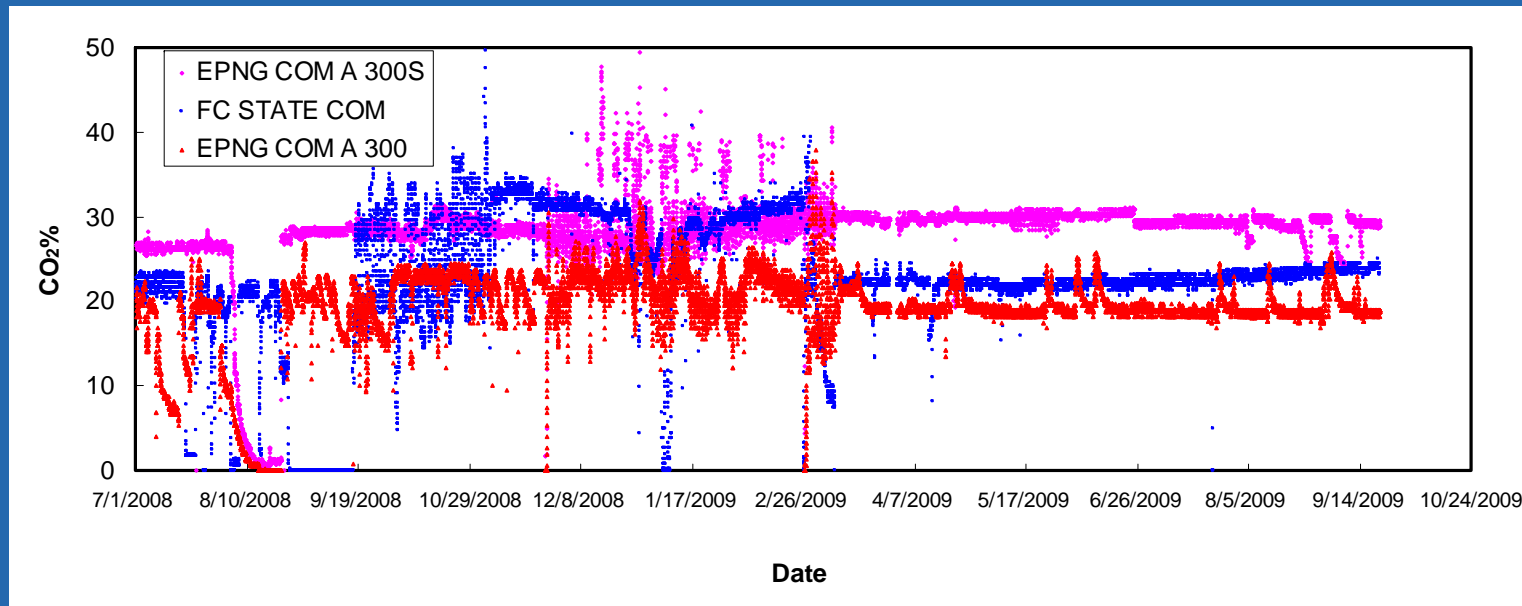
**A total volume of 18,400 tons of CO<sub>2</sub> was injected**

# Offset Producer Wells

- CO<sub>2</sub> concentration change in the produced gas stream is an important tracking mechanism
- Used to determine the subsurface CO<sub>2</sub> movement and the CO<sub>2</sub> breakthrough point
- Sensors deployed for the 3 immediate offset wells



# CO<sub>2</sub> Concentration Change Three Monitoring Wells



Gas samplings were performed regularly in surrounding wells.  
Increase in N<sub>2</sub> concentration was noticed in two wells.

	10/24/07	01/04/08	04/30/08	07/28/08	09/11/08	11/13/08	02/25/09	05/20/09
N <sub>2</sub> %	0.051	0.039	0.147	0.078	0.448	<b>2.020</b>	<b>1.724</b>	<b>1.512</b>
CO <sub>2</sub> %	19.8	19.4	19.7	20.6	19.4	23.7	21.4	20.0
CH <sub>4</sub> %	75.9	78.9	76.3	78.0	76.7	72.1	73.7	74.8

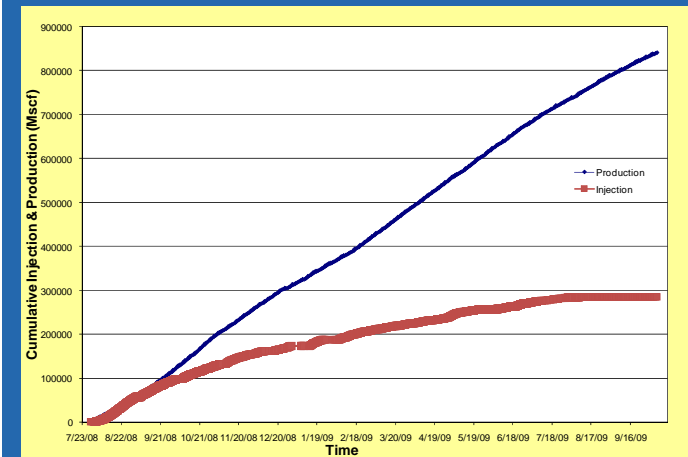
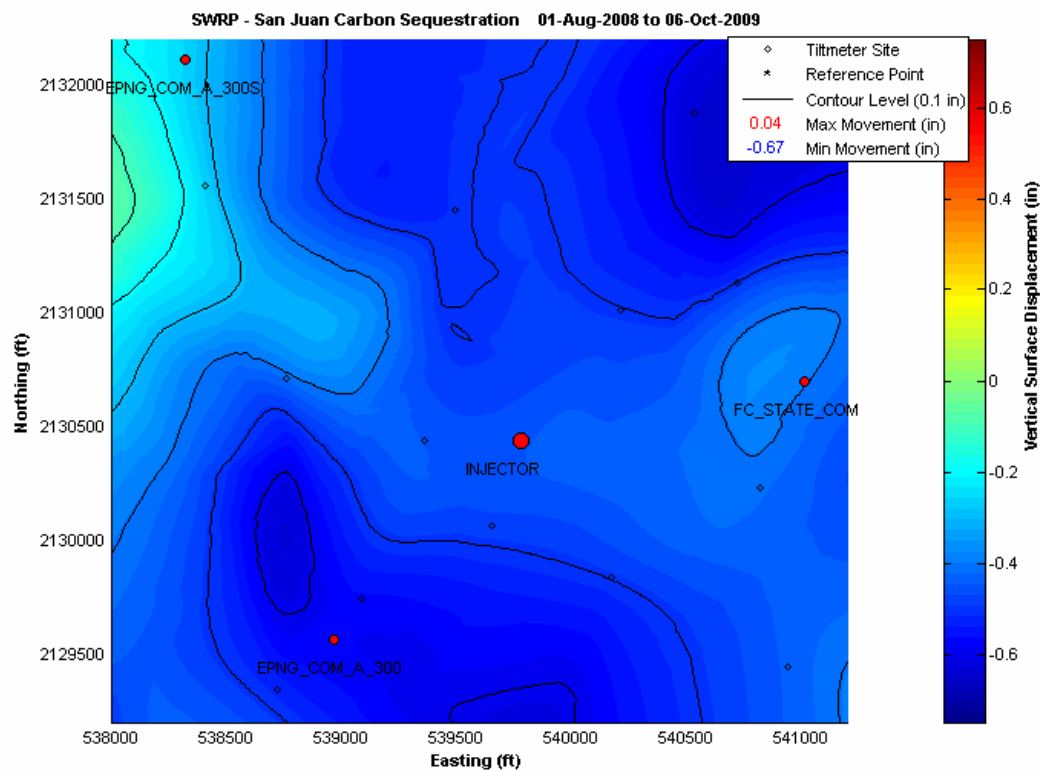
# Tiltmeters

- Designed to measure very small changes (*relative* deformation) from the horizontal level
- A total of 36 surface Tiltmeters were installed in shallow 40ft deep boreholes
- Tiltmeters go through a settling process, which lasts approximately 2 weeks
  - 2 months settling for Pump Canyon due to permitting delays
- To determine the *absolute* changes in elevation, two differential GPS stations were integrated into the above Surface Tiltmeter Monitoring (STM) array



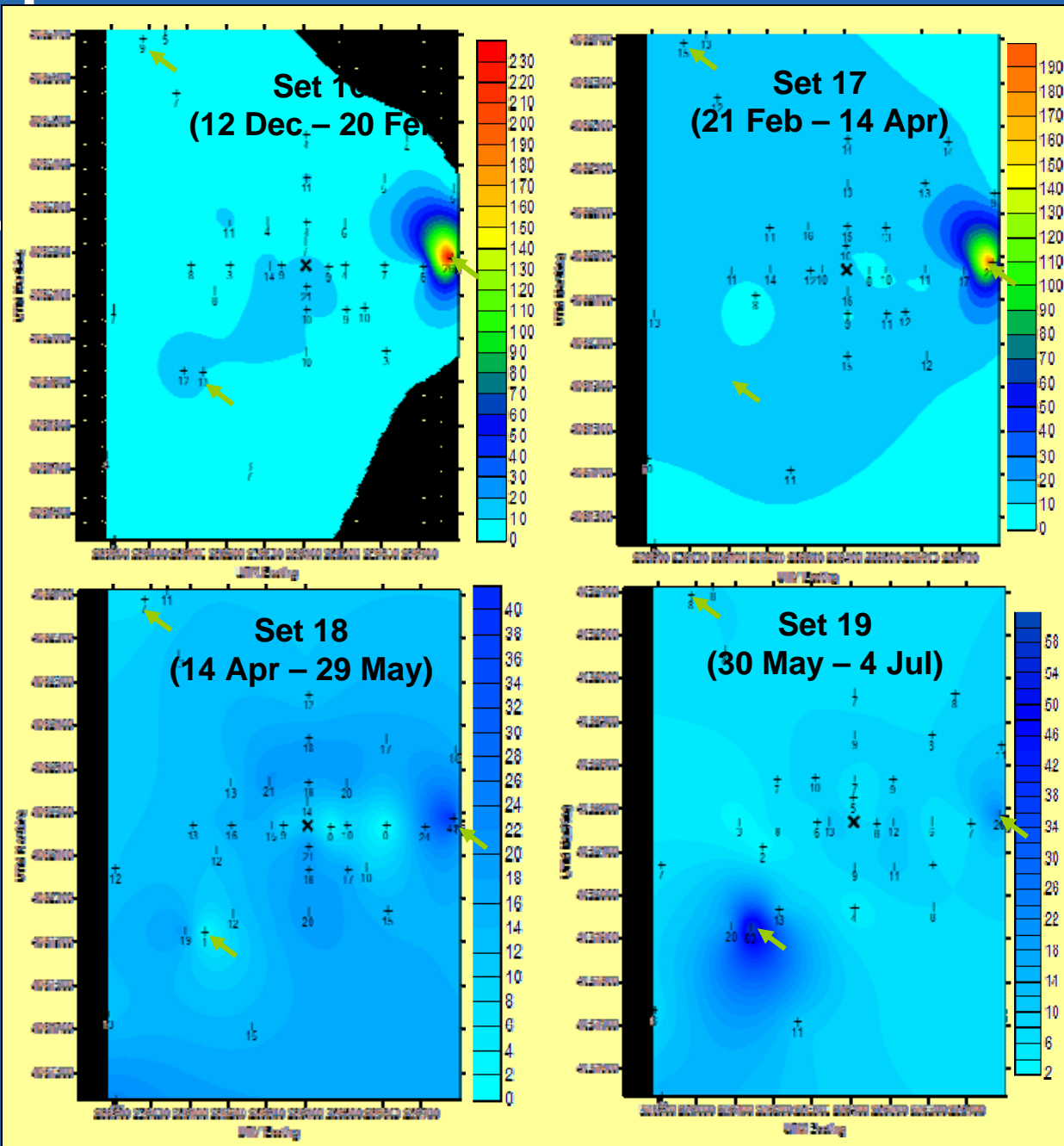
# Tiltmeters Results

- No significant deformation in the area, verified by GPS



# Tracer-Plume Breakthrough

- NETL simulations predict breakthrough of CO<sub>2</sub> at E offset well by December 2008 and at SW offset well by June 2009
- Conservative tracer breakthrough expected to precede CO<sub>2</sub> breakthrough.
- Consistent with gas sampling data



Passive Atmospheric Concentrations of PMCH

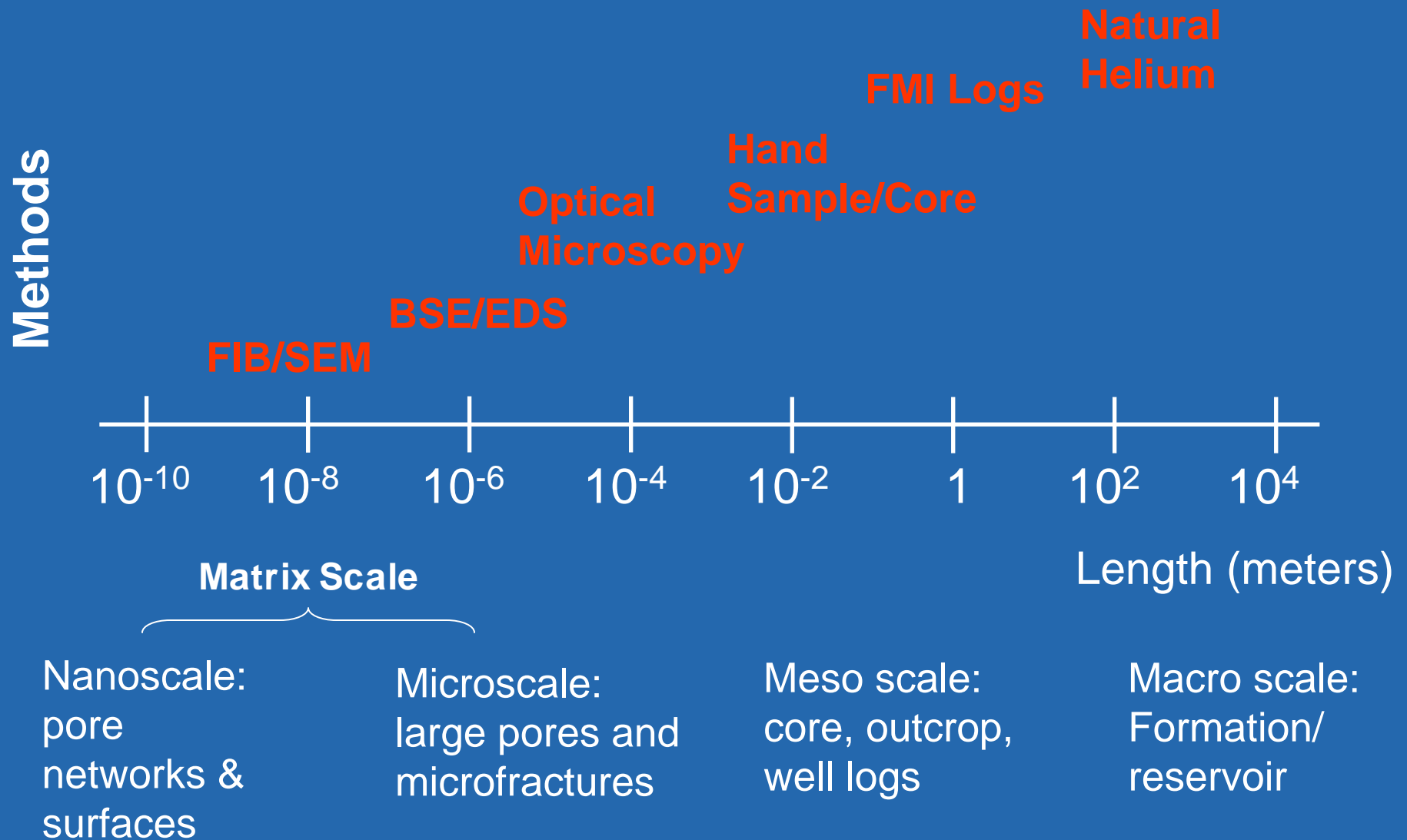
# Investigation of Caprock Seal Integrity

## *Research focus:*

1. How do caprock matrix properties contribute to sealing capacity?
2. What are possible leakage pathways and how are they best characterized?
3. Natural helium offers a temporal and spatially integrated assessment of flow conditions and exists everywhere – can we take advantage of this to characterize large scale seal integrity before injection begins?

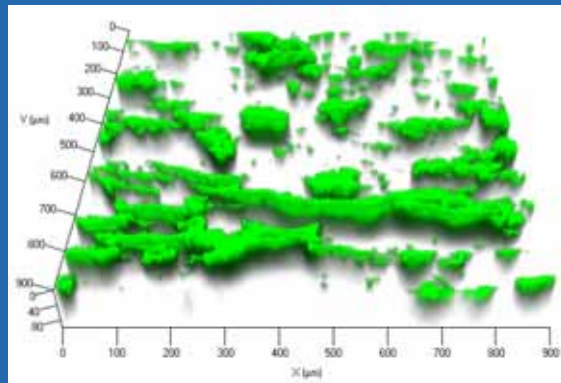


# Multiscale Investigation of Sealing Behavior

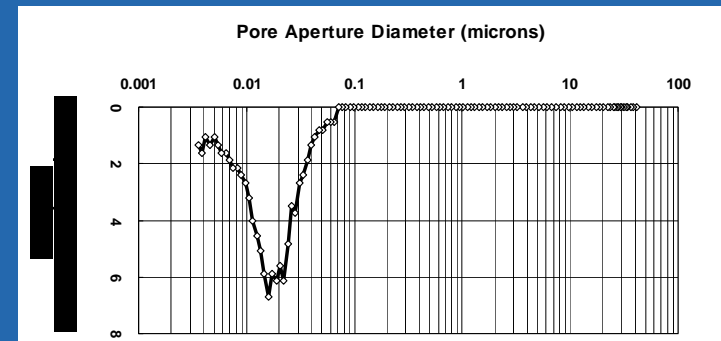


# Matrix Scale: Nano to Micro

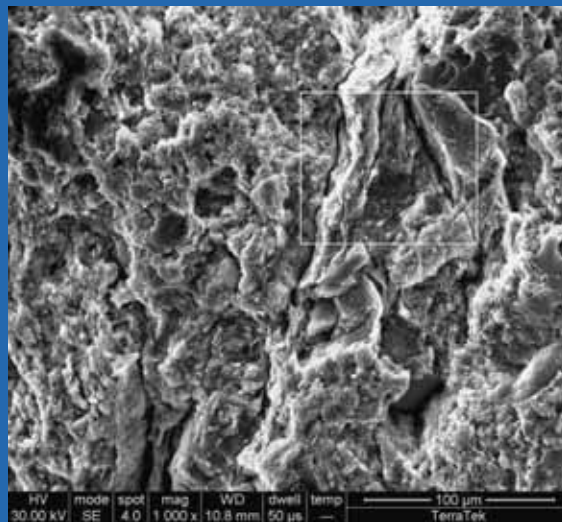
LSCM at  
2062.10 ft



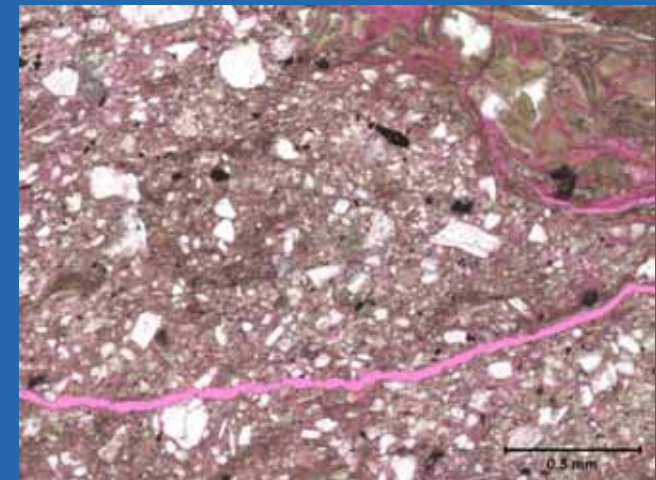
MICP at  
2062.40 ft



SEM at  
2062.30 ft



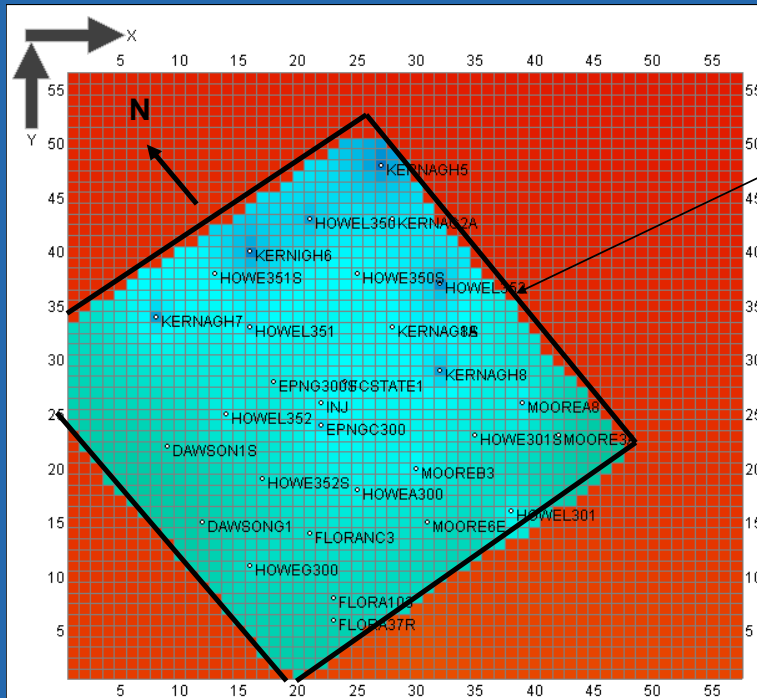
Thin section  
at 2062.30 ft



# Major Findings

- Matrix seal quality is high
- Fractures are present, some of which are “open”
- Some forms of mineralization may be chemically sensitive to CO<sub>2</sub>
- Helium and neon data lead to additional conceptual models

# Reservoir Modeling

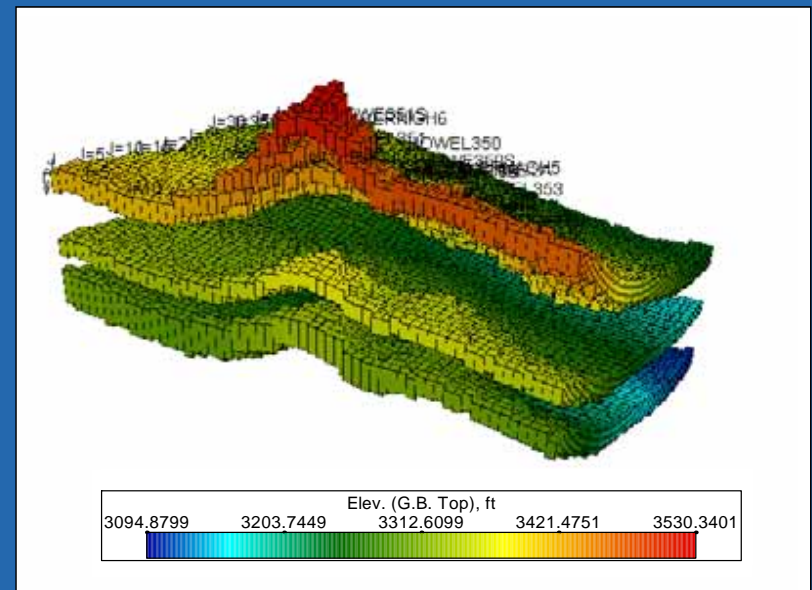


No Flow  
Boundary

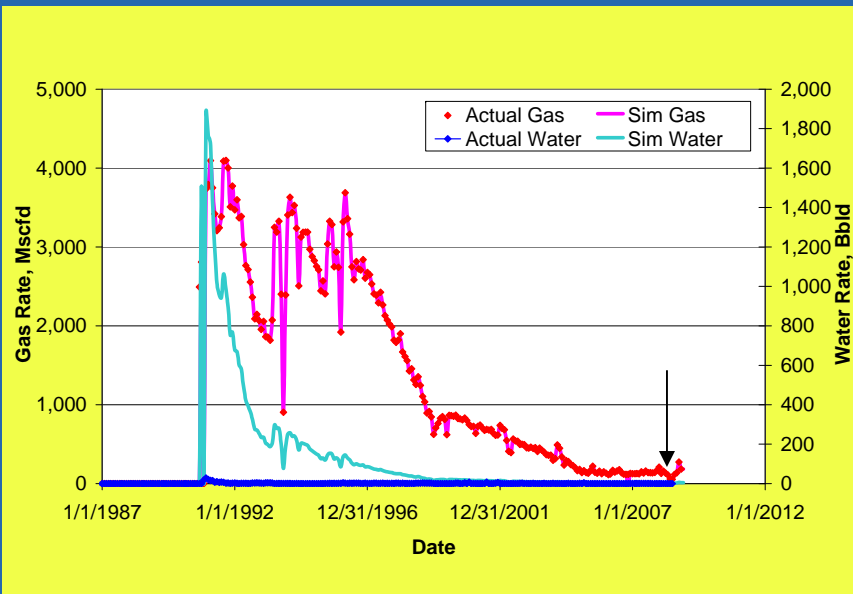
- *COMET3* reservoir simulator model
- 3 layers, 9-section model
- 27 producing wells, 1 injection well
- Y axis of Comet grid aligned with face cleat orientation (N35E)

- Elevation and thickness maps generated in PETRA based on logs from 21 wells.

- Maps were included in reservoir model

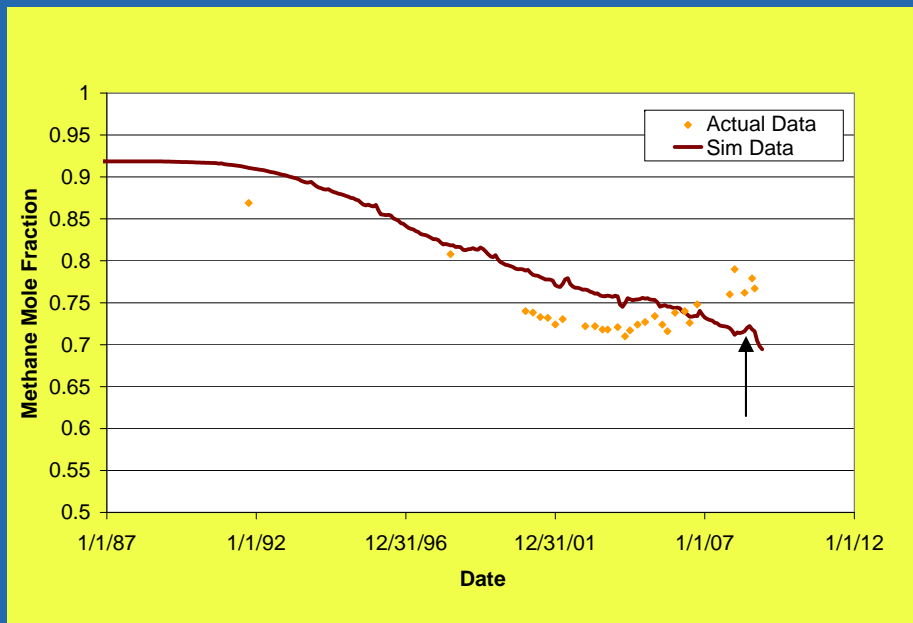


# History Match Results

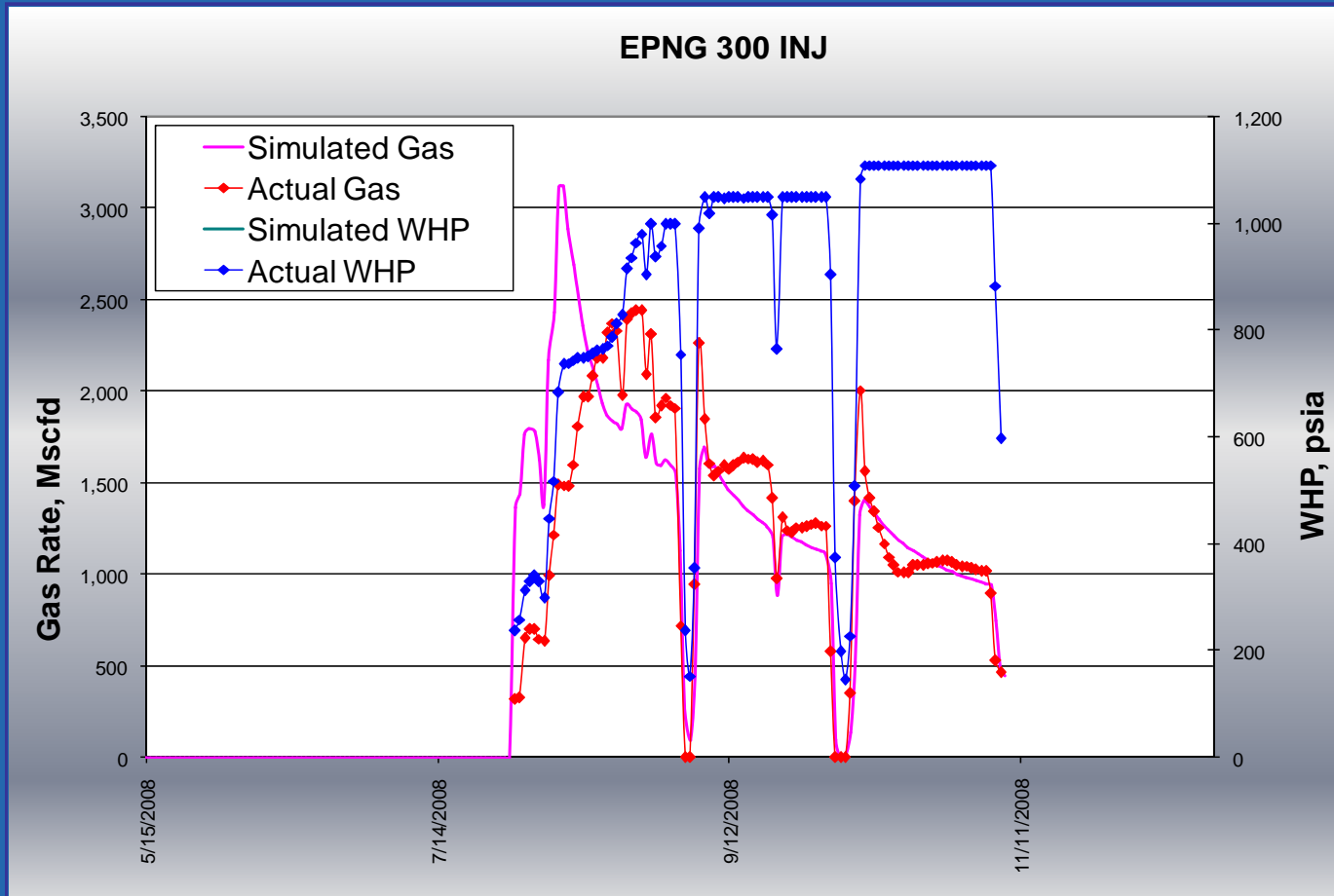


- Permeability optimized at 550 mD
- Porosity at 1.6%

- Gas rate and methane mole fraction of produced gas matched
- Water data of poor quality: not matched



# History Match Results Injector



Peak too early probably due to overestimation of near-well permeability and/or underestimation of pressure but cumulative injected gas volume acceptable.

# Model Update

- **Permeability allowed to be higher in bottom coal**
  - **Injectivity profile test results show 83% of the CO<sub>2</sub> going into lowermost layer**
  - **Logs show coal of better quality**
- **Included produced nitrogen composition from gas samples**
- **Updated production/injection data until April 2009**
- **History match under way**

# Conclusions

- **Injection is a success: 316 MMcf of CO<sub>2</sub> injected at injection rates up to 2,500 Mcfd (high permeability)**
- **However coal swelling and reservoir pressuring decreased injectivity: rates down to 500 Mcfd**
- **All ground deformation techniques converge to the same conclusion**
  - **Effectiveness was probably limited due to the small amount of CO<sub>2</sub> injected**

# Conclusions

- **CO<sub>2</sub> sensors are an excellent means of monitoring breakthrough**
  - **Monitoring N<sub>2</sub> concentration might be as important**
- **Reservoir model adequately predicted production and injection performances**
- **Automated monitoring will end sometimes in the fall of 2009 and long-term (non-automated monitoring) should last another year**