PUMP CANYON TEST SITE

Prepared For:

2009 Regional Carbon Sequestration Partnerships
Annual Review Meeting

Prepared By:

George J. Koperna, Jr.
Advanced Resources International, Inc.

Pittsburgh, November 16-19, 2009

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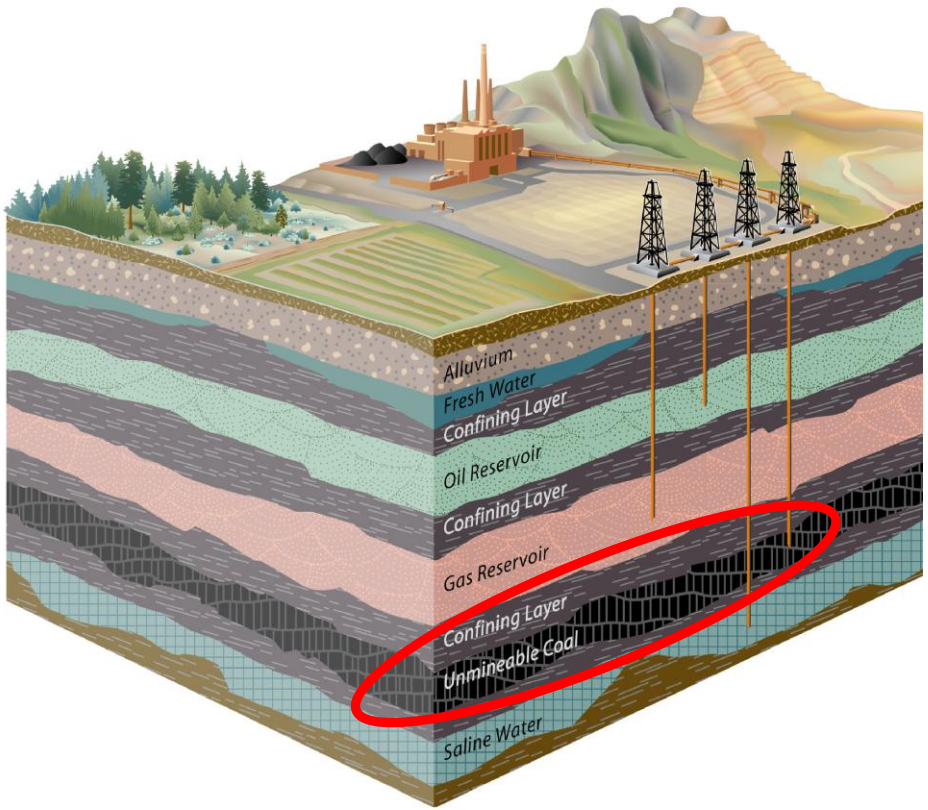
Presentation Outline

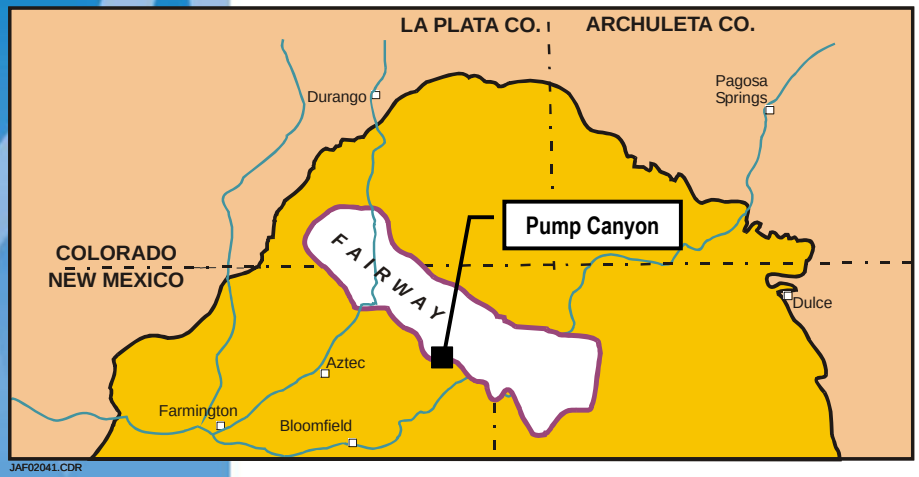
- Introduction
- Operations
- Reservoir Characterization and Modeling
- Monitoring, Verification and Accounting
- Next Steps

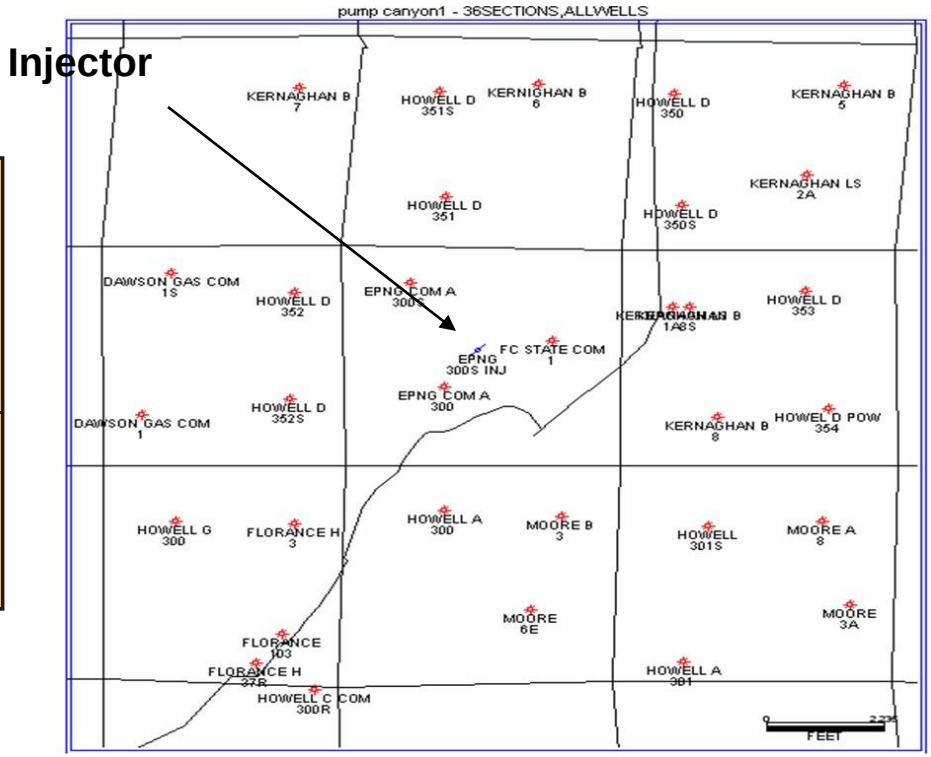
Objectives

- Field-test the effectiveness of CO_2 sequestration in deep, unmineable coal seams via a small-scale geologic sequestration demonstration
- Develop a better understanding of the efficacy of enhanced coalbed methane recovery processes via carbon dioxide injection (CO_2-ECBM) into a pressure-depleted reservoir
- Monitor plume migration to prevent any leakage



Site Description





Basic Coal Information

- 3 Fruitland Coal Seams
  - Upper Coal
  - Middle Coal
  - Basal Coal
- Kirtland shale overlap coals and acts as a seal

Property	Value
Average Depth to Top Coal	**3,012 feet**
Average Net Thickness	**60 feet** **Upper Coal: 16 feet** **Middle Coal: 15 feet** **Basal Coal: 29 feet**
Initial Pressure	**1,500 psi @ 3,600 ft above sea level**
Temperature	**126ºF**

Reservoir Cross-section

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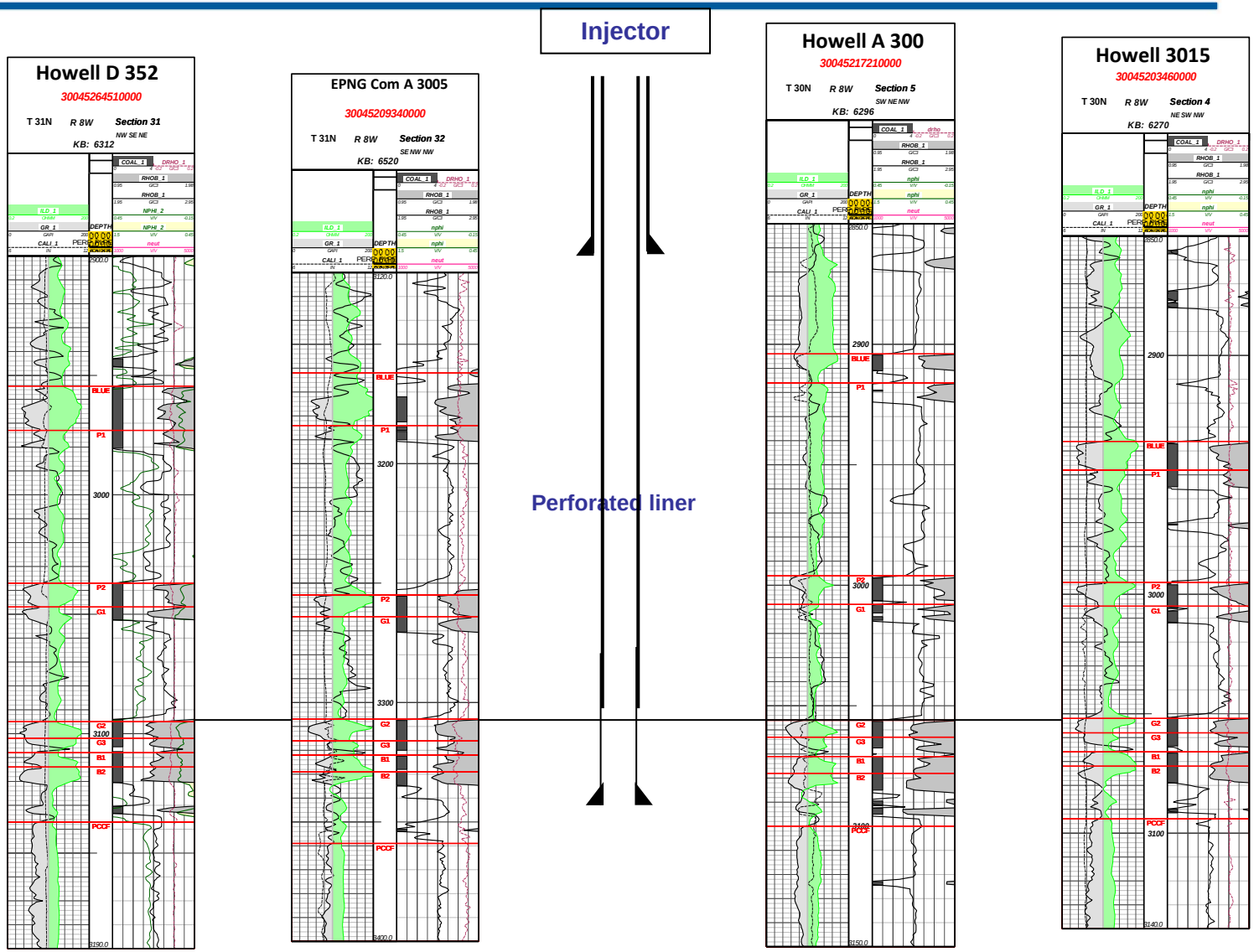
Kirtland Shales

Upper Coal

Middle Coal

Basal Coal

Pictured Cliffs



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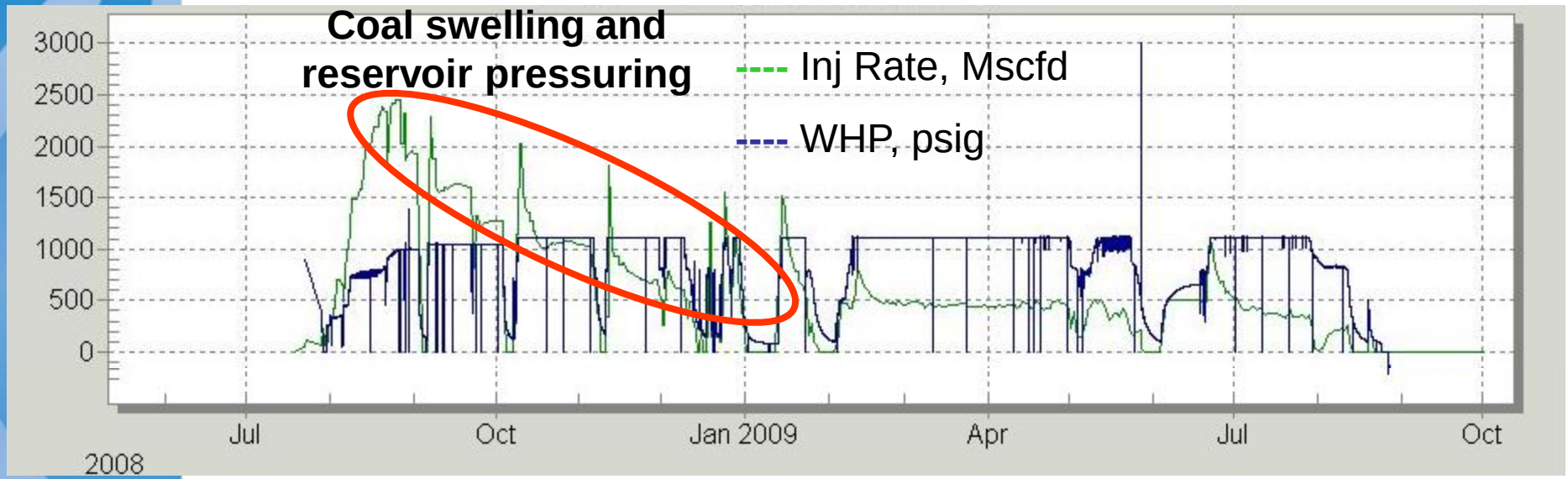
Operations

- Tiltmeter array installed (May 08)
- CO_2 injection well drilled & completed (June 08)
- Baseline Vertical Seismic Profile (June 08)
- CO_2 Sensors installed in three immediate offsets to the injection well (July 08)
- CO_2 injection began (July 08 – July 09)
  - Maximum injection rate of 3,800 Mcf/day.
  - Ramp up to maximum WHIP of 1,100 psia (declining injection rate)
  - Injection profile test (September 08)
  - Build up tests performed September 3-4
  - Tracers began in two phases (October 08)
  - Bottomhole pressure gauge installed
- Time-lapse VSP (September 09)

Injection Profile

- The initial plan was to inject CO_2 in stages from bottom to top to minimize breakthrough
- Due to delays in permitting, CO_2 was injected simultaneously in the three layers



A total volume of 18,400 tons of CO_2 was injected

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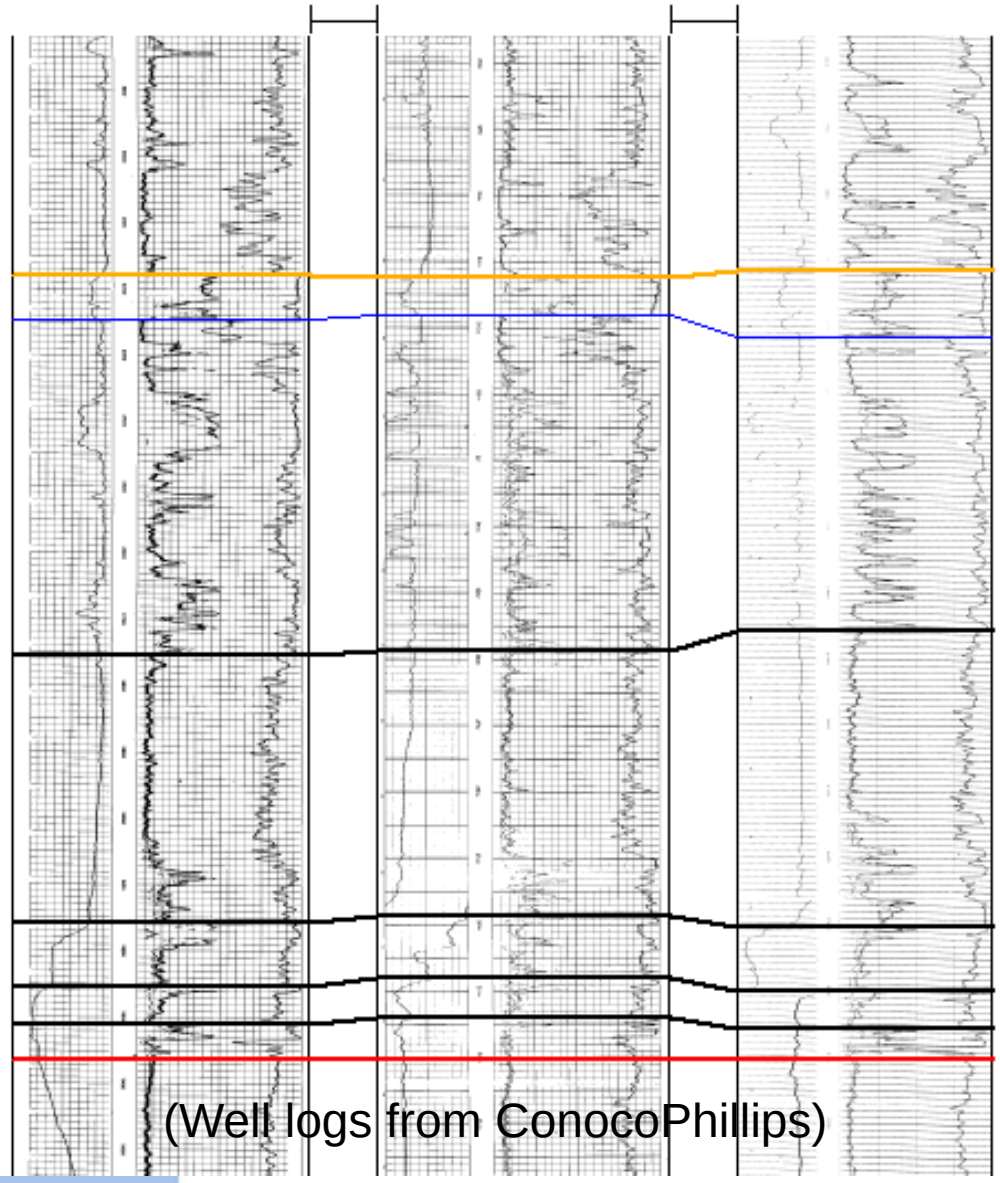
Investigation of Caprock Seal Integrity

CO_2 Containment Assessment:
Develop methodology for characterizing sealing quality at CO_2 sequestration sites

Approach:
Integrate petrological, petrophysical, geomechanical, isotopic, and geochemical data

Unique Research Question:
Can natural helium be used to characterize sealing behavior of rock for CO_2 storage?

Core Points



(Well logs from ConocoPhillips)

Goal: 120 ft total
Reality: **60.5 ft total**

Ojo Alamo (29.7 ft)

Upper Kirtland (22.5 ft)

Lower Kirtland Shale (8.3 ft)

Fruitland

Pictured Cliffs

Multiscale Investigation of Sealing Behavior

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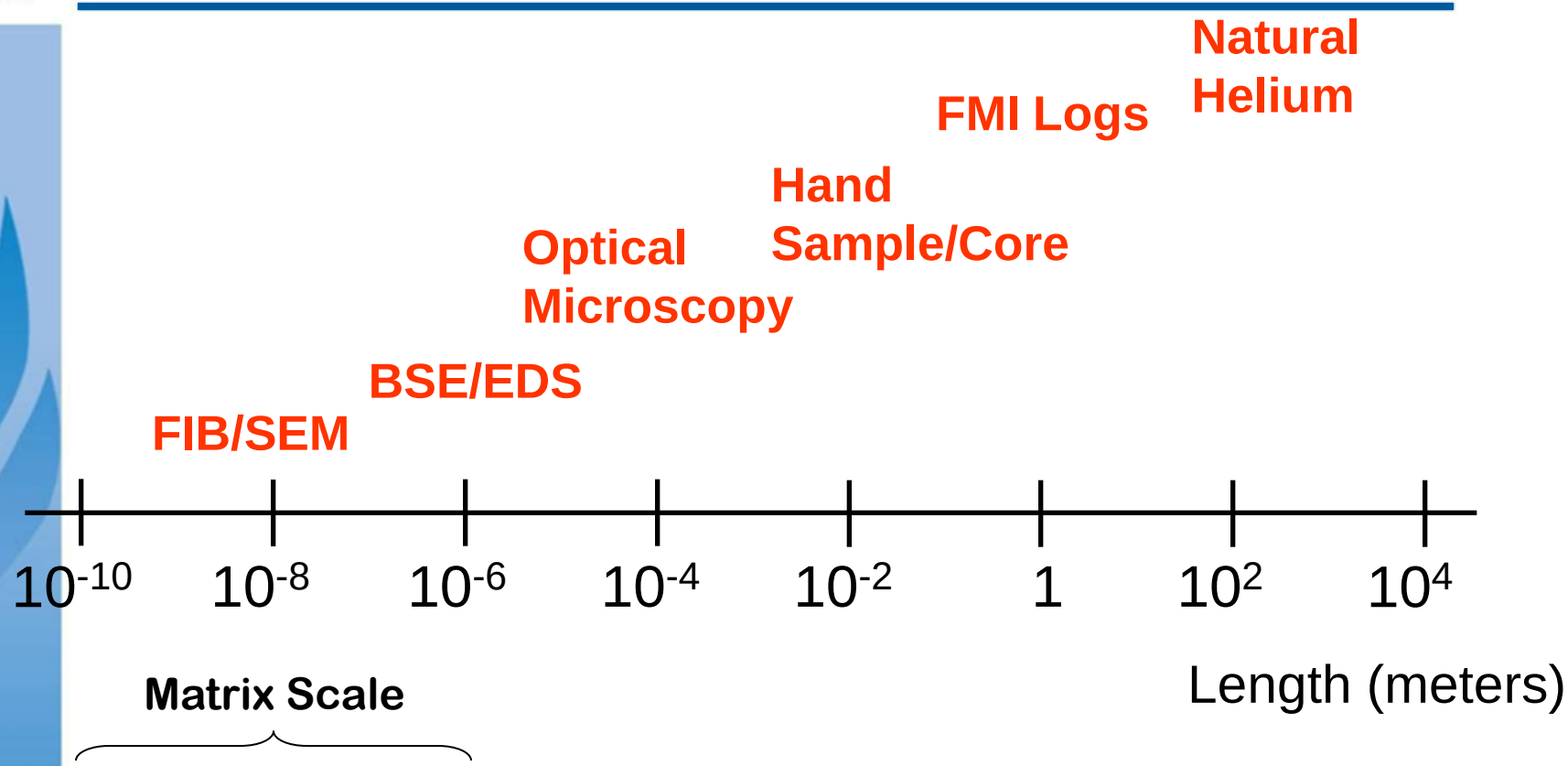


Nanoscale: pore networks & surfaces

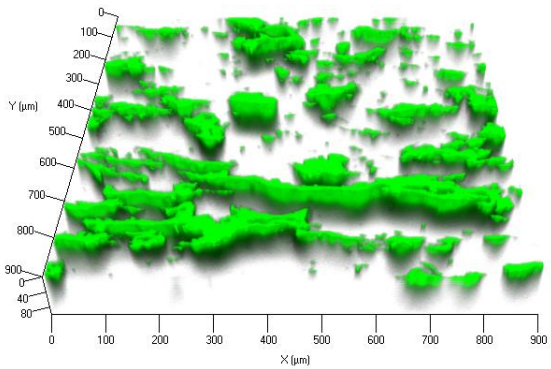
Microscale: large pores and microfractures

Meso scale: core, outcrop, well logs

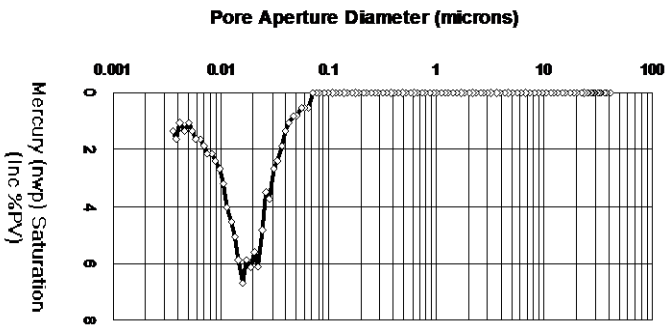
Macro scale: Formation/ reservoir

Example: Matrix Scale Results (Nano to Micro Scale)

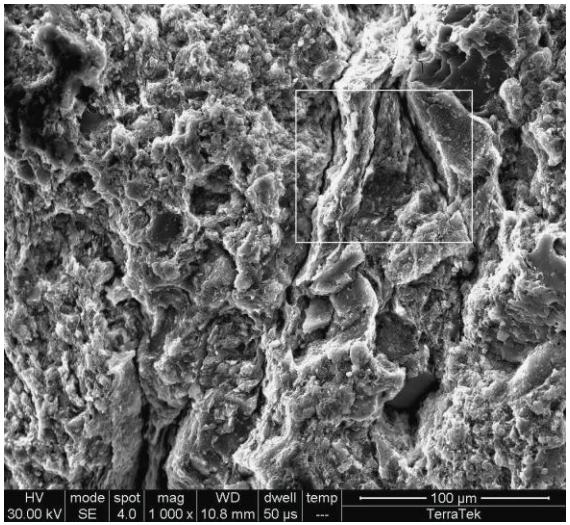
LSCM at 2062.10 ft



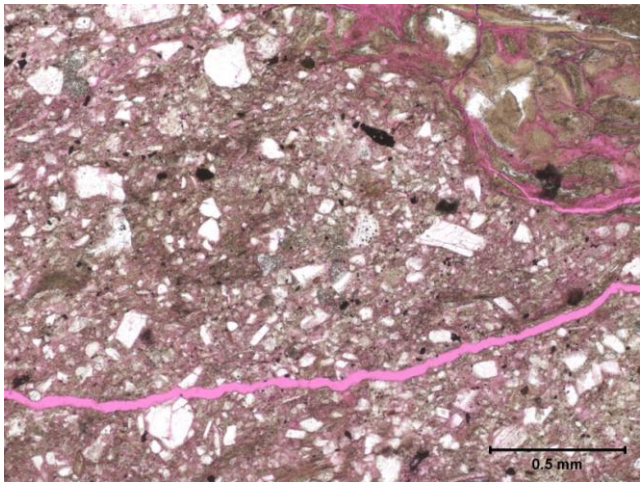
MICP at 2062.40 ft



SEM at 2062.30 ft



Thin section at 2062.30 ft



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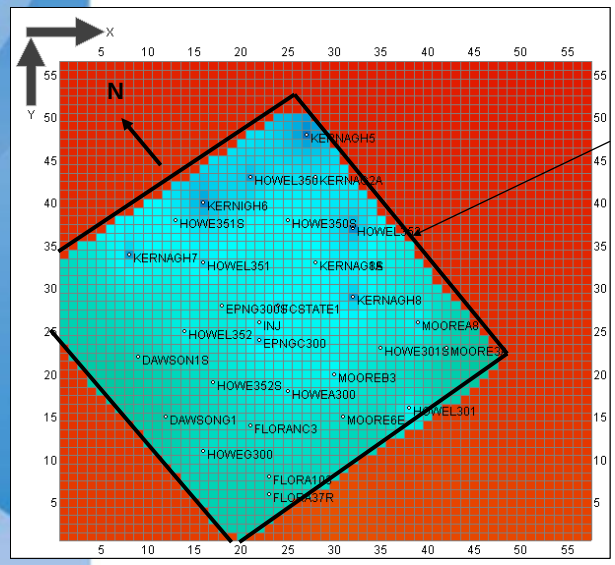
Major Findings

- Matrix seal quality seems high
- Fractures are present, some of which are “open”
- Some forms of mineralization may be chemically sensitive to CO_2
- Helium and neon data lead to additional conceptual models

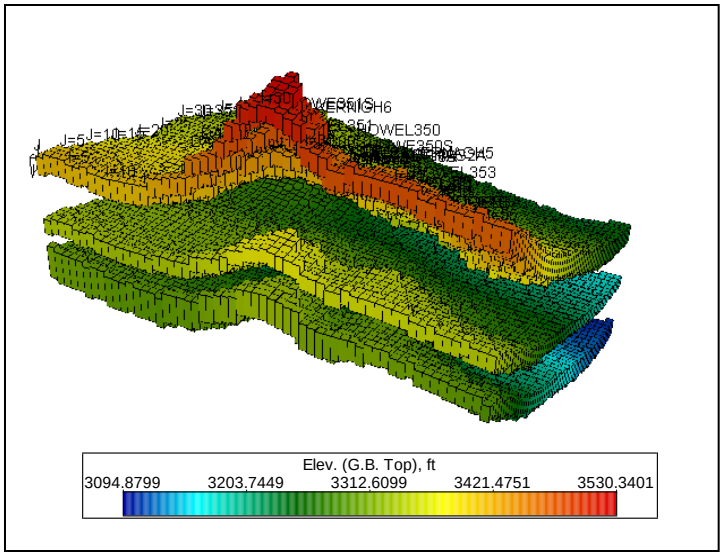
Model Construction

Property	Value
Average Depth to Top Coal	3,012 feet
Average Total Net Thickness	60 feet Upper Coal: 16 feet Middle Coal: 15 feet Basal Coal: 29 feet
Initial Pressure	1500 psi @ 3600 ft above sea level
Temperature	126ºF

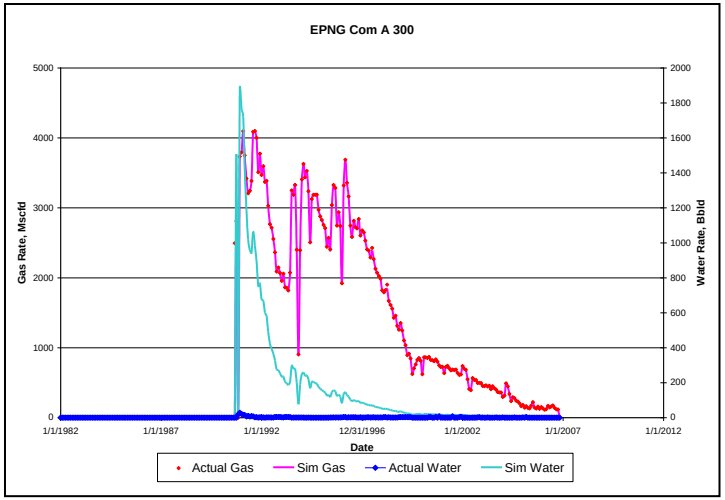
- ***COMET3*** **reservoir simulator model**
- **3 layers, 9-section model**
- **Isotherms, cleat orientation available**

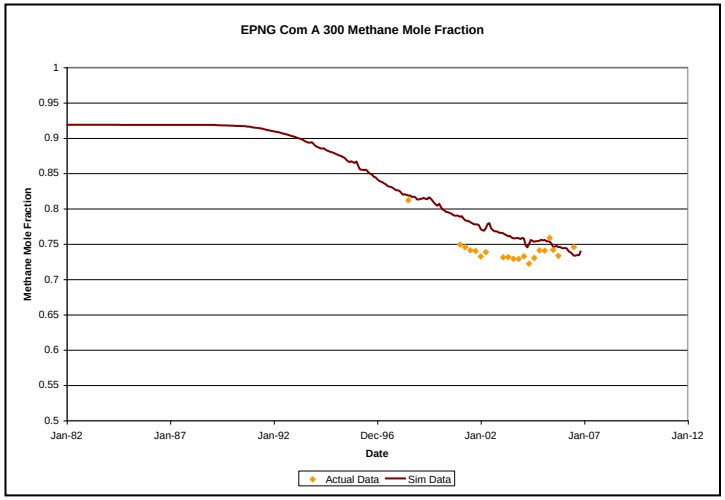


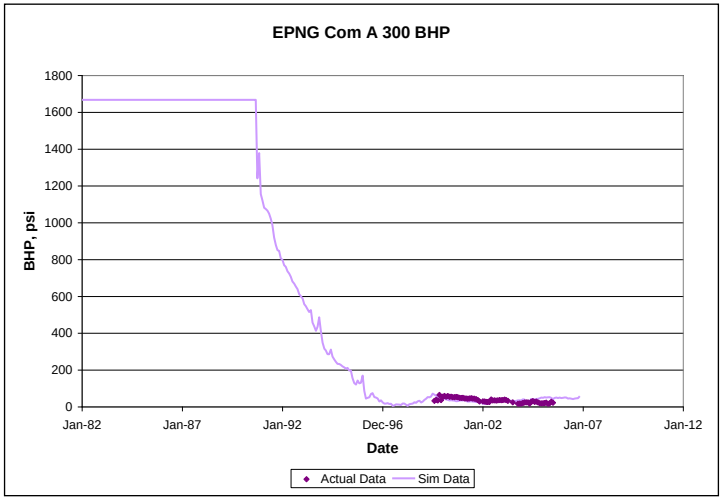
No Flow Boundary



Current Model Results
Offset Well EPNG Com A 300

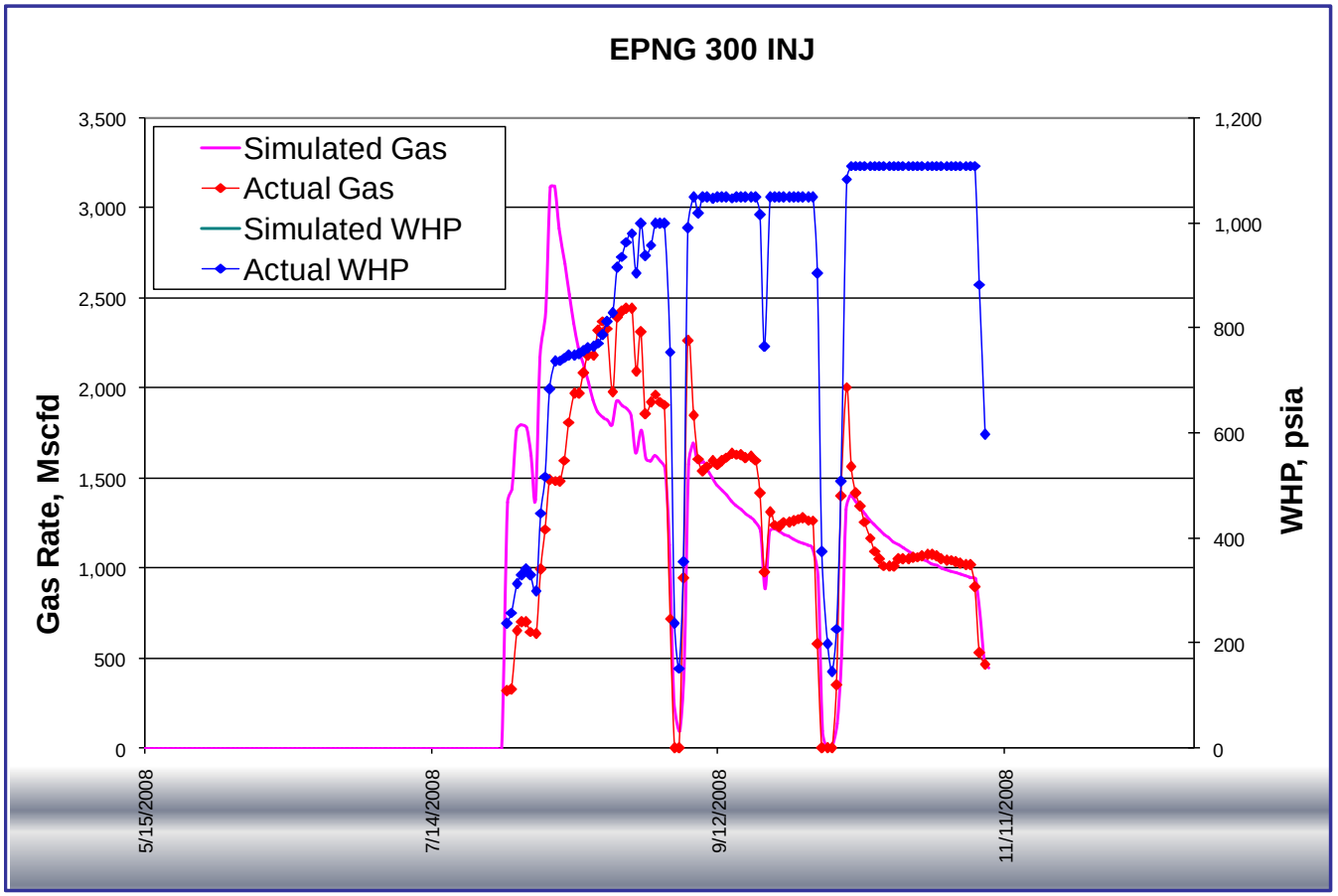






- **Permeability optimized at 550 mD**
- **Porosity 1.6%**

Current Model Results Injector



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

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Model Update

- Permeability may be higher in bottom coal
  - Injectivity profile test results show 83% of the CO_2 going into lowermost layer
  - Logs show coal of better quality
  - Operator “information”
- Included produced nitrogen composition from gas samples
- Updated production/injection data until April 2009
- “Re”-history match under way

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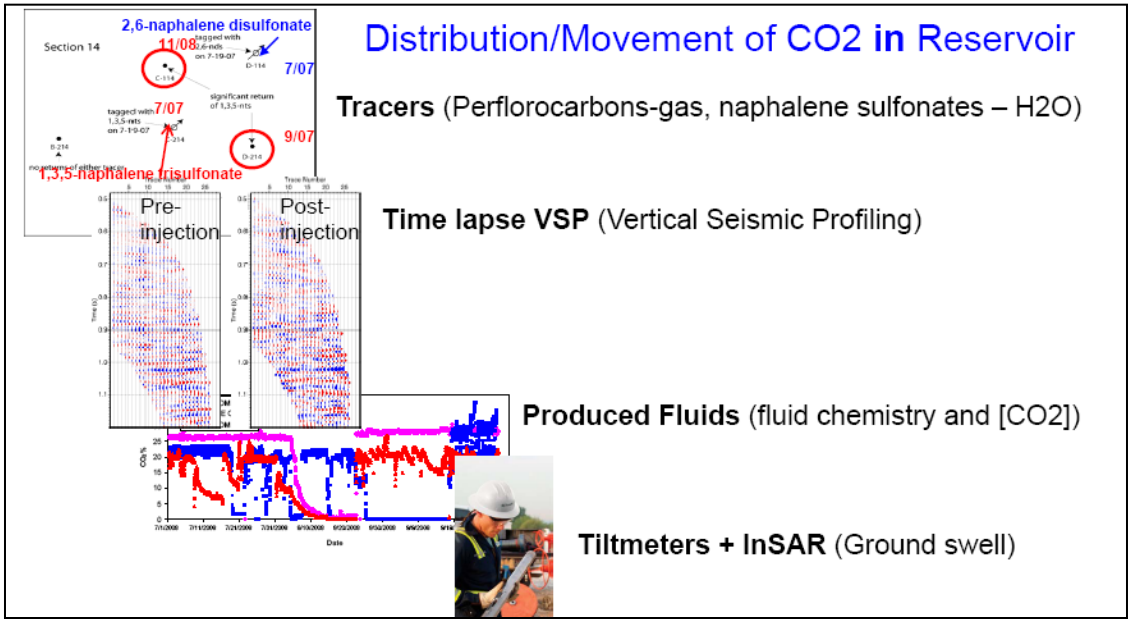
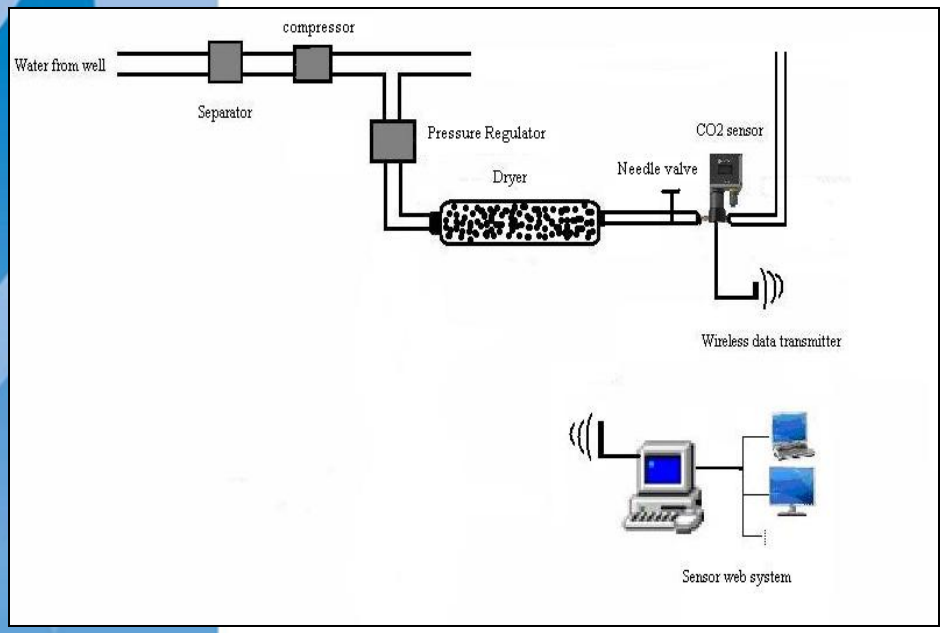
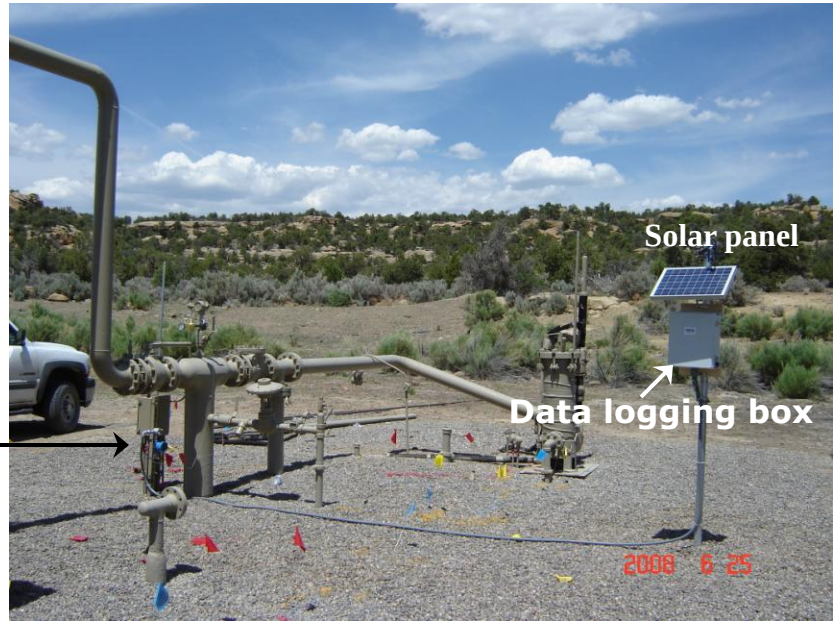


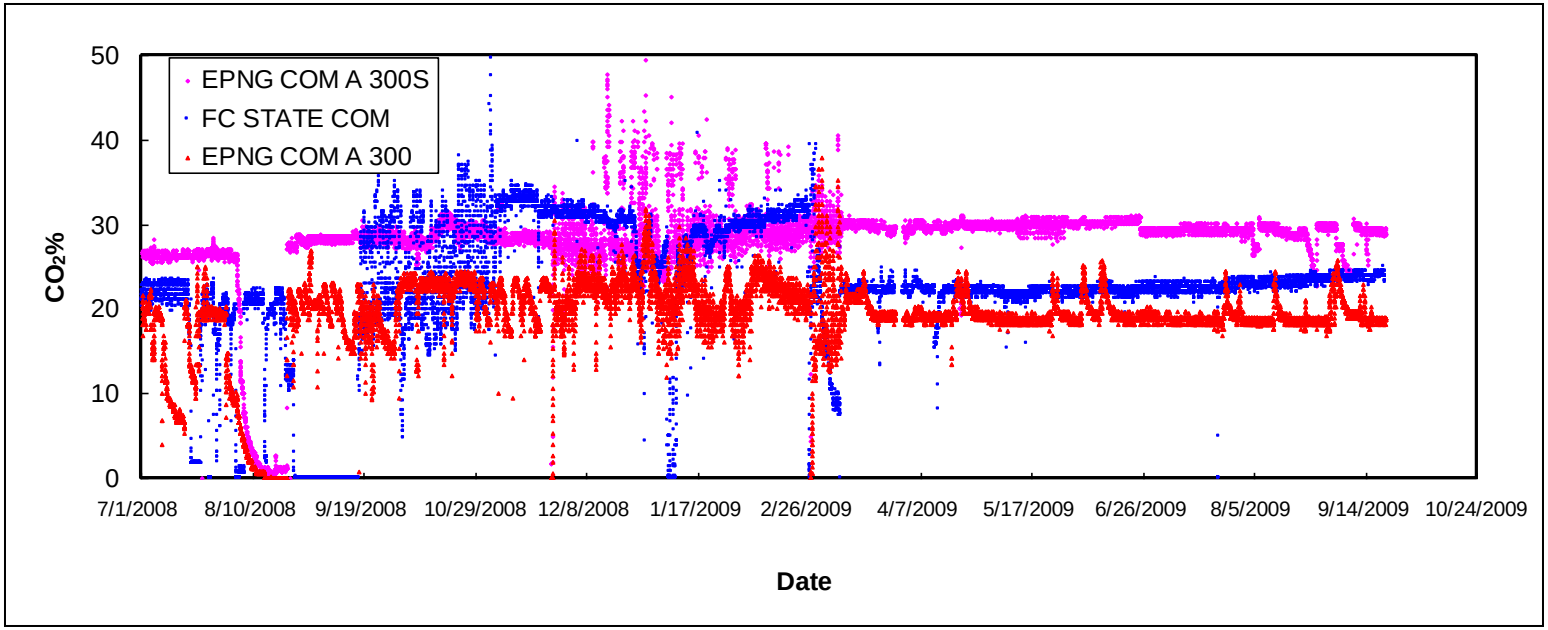
CO_2 Sensors - Experiment Design



CO_2 sensor



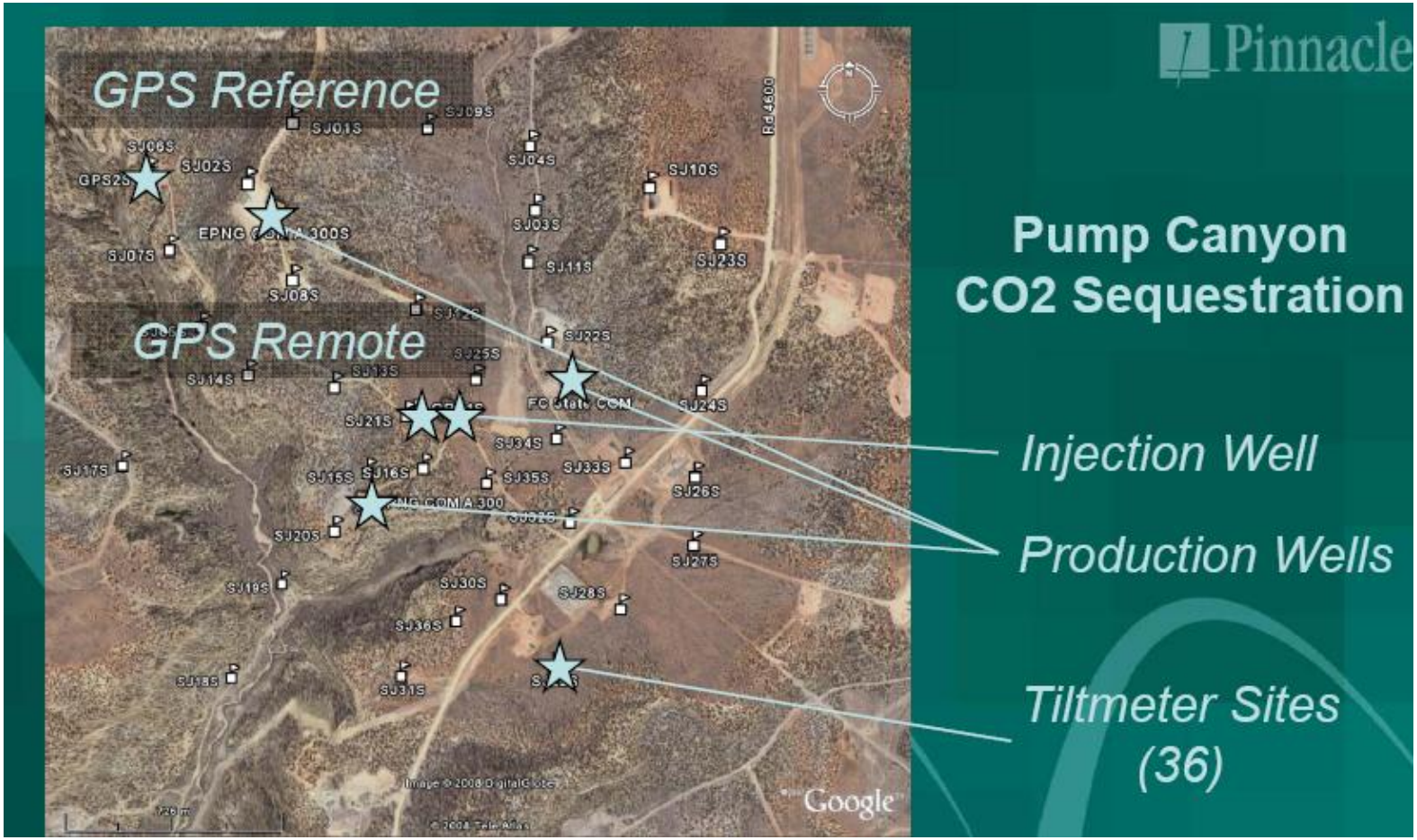
CO_2 Sensors Results



Gas samplings were performed regularly in surrounding wells. Increase in N_2 concentration was noticed in two wells (SW and E).

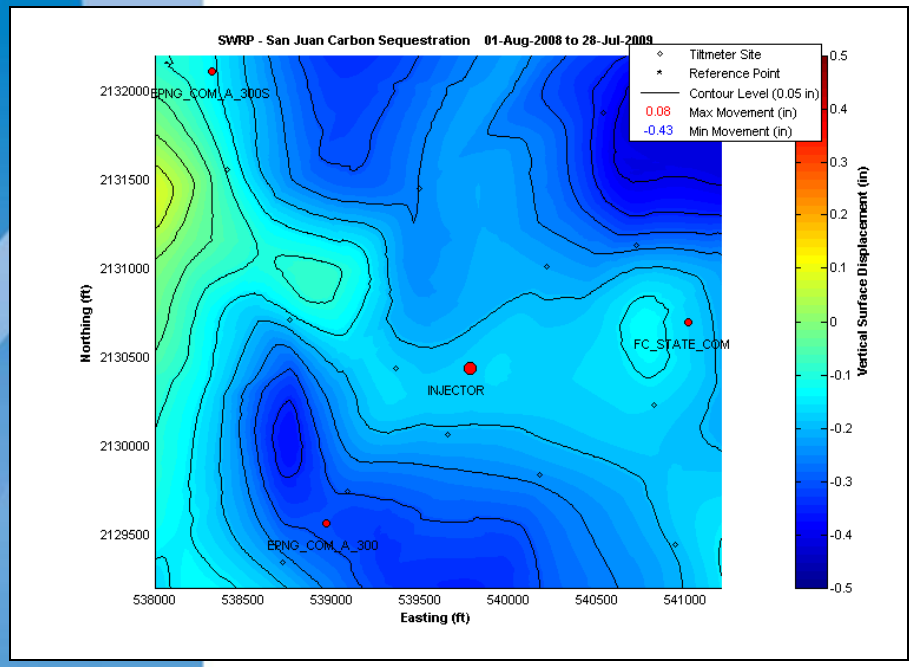
	10/24/07	01/04/08	04/30/08	07/28/08	09/11/08	11/13/08	02/25/09	05/20/09
N_2%	0.051	0.039	0.147	0.078	0.448	**2.020**	**1.724**	**1.512**
CO_2%	19.8	19.4	19.7	20.6	19.4	23.7	21.4	20.0
CH_4%	75.9	78.9	76.3	78.0	76.7	72.1	73.7	74.8

Tiltmeters

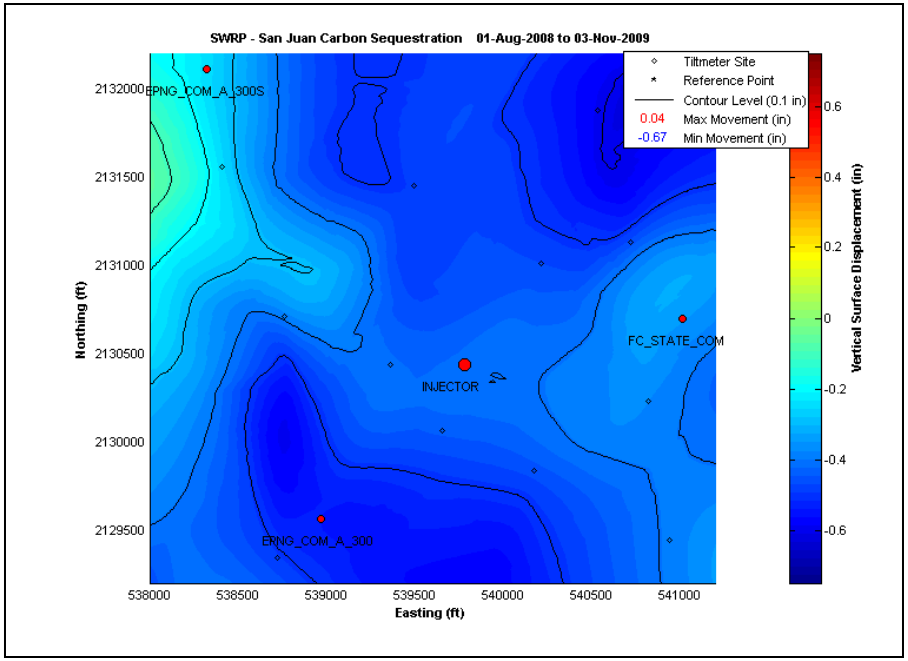

Pinnacle
GPS Reference
GPS Remote
Pump Canyon
CO2 Sequestration
Injection Well
Production Wells
Tiltmeter Sites
(36)
Google

Tiltmeters

End of Injection



Current



- No significant deformation in the area
- In addition, 2 GPS stations were installed and InSar analysis conducted. All methods lead to the same conclusion.

Soil Gas and Tracers

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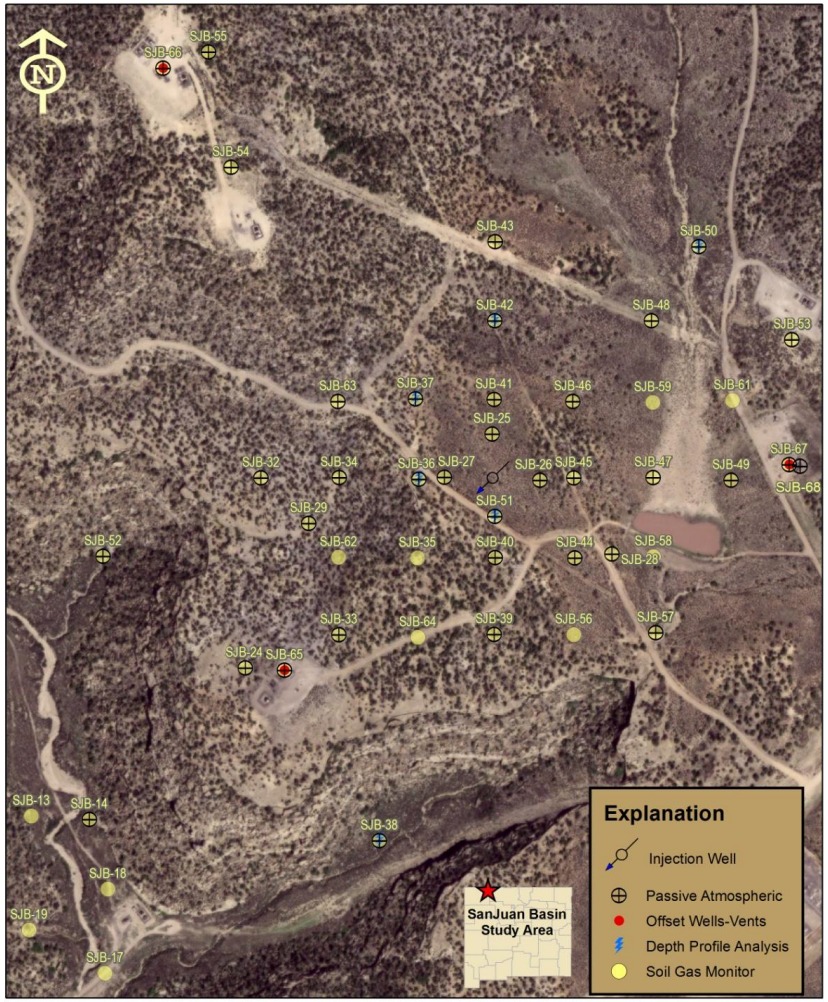
Monitoring Protocol

- Soil gas (1 m nominal depth) and atmospheric grid surrounding injection well at 100 m spacing with additional locations near well pad, in canyon and near offset producers.
  - Data still being analyzed
- Four depth profiles in soil up to 2 m.
- Vents from CO_2 monitors on 3 offset producers



1:5,000

100 50 0 100 Meters

WGS-84,UTM 13

SanJuan Basin CO_2 Tracer and Soil Gas Study Area

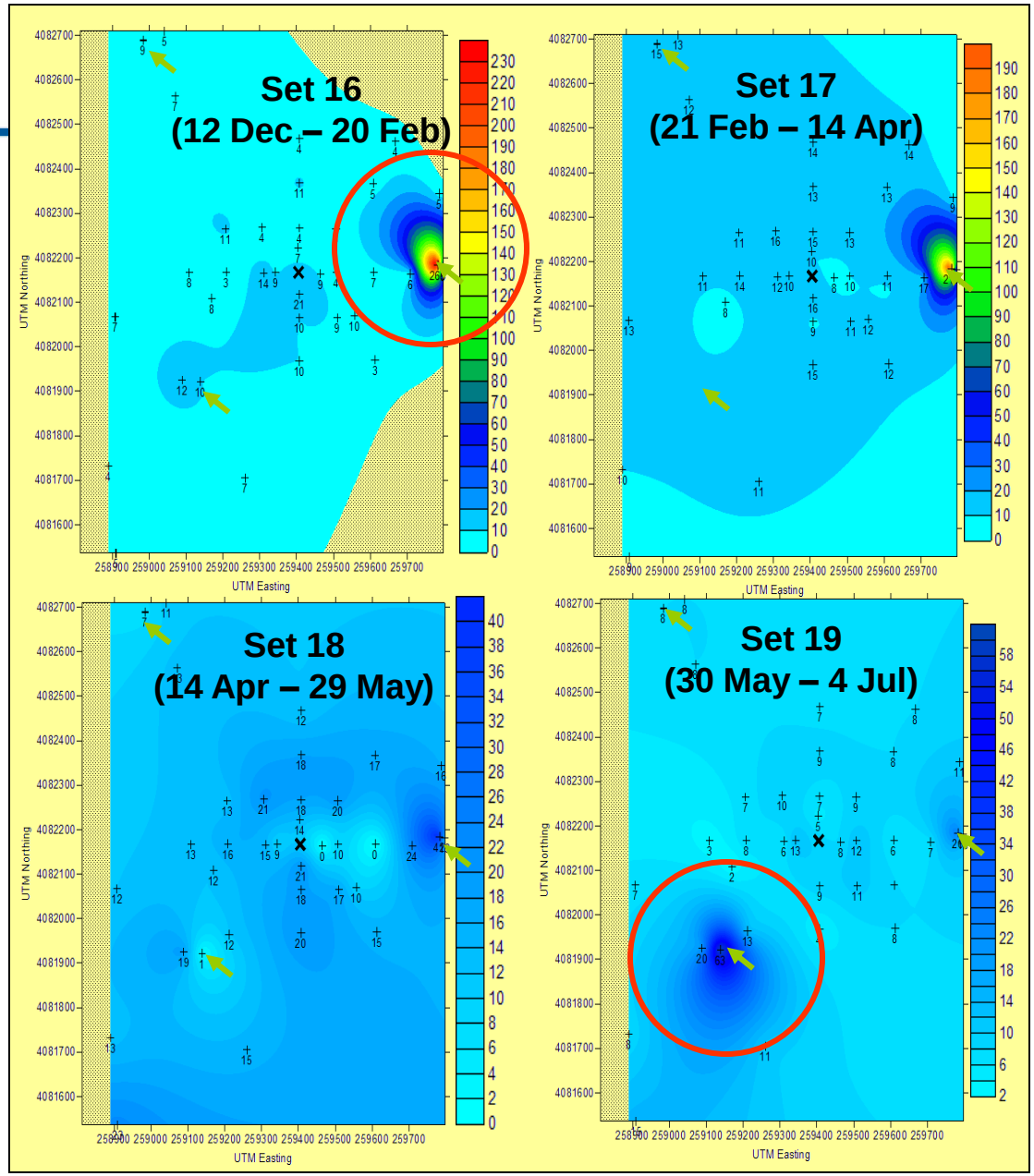
Archuleta Quadrangle, New Mexico

prepared by: Garret A. Veloski, US Dept. of Energy, National Energy Technology Laboratory

Updated Sept.17, 2009

Tracers Results

- CO_2 breakthrough at E offset well in February 09 and at SW offset well in July 09
- Conservative tracer breakthrough expected to precede CO_2 breakthrough.
- Consistent with gas sampling data



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VSP Data Collection and Analysis

- Pre-injection VSP run on June 2, 2008
- Post-injection VSP run on September 17, 2009
- Analysis in progress

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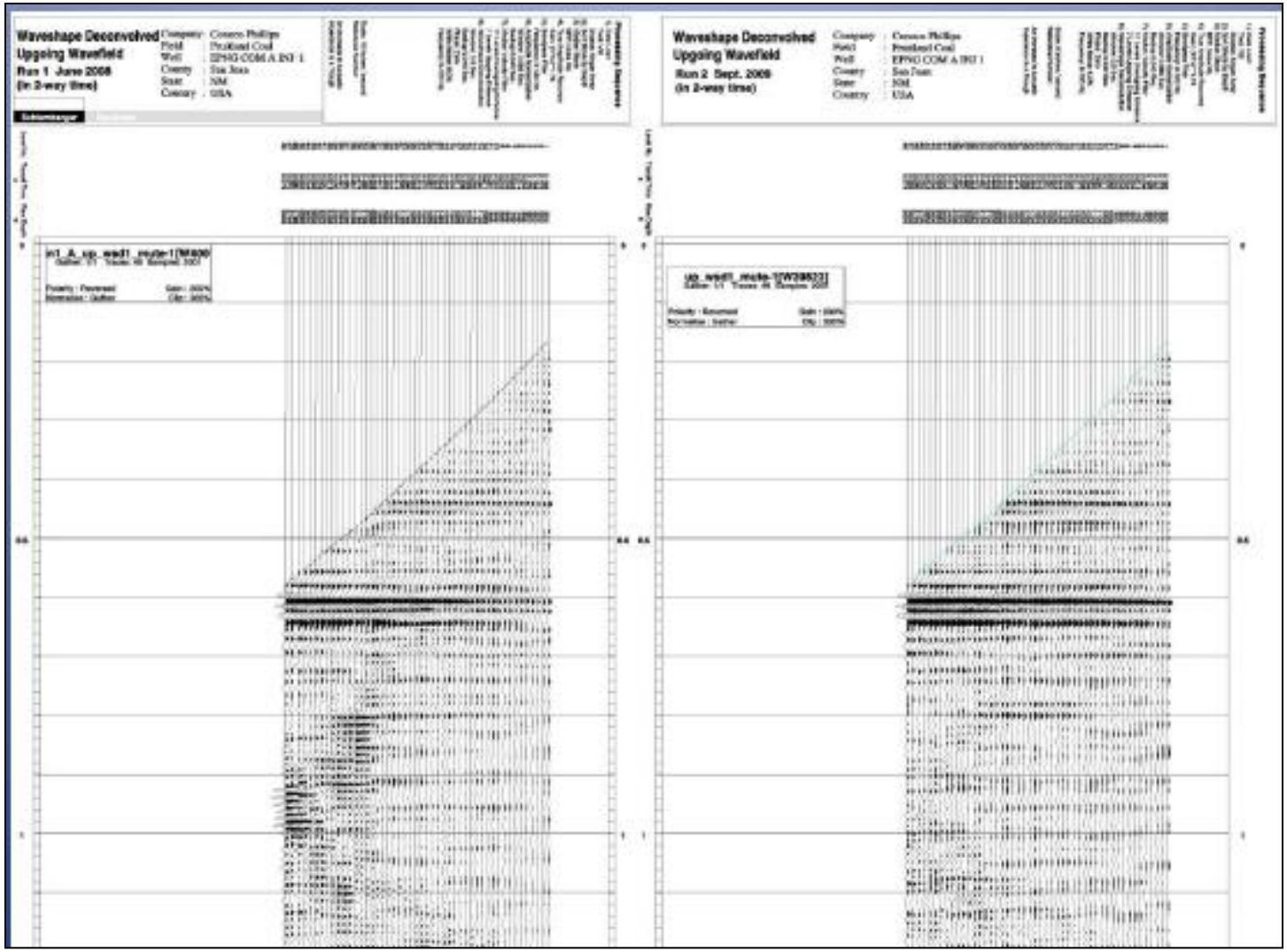
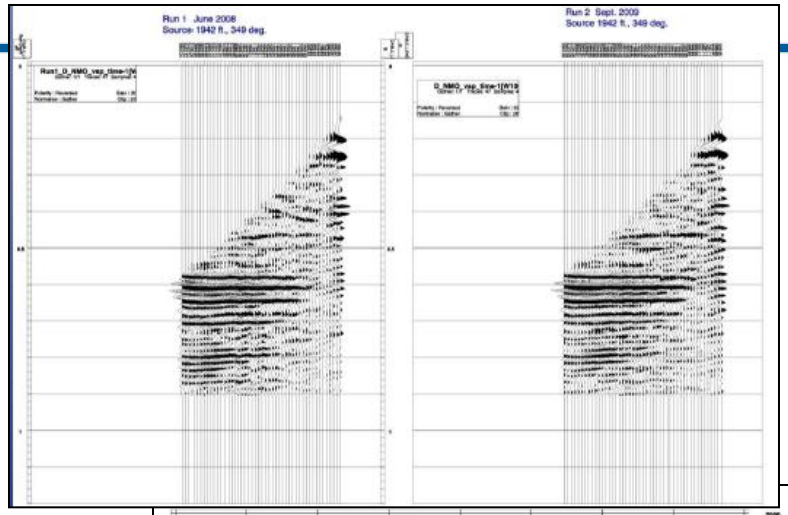
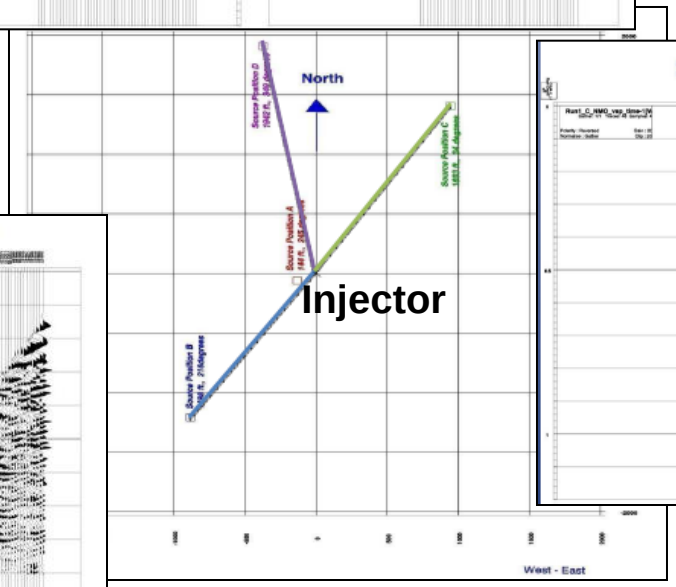
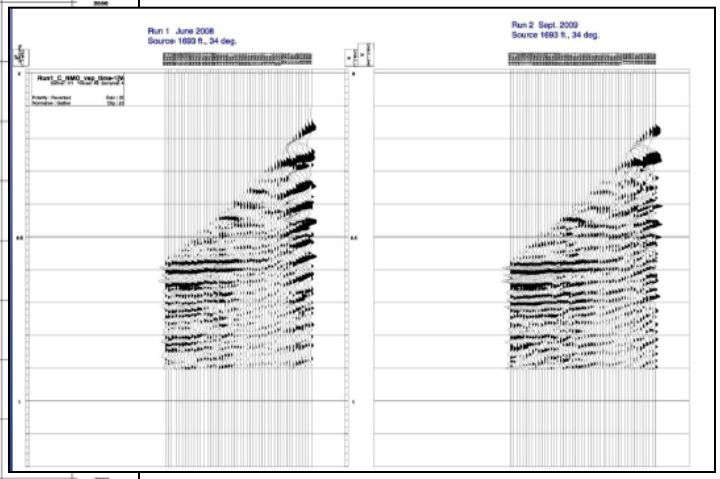
Comparison of Zero Offset VSPs

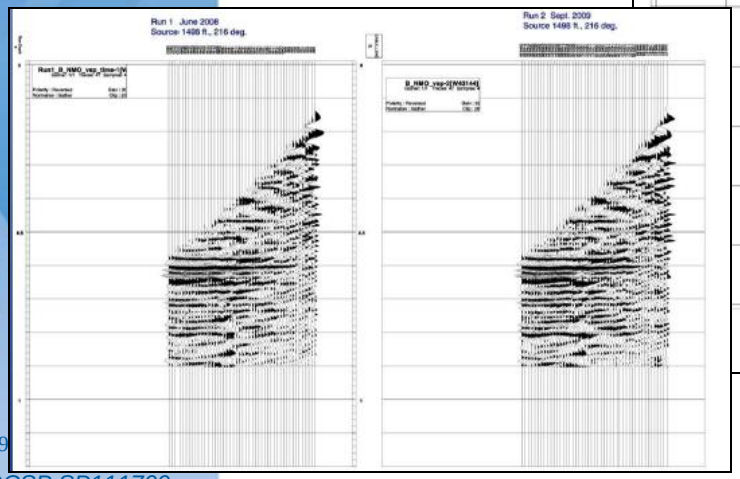


Comparison of Offset VSPs









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Next Steps

- Complete VSP analysis
- Tie tracers, VSP, gas analysis and production information to reservoir model
- Understand what a commercial application might be capable of in the San Juan Basin
  - Stimulated wells
  - Horizontal wells

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