EERC Technology… Putting Research into Practice

Carbon Storage in Lignite Coal

Plains CO_2 Reduction (PCOR) Partnership
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Lignite Field Validation Test
Burke County, North Dakota

PCOR Partnership

NETL

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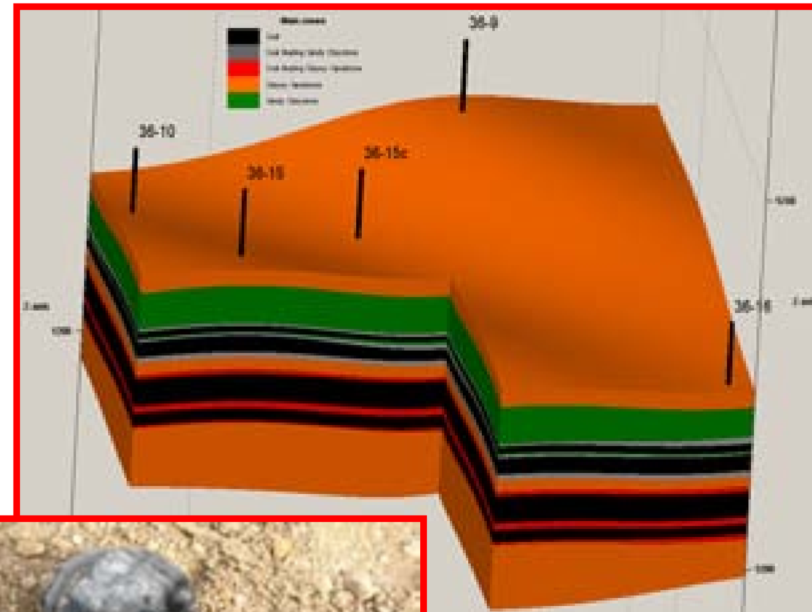
Goal and Objectives

Goal

- Determine the feasibility of simultaneous carbon dioxide (CO_2) sequestration and natural gas production from a lignite coal seam.

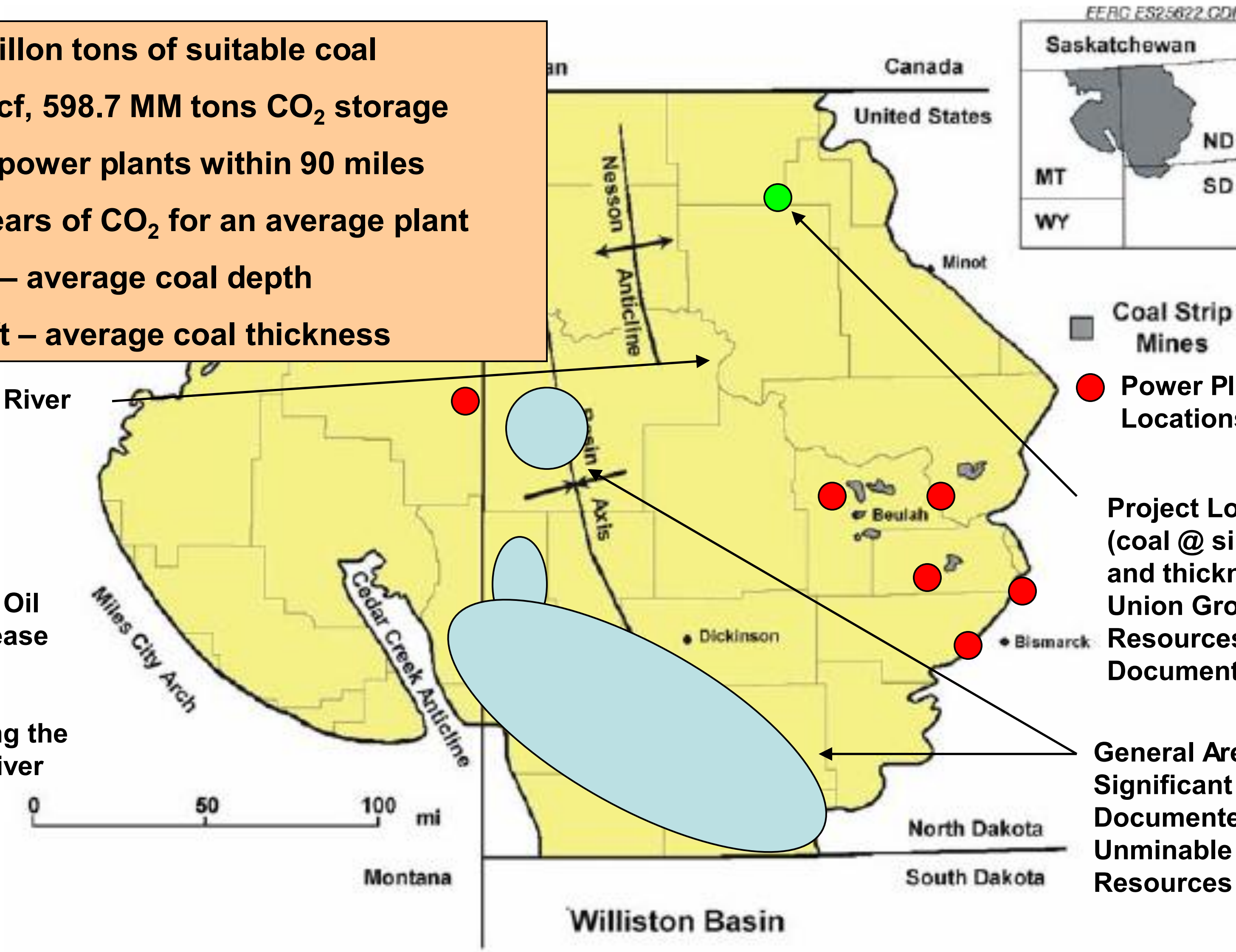


Objectives

- Inject CO_2 into lignite coal seam and monitor CO_2 fate in the reservoir.
- Determine the potential for coalbed methane (CBM) production from the lignite seam.

Storage Resources

- 27.5 billon tons of suitable coal
- 10.3 Tcf, 598.7 MM tons CO_2 storage
- Eight power plants within 90 miles
- 100 years of CO_2 for an average plant
- 500 ft – average coal depth
- 5−10 ft – average coal thickness



Missouri River

Significant Oil and Gas Lease Activity in Counties Surrounding the Missouri River and South

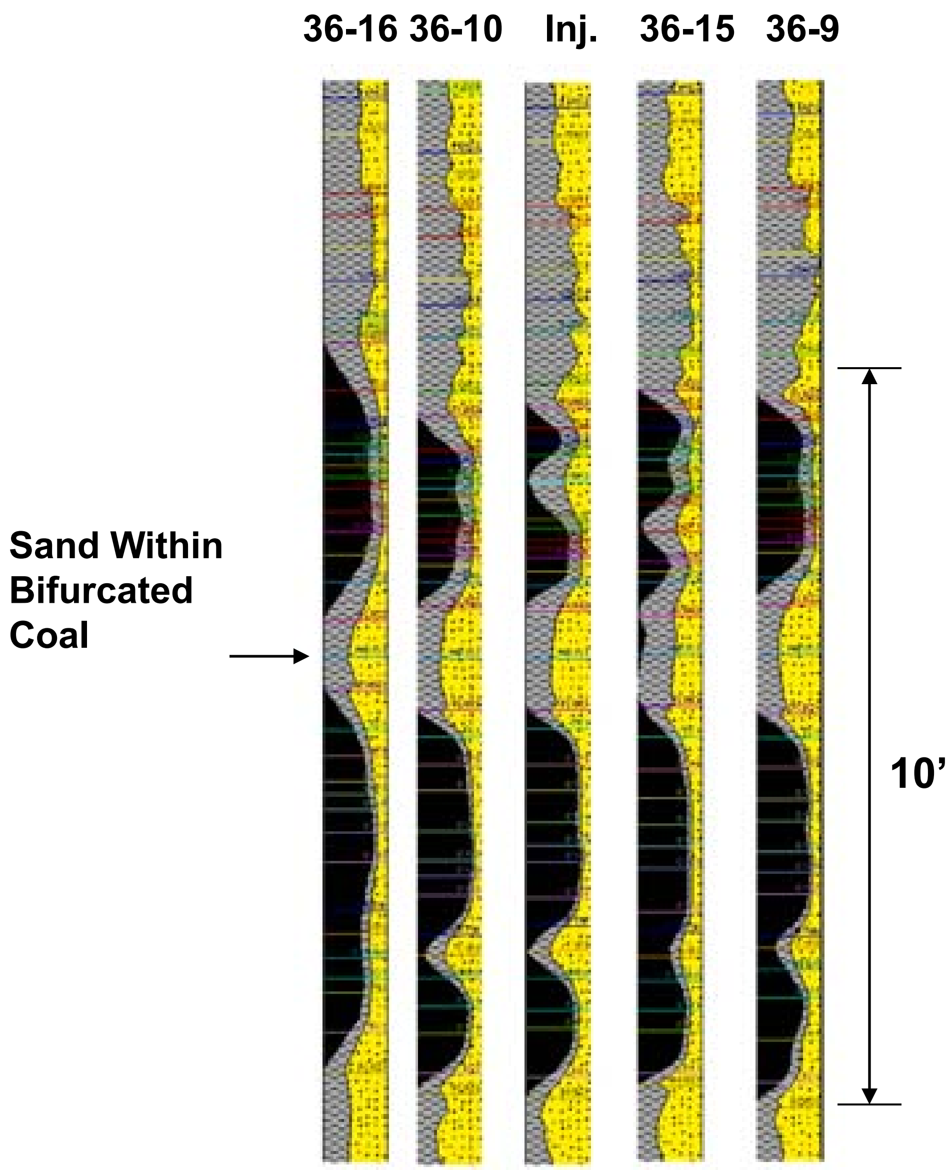
Project Location (coal @ similar depth and thickness in Fort Union Group) − Resources Are Not Documented

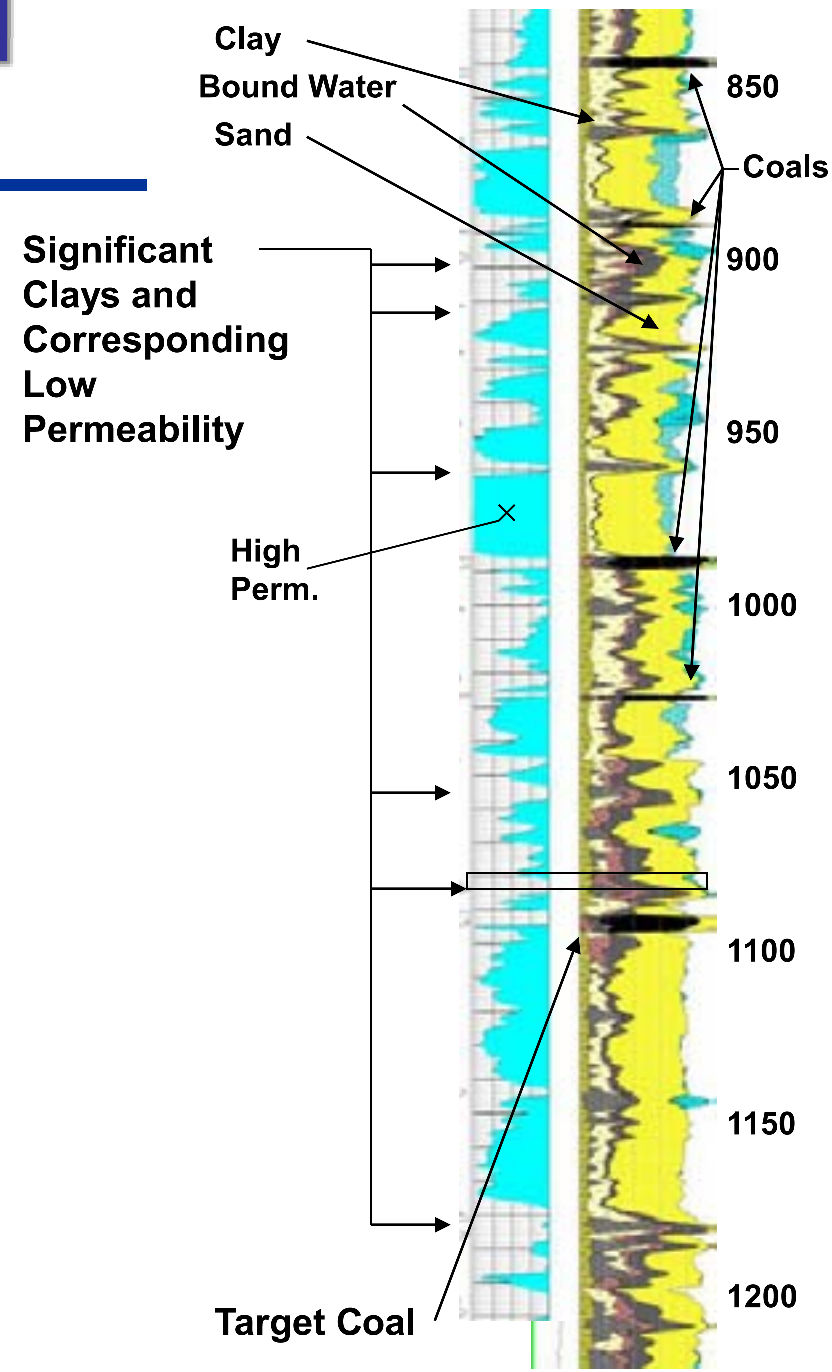
General Area of Significant Documented Unminable Coal Resources

Scope of Work

- Site characterization
- Modeling
- Injection
- Monitoring, verification, and accounting (MVA)

Potential Caps and Coal Seam Detail





Coring and Analysis

- Maceral analysis – low gas potential, modest cleating potential
    - Vitrinite 52%
    - Lipinite 2.1%
    - Inertinite 45.9%

- Coal analysis
    - 26% moisture
    - 10% ash
    - 28% volatile matter
    - 36 % fixed carbon
    - 7657 Btu/lb
    - 0.16% sulfur

- Adsorption isotherm – 350 scf/ton CO_2 @ 350 psia; 23 scf/ton CH_4 @ 350 psia; Gas content 0.75-1.72 scf/ton.

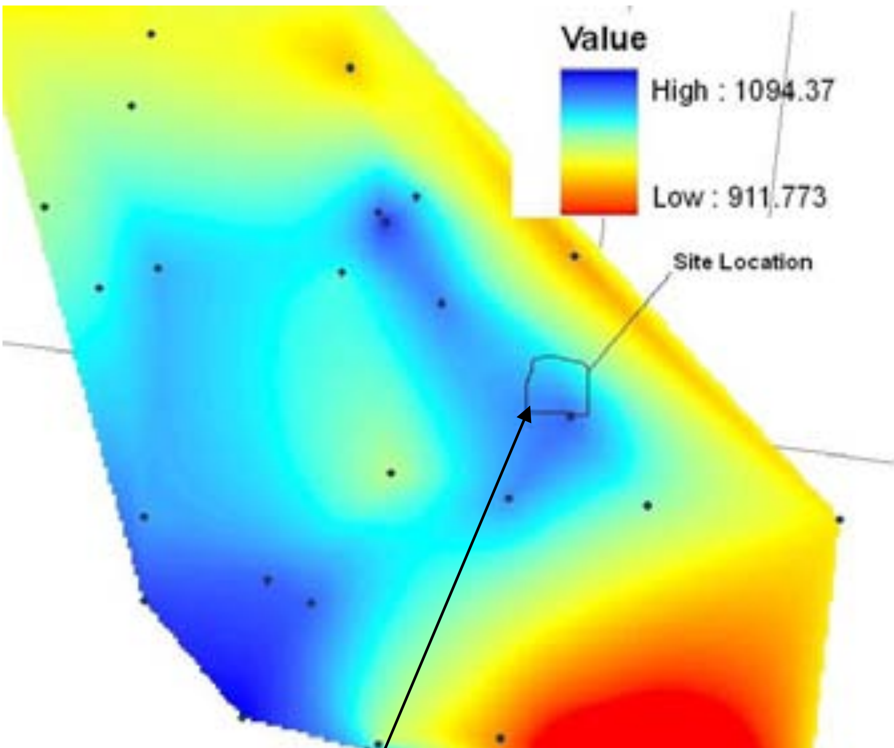
- Laboratory permeability – 0.5–0.6 md
- Porosity – 1.8%, after drying 6.1%
- Vitrinite reflectance (Ro) – 0.24 (subbituminous − 0.47)

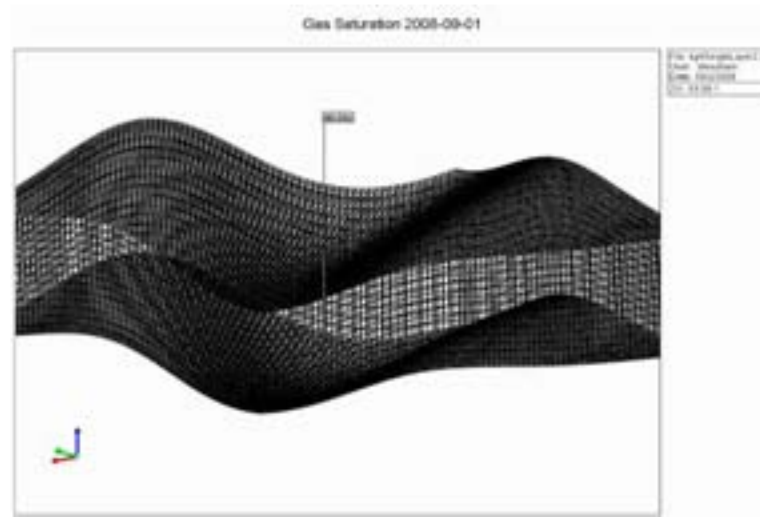
- Classification – (subbituminous C – lignite)

Site Development

- 5-spot well pattern
- Cemented and perforated
- Completed NFIT
  - 330–350 psia reservoir pressure
  - 0.005–5 mD
  - 460–480 psia fracture closure
  - (-1.3 to -3.3) skin factor
- Determined underpressured Implications:
  - Compartmentalization
  - Greater pore space
  - Underbalanced drilling desired
  - Higher injection pressure differential
  - Low gas content
- Multiwell testing revealed permeability direction SW−NE

Modeling





Arc-GIS

Coal more shallow to the NE: 1100’–1000’

Injection

- Total Injection = 90 tons
- Period = 16 days
- Permit = max. 780 psig; avg. 720 psig

Results:

- Heating CO_2 at the surface and injecting high-pressure gas provides for a greater injection rate than pumping cold liquid.

- Attempts to decrease density and viscosity by lowering downhole pressure did not allow for high enough injection pressure to improve injectivity.

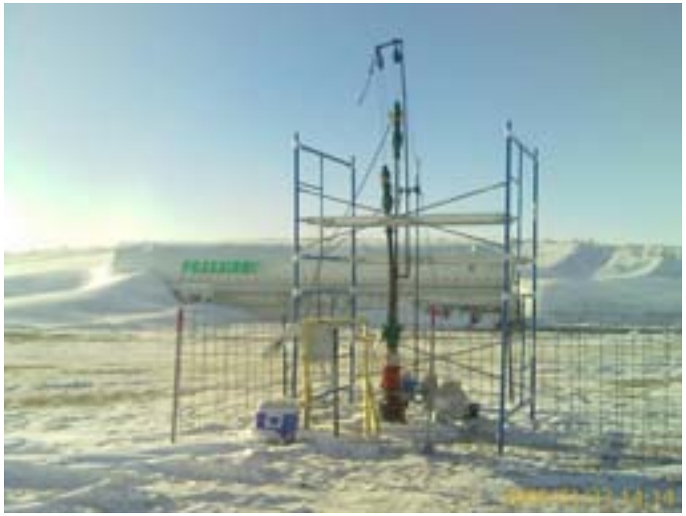
- Injection at 1.4 gpm was achieved.

- Approximately 25% of the initial injection rate was lost over the first 2 days.

EERC LB35467.CDR

MVA

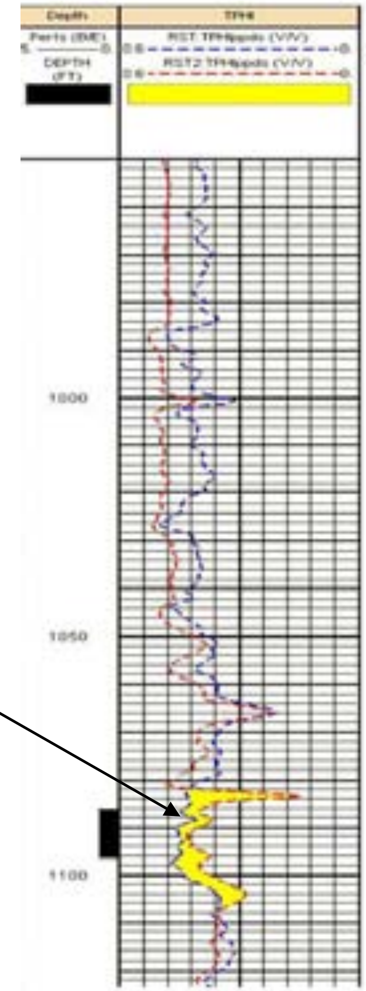
- Wells outfitted with downhole and surface data acquisition telemetry.
- Reservoir Saturation Tool (RST) used to identify free gas.
- Microseismic – potentially locate CO_2 during injection.
- Cross-well seismic – potentially locate CO_2 after injection.
- Fluorocarbon gas tracer – used to positively identify injected gas.
- Gas and fluid sampling



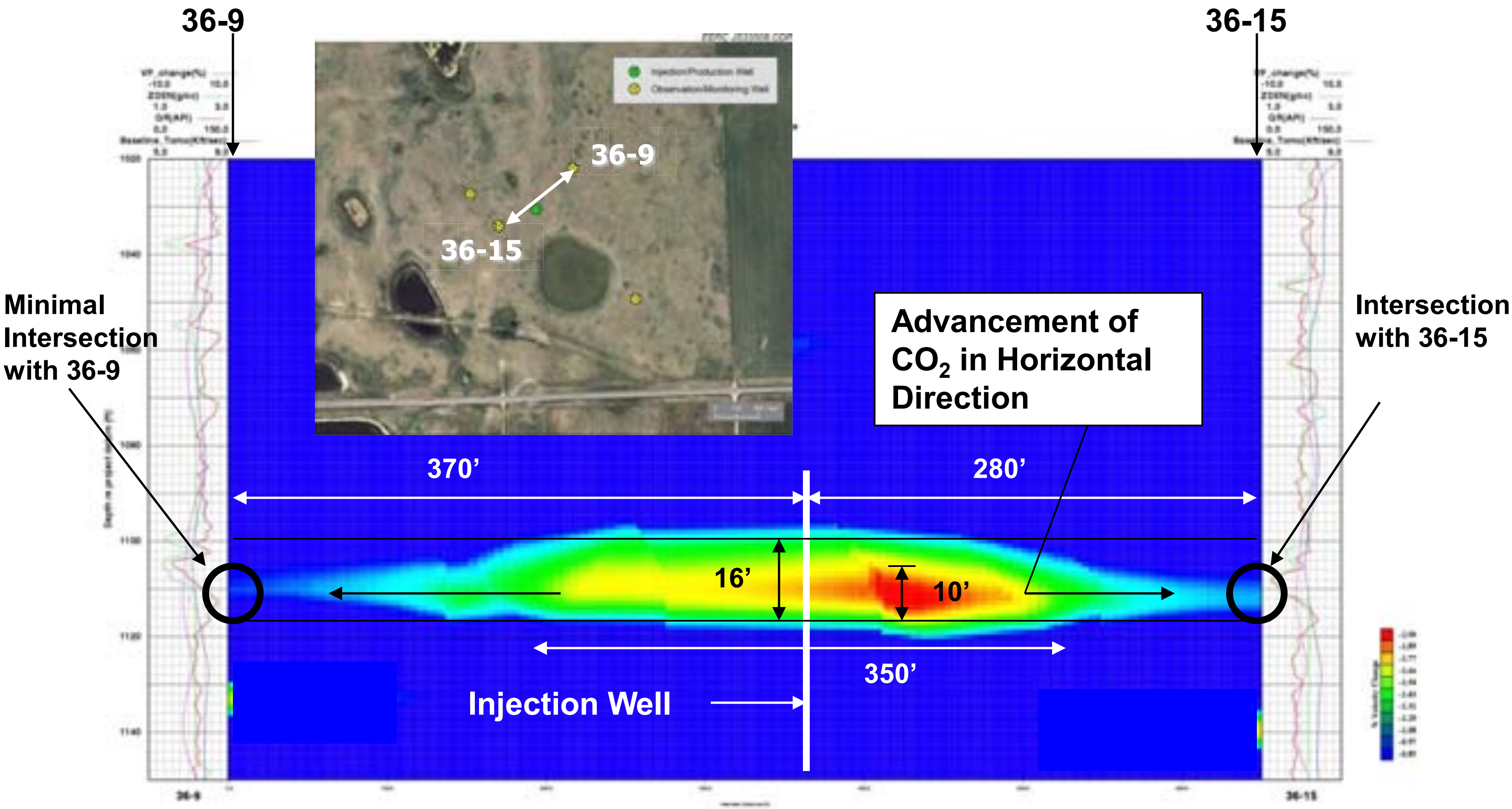
RST Results

- RST completed in all five wells.
- CO_2 identified in the injection well within the coal zone.
- CO_2 not identified in the monitoring wells.

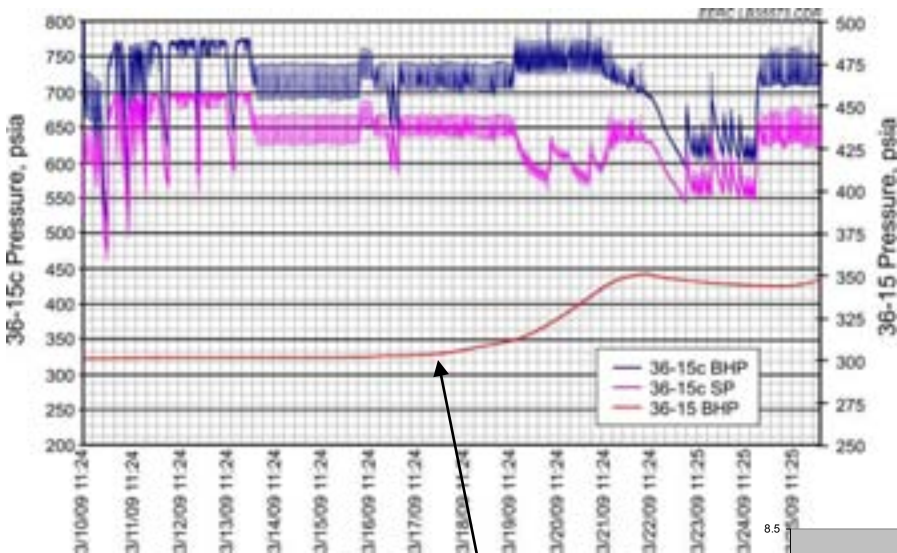
Identification of Free Gas



Seismic Results



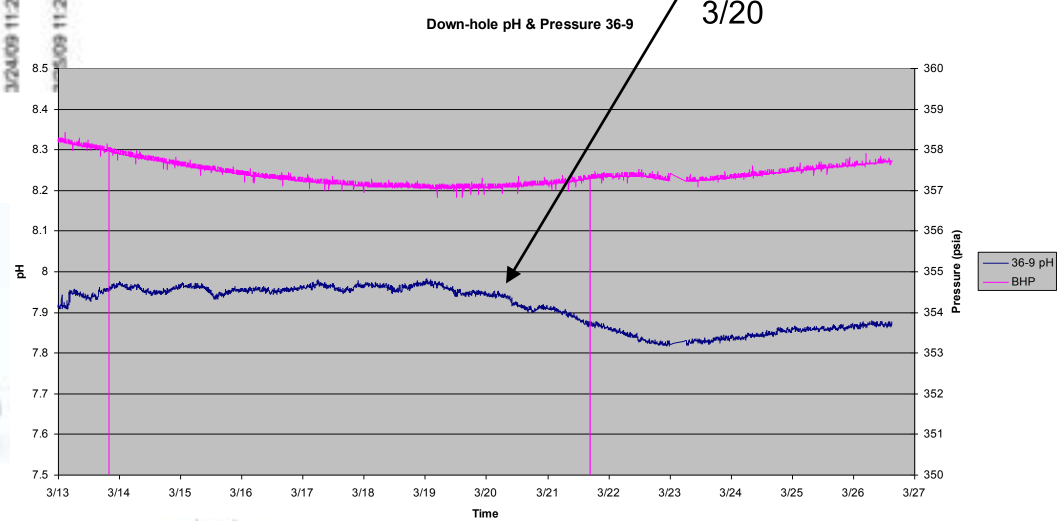
Verification Measurement Results



- Downhole sensing included temperature, pressure, conductivity, and pH.
- pH decrease is a good indicator of CO_2.
- pH deflection appears to occur at the same time of pressure rise

36-9 beginning of pH deflection and pressure rise on 3/20

36-15 beginning of pressure rise on 3/17



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Results

What is the disposition of CO_2?—bottomline—in the coal.

- No significant fracturing indicated from microseismic monitoring.
- Downhole measurements of pressure and pH corroborate cross-well seismic results.
- Low permeability and no presence of CO_2 at NW and SE monitoring wells further support an estimated elliptical plume shape elongated in the NE–SW direction.
- Cross-well seismic suggests the following:
  - Migration within the coal zone.
  - Equivalent migration distance in the NE and SW directions.
  - Timing the presence of CO_2 at monitoring wells suggests an elliptical flow in the preferred NE–SW direction.
  - Progression of CO_2 along the centerline suggests preferential adsorption of CO_2 into the coal or higher permeability of the sand in the bifurcated coal.
  - Adsorption or porosity occupation @ 18.1 scf/ton.

Feasibility and Economics

- Assumption: 500-MW power plant
- Annual emissions of CO_2 = 4.5 million tons/yr
- Land area for 1 year of storage = 20 sq. miles
- Assumption – 10' coal @ 1000' depth (350 scf/ton storage)
- Developmental scope:
  If injection rate = 1.4 gpm; 1400 wells
  If injection rate = 140 gpm; 280 wells
  If injection rate = 140 gpm + multilateral drilling; 80 wells

- Simple completions = $60,000/well
- Advanced completions = $500,000/well

- Advanced completion techniques can reduce development costs by 50%.

- Development cost range – ($40−$100 million)

- Economic financing consideration for drilling and completion:
  100 years: $0.51/ton of CO_2 (life of the resource)
  30 years: $1.70/ton of CO_2 (long-term financing)
  10 years: $5.10/ton of CO_2 (short-term financing)

Conclusions

- Lignite coal appears attractive for storage of CO_2. Additional work is recommended to further understand in-situ adsorption and effective injectivity.

- Injected CO_2 appears to preferentially travel along the path of the coal and can be contained within the expected injection zone.

- CO_2 enhanced methane production from lignite coal remains in question.

- Injectivity greatly impacts costs to drill and complete a sequestration project. Further work targeted at improved injection rates could lower drilling and completion costs by 50%.

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