THE PLAINS CO_2 REDUCTION (PCOR) PARTNERSHIP – DEMONSTRATING CO_2 STORAGE IN CENTRAL NORTH AMERICA

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Zama Acid Gas EOR, CO_2 Sequestration, and Monitoring Project

Project Goal
- To validate the sequestration of CO_2-rich acid gas in a depleted oil reservoir.

Objectives
- Inject a stream of acid gas (70% CO_2 – 30% H_2S) for simultaneous acid gas disposal, CO_2 sequestration, and enhanced oil recovery (EOR).
- Determine the effects of acid gas injection on target reservoir and caprock formations.
- Implement a cost-effective approach for measurement, mitigation, and verification (MMV) for sequestration of a CO_2-rich acid gas stream.

Officially recognized by the Carbon Sequestration Leadership Forum in March 2007 as an official Geological Storage Project

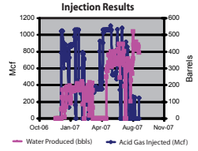
MMV Operations

Monitor the CO_2/H_2S plume through:
Perfluorocarbon tracer injection.
Reservoir pressure monitoring.
Wellhead and formation fluid sampling (oil, water, gas).

Monitor for early warning of reservoir failure through:
Pressure measurements of injection well, reservoir, and overlying formations.
Fluid sampling of overlying formations.

Determine injection well conditions through:
Wellhead pressure gauges.
Well integrity tests.
Wellbore annulus pressure measurements.

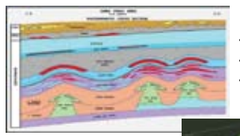
Injection Results



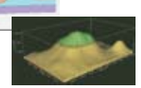
- Injection rates are being varied to match production and maintain pressure.
- No oil production has occurred since acid gas injection started (positive indication that injection is working properly).
- Cumulative injection is approaching 8000 tons.

Relative Permeability
- Completed to determine CO_2 and formation brine displacement characteristics of the pinnacle caprock (anhydrite).
- Prior to testing:
  - Capillary pressure testing to determine pore throat opening size
  - Petrographic analysis
- Two samples were tested using formation brine, CO_2, H_2S, and an acid gas mixture of 70% CO_2 and 30% H_2S.

Results show very low permeability in the caprock, indicating low potential for natural fluid flow out of the pinnacle.



Carbonate Reservoir
- About 40 acres at the base (0.16 km^2)
- 400 feet tall (120 m)
- One production well and one injection well



Acid Gas–Brine Partitioning Results
- Completed to assess the potential for early detection of acid gas in case of leakage into overlying aquifers.
- Performed at 140°F and 1960 psi, the conditions of the Zama F-pool pinnacle reservoir.
- Brine composition 119,000 ppm total dissolved solids (TDS).

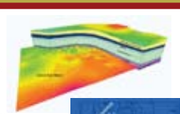
Results indicate CO_2 will lead H_2S in the sweep displacement front. May provide warning of a potential future breakthrough of acid gas.

Rock Mechanics Results
- Lab testing of eight core samples has occurred, primarily dolomite from the Keg River reservoir and dolomite and anhydrite from the Muskeg caprock.
- Tests include:
  - Bulk density.
  - Acoustic velocity.
  - Uniaxial strength.
  - Triaxial strength.
  - Residual friction measurements.

Results indicate that the caprock is significantly stiffer than the reservoir rock and is, therefore, a competent seal.

Geology and Hydrogeology Results
- Conducted to better understand the storage characteristics of regional aquifer systems and the fate of acid gas in case of leakage outside the pinnacle.
- Leakage migration, should it occur, would be a very slow process (thousands of years) and would likely be limited to much less than a kilometer from the site because of dissolution, dispersion, and residual gas trapping along the migration pathway.

Results indicate there is minimal potential for acid-gas migration to shallower strata and potable groundwater.



Zama Path Forward
- Injection of acid gas will continue through Year 4 of Phase II.
- Core samples will be collected from an acid gas disposal zone to examine the mineralogical and geomechanical changes that can occur in a carbonate rock exposed to high-pressure acid gas.
- Geomechanical data will be used to populate a database that will support the creation of a geomechanical model of the pinnacle reef.
- Geochemical modeling activities will be conducted to predict the long-term effects of acid gas injection on the reservoir and caprock formations.
- A Regional Technology Implementation Plan will be developed.

PCOR Partnership

EERC Energy & Environmental Research Center, UND University of North Dakota Grand Forks

NETL

Phase II Partners

CO_2 Sequestration and Enhanced Coalbed Methane in Lignite Coals Project

Project Goal
- Determine the feasibility of simultaneous CO_2 sequestration and natural gas production from a lignite coal seam.

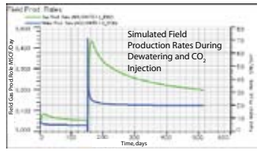
Objectives
- Inject CO_2 into lignite coal seam and monitor CO_2 fate in the reservoir.
- Determine the potential for coalbed methane (CBM) production from the lignite seam.
- Determine the potential for production enhancement by CO_2 injection.
- Develop Regional Technology Implementation Plan for CO_2 sequestration in lignite coal.

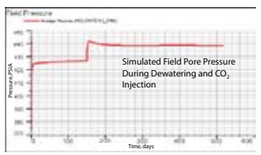
Input Parameters and Preliminary Results of Simulations using Schlumberger's Eclipse Software

Characteristics	Reported Value
Depth H, ft	1040–1175
Reservoir Temperature T, °F	70.8–73.5
Reservoir Pressure, psi	478.4–540.4
Coal Thickness h, ft	7–9
CO_2 Langmuir Pressure $PLCO_2$	psi528.–1150.2
CO_2 Langmuir Volume $VLCO_2$, scf/ton	1125–1779
CH_4 Langmuir Pressure $PLCH_4$	psi518.26
CH_4 Langmuir Volume $VLCH_4$, scf/ton	71.42
Ash Content, %	6.0–8.8
Moisture Content, %	24.1–39.2
Coal Gas Concentration C, scf/ton	0.02–22.68
Coal Density	1.29–1.75
Diffusion Coefficient D, ft²/day	0.358–49.2 × 10^{-7}
Desorption Time t, h	3.76–516.9

Core Evaluation Activities
- Lab studies on the recently collected core will examine:
  - Gas content.
  - Gas specific gravity.
  - CH_4 and CO_2 isotherms.
  - Diffusion coefficient.
  - Gas desorption time.
  - Coal ash and moisture contents.
  - Coal density and compressibility.
  - Rock porosity and permeability.

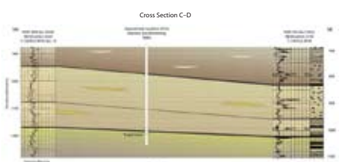
Test Design Activities
- Analysis of the existing well data served for choosing the location of the test site and supported the creation of a preliminary numeric model of the coal seam using ECLIPSE.
- Five-spot-well configuration allows for effective and efficient operation and monitoring of the water production and CO_2 injection program.





Formation Logging Activities
- Schlumberger Platform Express Log Suite
  - Measurements
    - Porosity
    - Resistivity
    - Natural radiation (sand/shale)
    - Bore hole diameter
- Sonic
  - Used for:
    - Pore pressure prediction
    - Determination of density
    - Estimation of rock elastic constants
    - Bulk compressibility estimation
- Additional log suites
  - Elemental capture spectroscopy
  - Multiarm caliper
    - Acoustical

Key Results To Date
- Well drilling is completed.
- Logging is completed, and logs are being processed in collaboration with Schlumberger.
- Core has been collected, and is being analyzed by TerraTek.
- Initial numerical model has been created.
- Preliminary simulations have been run which provide guidance for the possible outcome of CO_2 injection activities in the coal seam.



Lignite Path Forward
- Pressure and water quality measurements from monitoring wells.
- May include tiltmeter and microseismic.
- MMV plans will be finalized after analysis of collected field data.
- CO_2 injection to occur in summer 2008.