Salt Creek and Monell CO$_2$ Projects

Status Update and 4D Seismic Applications

EORI – Wyoming CO2 Conference

June 2010

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Agenda

- Overview of Monell and Salt Creek Fields
- Current Salt Creek CO$_2$ Development
- Reservoir Management
- Salt Creek Efficiency Improvements
- Salt Creek 4-D Seismic Monitoring
- Questions
Anadarko’s Wyoming EOR Assets

- **Fields**
  - Monell
  - Salt Creek

- **Pipelines**
  - 33 mile, 8”
  - 125 mile, 16”

- **CO₂ Supply**
  - XOM Shute Creek
Salt Creek & Monell Tertiary Performance Overview

Producing 14,350 BOPD gross
Injecting 485 MMcfd of CO₂
Salt Creek Overview

**General Facts & History**
- Discovered in early 1900’s
- 1.7 Bbbl OOIP (prod 0.7 Bbbl)
- 11 productive intervals
- 2004: 1st CO₂ injection
- Planned sequestration of 1.65 Tcf CO₂

**Current Status**
- 10,800 BOPD from CO₂
- 420 MMCFD CO₂ injection
- 338 CO₂ injectors (20-acre 5-spots)
- Commission Phase 7 3Q2010

![Barrels Oil per Day](chart)

*Year*
Geologic Overview

- WC2 Depth: 1500-3000’
- Thickness: 85’ Net
- Average F: 19%
- Average K: 52 md
- Marine Shoreface

OOIP: 328 MMBO
CUML 121 MMBO

OOIP: 1099 MMBO
CUML 465 MMBO
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Wall Creek 2 CO₂ Flood

- Oil: 39° API
- MMP: 1,275 psi @ 105°
- Miscible areas on flanks
- Flood Type: (WAG) Water Alternating Gas
- Producers: Flowing wells (against surface backpressure of 200 – 400 psi)

338 Patterns
~ 700+ Active Inj / Prd Wells

~ 9 WC1 Patterns Commissioned in Ph 7
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Reservoir Management

- Diligent Surveillance Necessary for Optimal Recovery
- BHP Surveys
- Injection Withdrawal Ratio (IWR)
- Injection Processing Rate (PVI)
- CO$_2$ Utilization
- Step Rate Tests
- Injection Profiles
- Tracer Surveys
- Produced Fluid Temperature Monitoring
- Automated well tests, and human QC (for proper allocation where necessary to known data points)
- WAG Management
- 4D Seismic
Temperature response at producer helping to determine communication

8 to W
8 to CO₂
8 to W
Overview of Monell and Salt Creek Fields
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Salt Creek Efficiency Improvements

- **Moved injection well’s chokes and meters to header buildings**
  - Minimize hydrate formation during winter operations

- **Installed temperature monitors on producers**
  - Allowed adjustments to WAG schedule to minimize freezing

- **Installed horizontal pump to increase CO$_2$ surface injection pressure**
  - Improve processing rates of downdip injection patterns

- **Testing a jet pump at one header**
  - To lower wellhead pressure and increase fluid production rate

- **Increased number of updip water injection wells**
  - Help maintain pressure downdip
Overview of Monell and Salt Creek Fields
Current Salt Creek CO$_2$ Development
Reservoir Management
Salt Creek Efficiency Improvements
Salt Creek 4-D Seismic Monitoring
Questions
Objective - Dynamic characterization of CO2 injection

- Wells provide point information
  - Injection volumes
  - Production volumes
  - Pressures
  - Timing

- Seismic provides spatial sampling, with multiple snapshots
  - How does CO2 move through reservoir over time?

Method

- Repeat 3-D seismic surveys
  Monitor CO2 advance through the reservoir over time
Reservoir Amplitude Map: 2005 3D
Salt Creek 4-D Requirements

- High spatial resolution
- Multiple surveys at short intervals
  - Rapid CO2 advance
  - Multiple surveys (6) at 10-12 week intervals
- High reproducibility
  - Semi-permanent geophone emplacement
  - Sources reoccupy same locations
  - Controlled amplitude
Seismic Acquisition

“Permanent” geophone emplacement

Vibroseis Source
Seismic modeling shows a brightening of WC2 trough with CO2 saturation increase.
Observations

- Strong 4D seismic response which appears to be a function of CO$_2$ storage, which is related to:
  - CO$_2$ injected
  - CO$_2$ produced
  - Porosity

- Timelapse response approaches steady state after 6-9 months CO$_2$ injection
Seismic Impact

- **Seismic responds to CO\(_2\) storage in Salt Creek**
  - Seismic response can be used to determine regions of inefficiently swept reservoir
  - Improves confidence in CO\(_2\) containment
  - Provides spatial framework for pattern analysis

- **Seismic added value in the pattern review and team integration process**
  - Provide spatial framework for pattern analysis
    - Decisions were made on the basis of the seismic—when to WAG, pattern realignment, etc

- **Seismic helped characterize reservoir heterogeneity in the WC2**
  - Using seismic in geologic modeling and reservoir simulation

- **Future applications**
  - Shoot monitor survey over Salt Creek Light Oil Unit, utilizing 2005 3D as baseline

We’d like thank John O’Brien, John Moran, Gerry Wilbourn, Stan Morris, Oscar Quezada, APC, and CGG Vertias for all their contributions to the 4D effort.
Questions?

The past…

Today