Monell Unit CO₂ Flood
Patrick Draw Field
Sweetwater County, Wyoming

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Anadarko’s Wyoming EOR Assets

- **Fields**
  - Monell
  - Salt Creek
  - Sussex

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

- **CO₂ Supply**
  - XOM Shute Creek
Monell Overview

- General Facts & History
  - Discovered in 1959
  - ~115 MMBOOIP (prod 40 MMBO)
  - 2001: Initiated pilot
  - 2003: 33 mile PL & 1\textsuperscript{st} CO\textsubscript{2} injection
  - 2006: Ph2 start-up
  - 2007: NGL plant commissioned
  - 2008: 9-spot drlg program (9 wells)
  - 2009: Ph3 development
  - Planned sequestration of 85 Bcf CO\textsubscript{2}

- Current Status
  - 3,000 BOPD
  - 48 MMCFD CO\textsubscript{2} injection
  - 39 CO\textsubscript{2} injectors
  - CO\textsubscript{2}-EOR cumulative of 3 MMBO
## Upper Cretaceous Stratigraphy

<table>
<thead>
<tr>
<th>Upper Cretaceous</th>
<th>Mesaverde Group</th>
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<tbody>
<tr>
<td>Lance Formation</td>
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<tr>
<td>Fox Hills Sandstone</td>
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<tr>
<td>Lewis Shale</td>
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<tr>
<td>Almond Formation</td>
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<tr>
<td>Ericson Sandstone</td>
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<td>Rock Springs Fm</td>
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<td>Blair Fm</td>
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West-East Cross Section

Patrick Draw Field

Table Rock

Wasatch

Normal Fault

Lance

Lewis

Almond

Fort Union

Sea Level
Monell Unit – Upper Almond Reservoir

Monell Unit Type Log

Lewis Shale

UA-5A Pay

UA-5B Pay

Lower Almond
Reservoir Highlights

- Cretaceous Mesaverde Almond SS stratigraphic trap
- Barrier island/tidal channel inlet/shoreface depositional system
- Very fine to fine-grained lithic, illitic, kaolinitic, and quartzose sandstones
- 20% Porosity, 30md Permeability, 40% $S_{wi}$
- 5 deg. dip, 25’ Net Pay, 5,000 Acres at 4,500’ depth
- Fractures and faulting are minor
- Oil zone confined up-dip by the depleted low pressure gas cap and down-dip by permeability pinchout
- ~115 MMSTB OOIP, 500 GOR, 43 deg. API sweet
- 20% Primary RF, 14% Waterflood RF
- 1,800 psi original reservoir pressure at 120 deg.F
- $CO_2$ Miscible with Oil (1450# MMP)
Monell Unit – Phase Development
Development Highlights

- Phase 1 implemented adding first 28 patterns of development
- "Water curtain" concept proven up as affective pressure barrier
  - Horizontal 1: MU 43-27H - 5,000' lateral water injection well
  - Horizontal 2: MU 44-27H - 6,800' lateral water injection well
  - Four vertical water injection wells to the north
- Flood response seen within 3 months of initial injection
- Phase 2 implementation added 12 patterns of development
  - Applied lessons learned from Phase 1 to Phase 2
    - Drilling, Completions, Facilities
- NGL plant installed and processing recycled CO₂ to recover NGL’s
- Monitor/idle wellbores converted to producers to test 9-spot concept
- Drilling campaign under way to test 9-spot pattern performance
- Future phase development planning currently under way
Operations Highlights

- **Drilling**
  - Currently drilling with coiled tubing drill rig

- **Completions**
  - 50/50 lease crude and diesel frac fluid

- **Wellbores**
  - Injectors: 5-1/2” casing; 2-3/8” IC tubing; Ni coated packer; inconell tubing hanger
  - Producers:
    - Pumping: 5-1/2” csg; 2-7/8” CS tubing; continuous sucker rod; 456 PU
    - Flowing: 5-1/2” csg; 2-3/8” IC tubing; Ni coated packer; inconell tubing hanger; H20 slip-stream line at wellhead

- **Flowlines**
  - Injection/Production: Continuous HDPE

- **Headers**
  - Latest design (A2) includes central injection/production manifolds in common facility
Operations Highlights
Operations Highlights
Operations Highlights
Operations Highlights
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Operations Highlights
Monell Unit Performance
Monell Unit – Production History

PATRICK DRAW FIELD, MONELL UNIT
CO2 FLOOD PROJECT PERFORMANCE

BPD, MCFD

Primary Secondary Tertiary CO2 Flood

Oil Gas CO2 Inj
Monell Unit Performance

Oil Production History

CO2 Inj History

Pilot 2001-02
1st CO2 Inj Sept.03

3,000 bopd

48 MMcfdi

Jan-01 Jan-02 Jan-03 Jan-04 Jan-05 Jan-06 Jan-07 Jan-08 Jan-09
Monell Unit – 9-Spot Type Well

Monell 9-Spot Review
Oil Production

BOPD

Normalized Time (days)

#6 Well
#7 Well
#14 Well
#17 Well
#18 Well
#121 Well
#157 Well
Type Well
Monell Unit – Future Development

- **Ph1**: Active
- **Ph2**: Future
- **Ph3**: Future

Scale: 1 FEET = 2,362
Monell Unit – Applied Tools

- Field/Pattern surveillance (OFM)
  - Dimensionless curves developed to help forecast performance
  - Allows pattern comparison and balancing
  - Will help identify problem patterns

- Bottom Hole Pressure Tool – Surface Injection Pressure
  - Calculates BHIP from SIP using phase envelope P & T segments
  - Assures that we remain below fracture pressure at all times

- CO₂ Injection Schedule
  - Developed to aid in balancing patterns and CO₂ utilization
  - Automated system that can be controlled by volume and/or pressure

- Production Allocation Tool
  - Ensure that production is allocated correctly from well test data

- Reservoir Simulation – History Matching
Monell Unit – Applied Tools

Graph showing data for different patterns:
- RF for PI II
- Recovery Factor vs. HCPVinj
- Multiple lines representing different patterns (e.g., Patt_24-26, Patt_22-25, etc.)

Table with data points:
- Daily Oil Rate (bbl/d)
- Daily Gas Rate (Mcf/d)
- Daily Water Rate (bbl/d)
- Daily CO2 Volume (Mcf)
- PDB Daily Prod CO2 Volume (Mcf/d)
- RatioGORCO2d (Mcf/bbl)

Graph legend includes:
- 2003-2008 dates
- Log scale for recovery factor
- Anadarko Petroleum Company

Anadarko Petroleum Company
PATTERN Patt_24-26
Salt Creek Overview

- **General Facts & History**
  - Discovered in late 1800’s
  - ~1.7 Bbbl OOIP (0.7 Bbbl cum prod)
  - 9 productive intervals & 4,400 total wells
  - 2003: Completed pilot, Ph1 & 125 mile PL
  - 2004: 1st CO₂ injection
  - 2005: Ph2 start-up
  - 2007: Ph3-4 start-up
  - 2008: 2Q Ph5 start-up
  - Flowing producers – identical inj/prod set-up
  - Planned sequestration of 660 Bcf CO₂

- **Current Status**
  - 7,000 BOPD from CO₂ (8,500 BOPD total)
  - 320 MMCFD CO₂ injection
  - 153 CO₂ WAG injectors (20-acre 5-spots)
  - CO₂-EOR cumulative of 5.5 MMBO
Phase 1-4 CO₂ Flood Performance

Salt Creek Phases 1-4 CO₂ Flood Performance

- **Oil Production (BOPD)**
- **Total CO₂ Injection (MMCFD)**

- **Legend:**
  - Green line: Oil Production
  - Red line: CO₂ Injection

- **X-axis:** Jan-04 to Jan-08
- **Y-axis:** Gross Oil Production (BOPD) from 0 to 9,000, Total CO₂ Injection (MMCFD) from 0 to 360
Anadarko’s Rockies EOR

Current Activity

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<thead>
<tr>
<th>Monell Unit</th>
<th>3,000 BOPD</th>
<th>50% Developed (based on area)</th>
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<tr>
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<td>Improved sweep via 9-spot pilot</td>
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<td>Five years of continuous injection without major breakthrough</td>
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<td>Unique CO2 flood pushing technological envelope</td>
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<td>Phase development allows flexibility to apply lessons learned</td>
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Future Development

1) Significant undeveloped resources at Monell and Salt Creek
2) Linch Fields ~ 15 miles north of Salt Creek
3) Apply lessons learned to future developments
Discussion?