The Anschutz Ranch East Field: Case Study

Development of a Gas Condensate Reservoir

*The Anschutz Ranch East Field: Case Study*

*SPE 10992, 11968, 12042, 12257, 13108, 14412, 14414, 14456, 22824*

**The Anschutz Ranch East Field**

**Located in the Western US Overthrust Belt**
- Wyoming – Utah border

**Structurally Complex Area**
- More than 350 dry holes drilled before Pineview Field discovered in 1975

**Fields are Anticlinal Structures Along the Hanging Wall of Thrust Faults**
Field Discovery

**Bountiful Livestock No. 1 spud March, 1979**
- Authorized total depth 11,500 feet
- Encountered Nugget reservoir target 3,000 feet deeper than forecast
- Penetrated over 940 feet of gross thickness

**Completed December, 1979**
- 128 ft of perforations below 13,000 ft
- IP 3.9 MMcfd, 1,054 BCPD
- CGR 270 bbl/MMscf

Post Discovery Interpretation – 1500 Acres

Fig. 3 - Post-Discovery Interpretation of Nugget Structure, Early 1980.
Additional Drilling Reveals a Bigger Prize

Offset drilling indicated original structure was larger
Anschutz 12-26 Spud January, 1980 encountered separate Nugget structure 2,000 feet deeper
Well completed December, 1980
- Perforations below 14,750 feet
- IP 0.88 MMcfd, 96 BCPD
- CGR: 109 bbl/MMscf

January, 1981 Interpretation – 14,600 Acres
### Additional Development Results

- Delineation drilling on the east lobe proved smaller areal extent
- Revised interpretation in 1982 decreased total area to 3,900 acres
- West lobe has over 2,100 feet of hydrocarbon column
- Estimated 2 Tscf gas-in-place

### One Reservoir or Two?

**Observations:**
- Different Gas-Water Contacts
- Different Reservoir Fluid Properties

**Implications:**
- One Reservoir or Two?

*Geological data suggests that the two reservoirs are connected by the overturned Nugget Section as shown in the X-Section.*
Anschutz Ranch East Rock Properties

Nugget Sandstone
- Triassic – Jurassic age
- Desert sand dune environment
- 1,050 feet average gross stratigraphic thickness
- 70–90 percent net-to-gross ratio

Porosity: 2 to 22 % – Avg. Near 10%
Permeability: 0.1 to 1000 md – Avg. 3 md

Reservoir grossly correlates into 3 major zones

Data Bank

Well logs
- Resistivity, porosity, dip meter

Fluid samples
- More than 20 recombination tests
- Multiple depths in multiple wells

Cores
- Several thousand feet

Pressure Buildup
- Repeated with time in several wells
Anschutz Ranch East – Nugget Type Log

Nugget Porosity by Zone
Nugget Permeability by Zone

Reservoir Fluid Properties

Rich gas condensate
  - Substantial compositional variation with depth

Slightly undersaturated
  - Dew point pressure 150–350 psi below initial reservoir pressure

Pressure depletion data (PVT) shows significant liquid drop out below dew point
  - 20–40% percent of hydrocarbon PV
West Lobe Condensate Samples

<table>
<thead>
<tr>
<th>Elevation, ft subsea</th>
<th>Deep</th>
<th>Shallow</th>
</tr>
</thead>
<tbody>
<tr>
<td>-4,400</td>
<td></td>
<td></td>
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<tr>
<td>-5,324</td>
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<td></td>
</tr>
<tr>
<td>-6,400</td>
<td></td>
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</tbody>
</table>

Deep      | Shallow

Compositional Gradient

<table>
<thead>
<tr>
<th>Elevation, ft subsea</th>
<th>-4,400</th>
<th>-5,324</th>
<th>-6,400</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reservoir Pressure, psi</td>
<td>5,150</td>
<td>5,310</td>
<td>5,490</td>
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<tr>
<td>Dew Point Pressure, psi</td>
<td>4,920</td>
<td>5,080</td>
<td>5,165</td>
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<tr>
<td>Gas-Oil Ratio (scf/stb)</td>
<td>5,639</td>
<td>4,561</td>
<td>3,523</td>
</tr>
<tr>
<td>Maximum Liquid Dropout, %</td>
<td>20.5</td>
<td>26</td>
<td>37.5</td>
</tr>
</tbody>
</table>
Field Development Issues

What are the technical options for developing and producing this reservoir?

Arrange options in descending order of recovery for the condensate gas.

How would you develop this reservoir under each option?

What tools would you employ to investigate risks and rewards?

Field Development Plan (FDP) Issues

Production mechanisms
- Depletion
- Full pressure maintenance (FPM)
- Partial pressure maintenance (cycling)

Injection fluid
- Lean gas, rich gas, nitrogen, CO₂, flue gas

Injection/production well pattern
- Well spacing
- Completion philosophy

2-D Compositional Cross-Section
- 17 Components, 6 Layers (Various Descriptions)
- Evaluate Depletion Strategies

3-D Black Oil Field wide
- HC Gas and N₂ Fluid Properties, 4 Layers (A really Homogeneous)
- Evaluate Injection Pattern and Well Spacing

3-D Compositional Pattern
- 11 Components, 6 Layers (Various Descriptions)
- Evaluate Injection Fluid Composition, Buffer Size, Pattern Sweep and Spacing

3-D Compositional Field wide
- 9 Components, 4 Layers
- Both Homogeneous and Heterogeneous Cases
- Validate Forecasts Using Superposition of Pattern Model

Initial Development Plan for West Lobe
(Based on Simulation Studies)

Produce under full pressure maintenance
Drill on 80-acre well spacing
Use inverted 9-spot well pattern
Complete wells selectively
  - Producers: Lower 2/3 of formation
  - Injectors: Upper 2/3 of formation
Inject 10% HCPV buffer of 35% N₂ - 65% HC gas followed by pure N₂
  - 50 MMCFD of N₂ provided by air separation plant
**Initial Development Plan for East Lobe**

**Produced Under Pressure Depletion**
- The liquid yield is too low to economically justify developing this part of the reservoir under a Full Pressure Maintenance Scheme
- It may have offered an economic incentive under a gas cycling scheme, however

**Why an Inverted 9-Spot Pattern?**
- Depositional environment resulted in NW-SE permeability trend
- Structural deformation and fracturing had caused anisotropy in a different direction
- Inverted 9-spot pattern allows subsequent conversion to suitable line drives of different orientations
One Possible Conversion: 9-Spot to Line Drive

Development Timeline

- **12/82**: Begin full field production upon unitization
- **6/83**: N₂ breakthrough in four wells
- **12/84**: Second 50 MMCFD N₂ plant operational
- **1985-1986**: Convert to line-drive pattern
  - Depositional permeability trend was dominant
- **1985-1986**: Workovers to open Zone 1 in producers
  - Try to improve reservoir sweep
- **1/86**: Maximum condensate production 45,968 BPD
- **12/87**: NGL/NRU operational (increase NGL sales)
  - HC gas sales limited by market conditions
- **8/88**: Development drilling complete
  - West Lobe 29 Prod, 18 Inj East Lobe 7 Prod
Final Structure Map Showing Line Drive Pattern

West Lobe Production History
Reservoir Performance Falls Below Expectation

Recovery forecast is substantially lower than forecasted by the 1983 simulation studies
Possible cause is poor sweep efficiency
- High permeability streaks/fractures in zones 1 and 2 resulted in pre-mature breakthrough
- Low permeability in zone 3 resulted in minimal production contribution

What Next?

What are your options for the continuation of this project?

How would you investigate these options?
Technical Options

Wellhead Compression

Well Stimulation Program
- Solvent injection for removal of condensate banks
- Selective hydraulic fracturing in Zone 3

Horizontal well drilling in Zone 3

Reservoir Simulation Studies
- New 1990–1994 simulation studies, incorporating improved reservoir description, fluid characterization, and better computing hardware/software

Conclusions of 1990–94 Simulation Studies

Continued FPM is not economically attractive
- Produced N₂ cut will increase rapidly
- Decline in condensate production will continue
- Sweep improvement options are costly

Field wide partial pressure maintenance is inefficient and economically unattractive

Blowdown is economically attractive with risk
- Water influx is not known
Maintain 100 MMCFD of N2 injection in 4 down-dip wells to retard aquifer influx

West Lobe Blowdown

- **10/92**: Initiate blowdown pilot in North End of field and increase gas sales
- **6/83**: Increase additional gas sales using makeup nitrogen
- **12/84**: Decrease injection and initiate field blowdown

Maintain 100 MMCFD of N2 injection in 4 down-dip wells to retard aquifer influx

4Q/98 Stop Injection and Begin Full Blowdown

West Lobe Blowdown Performance

Anschutz Ranch East
West Lobe Blowdown Performance

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Cumulative Production and Recovery Factors

Jan 1997 West Lobe Cumulative Production
- 112.2 MMbbl cond (121.6 MM Nov 2011)
- 91 MMbbl NGL
- 289 Bcf HC gas

Expected Ultimate Recovery Factors
- Cond 38% (would have been <20% under pressure depletion)
- NGL 65%
- HC Gas 60%

Summary

The FPM plan was both technically and economically successful

Reservoir heterogeneity had a large impact on rate/recovery performance

Poor sweep resulted in earlier-than-expected nitrogen breakthrough and lower-than-predicted condensate recovery

The flexibility to modify development plans based on field performance was critical to maximizing profitability of the project.
Question

What would you do differently today?