Status report and direction of Chevron’s RD&D pilot oil shale project, Piceance Basin, Colorado

31st Oil Shale Symposium
Colorado School of Mines, Golden CO, Oct 18, 2011

Author: Greg Minnery

Co-authors: Mark Looney, Eric Flodin, Chris Skelt, Doug McCarty, Eric Daniels, Marcus Wigand, Mike Shook, Jim Koffer, Julie Justus
Oil Shale Outline:

Chevron Major Technology Project

- Recap of RD&D work to date
- Project goal and approach to recovery
- Location and resource size
- A look at some of the data
  - Geophysical (seismic, logs, core)
  - Mechanical (fracturing)
  - Environmental (hydrology)
- Use of oil shale mine for frac testing
<table>
<thead>
<tr>
<th>Date</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/04</td>
<td>Project Initiated</td>
</tr>
<tr>
<td>9/05</td>
<td><strong>Applied for Lease</strong></td>
</tr>
<tr>
<td>1/06</td>
<td>Received Notice from BLM as a Finalist for RD&amp;D Lease</td>
</tr>
<tr>
<td>2/06</td>
<td>Submitted Plan of Operations</td>
</tr>
<tr>
<td>3/06</td>
<td>Public Forums – Start</td>
</tr>
<tr>
<td>4/06</td>
<td>Public Forums – Wrap-up</td>
</tr>
<tr>
<td>8/06</td>
<td>Environmental Assessment Released for Public Comment</td>
</tr>
<tr>
<td>9/06</td>
<td>Public Comment Period Ends</td>
</tr>
<tr>
<td>1/07</td>
<td><strong>Lease Issued &amp; Signed, Permits Filed</strong></td>
</tr>
<tr>
<td>6/07</td>
<td>All Permits to Drill Corehole on Lease Received</td>
</tr>
<tr>
<td>9/07</td>
<td>Surface Construction at Lease Completed</td>
</tr>
<tr>
<td>11/07</td>
<td><strong>Corehole Spud</strong></td>
</tr>
<tr>
<td>3/08</td>
<td>CVX Submits Comments on BLM PEIS</td>
</tr>
<tr>
<td>5/08-7/08</td>
<td>Corehole Packer Testing</td>
</tr>
<tr>
<td>7/08</td>
<td><strong>Spud of First Hydrology Test Wells</strong></td>
</tr>
<tr>
<td>9/08</td>
<td>CVX Submits Comments on Proposed Oil Shale Commercial Leasing Regulations</td>
</tr>
<tr>
<td>12/08</td>
<td>Completion of Major Drilling Operations</td>
</tr>
<tr>
<td>2009-10</td>
<td><strong>Core / Log Analysis, kerogen charac. and conversion, fracture models</strong></td>
</tr>
<tr>
<td>2011(plan)</td>
<td><strong>POD update, tracer study, begin monitoring, boulder fracs, mine refurbish</strong></td>
</tr>
</tbody>
</table>
Oil Shale Goal

- The Goal is Developing and Demonstrating an Environmentally Acceptable, Sustainable, and Commercially Scalable In Situ Oil Shale Technology

- Integrated Effort between many Chevron companies, National Labs, and Universities

Chevron’s Approach

- identify the experts (labs, universities, internal)
- start at molecular level (kerogen, mechanics, environmental)
- laboratory and model validation, then field testing
- develop range of solutions, no “silver bullet”
Chevron’s Oil Shale RD&D Lease

10-Year Research Development and Demonstration Lease received 2007

(9 B BBLS)

(282 MM BBLS)
Hydrology well configurations

Northwest Pad

About 700 feet of open hole in deep wells will require zone isolation and a dual completion to monitor both the L4 and L3 zones.

Schematic of hydrology wells on a typical monitoring pad, showing the zone of open hole below casing and the intended sampling interval. Because the test interval was changed from the Mahogany to the R-4, Uinta Fm will not be monitored and the L3 zone will be added.

(The Uinta Fm will not be monitored)

(NOT TO SCALE)
Aquifer tracer study in the A-Groove

Purpose: Obtain field-scale estimates of the following hydrologic solute transport properties:

- Effective hydraulic conductivity and specific storage
- Specific discharge
- Effective flow porosity
- Flow heterogeneity
- Effective matrix diffusion

Data used in larger GW flow and solute transport models to help assess potential impacts of extraction process and design monitor wells.
Estimated potentiometric surfaces on Chevron lease for A-Groove and L5
Corehole Operations

1836' Green River Formation

Oil Shale Core

Core Analyses

- Digital WL Photos
- Onsite isotube gas
- Total and Spect GR
- CT Scan
- Core Description
- Rock Mechanics and Shock Testing
- Elemental Analysis
- Bulk Density
- Fischer Assay
- Best Rock QXRD
- Geochemical
  - TOC/RE
  - Grain density
Oil shale lease resource numbers

<table>
<thead>
<tr>
<th>GPT (avg)</th>
<th>Barrels (per 160 ac)</th>
<th>Barrels (8 section)</th>
</tr>
</thead>
<tbody>
<tr>
<td>28</td>
<td>48.2 MM</td>
<td>1.5 B</td>
</tr>
<tr>
<td>22</td>
<td>42.2 MM</td>
<td>1.4 B</td>
</tr>
<tr>
<td>32</td>
<td>58.6 MM</td>
<td>1.9 B</td>
</tr>
<tr>
<td>30</td>
<td>55.7 MM</td>
<td>1.8 B</td>
</tr>
<tr>
<td>23</td>
<td>27.4 MM</td>
<td>0.9 B</td>
</tr>
<tr>
<td>25</td>
<td>17.0 MM</td>
<td>0.5 B</td>
</tr>
<tr>
<td>22</td>
<td>32.5 MM</td>
<td>1.0 B (R1)</td>
</tr>
</tbody>
</table>

Total: 282 MM 9 B bbl
The Challenge: To Produce and Protect
Fracture quantification with depth in core and example of fractures in core and image log: CVX Corehole @ 1367 ft MD (MAH).
Conceptual Model: Tectonic Fractures

(Technical Description)

Tectonic fractures at maximum burial and lithification, forming preferentially in the lean zones.

Legend:
- Organic rich layers
- Lean layers

(Additional Information)

Early Event

(Future dissolution surface)

Eric Flodin, Chevron, 2010
Mechanical stratigraphy
Rich – Lean Zone Variations

GR outcrop above No Name Creek near CVX-COP mine

Green River outcrop near White River City along Piceance Creek, CO

R8
A-Groove
R7 (Mahogany)
50 Feet
Conceptual Model: Compaction-induced fractures

- during uplift, upper portion of GR inundated by freshwater dissolving halite and nahcolite
- leaching of soluble salts created cavities leading to vertical, brittle collapse in rich and lean zones
- secondary fractures generated by collapse and slip along earlier formed joints with widely varying orientations

Eric Flodin, Chevron, 2010
Profiles for some common minerals in Green River core

A. Derkowski and D. McCarty, Chevron
3. Principal minerals from QXRD Plugs and trenched samples

Table shows data from trenched samples. Note heterogeneity—many mineral fractions present over wide ranges. Plugs versus trenched samples give different pictures, particularly for minerals present as nodules.
Cross-well seismic and tomography
Multi-component Seismic

SOUTH PAD TO NE PAD SEISMIC

Density Porosity
Chevron-ConocoPhillips Red Point Mine
Fracture testing in Red Point Mine

Potential drilling plan for Red Point Mine testing

Approximate mine layout beneath mesa

Red Pt Mine portal

© 2011 Chevron U.S.A. Inc. All rights reserved
Conclusions

• Oil shale is part of Chevron’s efforts to expand and diversify global energy supplies

• Chevron has been making steady progress on oil shale research and is poised to begin testing on the lease

• Chevron’s approach is methodical and measured
  ■ DOE national labs, contractors & universities are key partners in Chevron’s alternative energy portfolio
  ■ Starting at the molecular Level – understanding the fundamental chemical structure of kerogen is critical

• Testing in the CVX-COP Red Point Mine will provide a scale-up for testing fracture technology before moving to the BLM lease

• Use of controlled rubblizaton and low temperature *in situ* kerogen conversion will provide a low energy, low water use, approach for a recovery technology.