The EGL Oil Shale Project

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Overview

Lease
Oil Shale Resource
Pyrolysis
Geomechanical Considerations
Heating Options
Conclusions
Piceance Basin

Millions of Barrels of Shale Oil per Acre of Land

For oil shale averaging 25 gallons per ton or more

The EGL Lease has >10 billion bbls in place in a 1400-ft interval averaging 25 gal/ton (USBM Report 7051)
Piceance Basin
Oil Shale Properties

- Amoco C-a Tract
- Mining Retort Project
- Oxy C-b Tract
- Commercial Mine Site
- Exxon Colony
- Mining Retort Project
- Unocal Mining
- Retort Project
- Natural Soda Project
- American Soda Project
- Shell In-situ Test Sites
& Preference Right Leases
- Chevron In-situ Test Site
& Preference Right Lease
- EGL In-situ Test Site &
Preference Right Lease
Research, Development, and Demonstration (RD&D) Oil Shale Lease

- **Intent of the RD&D Lease**
  - Attain commercial conversion in ten-year lease term and possible five-year extension

- **Requirements for Commercial Conversion**
  - Production of shale in a manner that reasonably demonstrates that an expanded operation would be commercial
  - Payment of a bonus based on fair market value
  - Consultation with state and local officials to develop a plan for mitigating the socioeconomic impacts
  - Post a reclamation bond
  - BLM determination (NEPA) that commercialization can be conducted, subject to mitigation measures, without unacceptable environmental consequences
Commercial Conversion

- Practical Considerations
  - Commercial-scale project that is acceptable to state and local officials
  - Avoid significant groundwater impacts from oil shale pyrolysis and subsidence until the BLM and State settle a wise multi-mineral plan to accomplish the Greater Public Good by co-producing the co-mingled minerals – nahcolite, dawsonite, natural gas, water, and oil shale
Proposed Pad Locations
EGL Lease Oil Shale Resource


Well drilled in the NW1/4 of EGL’s 160-acre Site

EGL site core provided by Shell Oil Company indicates higher grade and thicker oil shale intervals

Carbonate-Kerogen Facies

Illite-Kerogen Facies
Primary Oil Shale Opportunities
(carbonate and Illite, includes the leach zone aquifers)

1. 410 feet  35 GPT  1260’ to 1670’
2. 830 feet  31 GPT  1150’ to 1980’
3. 1020 feet 29 GPT  1150’ to 2170’

Illite Oil Shale Opportunities
(isolated from the leach zone aquifers)

1. 230 feet  25 GPT  1940’ to 2170’
2. 440 feet  22 GPT  1940’ to 2380’

*Illite is an attractive low reclamation risk RD&D and commercial opportunity*
EGL Project Site Core Photo

(Shell Well 24-21-298)

Typical Leach Zone Core
Illite Core Photo

(Shell Well 24-21-298)

Interval 2121 to 2122 Assay Results

15 wt% TOC  35 gpt FA  2.7 wt% Water
### EGL Lease Illite Oil Shale Resource Detail

<table>
<thead>
<tr>
<th>Unit</th>
<th>Oil Shale (US gal/ton of Rock)</th>
<th>Composite Oil Shale (US gal/ton of Rock)</th>
<th>Hydrogeology</th>
<th>Notes</th>
</tr>
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<tbody>
<tr>
<td>R3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R2</td>
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<td>R1</td>
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<td></td>
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<tr>
<td>Wasatch Fm</td>
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</table>

**Resource Data**

- **Source:** John R. Dyni—Open-File Report 98-483 (1998), USGS
- **Drill Hole:** Sulfur Creek 1
- **Location:** Sec. 21, T2S, R98W
- **Well drilled in the NW1/4 of EGL’s 160-acre Site**
- **EGL site core provided by Shell Oil Company indicates higher grade and thicker oil shale intervals**

**Legend:**
- Dissolution Surface
- Lowest Nahcolite
- Illite Contact
- Leached Zone Aquifer System
EGL Site Illite Opportunity

- A reasonably thick and rich oil shale interval
- No nahcolite, halite, or related dissolution features
- Isolated from leach zone aquifers (drinking water protection)
- Low water content, permeability, and porosity
- Greater hydrostatic and fracture pressure
- Relatively unknown geology, geomechanical, and pyrolysis
Illite shales have oil yield properties similar to the overlying carbonate shales.

<table>
<thead>
<tr>
<th>Depth (ft)</th>
<th>Lithology</th>
<th>TOC, wt%</th>
<th>Calc. FA oil yield, * gal/ton</th>
<th>Meas. FA oil yield, gal/ton</th>
<th>Meas. FA oil, mg/g</th>
<th>Calc. FA oil yield, * gal/ton</th>
<th>Rock Eval S1+ S2, * mg/g</th>
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<tbody>
<tr>
<td>1864</td>
<td>carbonate</td>
<td>15.08</td>
<td>33.7</td>
<td>31.4</td>
<td>118</td>
<td>171</td>
<td></td>
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<tr>
<td>1995</td>
<td>Illite shale</td>
<td>14.96</td>
<td>33.4</td>
<td>33.6</td>
<td>125</td>
<td>158</td>
<td></td>
</tr>
<tr>
<td>2121</td>
<td>Illite shale</td>
<td>14.95</td>
<td>33.4</td>
<td>36.5</td>
<td>136</td>
<td>145</td>
<td></td>
</tr>
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</table>

**For type I kerogen, S1+S2 should be about 10% higher than FA oil, because gas is included in S2
Illite shale oil is similar to carbonate shale oil but with higher levels of long-chain alkanes (wax).

Microscale sealed vessel (MSSV) pyrolysis (2121-2122 ft) interval shale from the Shell core for 72 h at 350ºC.
Retorting

The heat needed for retorting is proportional to the final temperature

<table>
<thead>
<tr>
<th>Approximate Final Temperatures</th>
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<tbody>
<tr>
<td>36.5 °C/yr 310 °C</td>
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<tr>
<td>110 °C/yr 325 °C</td>
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<tr>
<td>365 °C/yr 340 °C</td>
</tr>
</tbody>
</table>

36.5 °C/yr for 8.1 yrs
110 °C/yr for 2.8 yrs
365 °C/yr for 0.9 yr
EGL Oil Shale Process

LLNL and Shell experiments predict oil yields of 80-85 vol% of Fischer Assay for the EGL Oil Shale Process

Slow In-situ Retorting:
- Cuts nitrogen content in half
- Doubles API gravity
- Doubles gas yield
- Recovers ~65% of organic carbon in oil and gas compared to ~75% for Fischer Assay
EGL Oil Shale Process

*Product gas provides enough energy to retort typical oil shale*

Graph showing heat, 1000 BTU/ton vs. grade, gal/ton with different lines indicating oil plus gas heat of combustion, oil heat of combustion, gas heat of combustion, heat required for 110°C/year to 325°C, and heat required incl. 5 wt% water.
Strength Reduction of Nahcolitic Oil Shale with Temperature

- Spalling/Rubblizing of Oil Shale
- Strength Decreases with Temperature
- Stress Increases with Temperature
Thermo-Expansion Fragmentation

Shale Oil Laboratory Experiment (Prats et al. 1977)
Leached Zone Shape from Shell Test

(Prats et al. 1977)
## American Soda’s Cavern Surveys

<table>
<thead>
<tr>
<th>Well</th>
<th>Inception to Date NaHCO₃ Tons thru May 2004</th>
<th>Cavity Diameter (ft)</th>
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<tr>
<td>20-14</td>
<td>181682</td>
<td>171.0</td>
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<tr>
<td>29-24</td>
<td>176604</td>
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<td>29-29</td>
<td>143760</td>
<td>177.6</td>
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<td>20-30</td>
<td>131643</td>
<td>170.6</td>
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<td>29-34</td>
<td>126910</td>
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<td>123651</td>
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<td>20-36</td>
<td>123097</td>
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<td>28-21</td>
<td>117551</td>
<td>169.0</td>
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<tr>
<td>21-16</td>
<td>113420</td>
<td>153.2</td>
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<tr>
<td>20-32</td>
<td>113160</td>
<td>158.0</td>
</tr>
</tbody>
</table>

**Legend**
- **Cavern Shape**
- **Seismic Method**

- **Surface**
- **Depth (ft)**
- **Distance from Centerline (ft)**

- **~500-ft high**
The EGL Process

*Based on a logical progression of commercial in-situ technologies in the Piceance Creek Basin*

- **225°F Horizontal Borehole Nahcolite Solution Mining**
  - 1991

- **350°F Vertical Borehole Nahcolite Solution Mining**
  - 2000

- **650°F Horizontal & Vertical Boreholes—Oil Shale Retorting**
  - 2007 RD&D

- Increasing Temperature
EGL’s (thick) Resource Retort Plan

Gathering and Treating System

Overburden

“Spider” Holes

Retort Interval

Sumps

Vapor Product Out

Condensate

Vapor

Condensate

Cool Heating Fluid Out

Heat In
Geomechanics and Pyrolysis Interaction

Increasing Temperature
(reflux, conduction, and convection heat transfer)

Thermo-Expansion
→ Fragmentation & Bulking
→ Pyrolysis & Void
→ Product

Method can be initiated in horizontal, vertical, and inclined boreholes
Nahcolite and Kerogen Recovery Similarities

- Nahcolite solution mining depends on oil shale thermo-fragmentation and fragmentation bulking space provided by 25% dissolution void.

- True in-situ oil shale retorting has greater thermo-fragmentation drive and greater void space for oil shale bulking, > 30 vol% kerogen removal.
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Heat Delivery Opportunities

- Avoid the introduction or creation of inert gases that are difficult to remove from the non-condensable fuel gas product
- Indirect heating using casing contained combustion, steam, or other heat transfer fluid
- Steam injection (removal from fuel gases by condensation)
- Hydrous-pyrolysis (Illite depth allows retorting temperature liquid water-filled retorts)
EGL Thermal Injection

Air Line to Burner

Gas Line to Burner

Air and Natural Gas Combine

Exhaust Gases Return up Annulus Inside Liner
Computational Fluid Dynamics (CFD) Simulation of Vertical Single Borehole

- 1,000 to 11,000 hrs (while cetane oil fraction is refluxing)
- Kerogen conversion, 0-100% (in color)
- Temperature isotherms at approximately 575° and 675°F
- Retorting front coincides with 575°F isotherm
CFD Modeling of Vertical Heat Transfer by Oil Refluxing and Thermal Diffusion into the Formation

Kerogen conversion, %
CFD Modeling of Vertical Heat Transfer by Oil Refluxing and Thermal Diffusion into the Formation

Height, m

Width

Kerogen conversion, %

Height (m)

Width
Enhanced Heat Transfer with Thermo-mechanical Fragmentation
EGL Progress to Date

- CFD modeling confirms reflux heat transfer
- Site-specific core confirms resource projections
- Focus on Illite shale avoids groundwater issues
EGL is Committed to

- Working with governmental agencies and the public
- Working with other energy and technology companies