SOME PERSPECTIVES ON VARIOUS METHODS OF OIL SHALE EXTRACTION
PICEANCE BASIN COLORADO

G. A. Miller, 2007

POSTER SESSION

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Some Perspectives on Various Methods of Oil Shale Extraction, Piceance Basin Colorado

ABSTRACT (Poster Session)

Prudent utilization of this 1.5 ± trillion barrel oil shale resource, which is about equivalent to 100 “Prudhoe Bays”, is critically important to our nation's future generations. Development will require a large, wide-ranging, R&D effort on: extraction techniques that achieve or approach 100% resource recovery, minimization of effects on the basin-wide hydrologic system, and methods to leave post-extraction soil, landscape, biota, and water resources in a long-term productive condition.

Low resource recovery, which is common for many extraction methods, will probably result in great efforts and expense by future generations pursuing “secondary” recovery of shale oil. Most of the basin ground water (25 MAF) is usable for many purposes. Ground water is potentially subject to significant degradation by leaching of retorted shale as proposed by most methods. Widespread land-subsidence (10's of feet or more) is likely to follow most methods of extraction.

This poster session presents a general, somewhat qualitative overview of several potential extraction methods, as they relate to the above noted problems. Past and proposed extraction methods are generally deficient in dealing with these problems. In terms of minimizing these problems, room and pillar (and other variations on underground mining), various current and past In-Situ and modified In-Situ proposals appear to be significantly inferior to surface mining.

G. A. Miller, Hydrogeologist
COLORADO OIL SHALE
THE RESOURCE

Underlies about 1300 mi² in Rio Blanco/Garfield Counties, the Piceance basin is at an altitude of about 6500-8000 feet. Shale thickness ranges from a few hundred feet to 2000 feet. Average grade for much of the shale is in the 20-30 gal/ton range (depends on lowest cut-off grade), total resource estimated in the 1.2 to 1.4 trillion BBI range. I assume 1.5 trillion BBI, this allows for lower cut off grade e.g., 100’ of 10 gal/ton shale, basin wide is almost 90 Billion BBI.

Carl Sagan “Billions and Billions” book notes a real stumbling block exists for the human mind to “grasp” the meaning of several million or a billion of anything! Thus, some comparisons: This resource is equal in size/volume to:

1. 100 Prudhoe Bay fields, thus, each 1% we “waste” is a Prudhoe Bay!
2. 7 + Lake Powells (25 Million acre-feet capacity)
3. 3 feet of oil over a “flat” state of Colorado – or a 1 Foot cover on Texas!
4. 70 years of average annual flow in Colorado River at Cameo.
5. Supply our current petrochemical industry with feedstock for 2,000 years.
6. 1 million Bpd production for several thousand years.

However, control any excitement the above numbers may engender, the Resource is ROCK – NOT – OIL! This trip-up has led to many misdirected decisions by many entities, (public, private, and political), for many decades.

A rational approach is to consider it as a “Bridge Fuel” for future generations, when a public realization of our finite crude oil leads to effective conservation/utilization practices. I recall this term was applied by a researcher during the seventies boom (my apologies, I don’t recall who).

Dr. Tell Ertl, an early researcher in oil shale, in viewing the importance of the resource, wrote “If our civilization has any conscience and if it has any regard for posterity, it cannot give serious consideration to any method of production of shale oil from the center of the basin that does not result in substantially complete recovery. Our civilization has passed the stage in which it can kill the whole buffalo merely to consume the tongue and liver as was done in this area less than a century ago.”
COLORADO OIL SHALE
THE RESOURCE – Origin and Past Development

Deposited as organic material in closed lake basin (mostly saline), 45-55 ± million years ago (Eocene). Organic matter accumulated, was buried by younger deposits, eventually “converted” to kerogen in marlstone Rock. Large amounts of Aluminum bearing minerals and Sodium bicarbonate, along with salt (Halite) were co-deposited. The total oil shale including low grade shale may be as much as 1.5 trillion BBL. Erosion over the past 10 ± million years created the present “basin” shape, with resistant beds of oil shale and sandstone holding up the basin “Rim”.

The Ute Indians reportedly called the shale “The Rock That Burns”. Reportedly, an early settler, at his new house “warming”, lost the building when the chimney constructed out of oil shale burned. Historic development in the deposit began in early 20th Century. Winchester (1923) reported many prospects, rim mines, and retorts constructed to 1900-1920. He cited about 200 references to oil shale (mostly western US, many by the Colorado School of Mines). Early sites were “claimed under the 1872 mining law. The mineral Leasing Act classified shale as a “leasable” mineral, older claims were recognized. Briefly: 1928-US Bureau of Mines started Rulison project (a short distance SW of Anvil Pts.); 1949- US Synthetic Fuels Act led to developing Anvil Points mine-retort; 1950’s Union Oil experiments, many others in 1960’s-1970’s; 1974 USDOI “Prototype Oil Shale Leasing Program” Leased Tracts C-a & C-b (5,120 ac – each), C-a planned as an open pit operation, C-b planned as deep room & pillar. Both migrated over time to modified In-Situ, closed shop in 1980’s. Shell Oil continued In-Situ experiments; 2006, Oil Shale Leasing Act called for 160 ac R&D leases, with 5000 + acre lease available upon successful demonstration of profitable (?) production in an environmentally acceptable manner. All Colorado R&D leases were for sites nominated near Basin Center, (1-2 million BBL/acre), with 2,000 ± feet of oil shale underlying 500 feet of overburden, saturated with ground water to within a few 100 feet of surface, conditions not conducive to testing a variety of R&D methods.

Past impediments to development are mainly related to a highly variable range in oil prices, water conservation, and a popular concept by the public that In-Situ “Out of sight” is preferred to any other extraction method.
Dawsonite
\[\text{[NaAl(OH)$_2$CO$_2$]}\]

Nordstrandite
\[\text{[AL(OH)$_3$]}\]

Occurs in Colorado oil shale in very large amounts, more than 6.5 Billion tons of extractable Aluminium (Al$_2$O$_3$). U.S. depends on imports for most of its supply. As a "leaseable mineral resource, these minerals appear to be inadequately recognized by BLM. Research indicates that with proper attention to retorting techniques, Alumina can be extracted from spent shale by solution processes.

Note:

$6.5 \times 10^9$ tons of Aluminum could supply current U.S. needs for hundreds of years. More likely, as a co-product with shale oil it would supply a significant portion of U.S. needs for millenia.

Figure 6. Geographic location and thickness of Colorado's dawsonite deposits (Beard and others 1974).
**WATER**

**Needs:** Assume 2BW/BO – 90,000 af/yr needed for 1,000,000 BPD (95% used for cooling and moisturizing, spent shale). Expect future technological changes to reduce this.

**Nearby Potential Sources:**
1. Colorado River 2,768,000 ac-ft/yr at Cameo, \( \approx 31 \times \) needs
2. White River 534,000, ac-ft/yr \( \approx 6 \times \) needs

**In-Basin Potential Sources:**
1. Present ground water storage, assume 25,000,000 AC-FT. Dewatering necessary for oil shale production, theoretically approximately 400 year supply, including annual recharge
2. In-Basin Stream Flow.
   Four creeks, annual out flow from basin (down stream of present irrigation) \( \approx 32,000 \) AF/Y, or about 35% of annual needs

**Comments**
Several Factors May Affect The Above:
1. Ground water recharge to reclaimed land may increase, however, improved productivity of reclaimed land may use more water by E.T.
2. Climate Changes. (+)? Or (-)?
3. Technology improvements will almost certainly lead to more efficient use, given the very long time frame of oil shale operations.
4. Competition for existing water sources is certain to increase with time.
# SOME COMPARISONS OF OIL SHALE EXTRACTION METHODS

**Picenace Basin, Colorado**

Emphasis on Resource Recovery, Hydrologic Effects, Land Reclamation

<table>
<thead>
<tr>
<th>Extraction Methods</th>
<th>Resource Recovery</th>
<th>HYDROLOGY</th>
<th>Water Use</th>
<th>Land Reclamation</th>
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<tr>
<td>Room and Pillar (R&amp;P)</td>
<td>75% in thin, single layer areas e.g. Mahogany zone, locally near basin rim; probably &lt; 50% in thick sections. Nacholite and Aluminum recovery</td>
<td>Dewatering, Aquifer alteration, spent shale leachate to aquifer</td>
<td>Dewatering effect on streams, springs, spent shale leachate, in part controllable.</td>
<td>1-4 BBI water/BBI oil, 75% ± used for spent shale management. R&amp;D needed to reduce water needs.</td>
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<tr>
<td>In-Situ (IS), Modified In-Situ (MIS)</td>
<td>30-80(?) % probably no Nacholite or Aluminum recovery</td>
<td>Dewatering for retorting. Significant problem w/spent shale leachate. Subsidence effects on recharge and flow system.</td>
<td>Local dewatering effect on springs, streams subsidence effects on drainage.</td>
<td>1-4 BBI water/BBI oil. Leaching to ground water, “Rinsing” of retort water usage may be comparable to surface retorting water use.</td>
</tr>
<tr>
<td>Open Cast</td>
<td>Near 100% (ore)</td>
<td>Dewatering, Some leeching through soil-backfill. Spent shale problem appears controllable. Increased ground water storage to perhaps + 50 Million acre feet.</td>
<td>Disruption of streams, springs. On-going reclamation necessary.</td>
<td>1-4 BBI water/BBI oil, 90% + of water use for spent shale management.</td>
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**Summary: Resource Recovery – 1% ± = one “Prudhoe Bay”.**

For R&P, MIS, IS, loss of 30-50 “Prudhoe Bays”

- Open-cast appears to offer significantly better control over long-term ground water resource.
- Post Open-Cast surface drainage can be optimally “designed”

- R&D needed to minimize water use.

- Open-Cast appears significantly superior to other methods.

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Note: As to the above comparisons, the Author has some knowledge, experience. In so far as other effects, conditions, etc. The author is not well informed.

**Following the comparison, the remaining posters concentrate on Open-Cast methods.**
Mined, Reclaimed Area

Topsoil, Alluvium, Weathered Uinta

Uinta Overburden

Water Table

Lean Shale Overburden

Bentonitic Clay

Mining Advance

Retorted Shale Cement

Unmined Area

Uinta

Oil Shale

DIAGRAMMATIC SECTION
Open Cast Cut
relative thickness of "cement" and "Aquifer"
of the "cement" is very low, in the range of $10^{-6}$ to $10^{-8}$ cm/s (shale/clay range).

in the range of $10^1$ to 10 cm/sec thus, a relatively flat water table.
in the range of 0.1 to 0.2.

\[ \text{er could contain 50 \pm million Ac-Ft in storage.} \]
\[ \text{to be 1,000 + mg/l TDS in "Shale Rubble" zone, less then 1,000 mg/l in Uinta rubble zone.} \]

should be higher than pre-mining.
would require construction of local buried aquitards.

\section*{DIAGRAMMATIC SECTION}
\textbf{Post-Reclamation Conditions}
Assumption and Notes:

1. 1.5 Trillion BBl (ore) available
2. 1,000,000 BPD (ore) mining rate
3. Begin where ore is shallow or crops out, early production, small mine
4. Minimum land or mineral ownership problems
5. “Rim Pillar”...If not mined, mine life is reduced
6. Start date, optional (see number 10 below)
7. Uncertainty as to Southern extent of operation
8. Concept will be “Permitted”
9. Production “Allocation” along mine front achieved
10. When the United States “really needs” this resource, it will be developed.
1. **Improved resource recovery.** With about 1.5 trillion BBL as a resource, every 1% "wasted" is equivalent to a "Prudhoe Bay".

2. Recovery of associated mineral resources - Nahcolite, Dawsonite, and other minerals. Estimated to equal several 100 year aluminum supply for U.S.

3. **Natural gas 100± TCF in entire structural basin.** Significant part of this underlies the oil shale. Oil, gas, coal, Uranium, Vanadium, probably present. Known gas resource can be recovered prior to oil shale recovery. Undiscovered coal, other minerals, and potential O&G are deep. Mining and O&G wells do not mix.

4. **Groundwater quality - quantity.** "Spent" shale is a huge problem, and Green River "overburden" contains some soluble salts. Properly "reclaimed backfill can become a prolific, high-storage aquifer. A post-open-cast mining reclaimed aquifer could contain 50 ± million Ac/ft.

5. **Energy requirements/source for retorting.** Several GPT "equivalent" energy currently needing for retorting. Expect improvements in waste heat recovery and other processes. Typically, less energy/bbl produced to retort "rich" shale, but "lean" shales make up a very large resource. Energy sources other that "product" or "ore" are desirable, e.g. solar, "Breeder" Nuclear, etc. A "catalyst", solvents, "bio-processing", or some means to lower retorting energy is needed.

6. **Mine water management.** Water handling" (both ground water and surface water) during open-cast mining will require creative methods. Mine dewatering, both from ore face and "reclaimed" aquifer will affect quantity and quality problems. Possible mine inflow from aquifers below the mine floor (along faults, etc.) needs study.

7. **Air emissions/controls.** In the 1980's, EPA estimated a 400,000 BPD "Cap" on Piceance production (limited by air emission controls). Perhaps 1,000,000 Bpd is a future limit, with development of better controls.

8. **Design of "Backfill" and land-water related reclamation.** Handling and placement of waste affects on-going mining as well as post reclamation soil productivity and water quality.

9. **Subsidence control for in-situ, room & pillar.** A large percent of resource recovery by these methods will probably result in at least several 10's of feet of surface subsidence. The effectiveness of control methodology is highly uncertain.

10. **Spent Shale Leachate Control.** Maybe most important aspect of shale oil recovery. Efforts to date range from moderately successful to ineffective, all are costly.

**Summary:** In view of past improvements in oil recovery (30% - 90% ±) copper (2% ± .2%), and other resources, we are just beginning on oil shale.
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