Oil Shale: Some Research Needs, with Emphasis on Piceance Basin, Colorado

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Abstract

The enormous size of the Piceance Basin oil shale resource (1.5 trillion bbl or about 100 Prudhoe Bays) and potential future importance to U.S. domestic energy supplies (about a 200 year supply of oil at the current level of demand) provide a strong impetus for timely research into how to best extract the resource and to minimize negative environmental impacts. Several hundred thousand barrels have been produced in the past, mostly to test retorting methods and the suitability of oil for various uses. Critical research is needed on the potential to extract several co-products that could equal or exceed the oil value. Much of the detailed research needed is process-related; however, there is a universal need for research towards maximizing resource recovery efficiently, recovery of co-products, and minimizing degradation of air, water and soil quality. A real possibility exists that a future emergency will require the rapid development these resources. Without more thorough research, rapid development is almost certain to result in inefficient recovery, wasted resources, and environmental damage.

Introduction

Much research is needed on the ~1.5 trillion barrel resource of oil shale in the Green River Formation in order to maximize resource recovery in an environmentally acceptable manner. This unique resource is equivalent to about 100 "Prudhoe Bays," or a 200-year oil supply at current U.S. use, or potentially thousands of years supply for current U.S. uses for petrochemical feedstocks and aviation fuels. It must be utilized in a well-planned program based on facts and technical expertise. Co-products have the potential to significantly enhance economics, to "smooth out" oil price fluctuations, to supply some U.S. shortages, and to lessen some environmental effects. The author wishes to acknowledge the assistance and review of portions of this paper by Robert Loucks, Roger Moore, and Brett Redd.

Research is needed on controlling air and water emissions and on post-recovery land and water reclamation, so as to ensure future productive soil and water systems. Improvements are needed in retorting efficiency, minimizing water use, air emissions control, and reducing conflicts between "side-by-side" recovery of shale oil, gas, oil, coal, and other resources in the basin. A basic need is more detailed data on the composition of oil shale, both areally and stratigraphically. Most of our research and analyses appear to be from studies of richer shale strata, which represent only a part of the total resource. Reportedly, there are many stored drill cores that may be available for further analyses. The following is a very brief summation of several research needs. Research needs apply to in-situ, room and pillar, open cast, and any other recovery methods. The R & D history on in-situ methods is much shorter than on surface retorting. Few of these topics are new, and this summary can perhaps be considered merely as a crude "road map," certainly it is not as a "blueprint."

Resource Recovery

Current R & D lease proposals (using in-situ methods) suggest recovery of only about 10-50 percent of the resource. Apparently, Nahcolite is the only co-product noted in the BLM leases. Reportedly, there is no minimum figure required for resource recovery from these and future leases. Such an implied government sanctioning of "high grading" of the resource probably is nationally unacceptable. Almost inevitably it would leave a remaining resource of low grade, and in conditions that can greatly hamper future recovery. *All* recovery methods need research to maximize recovery. Note: a 1% loss or recovery, basin-wide is about equivalent to a "Prudhoe Bay." Also, high recovery of shale oil implies a high recovery of co-products. Using current technology, some form of surface mining is the only method that can approach recovering 100 percent of the resource.

Environmental Issues

Research is needed on:

1. Air emission controls, which may be *the* limiting factor on production rates. Some "captured" pollutants could become co-products.
2. Minimizing water use, and controlling water quality degradation. We need to utilize local water sources efficiently, including the 25 million acre-feet of ground water basin storage in the Uinta-Green River Formations, and possibly much more in deeper sources. This stored ground water, which is subject to mine dewatering, could potentially supply water to a million barrel per day industry for several hundred years. Research on mine dewatering is needed to minimize both costs and unwanted effects on stream flow and springs, and on controlling inflow into mines and in-situ retorts via fracture zones.
3. Post-recovery soils reclamation, in order to preserve or increase productivity.
4. Minimizing unwanted water quality effects of the long-term management of spent shale.
5. Subsidence effects on water, soil and streams, whether from in-situ or underground mining with surface retorting.

Co-Products

The potential exists for producing several co-products that could *substantially* improve profitability (and royalties) and could cushion oil price swings. Some co-products may be critical to the U.S. economy. Figure 1 diagrammatically shows several places where co-products might be recovered via surface retorting. Recovery of several minor or trace elements may be economical and could reduce unwanted effects on air and water. Potentially, co-products could be recovered from mined ore, spent shale, oil products, and retort gases (Fig. 1).

1. Research is needed on the mineral (or kerogen) residence of potential co-products and their stratigraphic occurrence.
2. Co-product recovery can affect mining plans and retorting methods. Research is needed on types of beneficiation and separation methods (pre- and post-retorting) and on recovery from raw shale, spent shale, off-gas and product oil. One patented beneficiation method suggests that some level of mineral-kerogen separation may be feasible.
3. Nahcolite apparently is the *only* co-product addressed in the current BLM leasing program. Nahcolite recovery prior to retorting could reduce retort energy requirements.
4. Aluminum, a 3 billion ton resource in the mineral dawsonite, has been recovered during limited past research. Aluminum recovery is sensitive to retorting techniques. Recovery of this co-product appears to be in our National interest.
5. Limited past research indicates that cement can be produced from spent shale, potentially in very large quantities. Cement production can reduce spent shale management problems, enhance land and water reclamation, reduce water needs, and significantly improve economics.

Lithium, gallium, sulfur, magnesium, fertilizer, possibly titanium, and other elements are potential co-products. Apparently, very little research exists on their recovery. Total per ton potential raw rock values of co-products *could exceed that of shale oil.*

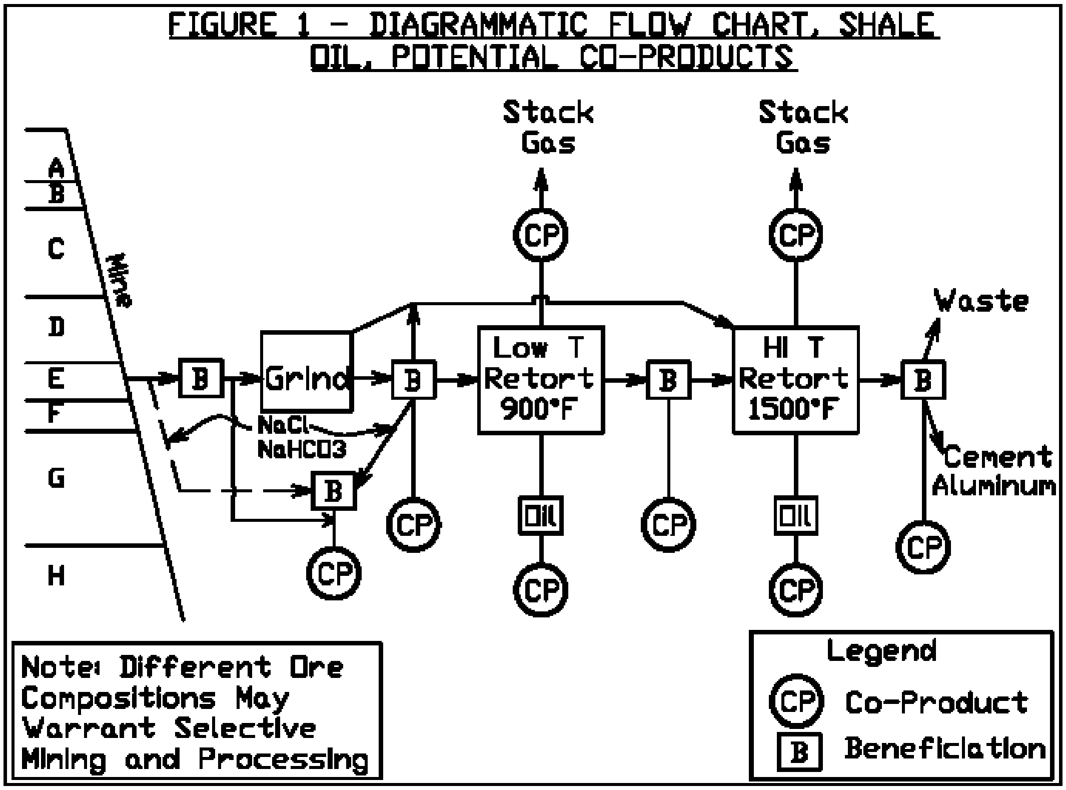

Figure 1: Opportunities for co-recovery of resources in oil shale retorting

Limited data from the U.S. Department of Energy N.U.R.E. program suggests that several rare earth elements and other potential co-products occur in the Green River Formation at concentrations in the tens to hundreds of parts per million range.

Retort Efficiency

Improvements are needed to enhance oil recovery and to reduce retorting energy and costs. Current energy needs for retorting are roughly 10% of the product stream (or equivalent.) This amounts to an unmarketable 10-20 "Prudhoe Bays," basin-wide. Resource recovery, economic returns, and potential environmental benefits from increased retorting efficiency could be very large. Figure 2 shows diagrammatically several sites where "waste" heat might be recovered at a surface retort.

1. Research is needed on waste heat recovery (primarily to preheat the shale) from spent shale, off-gas, and from products. Waste heat recovery can be considered a co-product.
2. Additional research is needed on non-product heat sources such as heat recovery from ongoing processing, solar pre-heat, and waste heat from nearby electrical power generation. Research is needed on the use of catalysts, bio-enhanced recovery, and use of solvents, and other means of reducing the energy needed to produce oil from kerogen.
3. Waste heat recovery from in-situ operations is complicated, in large part by the remote nature of retorts and by complex permeability patterns in both new and spent retorts. R & D is needed on air/gas cooling of spent retorts, both to minimize water use and to provide a pre-heat source for nearby new retorts. There may be as much as the equivalent of 10% of the heat energy in the product oil remaining in a hot retort. This could be equivalent to more than

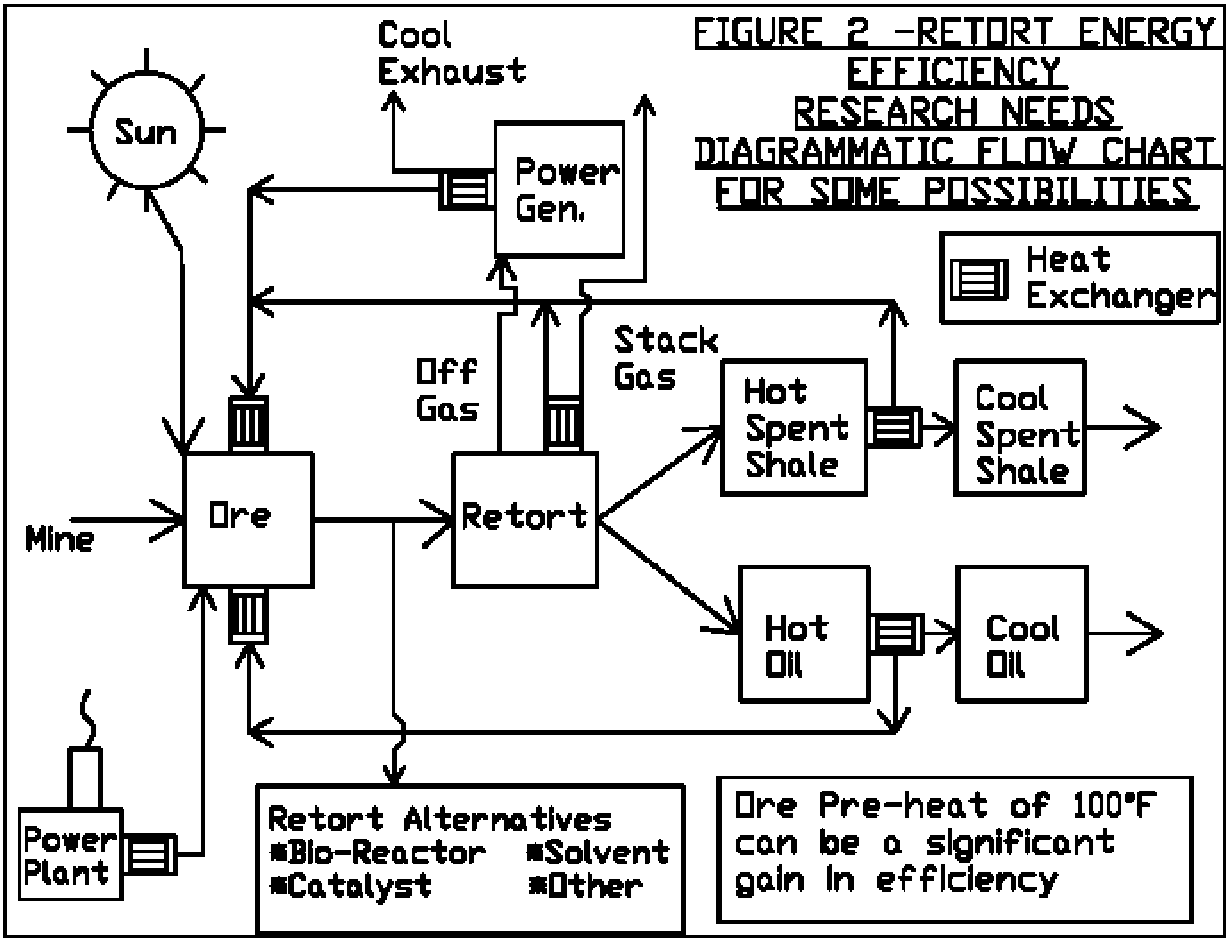

Figure 2: Opportunities for heat recovery during retorting

10,000 barrels for large retorts. Presumably, heat recovery by air/gas cool-down to near-boiling temperature could recover most of the available waste heat, and still allow for possible leaching of several potential co-products.

Retorting Temperatures

Low temperature retorting minimizes carbonate decomposition, and the spent shale contains residual hydrocarbons. High temperature retorting requires more energy and produces more CO_2, but is essential for cement production and for some co-product recovery. Research is needed on trade-offs involving energy, co-products, and environmental effects. Different ore compositions may require selective mining and different retorting methods, especially for co-product recovery.

Conflicts with Other Basin Resources

Large resources of ground water, natural gas, deep coal, and possibly oil, and uranium-vanadium underlie the oil shale. Conflicts with agriculture and wildlife resources need to be minimized. Research/planning is needed to develop policies and methods that minimize conflicts with these resources during recovery.

Landscape: Post Recovery

In general, in-situ and room-and-pillar recovery methods tend to cause significant surface subsidence, which can affect springs and streams. Open cast methods here can result in an elevated reclaimed land surface, and would affect the hydrologic system. Cement production and removal can control open cast surface rise.

Summary

Past R & D oil shale operations have produced several 100 thousand barrels of oil from this very large resource, thus production methods that work are known. A real possibility exists in our present-future world that a U.S. petroleum shortage will occur and lead to a classic Government Crash Program to produce shale oil. This is not good, especially if we are woefully short on critical knowledge on how to recover the resource efficiently and in an environmentally acceptable manner. Much of the basic needed research could be federally funded (National Laboratories, university grants, U.S. Geological Survey, E.P.A., *etc*.). Promising results would no doubt prompt further studies by private industry. The 80% government-owned oil shale resource *could*, if appropriately administered, become a positive factor in promoting prudent and effective research and development. A pilot mine or mines program is needed to provide ore and to test techniques. Based on the Canadian tar sands experience, several decades of carefully planned research and pilot plant production may be needed. Therefore, a real sense of urgency applies to plans to recover this resource.

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