A MARKETING PROSPECTUS FOR SHALE OIL

G. E. Ogden and R. D. Ridley

Occidental Oil Shale, Inc.
5000 Stockdale Highway
Bakersfield CA 93309

Technical developments in shale oil production achieved in the past few years signal the potential beginning of a new liquid hydrocarbon industry. Construction work has begun on commercial scale projects and coupled with the growing sense of national urgency, there is good optimism that significant shale oil production will be forthcoming. These events have generated a need to take a closer look at definition of shale oil markets.

In contrast to past efforts which have dealt hypothetically with this subject, our marketing development efforts are directed at an established objective; that is, to define the specific markets which will return an optimum price for a commercial quantity of shale oil in the mid-1980's. Consuming sectors of the petroleum market have been evaluated and compared. The transportation element has been costed for various geographic regions of interest and combined with quality differentials to identify economic alternates.

Before delving into the distribution logic, some commentary about the nature of the product is warranted. While most of the shale oil technology developed to date is derived from a variety of above ground retorting tests, oil shale projects currently underway indicate that the early production will come from a modified in situ process with later production possibly being a blend of oils from several recovery processes. Many of the early plans called for a prerefining step at the production facility to improve the oil's transportation characteristics and marketability. Strong demand projected for hydrocarbon liquids in the mid-1980's has tempered the concern over marketability of as-produced shale oil and consequently has moderated the need to upgrade at the production site. The capital intensive production operation tends to make developers favorably consider minimizing the initial investment, which can be accomplished by eliminating the oil upgrading step. Concerns over water availability and general high industrial profile in Western Colorado are also factors which will increase the probability that any processing of the oil will be accomplished downstream in existing industrial complexes. Consequently, the commodity of interest in this discussion is the as-produced shale oil from modified in situ retorting.

While shale oil will not be completely interchangeable with crude oil, its properties are sufficiently similar that it will act as a substitute in several applications. The major quality difference between shale oil and conventional crude oil is nitrogen content. Shale oil contains approximately 1.5 weight percent nitrogen compared to 0.1% for typical crude oils produced in the Rocky Mountains. Since nitrogen is an undesirable contaminant in catalytic refining processes, facilities will have to be constructed specifically for its removal. Refining technology is fully developed for this processing step and, in fact, California crudes ranging up to 0.7% nitrogen are routinely refined on the West Coast. The impact of the nitrogen can also be lessened by blending with crude oil in an existing refinery. To verify

this, a successful refinery test run was conducted on as-produced, in situ shale oil at the Chevron refinery in Salt Lake City in November, 1977.

There are also significant differences from crude in fractionation yields. These differences are explained in some detail in the refining quality discussion. A very important shale oil property is its relatively low sulfur content, 0.5-0.7 weight percent. The low sulfur content may allow the oil to be burned directly in boiler applications in its as-produced state. This factor also influences planning against incorporating an upgrading step with the production operation.

Because of its similarity to petroleum, it is expected that shale oil will compete in the same markets with crude oil or products derived from crude. The supply of crude oil to meet incremental U.S. demand is widely accepted to be foreign sourced in the 1980's and reference is made throughout the discussion to economics relative to cost of foreign crude oil.

With that overview in mind we can turn to examination of the logistic factors, the potential consuming industries, and the business and governmental influences.

Geographical orientation of the existing markets will have a strong influence on shale oil disposition, particularly in the early years. As production of shale oil expands we can expect industrial consumers to react to the supply source by locating new facilities to take advantage of logistics. However, at the outset, the processing plants that will absorb the shale oil are essentially in place. Figure 1 shows in general the concentration of the refining industry, the primary petrochemical plants and the utilities running on oil.

The refining industry is the most widespread and while large concentrations are shown in California, the Gulf Coast, the Great Lakes, and the Philadelphia area, a sufficient capacity to absorb 100-200 MB/D of shale oil exists in the Rocky Mountain/Kansas area. In perspective, the U.S. refining capacity stands at 17.6 million B/D of which 5 million B/D is located in the Rocky Mountain/Midwest area. Demand for refined products, of course, is equally widespread and should continue to grow at a moderate pace. Because of its wide geographic distribution, the refining industry has the most flexibility to modify or locate new facilities to take advantage of the logistic flow of the shale oil.

The primary petrochemical industry does not have this luxury. The great majority of the large volume petrochemical operations are centered near the U.S. Gulf Coast. There they have the necessary economic linkage with plants producing intermediates and finished products along with established outlets for by-products. If a large plant were to be constructed in the Rockies, it would have to achieve sufficient benefit to overcome the transportation penalty associated with hauling nearly all the output to the U.S. Gulf for secondary processing or by-product disposition. As traditional supply sources change, we may see evolution in this direction but it will be very slow and in small steps.

The large market for oil in direct burning applications is the utility boiler market. There is some question as to how long this outlet will

exist in light of Government policy trending against using liquids for power generation. As shown on Figure 1, oil use today is centered in three regions: California, the Great Lakes, and the Northeast. There may be a growing use in the Gulf Coast area if economics permit gas fired applications to be converted to oil, but for the very long term oil based generation is likely to be a shrinking market. As new nuclear and coal plants come onstream, they will be put in base load service and existing oil generation will be subordinated first to peak shaving and ultimately retired. With the exception of areas where very tight emission standards are required and/or nuclear and coal plants are faced with very long delays, new oil fired generation capacity is unlikely.

With the qualitative overview in mind, we can now turn to the quantitative impact of the geographical element. The table below attempts to ascribe a transportation premium or penalty for shale oil with respect to common foreign crude oil in the regions of interest. The East Coast was not included in the table since it would represent an extreme physical distribution problem for Rocky Mountain oil. The transportation costs are estimated average values for 200 MB/D and 1,000 MB/D. The estimates assume pipeline transportation to a typical destination within the area. Where existing pipelines are in place, actual tariffs are presumed. Tariffs are approximated for new pipelines using $.20/bbl per 100 miles for 200 MB/D, and $.10/bbl per 100 miles for 1,000 MB/D.

RELATIVE TRANSPORTATION ECONOMICS
SHALE OIL VS. FOREIGN CRUDE OIL, $/BBL

	Shale Oil		Crude Oil	(Penalty)/Premium	
	200 MB/D	1000 MB/D		200 MB/D	1000 MB/D
Los Angeles	1.80	.90	-0-	(1.80)	(.90)
Rocky Mtn.	.60	.30	.80	.20	.50
Chicago	1.20	1.20	1.20	-0-	-0-
U.S. Gulf	2.40	1.20	-0-	(2.40)	(1.20)

The table shows the quantitative effect of transportation in 1977 dollars on a value relationship with crude oil. Location impact may result in a $0.20-$0.50/bbl premium for shale oil routed to a Rocky Mountain destination to a $.90-$2.40/bbl penalty for a West Coast or Gulf Coast market. The obvious conclusion is that there is a sizeable transportation advantage for shale oil if a market can be created in the Rocky Mountain/Upper Midwest area instead of a Coastal location.

Definition of quality differentials is much more difficult to accomplish with any degree of certainty. In the long term context, where the liquid demand exceeds supply, today's quality relationships are apt to be distorted. For the purpose of this discussion, however, it is assumed that foreign crude can still be purchased for incremental liquid input.

Refining value of shale oil has probably been investigated in greater detail than the other potential applications. Most of the efforts to prescribe a refining cost for shale oil, however, have viewed the problem in a very hypothetical context. Most of the data is developed for complete new facilities turning out a product slate that may or

may not relate to the actual market conditions in the environment where the oil is likely to be consumed. For the reasons discussed earlier, there is good probability that the shale oil will not be upgraded at the production facility, but rather will be integrated into existing refineries in its as-produced state.

Also, there has been no reported extensive testing on in situ shale oil which is likely to represent the quality of the majority of the early production, based on projects presently underway. Consequently, there is some divergence of opinion on the relative value of shale oil to conventional crude oil.

In our efforts to date at defining this value, we have attempted to cost the effect of integrating as-produced, in situ shale oil into typical Rocky Mountain/Upper Midwest refineries as a substitute for the crude mixes run at those locations. Figure 2 shows the various geographical areas that were analyzed in this fashion. The dollar figures superimposed are the additional refining costs resulting from substituting shale oil. While the numbers range from $2.05 to $3.00 per barrel in 1977 dollars, an additional refining cost of $2.50 probably reflects a good estimate of the average additional cost. It should be noted that these cost figures include a reasonable rate of return on invested capital.

This additional refining cost appears lower than many of the recently published figures but it can be qualitatively reconciled when put in the context of the market environment in the mid-1980's. First, the existing U.S. and worldwide supplies of light crude oil are declining at a significant rate. The refining supply barrel is getting heavier, and more importantly contains a higher volume yield of residual boiling range material. We can see the impact of this phenomenon already in the U.S. noting the very depressed prices for high sulfur residual fuel which is in long supply. In situ shale oil has only 4%, 1000°F. + boiling range material compared to 20% for North Slope crude and 18% for Arabian light crude. These crudes are by no means the worst and are actually significantly better than Kuwait, Arabian Heavy and others which represent a good proportion of the unused worldwide production capacity. Upgrading crude residual material to clean transportation fuels is probably more costly than starting with shale oil.

Another factor that has historically been represented as a negative for shale oil is the very low gasoline yield. Nearly all the refining studies on shale oil have discounted its value because of the need to convert a greater proportion of the distillate to gasoline. However, the strong trend today indicates tapering gasoline growth. The major forecasters are nearly unanimous in projecting a peak in U.S. gasoline demand between 1980 and 1985. The conclusion is that the great majority of facilities to manufacture gasoline will be in place when shale oil comes on the market and the demand growth will take place in the distillate range. If this trend proves to be true, a refiner in 1985 will place a premium value on high distillate yield as opposed to high gasoline yield. The potential yield premium will act to offset the additional refining cost.

While the shale oil yields were very unbalanced with the refinery product mix outlook in 1970, those same yields will be highly attractive in 1985.

The market price for shale oil as a utility boiler fuel can be quantified in a fairly narrow range but is subject to environmental and governmental restrictions. Pricewise, where supply imbalance or regulatory effects do not create distortions in the market, 1% sulfur residual fuel sells for approximately the same price as Arab Light crude. This grade of fuel oil is currently burned in the Great Lakes area for power generation as well as industrial fuel applications. Since shale oil in an untreated form approximates the quality of 1% sulfur residual fuel, we suspect that its value in that application will approach that of Arab Light crude oil. Since we have defined refining costs for processing shale oil to transportation fuels, it is probable that its highest value will result from 1% sulfur boiler fuel.

However, the areas where 1% sulfur fuel oil can be burned are shrinking. Emission restrictions have forced many utilities to use 0.5% and lower fuels and the trend is continuing. Looking forward to the mid-1980's, there may be a market for only a small volume, say 50,000 B/D, for this application.

The potential petrochemical feedstock market has not yet been fully explored. There are some negative aspects of shale oil for petrochemicals. The existing petrochemical plants (olefins, aromatics) are tailored to the light fractions of petroleum such as LPG and naphtha. Shale oil's low yield of light hydrocarbon places it at a disadvantage with respect to crude oil. No attempt has been made to quantify a penalty for this application.

On the other hand, there is good reason for some optimism. Shale oil's very respectable hydrogen content (12%) suggests that new petrochemical technology could be tailored to this input economically. In a very forward thinking manner, members of the petrochemical industry have expressed interest in exploring new applications. However, the competing uses will likely comprise the total early market for a shale oil industry and it will only be in the long term that a petrochemical market will come into play.

The other factors that will have an influence on shale oil distribution will not be directly economic. Government policy may leverage through incentives a particular use for the long term benefit even though it may not be the most economic short term application. As an example, there may be legislation penalizing burning oil in a stationary boiler. National policy seems to be aligned in the direction of converting power plants from oil and gas to coal. For these reasons we suspect that the fuel oil application will not provide a long term market for a shale oil industry; nevertheless this outlet will be of real value for the early stages of an oil shale industry since it can utilize raw shale oil without major capital expenditure.

General business factors should be taken into account in this assessment particularly for the first 200,000 barrels per day of production. There is almost no disagreement that early production of shale oil will be a high risk, capital intensive venture. The production venturers will be inclined to limit their capital exposure to the production and look for a manufacturer to risk the upgrading capital. In this context, the fuel oil market has a strong advantage. Very little capital will need to be exposed to consume the shale oil, very little lead time

will be required and there will be a minimum risk of non-success in the application. Refining on the other hand will require substantial capital modifications, a three year minimum lead time and some risk, in the first cases.

Viewing the industry sectors in summary, a petrochemical market is the most remote. The transportation cost to reach it is high and the upgrading technology for shale oil has not yet been developed. Because it represents one of the more beneficial uses of petroleum, however, we expect that ultimately a market will develop in this sector.

Industrial and utility boiler fuel represent an attractive market for shale oil. Because of the low investment required and a geographically economic location, the first use of shale oil may be for this application in the Great Lakes area. The disadvantages of this market are its susceptibility to environmental and regulatory prohibitions and limited volume demand.

The large market for shale oil is expected to be as refinery input. Refined product growth is expected to continue and sufficient plants to absorb sizeable volumes of shale oil exist in economic proximity to the production area. Conversion of shale oil to transportation fuels is consistent with government policy on use of liquid hydrocarbons. The only deterrent to this application is the substantial capital investment for upgrading facilities. In graphical form, Figure 3 presents our projection of the time related consumption of shale oil.

FIGURE I
POTENTIAL SHALE OIL MARKETS

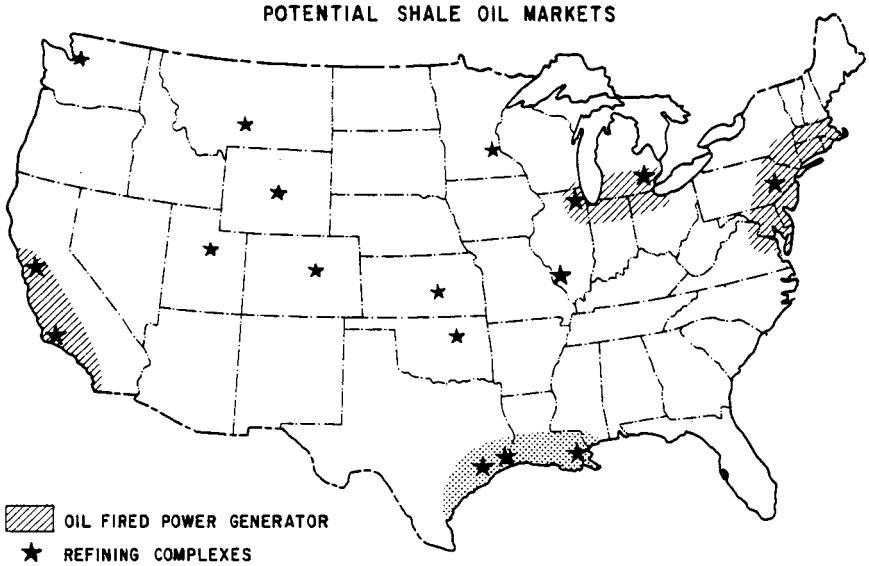
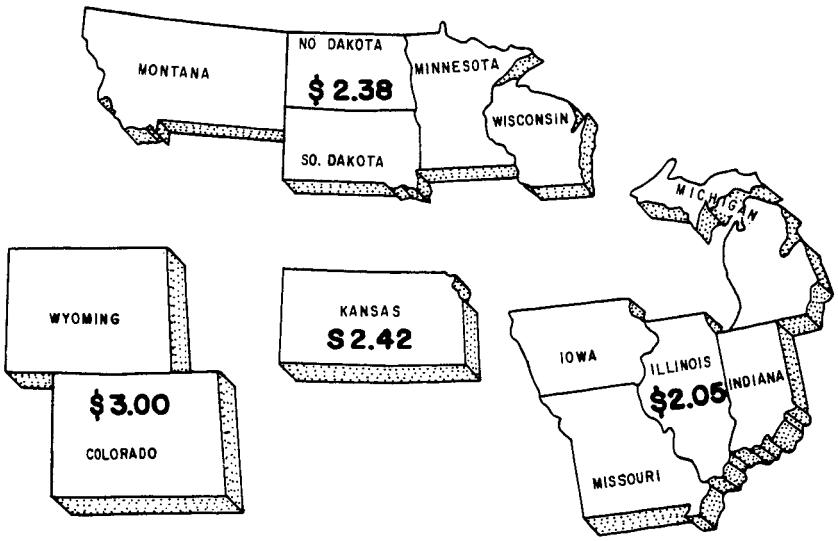


FIGURE 2
SHALE OIL REFINING - ADDITIONAL COST



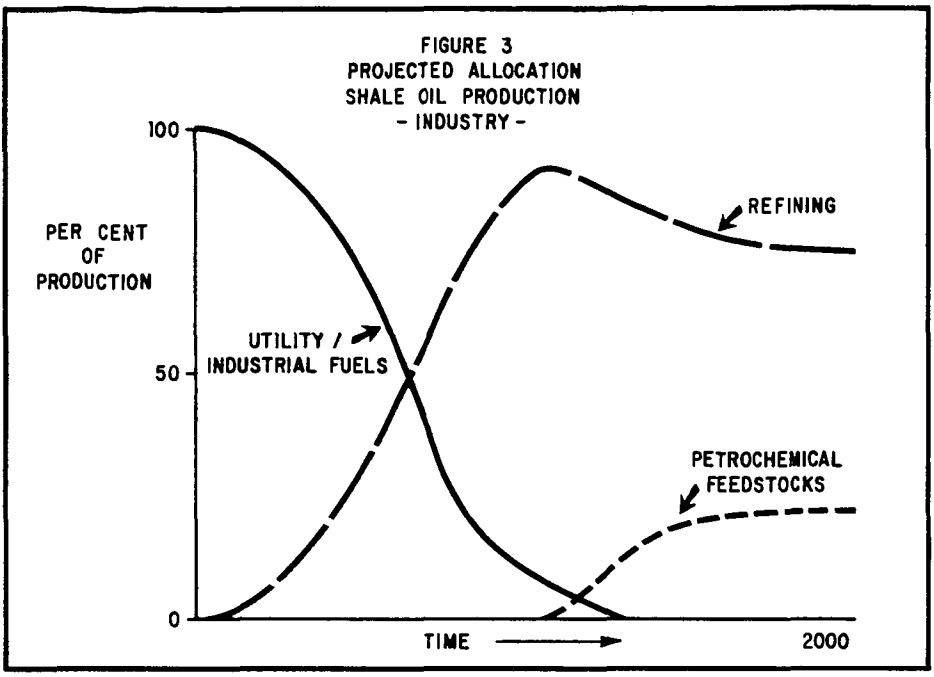


FIGURE 3
PROJECTED ALLOCATION
SHALE OIL PRODUCTION
- INDUSTRY -
100
50
0
PER CENT
OF
PRODUCTION
UTILITY /
INDUSTRIAL FUELS
REFINING
PETROCHEMICAL
FEEDSTOCKS
TIME
2000