Mining Could Increase Petroleum Reserves

"Depleted" U.S. oil fields contain huge amounts of petroleum; mining could recover at least half of it

U.S. deposits of oil sands represent only a modest source of liquid fuels that could, at best, supplement fuels from other sources while alternative energy sources are being developed (*Science*, 14 March 1980, p. 1191). Oil shale and coal are generally considered to be the most favored sources of liquid fuels for the future, but mining them and converting them into liquids present problems that now can be solved only at great expense. Yet this country has another source of liquid fuels that some scientists believe could be exploited relatively easily to provide as much petroleum as has already been produced in the entire history of the United States. That resource is the petroleum left in the ground after oil fields have been depleted by conventional techniques.

This is one of a series of occasional articles about the prospects and problems of alternative energy sources.

Conventional primary and secondary production techniques, which involve simply pumping out the oil or injecting water to force the oil toward wells, typically remove less than a third of the petroleum in place. Even tertiary techniques, in which surfactants and other chemicals are used to increase the mobility of the oil, remove only an additional 5 to 10 percent. The United States once had more than 450 billion barrels of oil in place. About 150 billion barrels of that were recoverable by primary and secondary techniques, and 80 percent of that has already been recovered, leaving fewer than 30 billion barrels as conventional reserves. Even when that 30 billion barrels is gone, however, there will still be 300 billion barrels remaining in the ground. Some experts think it may be possible to recover at least half that amount by using mining techniques.

Petroleum mining should not be confused with the surface mining techniques used to extract synthetic crude from the Athabasca oil sands in northeastern Alberta. Instead, it is an underground process that can free petroleum that is unrecoverable by other techniques. The simplest, and potentially most effective, technique is known as drip drainage. It can be used on any oil field that is shallower than about 1500 meters and that is underlain by unfractured or competent rock; it cannot be used in deeper mines because of heat from the earth's interior.

To initiate drip drainage, a shaft is sunk into a competent rock layer below the reservoir (Fig. 1). Tunnels are drilled into the rock there; these tunnels are used to drill holes up into the reservoir at intervals of about 30 meters. The oil then drains through these holes and into a closed piping system in the lower tunnel, from which it can be pumped to the surface. In some cases, the process can be speeded by introducing water slowly into the reservoir from the surface or from other tunnels above the oil-bearing zone. According to Sheldon P. Wimpfen of the U.S. Bureau of Mines, drip drainage could potentially recover 45 to 50 percent of the oil remaining in a "depleted" oil field.

The mining of rock outcrops for their oil content has been recorded since antiquity, and oil mining operations were a feature of many local economies prior to the industrial revolution. Postindustrial efforts to mine petroleum have been conducted in Pennsylvania, Ohio, Kentucky, California, Texas, and Kansas. Many of these efforts were reviewed in 1932 by George S. Rice in Bulletin 351 of the Bureau of Mines. Rice concluded that the techniques used then—which were much the same as those being proposed now—were technologically sound, but that oil produced in this fashion could compete economically only if petroleum should reach what then seemed the high price of $2 per barrel.

Conventional economics did not play a role, however, in the first European operations that successfully demonstrated oil mining. One such mine was opened in 1917 at Pechelbronn in the Alsace region of France. The need for oil at any price was stimulated by World War I, but the continuing operation of the mine was sustained by the exceptionally low wages that prevailed during the postwar depression. Because the rock zone underneath the oil-bearing zone was fractured, the primary mining method at Pechelbronn involved driving galleries into the marlstone overlying it and sinking pits into the oil zone. Oil would then gravitate to the pits, from which it would be pumped to the surface. By the end of World War II cumulative production by mining totaled nearly 5.4 billion barrels.

In 1919, Germany began producing oil in the same manner at the Wietze field near Hanover. In addition, they hoisted oil sands from the deposit to the surface and washed the oil from them in much the same way that is now used in Canadian surface mining operations. Ten years later, nearly a quarter of Germany's oil was produced by these two mining techniques. By 1950, more than 5 million barrels of petroleum had been obtained from the Wietze field by mining. During World War II, the Japanese also used the Pechelbronn technique on a field at Higashiyama. By 1946, mining yielded 37,000 barrels per year, 2.5 percent of Japan's total production.

The largest existing oil mining operation was begun in 1972 in the Yarega field in the Soviet Union, about 1200 kilometers northeast of Moscow. There, a reservoir of heavy oil exists about 185 meters below the surface. To tap the field, Soviet engineers have sunk mineshafts to a rock formation about 20 to 30 meters above the oil-bearing stratum. From there, inclined shafts called winzes were sunk to the bottom of the oil zone, where hexagonal production galleries, about 24 meters in diameter, were dug out. In each gallery, about 250 production holes are drilled to lengths of 200 to 240 meters, radiating in all directions. Each gallery drains about 4.5 acres.

At the same time, steam injection wells are drilled into the reservoir from the upper working level. To initiate production, steam is injected into the upper wells at a pressure of 75 pounds per square inch. The steam heats the oil and makes it mobile enough to flow by gravity through the lower set of holes to the production galleries. From there, it is pumped to the surface. The chief advantage of this process, compared to conventional in situ steam stimulation, is that intense heating of the reservoir is achieved with relatively small amounts of steam injected at much lower pressures. The first mine had a production of 972,000 barrels per year at a cost reported in 1976 to be about $5.29 per barrel. The Soviets are now producing an annual 1.5 million barrels of oil from Yarega and plan to increase production to 6.7 million barrels. Soviet engineers reportedly plan to use the same technique to recover heavy oil from undersea mines at the old Baku offshore field in Azerbaijian and to develop new fields in the Caspian Sea. Resource Sciences Corporation of Tulsa is the U.S. licensing agent.

The only oil mining operation in the United States is run by Conoco Inc. at its Lakota field in Johnson County, Wyoming. That project is unusual because the oil-bearing zone outcrops on a hillside. Conoco has driven an adit directly into the reservoir and, from it, drilled five 600-meter holes further into the formation. The mine is presently producing about 50 barrels per day, but Conoco, reportedly disillusioned with the technique, has no plans for further projects. Independent observers argue, though, that Conoco picked a very difficult approach by drilling directly into the reservoir. The health and safety problems associated with such a shaft are much greater than those associated with tunnels either above or below the reservoir. Most experts thus think that tunneling through the deposit will rarely be the method of choice.

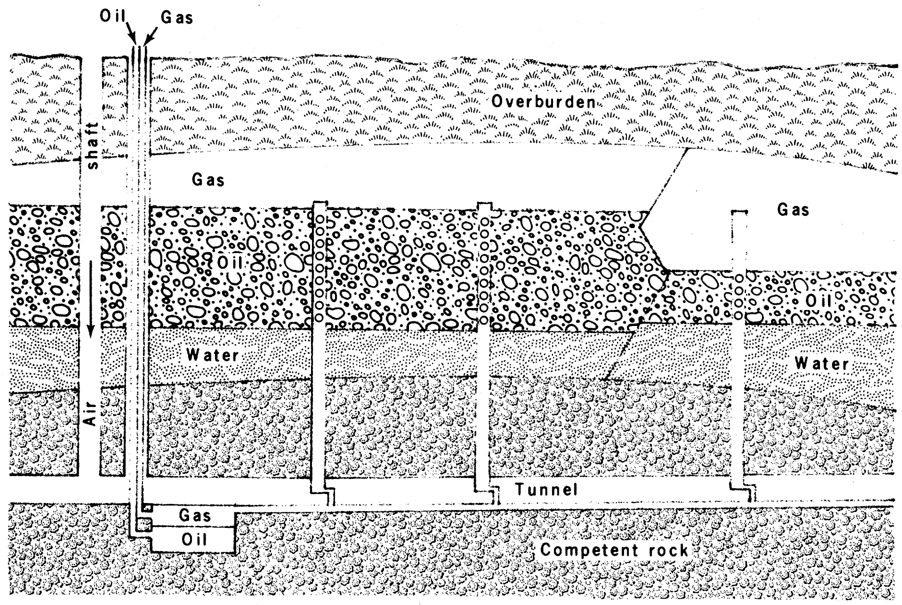

Fig. 1. Oil and gas flow by gravity from the reservoir through holes into a closed piping system in the lower tunnel. From there, they can be pumped to the surface. [Source: Energy Development Consultants, Inc.]

Petroleum mining has received a mixed reception among government officials. The Bureau of Mines, where many of the ideas originated, is optimistic about its prospects. The Bureau commissioned two major reports on petroleum mining, both of which were presented in 1978. One was by Energy Development Consultants, Inc. (EDC), of Golden, Colorado, and the other by Golder Associates of Kirkland, Washington. Both concluded that petroleum mining was a feasible operation that could produce as much as 200 billion barrels of oil. The EDC report, for example, concluded that mining one square mile of a reservoir 100 feet thick would involve a capital investment of about $50 million. The operation would produce 1500 barrels of petroleum per day at a 1978 cost of about $14 per barrel.

The Golder report points out several areas that require further research. The most basic need is for better estimation of "the true in-place quantity and distribution of hydrocarbons after conventional depletion." Such studies have never been conducted in the detail necessary for mining purposes. It also called for further research on techniques for processing the oil on the surface.

John S. Hutchins and Ernest Bond of EDC and Dan M. Bass of the Colorado School of Mines also proposed an alternative way to recover heavy oil called the flip-flop process. In this technique, the upper surface of the reservoir is exposed, perhaps in an underground cavern, and dikes are built around the edge. The surface is then covered with hot saline water saturated with surfactants and other additives. The hot brine seeps into the reservoir, warming the oil, which then floats to the surface. The name derives from the fact that the oil and water exchange places, or flip-flop. This approach has never been attempted and is very controversial. Some critics argue that the energy lost to the air from the surface of the hot brine would be greater than the energy value of the petroleum recovered. Hutchins concedes that this is a remote possibility, but argues that research on the kinetics of the process needs to be conducted.

Shortly after these two reports were presented to the Bureau of Mines, however, the program was transferred to the Department of Energy (DOE), which has been notably less enthusiastic about petroleum mining. DOE commissioned a third report, this one by William F. Reed, Jr., of the Engineering Societies Commission on Energy, Inc., of Washington. This rather pessimistic report was devoted primarily to oil sands, but included a brief discussion of petroleum mining. Reed concluded that mining of both oil sands and depleted oil fields will make only a minor contribution to national energy requirements in the foreseeable future, providing perhaps 20,000 barrels per day (bpd) by 1987 and 100,000 bpd by 1995. He did recommend, however, that DOE finance relatively small (10,000 bpd) oil extraction facilities to test some of the techniques.

DOE also convened a small symposium on petroleum mining at its Bartlesville Mining Research Center last December after a glowing story about petroleum mining—based largely on the Golder and EDC reports—appeared in the Washington *Post*. Participants at that meeting report that DOE representatives were largely skeptical about the prospects for oil mining and that the meeting was very low key. In particular, the DOE officials argued that both the earlier reports were overoptimistic. DOE is continuing to support some research on petroleum mining, but the funds available this year are less than $300,000.

For the present, then, it appears that any major motion toward petroleum mining will have to come from industry, and the number-one candidate is Shell Oil Company. Last year, Shell bid nearly $3.6 billion to purchase Belridge Oil Company—the highest purchase price ever in a corporate takeover. Belridge's principal assets are some 376 million barrels of proven reserves of heavy oil and some deposits of oil sands. Shell thus paid about $9 per barrel for the oil, or about 50 percent more than the going rate in such transactions.

Shell will say very little about its plans for Belridge, since the deal has not yet been consummated but it is generally assumed that Shell will use some type of oil mining operation on the Belridge deposits. Through its Canadian subsidiaries, Shell has access to technology for both surface mining and in situ processes, and the company is expected to use one or both on its new acquisitions. If the company does so, the United States could have a significant oil mining industry much sooner than anyone expected.

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