OIL SHALE Mine and Engineering Experiment Station
RIFLE, COLORADO

UNITED STATES DEPARTMENT OF THE INTERIOR
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BUREAU OF MINES
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OIL-SHALE DEPOSITS OF COLORADO, UTAH, AND WYOMING

The Green River oil-shale formation of Colorado, Utah, and Wyoming is indicated by the shaded areas on this Geological Survey map. From 1,000 square miles in the Piceance Creek Basin, the most attractive area for industrial operations, about 400 billion barrels of oil could be recovered. The Oil-Shale Mine and Engineering Experiment Station of the Bureau of Mines is just west of Rifle, Colo., and the Petroleum and Oil-Shale Experiment Station is at Laramie, Wyo.
VISITORS INVITED TO VIEW THE OIL-SHALE PROJECT

In northwestern Colorado, only a few minutes' drive off U. S. Highway 6-24, between Rifle and Grand Valley, a history-making experiment is taking place in the mining of oil shale and the transformation of this material into gasoline, diesel fuel, and other useful products essential to a strong America. The site is that of the Oil-Shale Mine and Engineering Experiment Station.

This intriguing development of the Bureau of Mines, U. S. Department of the Interior, is open to the public and is being viewed by thousands of persons from all parts of the United States.

Special tours, conducted each weekday, permit visitors to follow, step by step, a sequence of fascinating events beginning with the mining of the gray-brown shale and ending with the refining of crude shale oil into gasoline, diesel fuel, and other important products.

The tours and lectures of the Bureau of Mines are so designed that every person can understand what is happening as he sees drillers at work in the mine, watches the shale being loaded underground with a huge electric shovel, follows the crushing and screening of the rock, and sees how the material is processed.

Nowhere else in the world can such a cycle of eye-filling events be observed, for the Bureau of Mines research in the field of synthetic liquid fuels is unique. The current work in oil shales at Rifle began in 1944 and is part of your Government's long-range program to make this Nation self-sufficient in liquid fuels, regardless of the international picture.

The oil shale being worked today is part of a tremendous deposit, from which at least 80 billion barrels of oil can be recovered from the richer beds in Colorado alone. If only this richer portion of the known shale were developed, it would yield almost twice as much oil as has ever been produced in the United States from petroleum and about three times the proved petroleum reserves remaining in the ground.
Experiments at the Oil-Shale Mine and Engineering Experiment Station near Rifle are constantly changing as your Government continues to seek better and more economical ways of transforming this vast reserve of shale into oil and the oil into commercial fuels and other products. The Bureau of Mines is not entering the commercial field of oil production; it is, however, showing how large-scale use of the idle shale can have vital importance to you and your fellow taxpayers.

As yet, no one can offer a time schedule for the commercial development of oil shale by private enterprise. However, recent improvements by the Bureau of Mines in mining and processing oil shale have lowered estimated product costs to a point approaching the competitive level. Meanwhile, the costs of finding and developing new petroleum have risen sharply, and consumption of petroleum products has continued at a rate far above the peak demand of World War II. All these factors make more imminent the day when an oil-shale industry will take its place in this Nation’s fuel economy.

Tours of the mine, oil-shale processing facilities, laboratories, and refinery start at the main gate of the experimental site, approximately 2 miles from the main highway (U. S. 6-24). Tours—free, of course—are conducted from Monday through Friday, at 9:00 a.m. and 1:30 p.m. There are no Saturday and Sunday tours. Because of limited parking facilities and steep roads, visitors ride to the oil-shale mine and other points of interest in Bureau of Mines vehicles.

Chambers of Commerce, clubs, school classes, and similar groups wishing to participate in tours at scheduled or special hours should write or telephone Boyd Guthrie, Chief, Oil-Shale Engineering Branch, Bureau of Mines, Rifle, Colo.
The Oil-Shale Project in Pictures

PLANT NESTLES AT FOOT OF ‘MOUNTAIN OF OIL’

An aerial view (p. 7) shows the Oil-Shale Mine and Engineering Experiment Station of the Bureau of Mines, approximately 7 miles west of Rifle, Colo. From mines at the base of the cliffs, high above the juniper-clad slopes, oil shale is carried in trucks 5½ miles down a twisting shelf road to the plant in the valley below. There, 2,200 feet lower than its point of origin, the shale is crushed and heated in retorts and the resulting crude oil refined. A half mile from the processing area are the living quarters of the staff. In the foreground are U. S. Highway 6-24, the Rio Grande Railroad, and the Colorado River.

OIL-SHALE MINING AREA

The site for mine buildings was carved from a mountainside. The general view (p. 8) shows: 1 and 2, Entrances to underground quarry development; 3, combined office and warehouse; 4, a "change house," where employees change clothing before entering and after leaving the mine; 5, shop and compressor building; 6, a portal, or entrance, to another mining area where various grades of shale are obtained for special research projects. Note the switchbacks on the road leading to the mining area. In these experimental operations, the oil shale being mined is known as the "Mahogany ledge." At this point it is 73 feet thick.
REMOVAL OF SHALE CREATES HUGE ROOMS

Underground rooms cut into the oil-shale formation by the Bureau of Mines could hold many houses. In a typical scene,
three pillars are shown at the right supporting the strong rock roof. Visitors touring the mine are told that three-fourths of the shale is removed and one-fourth left for support. The distance from the floor to the ceiling in the portion of the mine
visible in this picture is 27 feet. In the part of the mine that is now being worked, however, the rooms are 39 feet high on the upper level and 73 feet high after a second operation in which a cut 34 feet lower is made. To the left and in the distance is a machine that is used to raise men to the desired level to place explosives in holes drilled in shale before breaking it down by blasting.

BROKEN SHALE REMOVED FROM MINE ROOM

With one scoop, the electric shovel in the foreground (p. 10) loads 3 cubic yards (approximately 3 tons) of oil shale into a 15-ton truck for removal from the mine. This truck uses diesel fuel produced from oil shale. Note the portable unit at the upper left, which is producing compressed air for the vertical drilling jumbo at the right. Use of these machines, plus other advances in drilling and blasting methods, have made it possible to demonstrate that oil shale can be mined at surprisingly low cost. In a test run at Rifle, an average of 148 tons was produced per man for each 8-hour shift worked underground, a total believed unprecedented in underground operations. This indicates the high degree of mechanization.

NEW EQUIPMENT CUTS TIME AND COSTS

A special rig (p. 11), designed by the Bureau's mining engineers at the oil-shale project, helps speed the job of drilling blast holes into the oil shale before placement of explosives that will break the rock for removal from the mine. Two men on the rig each operate two drills. Each drill can be moved up and down or to the side and placed at any desired angle.
CRUSHERS BREAK ROCK INTO DESIRED SIZE

After leaving the mine, the oil shale is taken to crushers. In the first building, a primary crusher reduces the pieces to 5 inches or less. In the next building, another crusher breaks it
into pieces of any desired size, from \( \frac{3}{8} \) inch to \( 3\frac{1}{2} \) inches. Another crusher in this building can reduce the particles to \( \frac{3}{8} \) inch or smaller for special needs. Crushed shale is stored in bins, each
holding 150 tons, until needed for retorting. When heated in the retort (beyond stack in background), organic matter in the shale is removed as oil vapor.

**OIL SHALE WILL BURN WHEN IGNITED**

Technically, oil shale contains no oil. Instead, it contains an organic material known as "kerogen" that is converted to oil when heat is applied. As shown here, a thin fragment of rich oil shale can be ignited with a match and will burn with a sooty flame and an oil-like odor.

**GAS-COMBUSTION RETORT**

When oil shale is heated to about 900° F., the organic matter in it "cracks" or undergoes a thermal decomposition, forming
oil, gas, and a cokelike carbonaceous residue. This process is known as retorting. Many different retorts have been invented but very few successfully handle Colorado oil shale. Still fewer have the characteristics requisite for reasonable capital investment and low-cost operation on an industrial scale.

Engineers of the Bureau's Oil-Shale Engineering Branch have invented a mechanism that has these characteristics. It is called the gas-combustion retort. It operates continuously, and requires no water for cooling purposes and no external heating.
or cooling equipment. All heat exchange takes place between gas and shale within the retorting vessel.

A new gas-combustion pilot plant is scheduled for completion in the summer of 1954 and will be operated experimentally to provide the engineering and cost data that are needed for projecting the design to industry-scale size. The plant shown in the photograph will process up to 300 tons of oil shale a day and provide an adequate supply of oil for refining studies.

**NEW EQUIPMENT CONSTANTLY BEING TESTED**

In this pilot-plant building at the Oil-Shale Engineering Experiment Station, the Bureau of Mines is testing experimental retorting and refining units in an unceasing quest for better
ways of processing oil-yielding rock. This 6-ton-a-day gas-combustion retort is the pilot-plant forerunner of the 300-ton-a-day retort. Shale moves down through the retorting vessel continuously while gas flows upward through the shale bed. Air is injected in the central portion of the retort, and the gas burns, providing the heat for the retorting. Oil and gas driven from the shale by the heat are carried from the retort with the gas stream, and the oil is separated from the gas by equipment to the left of the retort. Part of the gas is recycled through the retort, entering at the bottom, and the remainder is vented.

OIL YIELD IS IMPRESSIVE

Here is a 103-pound block of rich oil shale and its equivalent in recovered shale oil. This block, less than 1 cubic foot in volume,

| Image 0x0 to 611x841 |

will yield 2.7 gallons of shale oil. An identical size block of average shale from the Mahogany ledge will yield about 1.75 gallons when treated in the gas-combustion retort described above. As recovered from the shale, the oil is extremely heavy or thick. Like petroleum, it must be refined to make gasoline, aviation jet fuel, diesel fuel, and other useful products.
REFINERY TRANSFORMS CRUDE OIL INTO PRODUCTS

In this equipment at the Oil-Shale Engineering Experiment Station of the Bureau of Mines (p. 17), the heavy oil recovered in the retorts is refined to make gasoline, diesel oil, and other fuels. A heater raises the temperature of the oil to approximately 1,000° F. at a pressure of 100 to 200 pounds per square inch. The resulting oil vapors then enter 1 of the 2 vessels at the right. There they are held at the proper temperatures long enough to produce the desired degree of “cracking,” which means that the larger molecules are decomposed into smaller ones to yield an oil containing higher percentages of gasoline and diesel fuel than the untreated crude oil. Some coke and gas also come from the cracking process. In the tallest tower (known as the flash fractionator), the liquid is separated into gasoline, diesel fuel, gas oil, and heavy fuel oil. In the smaller vessels to the left, the gasoline and diesel fuel are refined further. Visitors to the oil-shale project gain a clearer idea of oil-refining methods as they view this equipment and hear Bureau of Mines guides explain the interesting processes.

PLANT LABORATORY

No plant project is complete without a well-equipped testing laboratory. The major tests and analyses conducted in this laboratory consist of assays of the raw and spent shale, examinations of crude oil, water, and gases produced by retorting, analyses of the various refined and partly refined fuels produced in the refinery, and studies to solve problems and find out more about the characteristics of oil shale and its products. Much larger laboratories at the Petroleum and Oil-Shale Experiment Station, Laramie, Wyo., conduct an extensive program of basic research on oil shale and shale oil.
ENERGY CONTENT OF OIL SHALE

A tremendous amount of energy is sealed in the oil shales of the Green River formation now being worked by the Bureau of Mines. If the plant represented by this diagram produced 10,000 barrels of shale oil per day, its annual output would be only about one-sixth of 1 percent of the oil consumed by the United States last year. Roughly 600 such plants would be required to produce the total amount of oil used in the United States every year. However, there is enough oil shale in northwestern Colorado to keep 600 such plants running for nearly 150 years. Successful utilization of the oil shale in Colorado would mean economic and military fuel security for a nation now drawing on its natural petroleum reserves at an unequaled rate.

HOW OIL SHALE WAS FORMED

About 50 million years ago, during a period known geologically as the Eocene age, there were two great fresh-water lakes. Lake
Uintah covered a large area in northwestern Colorado and east-central Utah, and Lake Gosiute occupied much of southwestern Wyoming. After the lakes disappeared, there remained structural and topographic depressions known as the Green River and Washakie Basins of Wyoming and the Piceance Creek and Uintah Basins of Colorado and Utah, respectively. The best oil-shale deposit in the United States was formed in the Piceance Creek Basin.

At its earliest stage, Lake Uintah was a broad, stream-flooded plain bounded by mountains or hills, except on the south, where the surface must have been fairly low. Streams from the surrounding mountains deposited clays, mudstones, and sandstones on the plain, and their depositions became the floor of the lake. They comprise what is now called the Wasatch formation, which underlies the Green River formation.

As the shallow fresh waters of the lake accumulated, they encroached upon the smooth plain, expanding the shoreline of
the lake until the basinlike structure was filled with water. Even when the lake was full, however, it was shallow compared with its large areal extent.

During the Green River epoch (a period that lasted some 5 to 8 million years), inorganic matter continued to be carried into the lake by streams from the surrounding mountains. Also, dust and pollen fell upon the surface of the water and finally settled to the bottom. Plant and animal life in the lake varied from time to time, depending on climatic conditions.

There is evidence that the lake sometimes overflowed during wet seasons but contracted again in dry seasons. Thus, large portions of the shallow lake bottom were repeatedly exposed, and extensive mud flats became dried and cracked. Carbonaceous mudstones and thin coal beds along the shore lines indicate that marginal swamps persisted for considerable periods.

During some periods, the lake became rich in foodstuffs, and under these conditions enormous quantities of minute organisms, including bacteria, fungi, protozoa, plant spores, and pollens, were produced. As the organic matter settled on the bottom of the lakes, it became encased in the inorganic matter that was being deposited at the same time. Putrefaction of the plant and animal organisms may have occurred in the cool, stagnant, lower levels of water; and, subsequently the organic matter became altered further (more or less bituminized), resulting in a solid, amorphous material. In time, under the influence of the weight of succeeding deposits, this combination of organic and inorganic sediments hardened, forming the rock known as "oil shale."

When environment suitable for the formation of oil shale was upset by influxes of sand and fresh water, by variations in water level, and by other factors, organic matter was absent from the sediments deposited on the bottom of the lake and barren layers of rock resulted. Accordingly, some of the strata of the Green River formation, which is approximately 3,000 feet thick, are barren, and others contain the solid organic matter called "kerogen."
Evidently conditions were especially conducive to the formation of oil shale for 200,000 years, more or less, when the Mahogany ledge was being laid down; however, conditions must have varied considerably during that time, as there is wide variation in richness from one stratum to another within this series of beds. Usually, the dark strata are relatively rich in oil, and the light ones are lean.

HISTORY OF OIL-SHALE MINE AND ENGINEERING EXPERIMENT STATION

Oil shale was utilized in England to produce an oil (though not necessarily for a fuel) as early as the 14th century. France had an industry producing fuel oil from shale some 20 years before the first oil well was drilled. On a restricted scale, liquid fuels have been produced commercially in several foreign countries for many years.

In the United States there was considerable interest in oil shale in the 1920's, and several oil-shale companies were formed. A few actually built small-scale plants, one of the best known being the Catlin Works at Elko, Nev. During the period from 1926 to 1929, the Bureau of Mines established and operated a small experimental plant at Rulison, Colo., about 2 miles southwest of the present Bureau plant.

In 1944, while this country was still at war, a group of statesmen foresaw the possibility of an oil shortage in the United States. Demand for petroleum was increasing at an extremely rapid pace, while the Nation's reserve capacity to produce oil had diminished, and it was becoming increasingly difficult and costly to find new reserves.

Former Senator Joseph C. O'Mahoney of Wyoming and former Representative Jennings Randolph of West Virginia took the lead in advancing legislation to promote the development of synthetic liquid fuels. They were aided by many who recognized these three facts: (1) That this Nation should not depend on foreign
oil in an emergency, (2) that the United States contains one of the outstanding oil-shale reserves of the world and has coal reserves of great magnitude, and (3) that American ingenuity could develop better and cheaper methods of producing synthetic liquid fuels than those used in foreign lands.

As a result of the efforts of such men, the 78th Congress passed Public Law 290, known as the Synthetic Liquids Fuels Act, and it was approved by the President on April 5, 1944. That act authorized the Secretary of the Interior, through the Bureau of Mines, to construct and operate demonstration plants to produce synthetic liquid fuels from coal, oil shale, and other substances, for the purpose of furnishing industry the necessary cost and engineering data to develop a synthetic liquid fuels industry.

This enabling act authorized work to extend over a 5-year period, and 2 amendments (Public Law 443—80th Congress and Public Law 812—81st Congress) each extended the period 3 years. Accordingly, research and development work to effectuate the purpose of the Synthetic Liquid Fuels Act is authorized to continue until April 1955.

In selecting a site for the oil-shale project, the objective was to find a place that would be typical of those on which commercial projects would be established later. From geological information available on various oil-shale deposits in the United States, it appeared that the Green River formation was the only one likely to become commercially important in the near future.

The Green River formation covers large areas in northwestern Colorado, southwestern Wyoming, and eastern Utah. The thickest and richest beds are in northwestern Colorado, however, and this area probably will be the first to be developed commercially. Accordingly, surveys were conducted over the Piceance Creek Basin in northwestern Colorado, which includes the area bounded on the east by Government Creek, on the south by the Colorado River, on the west by Roan Creek, and on the north by the White River.

From investigations of this area, it was determined that opencut mining would not be practical, at least not for a long time, be-
cause the soil and lean shale covering the richest beds are too thick. Therefore, only regions adaptable to underground mining operations were considered in further studies.

Nineteen possible project sites were compared in detail on the basis of topography suitable for locating the mine, processing plant, and houses; terrain suitable for access to the mine and transportation of shale; water supply; proximity to existing power and communication systems; and proximity to a shopping center.

Finally, the Anvil Points area on Naval Reserve land, a few miles west of Rifle, was selected as the most desirable site for the project. The shale was of average quality for the general area, and the site was well-adapted to a small oil-shale operation. Undeveloped in any way, the area had no roads and was covered with sagebrush and juniper trees. Thus it was necessary to “start from scratch,” installing utilities as well as buildings.

Construction was begun in the spring of 1945. Roads and structures were started, and a mine was opened to supply shale to a retorting plant. Excavation for water and sewer systems was undertaken, as well as construction of power-transmission and telephone lines. Fifty demountable houses and several plant buildings were moved from the Bureau of Mines Helium Plant at Cunningham, Kans., which was closed after the war, and were reerected on the Rifle project site during 1945 and 1946. Before the road from the plant to the mine was completed, supplies were packed to the mine site on mules, and the miners rode horses to work. A portable compressor was pulled up the mountainside by manpower and horses in the early summer of 1945 to supply the compressed air required for an early start on the mine.

Late in 1945, the contract for the detailed design (based on design specifications furnished by the Bureau), fabrication, and erection of the first retorts was awarded the Southwestern Engineering Co. of Los Angeles. Erection of this plant and installation of the crushing and screening equipment were completed in the spring of 1947, and the first batch of shale was retorted on May 8, 1947. During this period, refinery-design studies were made, and early in January 1946 a contract for the detailed design, fabrica-
tion, and erection of the shale-oil refinery was awarded the Re­
finery Engineering Co. of Tulsa, Okla. Operation of the refinery
was begun July 11, 1949.

ACCOMPLISHMENTS AT RIFLE

Assuming that the costs of mining oil shale would be roughly
equivalent to those of mining coal in underground mines, many
persons thought that such high costs would be the principal
handicap to the establishment of an oil-shale industry.

Others, recognizing that the physical characteristics of oil shale
are favorable to mining in extremely large underground openings,
predicted lower costs. Few, however, anticipated that oil shale
could be mined as cheaply as has been demonstrated at the
Bureau’s Underground Quarry near Rifle.

In a production test run during September and October 1949,
its crew attained an average direct mining cost of 29.2 cents a
 ton and an average production of 148 tons per man-shift of
underground labor. Indirect costs, such as depreciation, had
to be estimated, for they could not be measured over a short
period. The total cost of mining the shale, crushing it, and
transporting it to the retorting plant is estimated at 48 cents a ton.
This estimate includes management, depreciation, taxes, and
insurance, but no depletion, profit, income taxes, nor off-site
installations such as power plants, waterworks, and dwellings
for workmen. Adding all these items (including 6 percent return
on the investment), the value of crushed shale delivered to the
retorts in an industrial operation would be about 75 cents a ton.

Studies have been made of many different retorting processes,
some of which originated in foreign countries and others in the
United States, and 8 different kinds of retorts have been operated
by the Bureau. These processes include: (1) Hayes, (2) flash
carbonizer of the Tennessee Valley Authority, (3) N-T-U,
(4) Royster, (5) thermal solution, (6) radiant, (7) gas flow, and
(8) gas combustion.
Bureau of Mines engineers have observed tests on two other processes. One of these was developed by the Union Oil Co. of California and employs a continuous, internal-combustion-type retort; the other was developed by the Standard Oil Development Co. and employs the "fluidized-solids technique." Under cooperative agreements with both companies, the Bureau has provided oil shale for test runs in their equipment.

Experimental work and cost studies made so far on the gas-combustion retorting process all indicate that it will be highly successful for industrial operations. The 300-ton-a-day gas-combustion retorting plant will provide the engineering information required for projecting the design to industry-scale size. A commercial retort would have a capacity of several thousand tons a day.

The experimental shale-oil refinery has been operating since July 1949 and already has demonstrated that gasoline, diesel fuel, distillate fuel oils, and heavy fuel oils can be made by thermal processing, followed by acid-treating and doctor-sweetening of the motor-fuel fractions. Although the cost of refining shale oil by this method would be somewhat higher than for petroleum, owing to higher refining losses, the cost still is within reason. Furthermore, the components lost, so far as liquid fuels are concerned (sulfur, nitrogen, oxygen, and unsaturated compounds), should have considerable value as raw materials for a chemical industry.

As in retorting, more than one refining process may be applicable to shale oil, and experimental work is being done on several such processes, both by the Bureau of Mines and by cooperating organizations.

Closely allied to mining, laboratory, and pilot-plant activities are cost-evaluation studies. Cost estimates are made on processes, beginning with the time they are tested in the laboratory and continuing through each stage of development. The primary purpose of estimates in the laboratory and small pilot-plant stages is to select the processes that offer the greatest promise for industrial use. Further development work is concentrated on
these. Later estimates, based on more conclusive data, are less subject to error and serve as reliable predictions of the commercial cost of manufacturing liquid fuels from oil shale.

Recent cost estimates are of interest because they show that the commercial cost of making shale gasoline and other liquid fuels on a large scale would closely approach the cost for the corresponding petroleum products.

The estimated selling price of shale gasoline at a refinery in the Los Angeles area, assuming a 6-percent return on the investment after income taxes, is 13 or 14 cents a gallon. For petroleum gasoline at refineries in the same area, the average selling price is about 12½ cents a gallon. Comparison of these figures explains why there is considerable talk nowadays about an oil-shale industry getting started in the relatively near future.
Questions and Answers

Question: Does oil shale contain oil?

Answer: No. Strictly speaking, the term "oil shale" is a misnomer, for the organic material it contains is a solid rather than oil, and the rock itself is a magnesium marlstone rather than a true shale. Under the influence of heat, the organic matter undergoes a chemical transformation, yielding a black, viscous, waxy oil. Because of the high wax content, the oil will not flow below about 85 degrees or 90 degrees F.

Question: What is the Mahogany ledge?

Answer: This is a section of the richest shale. 50 to 110 feet thick and averaging approximately 30 gallons per ton, which is considered to be of probable commercial importance during the near future. It contains the mahogany marker, a layer of altered volcanic ash about 6 inches thick near the upper extremity of the ledge.

Question: What are some of the elevations and distances on and about the project?

Answer:

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<td>U. S. Highway 6-24 to mine</td>
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<td>Rifle to Grand Junction</td>
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Elevations:  

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<td>Colorado River at water intake</td>
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<td>Residential area (ave.)</td>
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<td>Office building</td>
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<td>Retorts</td>
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<td>South Point</td>
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**Question:** How large can underground rooms be made without artificial support between pillars of oil shale?

**Answer:** In 1946, a test room 50 feet wide and 100 feet long was opened to determine how large rooms can be made without danger of roof failure. The width was increased periodically by 10-foot intervals until it was 80 feet wide. Then the length was extended to 200 feet. In 1951, a slab of shale about 20 inches thick fell from the roof, and it was concluded that underground rooms should be less than 80 feet wide.

**Question:** Does the naval reserve include most of the Green River formations?

**Answer:** No. There are three naval reserves; Nos. 1 and 3 are in Colorado, and No. 2 is in Utah. About 60 square miles of oil shale is within the naval reserves in Colorado. Altogether, however, Colorado contains about 2,500 square miles of oil shale, of which approximately
1,000 square miles is known to be thick and rich enough to have commercial value. The naval oil-shale reserve in Utah covers about twice as much area as the two in Colorado, but the beds of richer shale are thinner.

**Question:** How much oil can be obtained from the shale in the Green River formations?

**Answer:** Involving process economics, this depends upon the leanest grade of shale that can be exploited successfully. If we consider only the Mahogany ledge, it is estimated that the best 1,000 square miles of this rich shale in northwestern Colorado contains 125 billion barrels. Of this, at least 80 billion barrels could be recovered. The Mahogany ledge averages about 30 gallons per ton. If it becomes economical to mine shale producing 15 gallons per ton, we have an indicated deposit representing about 500 billion barrels in this 1,000 square miles. Of this, about 400 billion barrels could be recovered. As now mined, one-fourth of the shale is left in the ground in the form of pillars or roof supports. Information concerning the oil shales in Utah and Wyoming is not yet adequate to permit satisfactory estimates of the shale oil available from those States.

**Question:** Is crude shale oil of good or poor quality?

**Answer:** Shale oil has been described by an official of one of the leading oil companies as “not as good as our best but better than our worst” petroleum crude oil. All the conventional petroleum products, with the possible exception of lubricating oil, can be made from shale oil. However, as shale oil is not a natural petroleum, the same methods of refining do not apply.
Question: Can you get above the cliff near the mine?
Answer: Yes. There are two routes. One is to climb the face of the cliff via a path that has been so laid out as to avoid any vertical or overhanging areas, and the other is by automobile through Rifle, Rio Blanco, and Piceance Creek. By foot it is only a few hundred yards, but by automobile it is more than 60 miles. The mine water supply comes from springs above the cliff that flow into small reservoirs from which the water is pumped to an underground storage tank. From there it flows by gravity down through a pipe to the mine. Occasionally a mine employee climbs to the top of the cliff to check this water-supply system. Other parts of the project use filtered and chlorinated Colorado River water.

Question: Is all research on oil shale and shale oil performed in the laboratory at the Oil-Shale Engineering Experiment Station?
Answer: No. All basic research and some bench-scale investigations are conducted in the laboratories of the Bureau of Mines Petroleum and Oil-Shale Experiment Station at Laramie, Wyo. The principal function of the service laboratory at Rifle is to maintain and improve control of the plant operations, although some work of a research nature is carried on to solve plant problems.

Question: Are there other methods of refining shale oil?
Answer: Yes. However, catalytic cracking, currently the most popular method of making gasoline from petroleum, is not applicable to shale oil, at least not without modification, because nitrogen compounds in shale oil "poison" the catalysts that have been found satisfactory for petroleum.
Until recently, hydrogenation has appeared too expensive because of the extremely high pressures required at high temperatures. However catalysts have now been found that will permit hydrogenation at much lower pressures (1,000 as compared to 10,000 pounds per square inch). If shale oil is hydrogenated, nitrogen compounds are removed as ammonia and sulfur compounds as hydrogen sulfide. The hydrogenate then could be cracked catalytically.