HYDROCARBONS OF THE UINTA BASIN
OF UTAH AND COLORADO

REVIEW OF GEOLOGY AND FIELD WORK
By CLARK F. BARB
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SURVEY OF BITUMEN ANALYSES AND EXTRACTION METHODS
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REVIEW OF GEOLOGY AND FIELD WORK

BY CLARK F. BARB

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INTRODUCTION

The following discussion is partly from abstracts of the work of other investigators and partly from data obtained by the writer in personal studies of the Uinta Basin of Utah and Colorado. The object above all else has been to give concisely such data as seemed pertinent or interesting, and this will account for some of the apparently unrelated statements and a certain lack of continuity. The investigations made thus far have brought out information that it seems worth while to make public, as investigators may find it of some value in similar studies.

An attempt has been made to give something of the general geology of the region, and this material is chiefly a resume or abstract of the publications of other authors. The present author had neither the time nor the geologic training required for a detailed field study. Some comments regarding the widespread occurrence of the tar* sands are believed to be original, as no mention of the total area underlain by tar has been found in the literature. The predictions of probable occurrences and possible locations of tar deposits in Colorado are based on the continuity of certain beds from Utah into Colorado.

A considerable part of the discussion in this publication is devoted to the deposit of bituminous sands near Vernal, Utah. This is a result of the fact that more work has been done on the material from that particular deposit.

The approximate locations of the deposits of all hydrocarbons are shown on plate 1, which also gives the approximate age of the surface formations in the basin. A road map of the area is given in plate 2. This map is a composite of all maps available, although the most detailed information is from the access maps of the U. S. Grazing Service. Through the courtesy of the Service these maps were made available and the road locations were transferred to the base maps of Colorado and Utah. Some road information came from the U. S. Indian Service and some from individuals. Locations are only approximate because of errors in transferring them from one scale map to another.

Certain cost estimates pertaining to the construction of a plant to process the tar sands of the basin are included in the appendix. These costs were determined by others and are based on the type of equipment used by the Abasand Company on the Athabasca tar sands of Canada. The estimates do not include equipment for mining the sand nor the cost

*As used in this paper, the word tar refers to any of the liquid or semiliquid hydrocarbons of the Uinta Basin.
FIGURE 1. Geologic sections Uinta Basin, Utah. (Data from U. S. Geol. Survey publications and well logs.)
of a water supply. They are based on equipment costs as of November 1941 and apply to a plant to handle 300 barrels of asphalt daily.

GEOLOGY

Oil and mining men have known for many years that the hydrocarbons of the Uinta Basin are interesting and peculiar. Several forms are found there not commonly found elsewhere in the United States and probably not in the world, at least in appreciable quantities. Among the hydrocarbons are gilsonite (uintaite), wurtzilite, ozocerite, tabbyite, albertite (nigrite), native asphalt, oil shales, glance pitch, natural gas, coal, and crude petroleum. Some names such as rubberite, barberite, and elaterite are used locally in referring to some particular deposit.

The Uinta Basin is described by Winchester as a topographic as well as a structural basin, and the reason for this description is apparent to the eye. When viewed from one of the cliffs on the south edge of the Uinta Mountains, almost the entire basin can be seen as outlined by its natural boundaries. The basin is usually described as being bounded on the north by the east-west range of the Uinta Mountains, on the south by the east-west horizon of the Roan or Brown Cliffs, on the west by the passes of the Wasatch Mountains, and on the east by the rimrocks of the Rangely dome and the Grand Hogback. The basin is approximately 175 miles from east to west, 40 to 120 miles from north to south, and covers an area of about 8,000 square miles in Utah and about 7,000 square miles in Colorado. It is drained by the Green River, which flows from northeast to southwest across the eastern third of the basin. The principal tributaries of the Green are the White River, Duchesne River, Bear River, and Uinta River, with their auxiliary creeks.

The surface geology of the basin is generally characterized by Tertiary deposits, although Upper Cretaceous and older beds have been exposed in the stream valleys or on the flanks of the boundary uplifts. The Tertiary formations, with a total thickness of 500 to 12,000 feet, seem to lie unconformably on an eroded Cretaceous surface all over the basin. In some areas it seems that the Upper Tertiary may lie unconformably on Lower Tertiary beds. This has been mentioned by Winchester and is indicated by Spieker who reports the Uinta formation as lying directly on the Cretaceous along Asphalt Ridge near Vernal. The relief of the valley ranges from elevations of 4,000 feet along the Green River Canyon to 10,000 feet along the Roan Cliffs and the passes of the Wasatch Range. The elevation along the northern rim is 5,000 to 7,000 feet along the foothills but in the peaks of the Uinta Mountain Range rises to 12,000 and 13,000 feet. Within the basin proper, following

2 Idem.
the cultivated belt along U. S. Highway 40, the elevation ranges from 4,500 to 7,000 feet. The basin can thus be visualized as shaped something like a frying pan with upflung sediments around the rim and with the bottom warped by minor disturbances.

Within the basin the Tertiary formations are relatively flat but have local dips ranging from 20 to 30 degrees. The general geologic section is given below.

**GEOLOGIC SECTION OF UINTA BASIN**

<table>
<thead>
<tr>
<th>System</th>
<th>Formation</th>
<th>Thickness (feet)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recent</td>
<td>Alluvium</td>
<td>25-100</td>
<td>Chiefly gravel and boulders from Uinta Mountains</td>
</tr>
<tr>
<td></td>
<td>Uinta</td>
<td>500-1,000</td>
<td>Clay, shales, and coarse sandstones. Many red beds, some brilliant.</td>
</tr>
<tr>
<td></td>
<td>Bridger</td>
<td>500-1,000</td>
<td>Clay, shales, and sandstones. Similar to Uinta.</td>
</tr>
<tr>
<td>Tertiary</td>
<td>Green River</td>
<td>2,000</td>
<td>Sandstones, limestones, conglomerates, and shales. Oil shale in upper portion.</td>
</tr>
<tr>
<td></td>
<td>Wasatch</td>
<td>1,000-10,000</td>
<td>Shales; sandstones, locally bituminous, conglomerates. Many red beds. Some coal. Green shales.</td>
</tr>
<tr>
<td></td>
<td>Mesaverde</td>
<td>500^,000</td>
<td>Sandstones and shales. Oil shows in sandstones. Coal beds in lower portion.</td>
</tr>
<tr>
<td>Cretaceous</td>
<td>Mancos</td>
<td>2,500</td>
<td>Shales, dull gray.</td>
</tr>
<tr>
<td></td>
<td>Dakota</td>
<td>200-500</td>
<td>Sandstones and shales. Usual appearance.</td>
</tr>
</tbody>
</table>

The thickness of many of the formations is questionable because of the variation across the basin or because of the different values ascribed by different authorities. As one drives across the basin from Price to Myton via Utah Highway 53, the entire Lower Tertiary section is exposed and is seen to be of great thickness. There apparently is an
unconformity between the Bridger and the Green River and between the Uinta and lower formations, at least in part of the basin. Winchester\textsuperscript{4} mentions the Bridger as lying upon older formations at the north side of the basin and obscuring the Green River and Wasatch. Spieker\textsuperscript{5} mentions the Uinta as lying upon the eroded Mesaverde just west of Vernal, which indicates that the Bridger, Green River, and Wasatch are missing. (Gale\textsuperscript{6} had called this particular Tertiary formation the Wasatch, which would be a logical interpretation.)

\textbf{FIGURE 2.} Old city pit, about 300 yards from county pit, west of Vernal.

Regardless of the questions relative to their exact ages, the interesting fact remains that the Tertiary formations, and apparently only the Tertiary, contain the many hydrocarbons of the Uinta Basin, excepting only coal. Along with this fact the statement that all of the Tertiary formations are said to have been laid down in a fresh-water lake may be considered.

The author has asked the question whether these hydrocarbons have originated from a common mother material in these fresh-water deposits. On the face of things it may appear so. Nightingale\textsuperscript{7} has stated his belief that the gas of the Hiawatha and Powder Wash fields probably originated in the Tertiary beds in which it is found. Winchester\textsuperscript{8} has made a similar comment, but other authors have ascribed the origin to shale beds of the Cretaceous. A rather superficial examination of the hydrocarbons

\textsuperscript{4} Op. cit.
\textsuperscript{5} Op. cit.
\textsuperscript{8} Op. cit.
indicates a common relationship. Among the common characteristics are a peculiar tacky feel, resembling that of partly dried varnish, a rubbery odor when burned, and a peculiar shale-oil odor when distilled or retorted. This shale-oil odor is not always strong, but it usually can be detected, and it was that feature which first led the author toward thinking of a possible common origin. Another characteristic is resistance to atmospheric oxidation, which is exhibited by both solid and liquid hydrocarbons from some deposits. The author does not know about all of them. Another common characteristic is the fact that an extremely flexible, rubbery varnish or similar coating can be made from several of them and a final characteristic, which it is hoped may be common, is the possibility that they may be converted into rubber.

There are deposits of bituminous sands in the Uinta Basin where the tonnage may be measured in billions. This refers to tonnage available by open-pit mining, in some cases by power shovel without blasting. Perhaps the largest tonnage is at the Sunnyside asphalt mine about seven miles up the canyon from the Sunnyside coal mines. This is on a branch of the Denver and Rio Grande Western Railroad, a few miles east of Price, Utah. At present this asphalthic sand is being recovered by blasting, the use of the power shovel and aerial tram, and by crushing, for surfacing roads in the Salt Lake Valley. Here is a cliff of asphalthic sand (said to be upper Wasatch) about 1,200 feet high and several miles long.

There is a deposit in Asphalt Ridge, about three miles west of Vernal, 12 to 15 miles long, which outcrops again in Whiterocks Canyon about 25 miles northwest. The deposit at Vernal has been described by Spieker, who estimates that some two or three billion barrels of bitumen can be recovered by open-pit and underground mining. Possibly one-tenth of this, perhaps less, could be recovered by open-pit work. This deposit can be mined with a power shovel, as Uinta County is now digging it out with a patrol and bulldozer to build roads. The bitumen can be extracted by treating the fresh sand with hot water.

After the sand has been exposed to the air it does not seem to be affected by water. The local people have been using it for roads and sidewalks for forty years, and it lasts. They also use the bitumen for roofs which seem to last well. In 1934 the Utah Highway Department surfaced several miles of U. S. Highway 40 with the Vernal sand. A picture of part of this road (taken in 1942) is shown in figure 8. Although apparently there has been almost no maintenance on this road, it has a remarkably clean edge with no ravelling. It also has a rubbery feel when one walks or drives upon it. It is slippery when wet.

In Whiterocks Canyon is an outcrop of sand similar to those at Vernal and Sunnyside. It was mined years ago for road material but is not being used now. This deposit is on the west side of the canyon about six miles north of the town of Whiterocks and seems to be at the Uinta-
Mesaverde contact, although the Mesaverde is reported to be eroded or covered here. The contact may be Uinta-Jurassic as reported by Lupton and later by Gale. Lupton also reported an outcrop of bituminous sand at the base of the Wasatch (Uinta?) in Deep Creek a few miles east of Whiterocks.

Abraham reports a bituminous limestone deposit in Utah County, underlying the area from Thistle east to Antelope Creek and from Colton to the Strawberry River. The age is not given but must be Tertiary. He also mentions a bituminous sand about 1^2 miles from Thistle. These deposits are at the extreme western end of the Uinta Basin.

Abraham also reports a bituminous limestone 20 miles north of the town of West Water in Grand County at the eastern end of the basin. This is said to contain 50 percent bitumen and the material has been classified as a progenitor of gilsonite. He mentions a series of deposits of bituminous sandstones along Argyle Creek (a branch of Minnie Maud Creek) in Uinta County. The age must be Tertiary, probably in the Green River formation or upper Wasatch. The material is called argulite. Abraham also lists a pure, solid asphalt found in Tabby Canyon, nine miles southwest of the town of Theodore and 30 miles west of Fort Duchesne. The material is called tabbyite.

Abraham mentions a vein of albertite (nigrite), which is found about eight miles west of Helper and five miles east of Soldier Summit in Uinta County. (This location obviously is in error.) Albertite is classified as an asphaltic pyrobitumen and apparently occurs in Lower or Middle Tertiary formations toward the west end of the Uinta Basin.

Wurtzilite is a hydrocarbon reported as found only in Utah, about 50 miles southeast of Fort Duchesne, and along the heads of Indian, Lake, Avintequin, and Sams Canyons, which lead into the Strawberry River. This hydrocarbon is sectile and resembles gilsonite. (It is also listed under the names elaterite, aegerite, and aeonite.) It occurs in veins apparently in the Green River formation near the central part of the Uinta Basin.

Gilsonite is probably the most important hydrocarbon of the Uinta Basin at this time, based on tonnage mined and commercial usage. The largest deposits reported occur in veins in the eastern end of the basin, near Watson and north of White River, although other veins are known. The bitumen is solid, is shiny jet black, and has a brown streak. It is hard and friable but melts slightly in the hand and leaves a tacky feel and brown coating. The veins usually are nearly vertical with a general trend west of north. The gilsonite veins are said to lie in the Green River and Wasatch formations. Many of them apparently are in the Green

River only. The material is known also as uintaite and is listed as an asphaltite.

E. V. Deshayes, U. S. Bureau of Mines, Salt Lake City, has given some interesting data regarding the location and characteristics of gilsonite veins and oil seeps in the Uinta Basin. His comments are given verbatim in the following paragraphs, and the locations of the veins are shown in the approximate positions on plate 1. The letter is in answer to a question regarding the locations of the most important gilsonite deposits of the eastern end of the basin.

It is true that most of the important uintaite ("gilsonite") veins are north of White River. The confusion probably arises from the fact that most of the "gilsonite" which was mined until very recent years came from the Black Dragon vein and the Rainbow vein, both of which are south of White River. The principal reason why the above veins were the first to be exploited on a large scale was that they were the closest to a standard-gauge railroad. The Uintah Railroad (narrow gauge) was built in 1903 from Mack, Colorado, to Dragon, Utah, and a few years later it was extended to Watson, Utah. This railroad provided a transportation outlet from the Black Dragon vein and the Rainbow vein to the D. & R. G. W. railroad. Prior to this time, a small amount of "gilsonite" had been mined from veins north of White River and hauled by wagon to Price and Heber, Utah, and Rifle and Loma, Colorado. These routes were over almost impassable trails and the distances were from 130 to 180 miles. Naturally, the production was small until the Uintah Railroad was built.

After practical transportation was provided, production rapidly increased to a maximum of about 60,000 tons a year. Because of competition from other materials, particularly "blown asphalt" from oil refineries, production gradually decreased again in recent years to 35,000 to 40,000 tons a year.

The original plans had called for the extension of the Uintah Railroad northward across White River to serve the Bonanza vein and the Cowboy vein, but about the time that the "select" ore in the Black Dragon vein and the Rainbow vein was nearing exhaustion, it became evident that the construction of U. S. Highway 40 had provided a cheaper means of delivering gilsonite to the standard-gauge railroads. Consequently, the Uintah Railroad was abandoned in 1938. Practically all "gilsonite" now mined comes from veins north of White River and is hauled by trucks to Craig, Colorado; Heber, Utah; or Price, Utah. Probably as much as 80 to 85 percent of the total goes by way of Craig.

I have marked the approximate location of the most important "gilsonite" veins by black lines on the enclosed road map, and have numbered them from 1 to 15. There are many other small veins of no conceivable importance at this time.

No. 1.—Nigger Baby vein. This is a short vein not exceeding 14 inches in width at the surface and of a poor quality of asphalt. It has not been exploited.

Nos. 2 and 3.—Harrison vein and Hardaway vein. Both veins are parallel to and south of the Pride of the West vein. They are two to three feet in width at the surface and have been opened to depths of perhaps 250 feet.
The ore has a very high melting point and is of poor quality. It has been possible to market only a very small amount of asphalt from the veins. They are probably of little economic importance because of the availability of vast amounts of asphalt of better quality in the other veins.

No. 4.—Rainbow vein. (The northwest extension of this vein is usually called the Pride of the West vein.) This vein is from three to 10 feet in width and several miles in length. It has probably produced at least 50 percent of all the "select" ore produced to date. All of the available "select" ore is said to have been worked out and operations were discontinued several years ago. There is probably a large tonnage of "seconds" (high-melting-point ore) still available.

No. 5.—Black Dragon vein. (This vein is actually part of the Rainbow vein system.) There is a gap of about a mile between the two veins where the vein has split into a number of parallel veins too narrow to work.) The vein has an average width of between four and five feet for a distance of about four miles. It has yielded a large tonnage of excellent "select" ore, but this grade was exhausted and the mines abandoned about five years ago. There is a considerable tonnage of "seconds" still available.

No. 6.—Little Emma vein. It is in the north rim of White River Canyon and has a width of about four feet at a depth of 400 feet. One shaft has been sunk to a depth of about 1,000 feet and at that depth the vein is about five feet in width. The ore is predominantly a high-melting-point pencillated grade. Very little "select" grade has been found. It is being worked on a small scale.

No. 7.—Wagon Hound vein. It is parallel to and northeast of the Little Emma vein. It is two to four feet wide at the surface and several miles in length. It probably conforms to the general rule of widening with depth. It has not been developed.

No. 8.—Chipeta vein. This vein is about 12 inches in width at the surface
and is about 500 yards southwest of the Bonanza vein. No work has been done on it. It probably does not exceed a half mile in length.

No. 9.—Bonanza vein. This vein has an average width of about eight feet for a distance of a mile. It then splits into two branches. The south branch is usually called the Little Bonanza vein and the north branch the Independent vein. Both branches continue to the northwest for about two miles and both are about four feet in width. This vein system is the second largest in the basin and probably contains at least 4,000,000 tons of excellent asphalt. It is now being worked on a large scale.

No. 10.—Cowboy vein. (This vein is sometimes called the Bandana vein.) It is about three miles northeast of the Bonanza vein and has a maximum width of 18 feet. It has an average width in excess of 10 feet for about four miles. The total length of outcrop is eight miles. The vein certainly contains at least 8,000,000 tons and probably more than twice that amount. The vein is being worked at three places. One shaft has been sunk to a depth of 900 feet, and there is no evidence that the bottom of the vein is being approached. The average depth of the vein probably exceeds 1,200 feet. No "select" ore has been found, but wherever the vein has been opened it contains an excellent grade of pencilled ore, highly desirable for many purposes.

Recent development work indicates that both the Cowboy vein and the Bonanza vein extend at depth much farther to the northwest than their outcrops. Both vein systems pinch out on the surface where the surface is capped by the Bridger formation. The fissures did not extend upward into the Bridger for more than a short distance and then only as narrow stringers. Shafts sunk in recent years where the veins pinch out in the southeast edge of the Bridger capping, show that the veins widen rapidly with depth and probably extend for a long distance under the Bridger formation.

No. 11.—St. Louis vein. This vein crosses U. S. Highway 40 one mile east of Gusher, Utah. Little is known about this vein but apparently it is short and of little importance. The outcrop is not exposed at this time. Some of the first "gilsonite" mined came from this vein, but the production is believed to have been small. There has been no production for at least 40 years.

No. 12.—Fort Duchesne vein. This vein is about two miles north of Fort Duchesne. It is a short vein with a maximum width of about 24 inches. It was worked on a small scale until recently.

No. 13.—Pariette vein. (This probably is the vein referred to by Eldridge as the Culmer vein.) The vein is about seven miles south of Myton, Utah. It is several miles in length, and though very narrow on the surface, it gradually widens to five feet at depth. One shaft has been sunk to a depth of about 1,000 feet at which depth there is no indication that the bottom of the vein is being approached. This asphalt has the lowest melting point (276 degrees F.) of any in the basin but it is of very good quality. The vein is being worked on a considerable scale at two places about two miles apart. The development work on the vein has not been extensive enough to permit an estimate of the tonnage of asphalt available in this vein, but it is probably quite large. By working the vein to great depth, the ore available might amount to several million tons.

There are many other small veins in the basin, four of which are marked on the map near Ouray. Most of these veins are less than 12 inches in width.
HYDROCARBONS OF THE UINTA BASIN

on the surface and so far as is known are quite short. However, all of the veins which have been worked have gradually widened with depth and for that reason it is quite possible that some of these narrow veins may prove to be sufficiently wide at depths of 300 or 400 feet to be worked.

There are several very small veins of elaterite in the region between Strawberry Creek and Indian Creek. I have heard that there are similar veins in the Sowers Creek and Antelope Creek region. I am not personally familiar with the above districts. Though the mineral is usually referred to as elaterite, a more nearly correct designation would probably be wurtzilite. Very little of this mineral has been mined in recent years. The production has probably not averaged more than 50 tons a year.

I have marked the location of three oil seepages by green crosses. They are a few miles east of the Utah-Colorado line, one just south of Evacuation Creek and the other two on Oil Spring Mountain east of Dragon, Utah. The amount of oil is very small, being barely sufficient to form a thin film of oil on a small flow of water.

There are numerous deposits of rock asphalt along both the north and south rims of the Uinta Basin syncline. Several of the largest are marked by red circles. A considerable tonnage of this material has been quarried from the deposit a few miles west of Vernal, Utah. This was used to surface U. S. Highway 40 in that vicinity. The deposit five miles north of Sunnyside, Utah, has been producing steadily for many years. It is a very large deposit containing 10 to 12 percent asphaltum, and has proved to be an excellent road-surfacing material just as it comes from the quarry.

The following notes regarding certain hydrocarbons have come, from various sources.

Cowboy gilsonite vein: That portion of the Cowboy that has an outcrop width of four feet or more is about 7^2 miles long; it thickens

FIGURE 4. County plant for making road material.
with depth near the center and toward the northwest end but thins with
depth to the southeast. The northwestern part where it is four feet wide
on outcrop is in sec. 32, T. 8 S., R. 24 E.

It has been stated that there is a southeastern extension of the Cow­
boy vein (across the White River) that measures 32 feet in width; how­
ever, the existence of the extension has not been definitely proved.

Big Bonanza, or Independence vein: This vein ranges from 14 feet
to 5 feet in width at surface over 3^2 miles of its widest part. It is
located in T. 9 S., R. 24 and 25 E.

Wall vein: This is a small vein traced from NW section corner of
sec. 18, T. 10 S., R. 21 E., to SE section corner of sec. 36, T. 10 S., R.
21 E. It measures 14 to 16 inches in width.

Elaterite: This comprises two veins on north side of Strawberry
River in sec. 6, T. 4 S., R. 4 W. Uinta special base-line.

Three small veins are on the east side of Dry Canyon in sec. 25,
T. 4 S., R. 7 W.

One vein (large as elaterite veins go, one to two feet in width) is
on the west side of Dry Canyon, sec. 34, T. 4 S., R. 7 W.

One vein of medium size is in sec. 6, T. 6 S., R. 6 W., on the north­
west side of Indian Canyon.

Ozocerite: A small vein that has never been worked is located in
Road Hollow, 9.9 miles up Indian Canyon from Duchesne.

A bitumen locally called "liverite" seeps to the surface of the
Strawberry River in sec. 3, T. 4 S., R. 6 W. The material probably is
soft, or unweathered, elaterite.

An interesting feature of gilsonite is the possibility of making it
from other materials. A sample, said to have been made from the asphalt
at Vernal, recently came to the author from Salt Lake City. This material
had all of the physical characteristics of the natural gilsonite but acted
differently on destructive distillation. It was so reactive that it was found
impossible to distill it to dryness as could be done with the natural
material. The reaction apparently became exothermic and could not be
controlled in ordinary glass equipment above temperatures of 750
degrees F. (The temperature refers to the liquid. Vapor temperatures
were about 525 degrees F.)

Ozocerite is a hydrocarbon found along U. S. Highway 50 between
Colton and Soldier Summit. This is at the southwest corner of the basin.
The material is a mineral wax and occurs in veins in the Green River
formation. It has the tacky feel of gilsonite and the other Uinta Basin
hydrocarbons, rather than the slippery feel of ordinary paraffin wax.
The wax has a high melting point and is used industrially where this
quality is desired. Abraham mentions the occurrence in meteorites of a
material similar to ozocerite, an occurrence of scientific interest only.

The prices of all of the hydrocarbons mentioned are not known, but
gilsonite is said to sell for $30 to $35 a ton and wurtzilite for about $80 a ton, f.o.b. railroad.

The summary given above indicates the widespread occurrence of hydrocarbons in the Uinta Basin, all of them apparently in the Tertiary formations of fresh-water origin. There are many coal deposits in the basin but they are almost all of Upper Cretaceous age and lie under the strong unconformity between the Cretaceous and the Tertiary. It is the group of hydrocarbons that seem to be peculiar to the Tertiary, however, that especially interests this author.

Deposits of the bituminous sands have been reported from several localities in Utah and Colorado. Almost without exception the deposits of appreciable size seem to be in Tertiary deposits of the Uinta Basin of northeastern Utah and northwestern Colorado. The most extensive deposits apparently are in Utah, but as mentioned previously several outcrops are known in the Colorado area of the basin. There is a seepage of tar near the Hiawatha oil field on the Colorado-Wyoming border in Moffat County, Colorado. The seep was not visited by the author, but it is in an area covered by the Wasatch formation and probably comes from that formation. Samples of the tar have been examined and resemble those from other seeps of this formation. Some of the local ranchers have used this material, mixed with crankcase oil, to repair leaky roofs. The oil is added to reduce the brittleness of the natural material. This asphalt has been picked up in sheets a few feet across and an inch or two thick.

Another seep is located in a gulch in sec. 1, T. 9 N., R. 101 W. in
Moffat County. This seep is about 100 yards long and the saturated section in view is from five to 15 feet thick. The formation dips about 20 degrees to the southwest and apparently is a part of the Brown Park deposit of Upper Tertiary age. It seems to lie unconformably on a yellow shale of pre-Tertiary age. The appearance of the material and its tackiness resemble the deposit at Vernal, Utah, about 60 miles southwest. This deposit apparently is at the contact of Tertiary and Cretaceous beds. It can be most easily reached from the R. T. Buffham ranchhouse on Vermillion Creek, sec. 10, T. 9 N., R. 101 W. The Buffham ranch can be reached from the Greystone postoffice or Ladore postoffice in northwest Moffat County.

No records of other seeps in this immediate area were found by the writer, and local ranchers have not reported any other deposits.

Another series of deposits is in the southwest part of Moffat County, where the Wasatch formation outcrops strongly. There is a deposit along the west side of the Keystone Basin, in which the old Price Creek post-office was located. J. O. Stone, a rancher near the old postoffice (mail address at Meeker, Colorado,), pointed out several-places where the tar had seeped out. He remarked that it often was associated with springs, and that it could be found all the way from the Keystone Ranch to Rifle. The Keystone Ranch is in sec. 3, T. 3 N., R. 96 W. Apparently the tar is found in the Wasatch beds, which form the lower part of the Gray Mountains west of the road along Strawberry Creek toward Meeker. Mr. Stone also mentioned a deposit of tar and a seep near a spring on the road about 15 miles west beyond the Keystone Ranch and into the Coyote Basin. This seep, however, could not be found by the writer.

There is a continuation of the seeps of the Gray Mountains in the Wasatch or lower Green River formation west of the road from Meeker to Rifle. Several of the deposits have been tested and short drifts were driven into the outcrops. Some of these were examined but the material in sight was rather low grade, and the saturated beds did not appear to be more than five to eight feet thick. However, the slopes were often covered with soil and some of the tar may have been covered. These seeps can be found from the White River to Piceance Creek west of the Meeker-Rifle road. From Piceance Creek south there is little evidence of the deposits, as the Wasatch and lower Green River are covered with soil and vegetation. It is probable that the tar occurs in many places where it has not been observed or reported, as the tar sand weathers to a blue-gray color that is not readily noticeable. Unless the stone was scratched or there were deposits of tar in sight the presence of the tar would not be suspected.

Dart Wantland, of the Department of Geophysics of the Colorado School of Mines, has commented on the deposit along the Rifle-Meeker road. He stated to the author that the asphaltic bed, apparently lower
HYDROCARBONS OF THE UINTA BASIN

Green River in age, was observed along the cliffs west of the highway. He pointed out, however, that the material was not observed in the canyons of Piceance Creek farther west. The beds dip rather steeply to the west and may be below the surface along Piceance Creek. This deposit south of Meeker has been known as the Petrolite deposit and the hills are sometimes called the Petrolite Hills.

A well drilled on the Piceance Creek structure, sec. 9, T. 2 S., R. 96 W., reported about 300 feet of Maltha or tar sand, starting at 785 feet. Apparently the thickness of the tar sand is much greater in the basin than on the outcrop. The well was drilled about 10 miles west of the outcrop.

**FIGURE 6.** Steaming sand, which falls into truck below.

From Rifle to De Beque (about 30 miles) no indications of tar seepages have been reported. Possibly the tar beds are buried or are far underground, as the Green River formation dominates the topography. Logs of many wells drilled along the Colorado River report shows of oil in the Wasatch formation, but no records of the nature of the oil have been found. It is not known if it is a heavy tar or a relatively light oil. There are many shows of gas in these wells, and it is possible that the oils are of fairly high gravity. Somewhere in the bluffs near De Beque indications of the tar sands might be expected, but none is mapped or reported. A few miles west of De Beque the Mesaverde formation and Mancos shales are on the surface and no tar seeps have been found. Formations of Cretaceous or older age are on the surface along the Colorado River from De Beque to the Utah line, and no tar has been found there.

Seeps have been reported, however, from the Book Cliffs and Roan
Cliffs to the north, especially on the Utah side. Range riders state that relatively few seeps have been observed on the Colorado side of the line. This does not exclude the possibility that tar sands may be found. They simply may not have been noticed because of lack of seepages. The range men mention many veins of hydrocarbons in the Book Cliffs in both Colorado and Utah but generally speak of them as being only a few inches wide. Several have been mentioned as occurring along the bluffs of Piceance Creek and its tributaries, southwest of Meeker. Apparently these are in the Green River or Bridger formations.

Still farther north, again in southwest Moffat County, Colorado, are mapped outcrops of bituminous sands, and these have been mentioned to the author by ranchers. The Oil Map of Colorado, prepared by R. D. George in 1919, shows these outcrops extending southeast through Tps. 4 and 5 N., R. 100 to 103 W., about 10 miles north of the Rangely oil field. The map shows the surface rocks as being of Triassic and Jurassic age, but the more recent geologic map of Colorado, published by the U. S. Geological Survey, gives a more detailed distribution of the surface formations. Apparently all formations are older than the Tertiary, and, if this is true, the bituminous sands are of older age than have usually been found in the Uinta Basin. This deposit was not visited by the writer and the characteristics of the tar are not known. This outcrop appears to be a continuation of Asphalt Ridge near Vernal, Utah, but in Utah the formations are of Tertiary age resting on Cretaceous and the sticky tar is chiefly in the Tertiary sediments.

Numerous deposits of tar sands have been reported in Utah and many are well known. Some of those have been described in another part of this publication. However, in the southeastern part of the Uinta Basin are several deposits or outcrops that apparently have not been recorded or described in the literature. Some of these were called to the author’s attention by Albert Turner of Grand Junction, Colorado. Mr. Turner described several seeps along the north rim of the Book Cliffs in Utah, approximately 40 miles due south of Ouray, Utah, and reached by following the new CCC government road from Ouray to Seep Ridge. He said that there are many tar seeps and flows of tar at the foot of the cliffs, and deposits of tar one hundred feet wide or more may be found. He also stated that many seeps may also be found along the cliffs about twenty miles west of the end of the new road. Many of these seeps were covered as oil-placer claims about the end of World War I, but no commercial work ever was done except as assessment work. These deposits apparently are from twenty to forty miles almost due east of the Sunny-side deposit, which is now being mined.

Winchester mentions several feet of Green River sandstone saturated with tar and occurring a few feet below beds of oil shale. He gives

one location in sec. 9, T. 12 S., R. 25 E., which would be a few miles northwest of Dragon, Utah.

Woodruff\textsuperscript{14} mentions a petroliferous sandstone about 13 feet thick at the top of the Wasatch formation. The location was given as an "oil tunnel" on Whiskey Creek, Colorado, approximately in sec. 18, T. 5 S., R. 103 W., which would be a few miles north of the town of Atchee, Colorado.

Woodruff\textsuperscript{15} discusses the characteristics of the oil shows found in the Wasatch formation in the De Beque, Colorado, oil field. Many wells found shows of oil in the Wasatch. All the oils apparently were of a paraffin base. There is no mention of tar or heavy asphaltic oil shows; in fact, the contrary is specifically noted. These oils apparently resemble the type of oil found in the Hiawatha and the Powder Wash oil fields in northern Colorado, which produce from the Wasatch formation. There is considerable similarity in the lenticular nature of the sands of the three fields as remarked by different geologists. It is interesting to find that a recent test on the White River structure west of Meeker, Colorado, found no tar or heavy oil in the Wasatch but did find distillate in the top of the Mesaverde sandstone. A log of this well is included in the appendix.

Woodruff further remarks on the nature of the Green River formation near De Beque and mentions a "paraffin or asphalt" mine in this formation near the center of sec. 1, T. 17 S., R. 98 W., east of Roan


\textsuperscript{15} Woodruff, E. C, Geology and petroleum resources of the De Beque oil field; U. S. Geol. Survey Bull. 531-c. p. 61, 1913.
Creek. The numbers apparently are in error, and the location cannot be spotted exactly on the map. It is about 10 miles north of De Beque. He refers to another "paraffin" deposit in the Green River formation on Parachute Creek about 11 miles north of Grand Valley and says that it has been prospected. He comments on the purity of the material but states that it contains crystals of calcite.

Thomas S. Harrison, consulting geologist of Denver, recently mentioned to the author his observation of brown, waxlike material in the cliffs west of Meeker, Colorado, and south of the White River. Fred N. Johnson, Jr., of Meeker, also mentioned a material like beeswax in the bluffs just west of Meeker and north of the highway. These cliffs apparently developed in sandstones of Mesaverde age. The author could not find the material described but had very little time for searching.

Woodruff also refers to observations made by F. M. Endlich near White River, Colorado, and by Arthur Lakes near Rifle, Colorado, both of whom observed "paraffin" in the Green River formations.

Lakes\textsuperscript{16} gives some interesting observations on the asphaltic sandstones near Rifle, Colorado. He mentions beds of sandstone 100 feet thick, which are impregnated with asphalt, and which can be traced for two or three miles. He does not give the exact location but places the deposit as ten miles north of Kellogg's Ranch and about 25 or 30 miles from the railroad at Rifle Creek. He gives a sketch showing the tar just under the Green River shales with the strata dipping 25 degrees or more. This location must be to the north of Rifle and possibly is on the Rifle-Meeker road. If so the deposit may be the one that has previously been described, which was prospected during World War I. Lakes tells of veins of gilsonite in many of the Book Cliffs and asphalt and gilsonite on Two Water Creek near White River. (This location would be in Utah.) He further mentions an oil spring on Whiskey Creek and gilsonite veins two or three miles west of the asphalt deposit near Rifle Creek. This location probably would be in T. 2 S., R. 95 W.

Ray Janes of Meeker, Colorado, has observed deposits of asphalt on Piceance Creek and on Hot Sulphur Creek approximately twenty miles west of Rifle, Colorado. According to the geologic map of Colorado these deposits are probably in the Green River formation. He also mentions streaks of tar in the cliffs of many of the creeks flowing into Piceance Creek.

Douglass\textsuperscript{17} discusses the oil and gas possibilities of the Uinta Basin and mentions several hydrocarbon deposits. He refers to a sandstone member of the upper Mesaverde or more probably Lower Tertiary age, which is often saturated to thicknesses of 200 to 300 feet and which outcrops for a distance of 200 miles. He refers to a Cedar Butte outcrop

\textsuperscript{17} Douglass, Earl. Possibilities of petroleum in the Uinta Basin district: Oil and Gas Jour., April 26, 1928, p. 120.
in Uinta County, Utah, where this sandstone lies unconformably on white Jurassic sandstone and the seepage from above has saturated the Jurassic to a depth of 700 feet. (Apparently this location is near the White-rocks deposit mentioned at other places in this review.) He also mentions strata of Green River age along Raven Ridge near the Colorado-Utah line, which are cemented together with petroleum residue. This ridge may be a prolongation of Asphalt Ridge near Vernal, Utah, and runs southeast towards the Rangely oil field. Douglass refers to an oil spring on Whiskey Creek, south of Dragon, Utah, but near the Colorado-Utah line, which flows a stream of pure paraffin oil. This oil was refined on the site into three grades of lubricating oil. He classifies the sandstone as upper Wasatch or lower Green River and mentions several hundred feet of oil shale just above the spring. He also refers to "Seep Ridge" farther west and mentions many springs from which a heavy tar flows and is deposited on the slopes. He gives the age of the formation as lower Green River or upper Wasatch and states that the same horizon produces ozocerite at Soldiers Summit, Utah. The conclusions of Douglass regarding the hydrocarbons of the Uinta Basin are worth reading by anyone interested in the oil possibilities of this area.

E. J. Mayhew, geologist of the Great Lakes Carbon Corporation, has recently sent information regarding asphalt seeps on "Seep Ridge" in Utah through George H. Mulvey of Ouray, Colorado. He makes specific reference to a tar lake known as Bryson's Lake in sec. 5, T. 18 S., R. 24 E., in Uintah County, Utah. This location apparently is in strata of Wasatch age. Mr. Mulvey stated that the tar deposits were so deep
and heavy that he found a bear trapped in them and unable to escape. This recalls similar prehistoric scenes at the brea pits west of Los Angeles.

Clark\textsuperscript{18} comments on the asphalt-saturated sandstone of the upper Wasatch formation near Sunnyside, Utah. He states that the sandstone beds are known to be asphaltic only in the high divide between Whitmore Canyon and Range Creek and in Range Creek Canyon. He mentions about 1,500 feet of formation that is more or less saturated with asphalt. He makes the additional comment that the beds may be in the lower part of the Green River formation rather than in the Wasatch. His description of the location would put the deposit in T. 14 S., R. 14 E., in Carbon County, Utah. The deposit apparently is southwest of the outcrops of oil shale.

Winchester\textsuperscript{19} remarks that gilsonite, elaterite, tabbyite, albertite, wurtzilite, and nigrite are asphaltic materials, and ozocerite is of the paraffin type. He states that the ozocerite is found only in veins that cut beds of the Wasatch formation, whereas the asphaltic materials are found in veins that cut beds younger than the oil shales and all asphaltic veins are found in beds of the Green River or younger formations. This statement regarding ozocerite is confirmed by the observations of Douglass on ozocerite and paraffin oil seeps and also by the shows of paraffin oils in Wasatch beds at De Beque, White River, Hiawatha, and Powder Wash, Colorado, and at LaBarge, Wyoming.

Espach and Nichols\textsuperscript{20} give analyses of crude oils from the LaBarge field in Wyoming and two of these indicate a paraffinic oil. The third oil might be of asphalthic or naphthenic type, judging from gravities and pour points. The color of all oil samples was green. The LeBarge field produces from beds of Wasatch age.

OIL SHALES

The deposits of shales and the analyses of shales and the contained oils have been described by many authors, and little discussion of these will be given here. The map (pi. 1) accompanying this report shows the area covered by the Green River and other Tertiary beds, and the shale areas roughly conform with the deposits of the Green River formation. Naval Oil Shale Reserves 1 and 2 are indicated on this map. No commercial oil-shale plants have operated in this area, although there was widespread interest in a pilot plant that operated during the twenties. Attention has recently been directed to oil shales as a source of oil because of the present petroleum shortage.

A bibliography of articles on shale will be found at the end of this report, and analyses of representative shales and oils are given by J. O. Ball in the section on analyses.

COAL

It is not within the province of this report to discuss the deposits of coal in the Uinta Basin, but reference is made to the great reserves that outcrop around the edge of the basin. These deposits have been thoroughly mapped and discussed in numerous U. S. Geological Survey reports, many of which are listed in the bibliography. It seems that the

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greatest coal deposits are found in the Mesaverde formation (or equivalent formations), which form rimrocks along the southern and eastern part of the basin. This coal is of Cretaceous age. Some deposits of Tertiary coal are found in the basin proper.

One interesting deposit, which is locally known as "the coal that won't burn," is found in the upper Wasatch or lower Green River cliffs southwest of Wamsutter, Wyoming, and outcrops for miles south into Colorado. This coal is also known as a mineral charcoal and has been tested for decolorizing purposes. It is said to have considerable value for this purpose, but no commercial development is known. This deposit is heavily impregnated with crystals of alum, and in it plant remains can be found in a state of excellent preservation. Many leaves are perfect in form and texture except for the charred appearance. Some of them appear to be formed of carbon crystals and have a frosty appearance.

It is interesting to find that in the asphaltic deposits along the Meeker-Rifle road there are many specimens of charcoal in the sandstone with the asphalt. It is possible that they may be part of the source material of the bitumen, but under the microscope many appear to be broken particles of char that were washed in and deposited with the sand. That is, they were carbonized before being deposited in their present position.

Lignite deposits are often found in the Green River and some in the Wasatch but generally do not appear to be of commercial quality.

OIL AND GAS

There has been little oil and gas production in the Uinta Basin within the area overlain by Tertiary sediments. The exceptions are the Hiawatha and Powder Wash fields of northern Colorado. The Rangely oil field in Colorado produces from the Mancos shale of Cretaceous age, which is also the surface formation. The Wilson Creek, lies, and Hamilton Dome oil fields and the Thornburg gas field lie to the east of the Tertiary outcrops. The surface formations are Cretaceous. The old Craig gas field also started in the Cretaceous. The De Beque field has the Wasatch on the surface but the field has not been commercially productive. The Cisco structure in Utah starts in the Mancos shale. The White River structure west of Meeker, Colorado, has the Wasatch on the surface. This field has produced some gas but no oil. The Garmesa structure north of Carbonera has produced some gas that runs high in carbon dioxide. The surface formation is Wasatch or lower Green River. The Clay Basin gas field in the extreme northeastern corner of Utah produces from the Wasatch formation. Tertiary sediments are on the surface. The small Ashley Valley gas field southeast of Vernal, Utah, produced some gas from the Mancos shale, which is the surface formation.

It seems logical to expect productive Cretaceous structures within the Uinta Basin proper, but in order to reach them several thousand feet
of Tertiary sediments must be drilled. The relatively great depth probably has retarded deep prospecting in the past. There are many surface indications of structure within the basin, which certainly must be reflected in the deeper beds, so that the area is not without structural possibilities.

BITUMINOUS SANDS OF VERNAL, UTAH

REFERENCES

In studying the deposit of bituminous sands near Vernal, Utah, the author has made use of the technical literature as well as of information obtained in personal interviews. The author has reviewed fairly intensively nearly all of the geologic publications that cover the Uinta Basin. The well-known book of Abraham, "Asphalts and Allied Substances," also has been studied intensively. Out of this literature have come a number of ideas that seem to be pertinent to the Vernal deposit.

Winchester calls attention to the similarity of hydrocarbons of the Uinta Basin and to the possibility that they may have a common origin. Eldridge refers to the effect of gilsonite or gilsonite deposits on the vegetation of the area.

Abraham cites the excellent roads that were made from bituminous oil sands or rock asphalt found in Oklahoma. He refers specifically to the resistance of the material extracted from these oil sands to oxidation and to atmospheric weathering and to air blowing when hot. He mentions a rock asphalt in Grand County, Utah, as being the progenitor of gilsonite. He refers to the manufacture of rubber from the material extracted from rock asphalt, stating that this method was used in Germany during World War I. There are numerous interesting comparisons in Abraham's book that indicate that the Vernal material may have definitely outstanding qualities.

He makes no mention of the use of the Vernal deposit, in as much as it apparently was not widely known at the time he was collecting his data. The author of this review has been struck, however, by Abraham's reference to the extraction of semiliquid asphalt from bituminous sands merely by treating them with hot water. In several cases, he makes the definite and specific statement that such asphalts are superior in qualities to any asphalt produced in refineries from crude petroleum. This quality seems to be inherent in rock asphalts all over the world, but the production of such asphalts has been retarded because of high costs.

Abraham has referred to the resistance of some rock asphalts to

25 Idem, p. 117.
26 Idem, p. 122.
27 Idem, p. 147.
oxidation by blowing with air. He states\textsuperscript{28} that one Oklahoma product resists such oxidation to a far greater degree than any refinery material made from crude oils that he had tested. Two other men have made similar comments to the author regarding the bitumen from the Vernal deposit.

The observations of Abraham are in line with those of the author regarding the deposits in eastern Utah, and, if operations in the Vernal area can be found to be economically feasible, it is felt that a research program or an experimental plant can be amply justified.

**GEOGRAPHY AND GEOLOGY**

The bituminous sand outcrop near Vernal, Utah, is approximately three miles west of the town, which is the county seat of Uintah County. The area lies in the northeastern part of Utah and in the northern part of what is usually known as the Uinta Basin. Vernal is an inland town, with the nearest railroad facilities at least 100 miles away. The town lies on U. S. Highway 40, which is the main highway running east and west and is paved the entire distance from Denver to Salt Lake City. The nearest railroad connection to the east is at Craig, Colorado, which is the western terminal of the Denver and Salt Lake Railroad. The distance to Craig is 124 miles, over good pavement, with fairly easy grades. The bus time is approximately three hours.

The nearest railroad terminal to the west is at Heber, Utah, which is on a standard-gauge branch line of the Denver and Rio Grande Western Railroad running up from Provo, Utah. The highway distance to Heber is 131 miles. The road is paved, but has some heavy grades. This road crosses Strawberry summit at an elevation of 8,000 feet. In stormy weather some trouble may be expected with heavy snow on this pass. The total distance west to Salt Lake City is 180 miles, and the entire road is paved, having rather heavy grades over the mountain passes, both up and down.

There are two possible highway outlets to the south or southwest from Vernal. One outlet is by way of U. S. Highway 40 to Myton, thence across country on Utah Highway 53, which ultimately connects with U. S. Highway 50 and comes into Price, Utah. This cut-off of about 70 miles to U. S. Highway 50 is partly graveled and is very bad. It is not considered as a feasible route for trucks. The other outlet to the south is by way of U. S. Highway 40 to Duchesne, thence over Utah Highway 33 to Castle Gate, Utah, which also is on U. S. Highway 50. Utah Highway 33 comprises some 45 miles of graveled road, which is said to be fair. The wear on tires of rapidly moving trucks, however, might be excessive on this graveled road. Both Castle Gate and Price are on the main line of the Denver and Rio Grande Western Railroad into Salt Lake City.

There is no feasible highway outlet from Vernal north into Wyo-

\textsuperscript{28} Op. cit., p. 117.
ming. It would be necessary to cross the Uinta Mountains, with heavy grades and bad roads.

The town of Vernal is the main trading post of Ashley Valley, which is a prosperous agricultural area. At present there are no appreciable mineral deposits that have been developed in this section. Some coal is found, which is mined and used locally. The country along U. S. Highway 40 east to Craig, Colorado, is very sparsely settled and is used chiefly for cattle and sheep grazing. From Craig east there are numerous settlements along the valley of the Yampa or Bear River. From Vernal west along U. S. Highway 40 there are numerous agricultural communities, which seem to be reasonably prosperous, but one definite draw-

![Diagram of Asphalt Ridge](image)

**Figure 10.** Diagrammatic cross section of Asphalt Ridge showing geologic formations, unconformity, and approximate dips of beds. Bituminous deposits are above or near the unconformity. Mesaverde sandstone contains oil shows and stains, but these are unlike the bitumen above it.

back to further development of this area is the lack of a railroad. The country from Vernal west is generally well supplied with water by streams from the Uinta and Wasatch Mountains. There also seems to be an abundance of water in the immediate area surrounding Vernal.

The general geology of northeastern Utah has been described by many geologists. The surface exposures generally range from Upper Cretaceous through the entire Tertiary series. The town of Vernal apparently rests on an outcrop of Mancos shale. A mile or so west of the town there is an outcrop of Mesaverde sandstone (Cretaceous), and this sandstone extends into Asphalt Ridge, which carries the outcrop of bituminous sands. It was observed that the Mesaverde sandstone had some oil shows and brown oil stains at frequent intervals in the outcrops. These oil shows were noticed in many places, but there was a long period of erosion at the end of the Cretaceous period, and it is difficult to determine definitely in Asphalt Ridge just where the Mesaverde sand-
stone stops and the bituminous Tertiary sandstones start. At the north end of the ridge, in sec. 25, T. 4 S., R. 20 E., there has been a fault of considerable magnitude with the downthrow on the north side. A hasty examination indicated a displacement of perhaps 300 feet, but this figure is a rough estimate. The bituminous sand, which was mined in the state pit far up on the outcrop of the ridge, is found in the bottom of the valley about one-quarter mile north, and on the east side of the gully the fault line is rather well defined. The general direction appeared to be southwesterly and northeasterly, but it could not be traced definitely because of heavy overburden. Spieker\textsuperscript{29} shows this fault line as running almost diagonally across section 25. This fault is interesting, as it may have some bearing on the quality of the asphalt, which may be found to the north or south of it.

All the formations, both Cretaceous and Tertiary, dip generally to the southwest, but the Cretaceous formations seem to have a slightly steeper dip. This indicates that there may have been an uplift to the east during Cretaceous time, with the center of disturbance possibly along the axis of Split Mountain, which lies approximately on the Utah-Colorado boundary, almost due east of Vernal about 20 miles. Apparently after this first movement there was a period of erosion and Tertiary deposits were laid down on the already displaced Cretaceous formations. It should be remarked here that some of the sandstones of the Mesaverde show extensive cross-bedding, which may give exaggerated indications of dip. During Tertiary time, deposits were laid down probably almost horizontally in the fresh-water Tertiary lakes of the Uinta Basin, and in post-Tertiary time there was an uplift of the Split Mountains, which gave the Tertiary deposits their present inclination of approximately 12 to 20 degrees.

The Tertiary formations of Asphalt Ridge were defined or described originally by Gale\textsuperscript{30} as belonging to the Wasatch formations. This conclusion can be readily understood as there is no indication of the Bridger or Green River formations in the immediate vicinity of Vernal. The natural assumption would be that they were eroded in post-Tertiary time. The formations that outcrop above the Cretaceous show the alternating red and gray colors, and at other exposures the formations are similar to those of the Wasatch. The most noticeable difference is in the color of the beds. The red is not the exact shade of red ordinarily seen in the Wasatch, but is more brilliant.

Spieker\textsuperscript{31} described the Tertiary formations of Asphalt Ridge, which lie unconformably on the eroded Cretaceous, as being Uinta. Spieker apparently traced the Uinta formation from its type section all the way through to Vernal. The puzzling thing is what became of the Bridger,
Green River, and Wasatch formations at this point. If they originally were in place here, they apparently have also been eroded, and the Uinta must lie unconformably upon them somewhere farther west and south.

Perhaps it is well to comment here, for the benefit of those not familiar with this area, that the Uinta is at the top of the Tertiary series and the Wasatch at the bottom, with several thousand feet of fresh-water sediments between them. (See the geologic cross sections, fig. 1.) The logs of wells drilled in the basin have indicated the saturated bituminous sandstone as being rather widespread over the area. The Western Venture well in the southeast quarter of sec. 6, T. 5 S., R. 21 E., reported an oil show at a depth of 1,270 feet, and about 30 feet of oil-

FIGURE 11. View of the north end of Asphalt Ridge looking west from Vernal saturated sand. This well was drilled less than one mile west of the outcrop and could be expected to strike bituminous formations.

In June 1942 the Union Oil Company drilled a well in the southeast quarter of sec. 21, T. 4 S., R. 20 E. It reports the base of the Duchesne River formation on the top of the Uinta formation at 1,230 feet. This log reports a trace of tar-coated limestone at 1,530 feet. It reports the approximate top of the Mesaverde sand at 2,035 feet. Good oil shows were reported in the Mesaverde sandstone at from 2,093 to 2,218 feet. This well was abandoned, however, as it apparently was not of commercial importance. When it was visited by the author in August 1942, the cores taken by the Union Oil Company were still on the location. These cores showed a section of approximately 100 feet in the bottom of the Uinta, which was saturated with asphalt, very similar in appearance and feel to that found farther east in the outcrop at Vernal. This well was drilled approximately three miles west of the state pit in sec-
tion 25 but is on the north side of the fault. It was noted in the Union log that a faint rotten-egg odor was noticed near the bottom of the last core taken. This of course indicates hydrogen sulphide. It may be remarked that the odor of hydrogen sulphide is not noticeable in the Vernal deposit. A copy of the Union Oil Company log is in the appendix.

Another well was drilled about 12 miles east and two miles south from Myton, Utah, which is about 35 miles southwest of Vernal. This well was reported as being drilled by the Utah Southern Oil Company, which reported a good showing of a heavy tarry oil at a depth of about 1,800 feet. It is said that several barrels of heavy oil were bailed from the well, but commercial quantities could not be obtained and the well was abandoned. The log of this well was not available, but some notes were obtained from M. F. Toles, the driller. A copy of his letter is included in the appendix.

There is another outcrop of bituminous sand about six or seven miles north of the town of Whiterocks, where the Whiterocks River comes out of its canyon into the valley. These white rocks, which gave the section its name, are almost vertical cliffs of sandstone, which are partly saturated with a tarry material. Some of this material was mined years ago for paving material. The writer visited the outcrop and noted that the surface formations are almost identical in color and texture with those at Vernal. However, they are nearly vertical, as they have been turned up against the flank of the Uinta Mountains. A mile or so to the south they probably are almost horizontal, as indicated by the surface formations. This outcrop is approximately 25 miles across country from the outcrop at Vernal. Local inhabitants report traces of this bituminous material in outcrops as far west as Strawberry Pass, which is nearly 100 miles west. These statements were not checked, however, by the author.

There is another outcrop of bituminous sandstone near Sunnyside, Utah, about 75 miles south of Vernal. This deposit occurs throughout a thickness of nearly 1,200 feet of sandstone in the upper part of the Wasatch formation. It is being mined at the present time as road material and is being used on highways in the Salt Lake Valley. The sandstone at Sunnyside is considerably harder than that at Vernal and is blasted and crushed for use. There is no attempt at extraction of the oil, but the crushed sandstone is shipped by railroad and used just as it comes from the plant. This deposit also is of Tertiary age and may have some relationship to those at the north end of the basin.

There are several other hydrocarbon deposits in the Uinta Basin that are peculiar and interesting. Among these is the ozocerite deposit near Soldier's Summit, at the western edge of the Wasatch Basin. This is a mineral wax similar to the paraffin wax obtained from crude oil but having a much higher melting point and a resinous feel. This ozocerite
occurs in vertical veins in the Wasatch formation and apparently is a filling material of fault fissures. The veins are said to narrow with depth.

Another striking hydrocarbon of the Wasatch Basin is gilsonite, deposits of which occur rather widely throughout the district. This hydrocarbon is a jet-black material, quite brittle and very friable. It occurs in vertical dykes or veins, which are said usually to become wider with depth. These veins occur apparently in the upper part of the Wasatch and in the Green River formations, although the total depth does not seem to be definitely known. As they appear in the valley, they definitely are of Tertiary age. Gilsonite has been used for making synthetic rubber and at the present time some work along that line is being done in Salt Lake City. The author, in August 1942, saw a sample of rubber that was said to be made from gilsonite. The rubber seemed to be of excellent quality. The minable supply of gilsonite, however, is limited as many of the veins are too narrow to work.

A noteworthy feature of all these solid hydrocarbons is the more or less parallel direction of all the veins. An interesting characteristic of the gilsonite is the fact that when crushed in the hand it leaves the same sticky, tacky feeling that is characteristic of varnish on the skin. The color of this material is a light brown. This same color and tacky feeling were found in the bituminous sand at Vernal, at Whiterocks, and at Sunnyside. It was observed to a lesser degree in the ozocerite at Soldier Summit.

Another hydrocarbon of the district is wurtzilite, which has some
of the characteristics of gilsonite. This material also has some resem­blance to the other bituminous deposit mentioned.

There are several other hydrocarbons in the basin which have local names, but which probably would fall within the general classification of those already mentioned. These different hydrocarbon deposits have been mentioned in connection with the Vernal deposit, with the idea of drawing attention to the possible common origin of all. Many of these hydrocarbons are known throughout the world as peculiar to the Uinta Basin. Certainly they are rarely found elsewhere in the United States. If there is a common relationship, it might be possible to process some of the larger deposits of bituminous sands and extract material of appreciable value. It is possible that all of these bear some relationship to the well-known oil shales of the Green River oil-shale formation, a relation­ship suggested to the author by the peculiar odor of the heated hydro­carbons.

All of these hydrocarbons, from the bottom to the top of the Ter­tiary series, apparently are of fresh-water origin, and the geochemical conditions under which they were formed may account for their odd characteristics. The geology of the entire Uinta Basin is interesting, but lack of time and space prevents further discussion of it here, except as it pertains to the Vernal deposit. A list of publications discussing the basin has been included in the bibliography.

BITUMINOUS DEPOSIT AT VERNAL

The bituminous deposit at Vernal has been very well described by Spieker,\textsuperscript{32} and any comments made here will be chiefly in confirmation of his work.

The tarry material saturates a considerable thickness of the sand­stone faces of Asphalt Ridge. These sandstone beds, however, cannot be traced consecutively from one end of the deposit to the other, a distance of some fifteen miles. The asphalt seems to have saturated the sand according to permeability and degree of cementation. In some places the asphalt seems to have partly saturated the underlying Mesaverde sandstone; in other places, particularly in the deep valley, in sec. 15, T. 5 S., R. 21 E., the asphalt appears to be far up on the bluffs of the Wasatch or Uinta formation and very little is found in the underlying Cretaceous, or even in the Lower Tertiary beds. The Mesaverde sandstone, however, shows stains very similar to the stains observed near Vernal. It appears as though there may have been two periods of saturation by oil, and by oils of quite different characteristics. The oil stain found in the Mesaverde does not appear to be the same material as the asphalt found in the Tertiary formations.

The asphalt occurs generally as a stiff, tarry material which almost

\textsuperscript{32} Op. cit.
completely fills the core spaces of the sand. When freshly mined the sand has much the feel and texture of dark-brown sugar. It can be molded in the hand much as ordinary brown sugar can. The sandstone is quite resistant to erosion and to abrasion by mechanical means, and this may be a definite difficulty in mining. It usually can be easily scratched off with a knife blade but is very difficult to break down with a pick. This is because of the rubbery and ductile nature of the tar. It acts as a tough binder. In many places in the Vernal deposit the tar has flowed out or seeped out and can be stripped off the ground or rock faces in large sheets. This almost pure material can be found in every stage of age and oxidation, from a material about like molasses to an oxidized material that resembles slack coal. When fresh it has a bright, mirrorlike surface. It is very black by reflected light. In thin sheets the material is a Vandyke brown by transmitted light. The harder material has a brown streak similar to gilsonite. In several places where the fresh tar is oozing from the sandstone beds, gas bubbles were noticed, breaking as the tar emerged. This indicates at least some gas in solution and under pressure somewhere down the dip to the southwest in the basin.

The thickness of the bituminous beds at Vernal ranges from a very thin film to almost 100 feet of apparently solid sand. Spieker has covered this point thoroughly, but it is believed that there may be a larger acreage of minable material than Spieker seems to have calculated. Spieker, for example, mentions one or two outcrops along U. S. Highway 40; it was observed by the writer, however, that almost the entire reverse slope of

the hill is a continuous outcrop, which may have been exposed by erosion since Spieker was over the ground. U. S. Highway 40 here follows a dip-slope grade westward for almost a half mile.

In the limited time available to the author, it was hard to estimate the approximate tonnage of sand that could be mined without handling excessive overburden. To make any accurate estimate would require some tedious detailed mapping of exposures and thicknesses. However, on the basis of approximately 1,600 cubic yards of sand per acre-foot, and with an average sand thickness of perhaps 20 feet, it is possible that about 32,000 barrels of oil might be recovered per acre of exposure. This assumes a recovery of one barrel of oil per cubic yard of sand. This rate of recovery per acre would be considered good in the average oil field. There must be at least a few hundred acres of exposure that are readily minable and have a thickness at least as great as that quoted above. This would run the estimate of easily recoverable oil into the millions of barrels.

An interesting peculiarity of the deposit was the fact that the freshly mined sandstone feels very cold. When the deposit was visited by the writer, the normal air temperature was found to be nearly 100 degrees F. Samples of freshly mined sands from the county pit were examined, and wherever handled this peculiar or distinct feeling of coolness was observed. It was noticed on samples of sand that had been exposed to the air for some time, even though they had been covered by overburden to a depth as great as that of the freshly mined material. This feeling of coolness apparently was due to water that coated the sand grains, which evaporated when it was exposed to the atmosphere or was held in the hand. It is probable that this water film is responsible for the fact that the oil is easily removed from the sand when it is treated with hot water. If the sand is allowed to stand until this feeling of coolness disappears, it responds much less readily to the hot-water treatment. This merely indicates that the water film has been at least partially removed and the oil has had a chance to coat the sand particles completely. This feeling of coolness was noted at Vernal and at Sunnyside, where mining operations also were under way. It was not noted at Whiterocks as no fresh excavations were being made.

The statements made above regarding the general nature of the bituminous sands at Vernal can be applied to those at Whiterocks and at Sunnyside also. In general it appeared that the rock at Whiterocks and that at Sunnyside were somewhat harder than that at Vernal. One other noted difference was the absence at Vernal of the odor of hydrogen sulphide, very strongly noticeable at Whiterocks and less strongly at Sunnyside. In other respects the nature of all three deposits seemed almost identical. There were seeps of fresh tarry material at Sunnyside and at Whiterocks, with small gas bubbles sometimes breaking, and the flows of tar which had oxidized could be found in every state of ductility.
After weathering, some of this material changed until it resembled a brittle soft coal.

Photographs of the deposits at Vernal, Whiterocks, and Sunnyside are included in the illustrations.

MINING OPERATIONS

All three of the bituminous deposits mentioned above have been mined at one time or another in the past. The Sunnyside deposit is now being mined on a commercial scale, approximately thirty tons per hour, for use as a paving material on Utah highways. The Vernal deposit has been mined fairly extensively in years gone by for the same purpose. At this time the operations at Vernal are small, as the only work being done is by the road department of Uinta County. Some of the operations at Vernal are shown in figures 2-9.

The present method of mining as used by the county commissioners consists in breaking the deposit with a road patrol carrying one very heavy tooth. This tooth merely acts as a plow to break up the oil-saturated sand. This material is then handled by a bulldozer, which pushes it over a grating, where it is subjected to jets of steam. These operations of breaking and mixing by the bulldozer, together with the steam jet, convert what apparently was solid sandstone into a road material of about the consistency of brown sugar, with some small lumps in it. This road material, after falling through the grating and steam jets, is dropped through a chute to trucks, which haul it out to the highway. The entire method is one of ingenious simplicity. As the photographs show, there has been no heavy capital investment for installations.

Another proposed mining method involves a somewhat different procedure, using a power shovel with a specially built bucket. This bucket would be relatively narrow at the top and wide at the bottom to prevent the asphaltic sand from sticking to the sides, thus enabling it to dig out sandstone faces without overstressing the shoveling equipment. The reasoning underlying this procedure seems logical after viewing the operations at the Vernal County pit and at Sunnyside. At Sunnyside the rock had to be blasted before it could be handled with a shovel.

Additional processing of the sand after mining is also proposed. The treatment consists essentially of stirring the sand in vats of hot water. This hot water seems to free the oil from the sand rather quickly and quite completely, and the heavy tarry material can be recovered for whatever use is desired. The process more specifically calls for running the saturated sand through a pulper, where it gets a preliminary treatment with warm water, and any lumps are broken down to relatively small size. From the pulper the sand is carried to a screen, where it is further treated with jets of hot water and the coarse material is screened out. The fine material and the oil drop into flotation cells of conventional design, where the oil is further separated from the sand and floated away.
on the surface of hot water. The oil or tar is skimmed off and may be further treated in a retort to remove suspended sand and water. Even after this treatment the tar carries a small percentage of extremely fine material, from 200 to 300 mesh, and this is rather difficult to remove, although it is stated that the fine material can be removed if necessary. For road material it is probable that the fine material is not objectionable; for use as fuel oil it might clog burners and cause trouble.

The percentage of recovery of oil from the sand seems rather phenomenal. The sand from the final washing cells comes out almost white and apparently perfectly clean. This cleanliness of extracted sand refers particularly to material freshly mined. Oil sand that has been exposed to the atmosphere does not respond so readily to treatment. It appears that the film of water previously mentioned probably is responsible for this ease of extraction. Apparently no chemicals are required in treating the fresh sand, but the quality of the water used does seem to affect the efficiency. It is stated that the water from Vernal or the Ashley Valley worked much better than the city water at Salt Lake City. A rough test made at the deposit at Vernal, using a tin can and water from Vernal, apparently gave a high degree of extraction and a very clean sand.

At the present time there is no commercial installation either of mining or extraction equipment at Vernal. There is a small testing plant at Salt Lake City with a daily capacity of four or five tons. Material from the county pit is hauled to Salt Lake City for testing and laboratory use. One complete test run was observed by the author on material taken at the county pit, hauled to Salt Lake City by car, and processed in the test plant. On this particular run the laboratory men, in order to have absolutely fresh material, excavated an outcrop to a depth of about six feet. The sandstone was drilled with approximately one-inch augers and the holes were then shot with ten and fourteen sticks of forty-percent dynamite.

These charges broke out a face about six feet deep and six or eight feet high, and the fresh material was immediately shoveled into paper-lined sacks in order to prevent its oxidation. It took two men about one and one-half hours to drill the two holes for shooting. This was because of the extremely gummy nature of the material and the difficulty of withdrawing the augers. As soon as the material was shot the freshly exposed face was observed carefully. The sand had a salt-and-pepper appearance, which apparently was due to free grains of white, rounded silica sand in a darker background of asphaltic material.

This fresh material when handled had the characteristic cool feel, and when it was rubbed rapidly between the palms of the hands the sand grains could be rubbed out completely. They separated as clean, free white grains. The asphaltic material remained on the skin as a dark-brown, sticky coating, which had the tacky feel of partly dried varnish.
This material could not be removed from the skin with plain water, either hot or cold, but could be imperfectly removed with soap and hot water. Kerosene or diesel fuel removed it almost instantly and left the skin perfectly clean.

The ability to rub the sand out was not observed on material that had been exposed to the air for any appreciable time. The exposed material would stick to the skin, but the sand grains remained in the asphalt.

Samples of fresh sand, as stated above, were run through the test plant at Salt Lake City and an excellent separation was obtained, using only hot water and agitation. The laboratory manager stated that experiments had been made using soap and sodium silicates, and that with these separation was sometimes more easily effected, but that the extracted oil had a tendency to emulsify. This is a normal reaction and is to be expected.

Some thought was given to the possibility of underground mining of this sand, but in the author's opinion it is not entirely feasible by present methods of mining. At several places in the Vernal deposit, at Whiterocks, and near Meeker, Colorado, tunnels have been driven back into the deposit 100 feet or more. These tunnels, however, are of nominal size and could not be considered large enough to extract material on a commercial basis. Something akin to coal-mining extraction or the stoping methods of metal mines would have to be employed. This would involve timbering problems which probably would be extremely difficult. One of the county commissioners of Uintah County, when asked about underground mining, remarked that he doubted if it would be successful. He said that this material had a tendency to flow after the tunnel had penetrated a few feet. Of course the roof could be supported by timbering, but the cost of timber and the quantities needed probably would be excessive.

There is a bare possibility that the underground oil might be recovered by the use of a hot water drive. This might be done by sinking wells and pumping in hot water, similar to the procedure used in Pennsylvania and the shallow sands of eastern Kansas and Oklahoma; or a modification of the Ranney mining method might be used. In the Ranney method it would be necessary to tunnel either through the sand or directly under it, and drill holes from this tunnel into the main sand body. Some combination of the Ranney method and a hot-water flood is possible. Heated gas or air, or possibly steam, might be used, but the author is skeptical regarding the feasibility of these. The cost of heating water for a water flood probably would be prohibitive. In the Bradford field of Pennsylvania, for example, the average property requires an input of about ten barrels of water for every barrel of oil recovered. Unless this Vernal deposit contains products of premium quality and premium price, it is doubtful that underground methods will be economically successful.
Facilities needed for mining at the county pits are relatively close at hand. Water of good quality may be obtained from the town of Vernal, approximately three miles east, or possibly from an irrigation ditch about one and one-half miles east. According to those familiar with the property, about one barrel of water would probably be required for every barrel of oil recovered. Coal for heating may be obtained near Vernal at a quoted price of about $2.50 a ton for slack grade. Electric power is reasonably close as several REA lines cross that part of the country. As fuel for heating water it might be possible to use the bituminous sand itself, for the oil content is high enough that the material probably would burn in a mechanical stoker. It is not known whether or not this has ever been tried, but it seems possible.

In mining the Vernal deposit it will be necessary to strip off the overburden and a certain amount of weathered bituminous sand. This will involve the question of disposal of waste and this question was given some consideration when the author visited the deposit. There is a considerable area of waste land lying to the east of the deposit and between it and the irrigated land of Ashley Valley. It should be possible to acquire title to enough of this land for disposal of waste from the mining operations. This waste will also include the sand from the extraction plant and this material will run into considerable tonnage, when the plant goes into commercial operation.

The top surface of the bituminous sands, ranging in thickness from a few inches to about two feet, probably has weathered to such an extent that extraction would be difficult. This material will have to be stripped off and disposed of. Observation at the county pit, which is now in operation, indicates that this top surface of weathered material can be used for local roads, and, therefore, need not be entirely a waste product. At the present time the county is mixing this somewhat weathered material with fresh sand, and it seems to make a perfectly satisfactory pavement. It would not be desirable, however, for plant processing.

The waste sand, which is rather fine, resembling ordinary sugar, must be disposed of either by conveyor belt or hydraulic system or some other method. It occurs to the author that if this sand is piled in hills of appreciable size (which probably would happen), in the event of a cloudburst or extremely heavy rain, it would probably wash down the hillside and out into the irrigated and cultivated fields of the valley itself. This ordinarily would lead to damage suits, and the possibility should be guarded against as much as possible.

It may be that the downhill slopes of the waste sand can be coated with some of the bituminous sand from the outcrop, which would prevent appreciable erosion. These particular references to possible damages will apply chiefly to the deposit near the town of Vernal itself. Toward
the southern end of the deposit there is a large acreage of waste land, which should take care of any possible problems of this kind.

In laying out a mining program for this deposit, it should be remembered that the formations dip to the southwest, that is, into the hill, at a rate of 10 to 20 degrees. As the shovels work into the mountain and down-dip, they will naturally leave an excavation in which water will tend to accumulate. Provision for drainage must be made, and the lowest possible point of drainage should be considered in estimating reserves. Any estimation of reserves below this point should consider the cost of pumping water which, under certain conditions, might be a serious problem.

![Old Dooley pit on Asphalt Ridge in sec. 25, T. 5 S., R. 21 E. (About 45 years old.]

**USES**

The most obvious uses of the extracted oil apparently would be for road oils, asphalt, roofing materials, and asphaltic cements, and for similar purposes. Streets, sidewalks, and highways in and near Vernal have been constructed of this material for the past 40 years, and the author made some observations of sidewalks and streets laid in Vernal about 1904 or 1905. Some were said to date back to 1895. In these cases the asphaltic sand was laid on a plain clay surface to a depth of about one and one-half inches. The material in these old installations is not in good condition at this time; it generally is hard and has been eroded considerably. Much of it still is in place, however, and after 40 years' use it could hardly be expected to be in good condition.

Streets and highways paved within the past 20 years generally are in fair to excellent condition. A number of the installations were purely
experimental and some of these are in only fair condition now. In one the asphaltic sand was mixed with copper sulphate, for what reason the writer could not learn. This installation has been in use for about 20 years on the main street of Vernal, and it is still a fair road surface, although rather rough. One installation on U. S. Highway 40, extending for several miles west of Vernal, was put down in 1934, and this road is uniformly good today, although the surface was only one and one-half inches thick. This material as taken from the mines or pits shows a tendency toward longitudinal cracking on the road. It is said to heal itself, however, when run over by traffic in warm weather.

There has been some use of the Vernal material in Colorado, particularly on the streets of Denver, where a few experimental batches were put in some years ago. This work was done by Luke Smith, a highway contractor in Denver. Mr. Smith stated to the author that some of the extracted oil from the Vernal deposit was shipped to him and he mixed it with sand from Clear Creek near Denver. This mixed material was used to patch holes in the pavement on some of the streets in Denver where the traffic was very heavy. Mr. Smith said that this material wore unusually well and stood out as bumps in the highway long after the original road material was gone. Later, all of the roadway was torn up and resurfaced with ordinary road oils.

Mr. Smith stated that in his opinion this material had unusual qualities as road-surfacing material and would justify some experimentation, if the transportation difficulties could be overcome. He said that some of this material was also used at the Denver municipal airport for patching the runways, which had been constructed of ordinary road oil in years gone by. He said that the heavy wind caused by the propellers on large planes had a tendency to sweep the gravel and even the rock out of the surfacing that was laid down originally. Some of these holes were patched with the Vernal mixture, and it was observed that this erosional effect caused by the propellers seemed to be almost entirely eliminated. He commented that probably the chief reason for this was the fact that the Vernal material does not harden with age as ordinary road oil does but retains its original elasticity and cementing quality for many years after it has been laid.

Mr. Smith mentioned the possibility of blending the Vernal asphalt with ordinary road oils in order to make a suitable paving material. He spoke of the tempering effect of this Vernal asphalt and suggested that from 15 to 20 percent of it added to ordinary paving material might have a very beneficial effect. He seemed to question the feasibility of using 100-percent Vernal material because of high transportation costs.

He warned, however, that unless the Vernal material is laid on a good subgrade or base just as any other road oil, it will not give satisfactory service under heavy traffic. He also made the comment that this road material does not become wavy, or corduroy, or washboard even
on hillsides with rather steep slopes, as the road oils that he was accustomed to ordinarily did. He commented that this might be a desirable quality for paving such as the runways of airports, where the landing shocks had a tendency to start waves of this kind.

It may be remarked here that another engineer experienced in airport construction made a similar comment to the author in discussing this characteristic of the Vernal material.

Another point regarding the use of Vernal material for roads and pavements was mentioned by several inhabitants of eastern Utah. They stated that the highways covered with Vernal asphalt do not become so icy in winter, or do not remain icy so long as highways on which other road oils were used. The only reason the author can give for this is the possibility that the Vernal material may be blacker or darker than the other road oils, which naturally would cause the pavement to absorb heat from the sun's rays and thus melt off the ice or snow more quickly. There does not seem to be any mechanical reason why this melting action should take place.

Another possible use of the Vernal material may be for the coating of pipe or other steel work to resist corrosion. This possibility occurs to the author merely from what little experience he has had with the material, and it is not known whether or not any comprehensive tests have been made. It was stated to the author by someone in eastern Utah that a gas company, which had had some corrosion trouble with its pipe line in the Ashley Valley, had used this material as a protective coating and found it very satisfactory. It was also said that an inhabitant of Vernal some years ago had set up some test specimens of pipe coating with different bituminous materials and tars and found the Vernal material to have superior qualities in this respect, but this statement has not been confirmed by the author.

It appears, by more or less superficial observation, that the Vernal material may have this quality because of its extreme sticky and tacky feeling. After it is once dehydrated it seems to stick to anything and is not easily removed except by organic solvents.

Still another possible use of the material may be in the manufacture of bituminous paints and varnishes. As stated previously, the tar has been used locally around Vernal for painting roofs, both wood and metal, and also for re-covering old composition roofs. Apparently, however, no one has made an intensive effort to prepare a really high grade bituminous paint or varnish from this particular deposit.

Such products, however, have been made for many years from gilsonite and wurtzilite and from some of the other hydrocarbons of the Uinta Basin. It is the author's impression that some of the bituminous varnishes prepared from gilsonite are rather high grade and command premium prices. This possibility of making a similar material from the Vernal deposit has been suggested, because of the tacky, varnishlike
feeling common to all of these hydrocarbons. This is merely a suggestion and can only be confirmed by experimental work.

Another possible use of the material is in the manufacture of rubber or a material that could replace rubber for some of our present-day industrial demands. Some experimental work is being done, but an entirely satisfactory product has not yet been obtained.

While in Utah, the author saw some samples of rubber which were made from gilsonite, or at least that was the origin ascribed to the samples. After checking with several persons of reputable character in Salt Lake City it was found that for many years people in that area have believed that rubber can be produced from gilsonite or wurtzilite with rather low priced equipment. The chief draw-back to the use of such material for rubber is the limited supply of hydrocarbons available. It occurs to the author that, if there is a common characteristic of gilsonite and wurtzilite, the Vernal material, and other hydrocarbons of the basin, there may be a possibility of making rubber substitutes from this source. At Vernal there would also be the possibility of an adequate supply to partially satisfy our immediate needs for rubber or rubberlike materials. If mining operations should be started on a commercial scale the production could be calculated in some thousands of barrels a day. In an emergency, it might be possible to process this into rubber if the need was justified.

It may be remarked that the sample of rubber which the author has and which was said to have come from gilsonite has all of the characteristics of rubber according to the simple tests that were run here.

There is a possibility also that high-octane gasoline may be produced by cracking this material, and if there is need for additional fuel of this type a small cracking installation might be justified. The author has little direct information regarding the cracking of this material and the products that may be obtained, except from some laboratory work which has been done in three different cities. The Kansas City Testing Laboratories reported a rather high yield of high-quality gasoline, and this has been confirmed by experimental work which was done at the Colorado School of Mines two years ago. It is not known whether or not the octane value of this product could be pulled up from the reported figure of 80-octane to the desired figure of 100-octane by the addition of another allowable material or by further processing.

It seems that the raw material from Vernal cracks very easily and at low temperatures. If the material was to be cracked for motor gasoline only, the installation of a cracking plant at Vernal would be difficult to justify, as will be pointed out in later paragraphs.

Another characteristic of the Vernal material may be mentioned as a curiosity only, as it probably has no commercial value. This characteristic, as reported by local inhabitants, is that the Vernal sand accelerates the growth of vegetable matter. It was observed that there was
vegetation growing all over the outcrops, even in what apparently was pure tar sand, but it was found in Vernal that lawns have been planted directly on material that was laid as sidewalks or pavements, and the grass seems to grow as well there as in other parts of the city.

The owner of one lot dug up a section of his lawn for the author's benefit. The grass was growing directly on top of the asphalt sand and the roots had penetrated through it, apparently without difficulty. The grass was in good condition and, if anything, greener than in other parts of the yard. It was noticed that, where the grass roots had grown through this asphalt sand, the bitumen had lost its original character as a resilient, rubberlike material and had become entirely dead and lifeless. It could be crumbled up in the hand without difficulty.

Incidental to this characteristic it was observed that the author of one of the U. S. Geological Survey Bulletins on gilsonite deposits made a similar comment regarding gilsonite, stating that the veins of gilsonite often could be traced across country by the eye merely by the band of vegetation that covered them.

The author of this review made some remark in Salt Lake City regarding this and was told that lawn grass could be grown on pure gilsonite merely by adding water. It was stated that the seed did not merely sprout and then die, but actually fed on the gilsonite and flourished. It is very likely that these bituminous deposits may carry some of the phosphates that are so common in the Uinta Basin and that the phosphates merely act as a plant food and fertilizer.

A further possible use of this material, which has been suggested
by mining men, is as a flotation agent in milling certain types of ores, although the author has not been able to confirm definitely the value for this purpose.

Another possible use of this material is as a heavy fuel oil for power plants, railroads, and steamships. The extracted oil is quite heavy, barely floating in water, and has a high pour-point, about 50 degrees F. This high pour-point will cause difficulty in handling the bitumen, which can, however, be cracked rather easily to a fuel oil with a pour-point slightly above freezing. In this case it would be fluid enough for normal use.

The foregoing list of possible uses may indicate a cure-all for industrial ills, but the author is not offering them for this purpose. He merely wishes to list the suggestions that have been made to him or that he has observed, with the idea that someone may see some possible use or outlet not apparent at the present time. After all, this is a perfectly new and virgin deposit and should be treated as such. Any work that may be done should be by men with perfectly open minds and without any preformed views or any thesis to defend. As stated at the beginning of this section, in the author's opinion the most immediate use of this material is for road oils, asphalt, and pavements.

MARKETS

In considering the possible markets for the Vernal material or for products which may be made from it, there comes up first the question of distances and transportation, and second, the distribution of population, which normally affects the marketing of any product.

The uses of road oil are partly independent of population, as major highways must be laid regardless of the concentration of population or distances between towns. Secondary-road systems will naturally depend somewhat on population itself. In the states immediately surrounding the Vernal deposit there is a good possibility of road-oil markets: in Colorado, in Utah itself, possibly in eastern Nevada, southern Idaho, and southwestern Wyoming. Within this area there are three or four transcontinental highways running east and west and about the same number running north and south. The exact mileage of these roads has not been calculated, but some estimate of the possible road-oil needs may be obtained from the annual consumption of road oils in these states in the past. The consumption figures for Colorado, Utah, Idaho, and Wyoming are given in table 1 on page 53. These figures are broken down into requirements for new highways and requirements for maintenance of old roads.

Under the conditions of the present emergency, it is doubtful that any new highway construction can be contemplated, and it is also doubtful whether or not maintenance may be carried on at a normal rate. For that reason any consideration of markets for road oils for the next two
FIGURE 16. Sketch map of Asphalt Ridge, Utah. (After Spieker.)
or three years should be based on maintenance figures only. This is assuming that shipments of the oil will be made only normal distances, and that there is no unusual demand for airport construction or for use in other areas. If the production should be found to be of premium quality, shipments may be made greater distances, and the demand may be increased accordingly.

The amount of oil required to satisfy the average maintenance needs of the states mentioned above is approximately 300,000 barrels a year, which would involve mining approximately 300,000 tons of sand each year, or 800 tons a day based on continuous operation. This assumes that approximately one barrel of oil may be recovered from one ton of sand. Judging from the analyses of this material that have been made available, this recovery probably could be made.

The calculations given above for road oil are based on the assumption that none of these states produces any road oil of appreciable value. That situation is not true in Wyoming, which is primarily a road-oil-producing state, particularly in the northern part near the Montana line. It probably would be very difficult to sell Utah road oils in Wyoming because of the local situation. This situation normally would not exist in Colorado, Utah, or Idaho.

If the possible markets include also the manufacture and distribution of gasoline, a different picture is evolved. In the first place, the manufacturing facilities at or near Vernal must be expanded appreciably in order to produce gasoline of good quality. This would require high-pressure equipment for cracking the crude oil and special equipment for chemical treating and additional processing of the finished products. The capital investment required would be much higher than that required for making road oils only. The capital investment for processing per barrel of daily capacity probably would be increased at least three times.

If the gasoline is being made as a motor fuel only and is not a premium-grade aviation fuel, the normal market would be only that of the ordinary automobile fuel.

As was mentioned earlier in this report, Vernal is an inland town in a relatively thinly populated section of Utah. The normal marketing area for ordinary motor fuels would be along U. S. Highway 40, either east toward Craig, Colorado, or west toward Salt Lake City. The country east toward Craig, which is 124 miles distant, is almost entirely unsettled. About 20 years ago there was an influx of homesteaders into that district, and at one time the population was considerable. The author recently observed, however, that probably 80 percent of those people have left the country. Therefore, looking east from Vernal, there is virtually no market for gasoline until one reaches the vicinity of Craig. At Craig the Texas Oil Company has a refinery with a capacity of 2,000 barrels a day, which can produce enough motor fuel to supply all of
northwest Colorado. Recently, the author finished a four-year survey of the oil and gas industry of Colorado in which a rather close analysis of marketing conditions was made. An estimate of the crude-oil reserves of northwest Colorado was balanced against the refining capacity of the refinery at Craig and the normal marketing demand of northwestern Colorado.

This survey indicated that there is enough crude oil in sight in Moffat County in fields that are now drilled to keep the refinery at Craig running for the next 40 years. This estimate was based on the 1940 gasoline demand of the Craig marketing area.

In view of this situation, the author does not consider it feasible to make gasoline from tar at Vernal, Utah, to compete with gasoline now being produced from crude oil at Craig, Colorado.

Looking westward toward Salt Lake City there is a different and better picture, because the country is more thickly settled and the competition from Colorado crude-oil is more distant. At Salt Lake City, about 180 miles to the west, however, there are two refineries, one of which is processing crude oil brought in from Lance Creek, Wyoming, by pipe line. Any gasoline produced at Vernal must meet the competitive price, which will be established by gasoline produced in Salt Lake City. It is entirely possible that the Vernal product could meet this competition on an economic basis, in as much as the Salt Lake City crude oil probably carries a freight charge of 50 cents a barrel.

The author has been unable to make a complete break-down of the gasoline-marketing situation in Utah, as he finds the state keeps no
detailed record of sales by counties or any political district. An effort was made while in Salt Lake City to obtain such figures, but they were not available. Those figures were available, however, for the survey made in Colorado.

It was also found in Salt Lake City that there were no figures available on the motor-car registration by counties in Utah. Otherwise an estimate of the probable requirements for a county could have been made on the basis of motor vehicles in use. The author, therefore, has been forced to fall back on a rather superficial study of the country as he traveled over it, and to estimate that the gasoline requirements in the counties immediately surrounding Vernal will be relatively small. This does not mean that a small refinery might not be able to produce gasoline economically to satisfy the local demand, but it appears doubtful that a widespread market could be depended upon. It certainly could not to the east, in competition with Craig. There also is a small refinery at Jensen, Utah, a few miles east of Vernal, where oil from the Rangely field is refined into products for local consumption.

If this Vernal material can be easily processed into a high-quality, premium-grade aviation gasoline, the picture would be considerably different. In such case, the output of a plant probably would be limited only by its ability to produce fuel rather than any normal market demand. The author, however, has no figures on which to base any estimate of this kind.

The markets of other possible products such as high-grade paints or varnishes will be limited chiefly by a national demand for material of this type and quality, rather than any local limitations. If the price of the finished product is sufficiently high, transportation costs cease to be an appreciable factor, and in such case, the limit of daily production would be merely the limit of normal demand for this type of material. The preceding statement would apply to almost any specialty product of premium quality that may be made from the Vernal material. It would be true also of rubber, if this material is found to be suitable as a synthetic-rubber stock.

The market for fuel oil, particularly heavy fuel oil of Bunker C grade, in the opinion of the author, is definitely limited, if not entirely non-existent. It is difficult for the author to visualize the mining and processing of material of this type, in a deposit as far from the railroad as the Vernal deposit lies, in order to produce merely a Bunker C fuel oil. It seems that it would cost more to deliver this material in Salt Lake City than Bunker C fuel ordinarily is worth. If military requirements necessitate the production of fuel oil under such conditions, however, the element of cost can be eliminated to a great extent, although it can not be ignored in any operation of the plant in normal times.
### TABLE 1

**CONSUMPTION OF ROAD OILS**

(Gallons per year)

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<th>1941</th>
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<td>Idaho</td>
<td>2,993,201</td>
<td>1,548,319</td>
<td>4,489,149</td>
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<tr>
<td>Utah*</td>
<td>4,200,000</td>
<td>1,680,000</td>
<td>Average for 3 yrs.</td>
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<td>Wyoming</td>
<td>4,231,846</td>
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<td>5,660,942</td>
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<tr>
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<td>265,000</td>
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<td>Average barrels per day</td>
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<td>1,200</td>
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*Detailed figures for Utah not available.*
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APPENDIX

WELL LOGS

The logs of some of the wells drilled in the Uinta Basin have been obtained and are given in the following pages. Some of the logs were in abbreviated form but give the points of most interest for this survey. Only those wells that have penetrated all or a part of the Tertiary series have been noted and reprinted.

Three wells were reported by the U. S. Indian Service at Ouray, Utah, for which no logs were available. Two of the wells are in sec. 32, T. 14 S., R. 20 E., and are marked "old oil workings" on the Indian Service map. One well marked "8 inch old Midwest well" is on Hill Creek in sec. 25, T. 14 S., R. 19 E. The road to this location is marked on the map as "impassable". These wells are in Uintah County about six miles south of Naval Shale Reserve No. 2. According to maps of Winchester the surface formation would be lower Green River or upper Wasatch.

The well logs generally indicate that wells which start in the Wasatch do not find the tar sands. Those which start in the Green River or younger formations generally log the tar. This was true in the Piceance Creek structure in Colorado, the Union Oil Company well west of Vernal, the Utah Southern well near Myton, the Midwest Exploration well southwest of Duchesne and a few shallow wells drilled west of Vernal. The Western Venture well near Vernal reported only traces of the tar and of gilsonite. Shows of gas were reported.

Lower Wasatch beds generally carry gas, paraffin oils, or distillate, according to the logs studied. This is true at Hiawatha, Powder Wash, DeBeque, White River, and Garmesa, all in Colorado.

WESTERN VENTURE CORP.


Commenced drilling Sept. 11, 1927 (Nov. 6, by engineer's report).

OIL OR GAS SANDS OR ZONES

No. 1, from 1,296 (G) to 1,300.

IMPORTANT WATER SANDS

No. 1, from 709 to 712.
No. 2, from 907 to 911.
No. 3, from 1,265 to 1,270.

Cable tools were used from 0 feet to 1,515 feet.

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<tr>
<td>1484</td>
<td>1508</td>
<td>24</td>
<td>sand</td>
</tr>
<tr>
<td>1508</td>
<td>1515</td>
<td>7</td>
<td>sand water rose 500 feet</td>
</tr>
</tbody>
</table>

MIDWEST EXPLORATION COMPANY. No. 1, Early.

Sec. 13, T. 4 S., R. 6 W., Duchesne County, Utah. Elevation 6,519.
Surface, Green River shales.
Oil shows reported at rather close intervals from 50 feet to 2,430 feet. Gas shows at 1,500, 2,600 and 2,866 feet.
Sulphur water reported at 844 feet.
Salt water reported at 2,608 and 2,732 feet.
Total depth, 4,760 feet. Abandoned in sandy shale (Green River).
A complete log of this well is in the files of the Argo Oil Company, First National Bank Building, Denver, Colorado.
A letter from Max Ball, Credit Foncier Bldg., Edmonton, Alberta, Canada, concerning (his well made the following comment:
"I do not remember the contact points; strictly speaking, there probably were none, for the well started in Green River shales and finished approximately in the formation down toward 5,000 feet. From about 75 feet to about 2,600 feet there were numerous showings of heavy oil, some of it almost of the consistency of liver, and, if I remember correctly, there were also a few small gas puffs."
This well was drilled a few miles southwest of the town of Duchesne (not Fort Duchesne) on a long, narrow anticline, south of and parallel to the Strawberry River.

PICEANCE CREEK, COLORADO STRUCTURE.

Drilled in 1929-30. Fordham well in NW. of NW. of sec. 9, T. 2 S., R. 96 W. Maltha or heavy tar sand at 785 feet. 300 feet of tar. Show of oil and gas at 1,400 ft. and 2,140 ft. Oil show in sand at 3,431 ft. 1,900,000 feet of gas at 2,985 ft. Abandoned at 5,130 ft.
The reported thickness of tar sand in this well is interesting.

FRONTIER REFINING COMPANY. Govt. No. 1.

S. of NW. of sec. 32, T. 2 N., R. 96 W. Elevation 5,975. Started in Wasatch formation. Chiefly sand and shale and some lime to 4,100 feet. From 4,100 feet to 7,000 feet chiefly sand with some shale and occasional coal beds. Frequent gas shows from 5,500 to 6,600 feet. Gas very wet and carrying distillate. Top of Mesaverde
formation (Cretaceous) not definitely established, but 5,500-foot level believed to be in Mesaverde. Mancos shale not reached. Total depth 7,005 feet.

No tar sands were observed in this well. Apparently it started too low in the formation to encounter the tar. This well was drilled about 14 miles north of the Piceance Creek well, which logged 300 feet of tar sand starting at a depth of 785 feet.

**UTAH SOUTHERN OIL COMPANY.**

M. F. Toles, Kevin, Montana, gave the following information regarding a well drilled about 12 miles east and 2 miles south of Myton, Utah, in 1928-29. The well was drilled for the Utah Southern Oil Company.

"The well was started in what geologists termed the Uinta formation. We were expected to have 1,200 to 1,250 feet of this formation. However, there was only 120 feet of the so-called Uinta, at which point or depth we encountered what was called Green River shale. This shale correlates with the light-colored shales that outcrop at Duchesne, Utah, and going up Indian Canyon from Duchesne to Helper, Utah. Water was encountered at 1,500 feet, also at 1,700 feet. At 1,800 feet we encountered what we thought was a crevice in hole. However, on further examination we found it to be a sticky substance very similar to the Vernal asphalt beds. In drilling this formation we had difficulty with tools sticking, but every time we made a run with the drilling tools, they would sink into formation 3 feet at each stroke of the walking beam. We would again pull tools out after letting them go 25 to 30 feet as described, and run the bailer which would always go as far as tools, but would be empty except for water.

"We had about 1,500 feet of water standing in the hole. This formation continued to 2,200 feet, where we again encountered the Green River shale. Hole was bottomed at 3,000 feet, still in the Green River shale. The only samples we were able to obtain while going through the above sticky formation was what raised to top of water at 300 feet from surface. This substance came up in pieces ranging in size from that of a pea to that of a hen's egg, and carried about 20 percent sand. When melted, which it would do by sitting near a stove or in the hot sun, it looked to me just like the Vernal oil."

Mr. Toles also drilled some test wells in the gilsonite area and made the following comments:

"With reference to the test holes we drilled for the Barber Company at Bonanza, in the gilsonite veins for testing quality of ore and depth of veins, I do not remember the exact depth of all these wells. They range, however, from 350 feet to 1,275 feet, the later being the deepest one before going out of the gilsonite. The average would probably be 700 feet. Their width was from 18 inches to 18 feet. We always started in center of the vein and could tell when we got to the bottom of the ore, as we would encounter a blue sticky mud 50 feet in thickness, which was more like putty than mud. Sometimes the gilsonite vein would stagger out of line with the hole, and we would be drilling a soft sandstone, which the miners called a 'dutchman'. We would always get back in the ore until we encountered the blue mud, which seemed to be the bottom of the ore."

**UNION OIL COMPANY—Government No. 1.**

Cottonwood Springs Bow, Uintah County, Utah.
Location: 1,650 ft. from South line and 330 ft. from East line of sec. 21, T .4 S., R. 20 E. S. L. M.
Elevation: 6,275 ft.
Spud: April 19, 1942. Abandoned: June 12, 1942.
T. D. 2,222 ft.
Casing record: 8%—140 ft.
5%—2,082 ft.
Well Log Assembled From Examination of Drill Cuttings (see accompanying drilled core descriptions) by Max L. Krueger.

**Feet**

0–26  Tan sandy clay and occasional boulders.
26–70  Clay and boulders.
70–105 Hard boulder conglomerate.
105–120 Hard quartz sand.
120–130 Hard sand with limestone boulder fragments.
130–160 Hard boulder conglomerate.
160–200 Sandstone with occasional boulders.
200–215 Pink sandy clay with scattered boulders.
215–225 Grey and white sandstone.
225–245 Grey and maroon clay and sandy silt with a few boulders.
245–275 Grey clay, sandy silt and silty sand.
275–280 Medium grained sandstone.
280–315 Clay, sandy white to tawny.
315–355 Clayey silt and sandy silt, maroon to pink to tawny, gypsiferous.
355–365 Clayey sandstone.
365–430 Soft sandy clay decreasing in sandiness downward.
430–435 Sandstone, tan.
435–460 Sandy grey clay.
460–470 Sandstone with some sandy clay and occasional boulders, pyrite crystals set in limestone fragments.
470–535 Gypsiferous clay, sandy red and pink.
535–550 Sandstone.
550–565 Sandy clays and sandy silts, calcareous to gypsiferous. Range in color from pink and red to maroon to white, light grey, tans and tawny colors. The maroon intervals are more clayey and softer while the grey colored sediments are much sandier.
565–575 Sand, tan, fairly hard.
575–620 Variegated clays, silts and sand.
620–640 Sandstone with admixed clays and sandy silts on occasion.
640–665 Tan sandstone and occasional limestone boulders. Some admixed sandy silts and clay fragments.
665^ 675 Ditto with a few more boulders.
675–700 Sandstone and variegated sandstone and silt fragments and a few boulders.
700–730 Grey and white, maroon sandy clay and silt.
730–760 Reddish clays and sandy silts and some admixed clayey argillaceous material.
760–795 Sandstone with occasional boulders and prominent limestone boulder fragments between 790 ft. and 795 ft.
795–820 Maroon and grey and cream sandy siltstone and claystone with occasional boulder fragments.
820–870 Vari-colored clays, sandy silts, silty sands containing admixed boulders.
870–900 Sandstone, with admixed vari-colored clays, silts and scattered boulders.
900–915 Clay and silt, very sandy. Maroon, grey, white and cream colored.
^ 5–940 Vari-colored clay and silt, pinkish cast.
^ 9^6–970 Sandstone with grey and white claystone or siltstone admixed.
970–1015 Sandy claystone or siltstone, vari-colored with limestone boulders.
1015–1055 Sandstone. Some admixed vari-colored sandy clay and occasional fragments of crystalline limestone.
1055–1085 Sandstone and vari-colored sandy clay and sandy silt.
1085–1165 Claystone or siltstone, very sandy, occasional limestone fragments.
1165–1205 Sandstone with occasional boulders.
Feet


1230 Base Duchesne River formation—to Uinta formation

1230-1250 Vari-colored claystone with occasional limestone boulders.

1250-1275 Sandstone with admixed vari-colored claystone and siltstone.

1275-1290 Sandstone and varicolored siltstone and claystone.

1290-1345 Sandstone with intercalations of clay and silt. Prominent pyrite crystals noted along with scattered boulders.

1345 -1383s Vari-colored sandy claystone and scattered boulders.

1383J-1393J Vari-colored sandy claystone and siltstone with maroon, drab brown and light blue-grey silts and sandy silt fragments predominating.

13931-1400 Vari-colored clays and silts.

1400-1410 Sandstone with admixed varicolored clays and silts.

1410-1425 Varicolored clays and sandy silts with very occasional boulders.

1425-1440 Predominantly sandstone with admixed vari-colored clays and sandy silts. Blue-grey silts predominating.

1440-1455 Red, blue, tan and dirty brown clays and silts and sandy silts. No cuts.

1455-1470 Sandstone with admixed vari-colored clays and silts.

1470-1500 Predominantly vari-colored clays and silts with some admixed sandstone. First dark grey chert grains appear at 1,490 ft.

1500-1530 Predominantly sandstone with admixed vari-colored clays and silts. No cuts.

1530-1585 Vari-colored clays and silts and some blue-grey chert fragments. First prominent appearance of grey chert material at 1,530 ft. This point also marks the appearance of a few tar coated limestone grains. The samples give a faint cut in carbon tetrachloride between 1,530 ft. and 1,540 ft. No cuts from 1,540 ft. to 1,585 ft.

1585-1630 Sandstone with some admixed chert conglomerate and vari-colored clays. Pyrite grains noticeable. No cut to 1,615 ft. and a very faint cut between 1,615 ft. and 1,630 ft. At 1,630 ft. the first time that a considerable admixture of tar stained sand grains showed on the ditch.

1630-1730 Tan sand with some tar sand. All samples down to 1,700 ft. showing fair cut. Some vari-colored silt fragments.

1730-1755 Hard grey chert conglomerate and sand.

1755-1800 Grey chert and limestone boulder conglomerate set in a sandy matrix. Faint oil cut 1,755 ft. to 1,770 ft. Good cut 1,770 ft. to 1,800 ft.

1800-1850 Sandstone, tar sandstone an d scattered boulders. Faint cuts throughout.

1850-1908 Black tar sand and grey chert pebble conglomerate. Cored 38 ft. of tar sand and gas burned in the barrel at 1,885 ft.

1908-1940 Sandstone and chert pebble conglomerate. All samples gave good cuts so it is probably tar saturated.

1940-1968 Sandstone with some admixed varicolored clays. Samples give cut throughout.

1968-2035 Conglomerate set in a sandstone matrix and some admixed vari-colored argillaceous material. Approximate top of the Cretaceous-Mesaverde sands and shales

2035 Sandstone?

2045-2093 Grey Cretaceous shales, lignitic shales and some thin streaks of coal with shiny lustre. Irregularly bedded.

2093-2218 Mesaverde oil sands, light brown, medium grained, fairly soft, massive. Give excellent, cut. No odor.

T. D. 2,222 ft.
## COST ESTIMATE FOR 300-BARREL PLANT
(Based on November 1941 prices)

### Item and unit

<table>
<thead>
<tr>
<th>Item and unit</th>
<th>300-bbl. unit complete (new)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SEPARATING PLANT</strong></td>
<td></td>
</tr>
<tr>
<td>2 20x30x10 soaker bin</td>
<td>$2,550.00</td>
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<tr>
<td>1 sand pulper tank</td>
<td>$1,700.00</td>
</tr>
<tr>
<td>10 38x38 flotation cells</td>
<td>$6,870.00</td>
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<tr>
<td>1 link belt conveyor-soaker bin</td>
<td>$550.00</td>
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<tr>
<td>1 36 in. Akins classified (dewater)</td>
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<tr>
<td>1 30 in. x 24 in. froth conveyor</td>
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<tr>
<td>9 miscellaneous steel tanks (wood)</td>
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<tr>
<td>Iron pipe and fittings</td>
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<tr>
<td>Iron and brass valves</td>
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<tr>
<td>Lumber, 75M ft</td>
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<tr>
<td>Roofing and siding</td>
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<td>Labor (building and installation)</td>
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<tr>
<td>General miscellaneous supplies</td>
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<tr>
<td><strong>Subtotal</strong></td>
<td>$30,335.00</td>
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<tr>
<td><strong>DEHYDRATION PLANT</strong></td>
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<tr>
<td>5 8 ft. x 16 ft. stills with film disk</td>
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<td>Foundation and brick work</td>
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<td>Stacks and fittings</td>
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<td>Manufacturing costs and miscellaneous</td>
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<td>Labor (building and installation)</td>
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<td>General miscellaneous supplies</td>
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<td><strong>Subtotal</strong></td>
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<tr>
<td><strong>BELT CONVEYORS</strong></td>
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<td>1 100 ft. x 20 in. crude sand conveyor</td>
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<td>1 50 ft. x 14 in. sand tailings conveyor</td>
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<td><strong>POWER</strong></td>
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<td>2 100 HP portable boilers and stack</td>
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<td>1 75 HP stationary boiler</td>
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<td>1 100 HP steam engine and generator</td>
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<td>6 pumps various sizes</td>
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<tr>
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<tr>
<td>Unforeseen expense 10% of gross</td>
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<td><strong>Total</strong></td>
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