INTRODUCTION

The largest single deposit of bituminous sandstones in the United States is found in the Uinta Basin. This deposit along with two other well-known occurrences of bituminous sandstones in the northeastern portion of the basin have proved reserves exceeding 1% billion barrels of oil. The reserve calculations are based only on sands which contain in excess of 9 percent bitumen by weight. The three principal deposits are favorably situated for strip mining and retorting operations or for "in situ" thermal recovery techniques. Numerous smaller deposits, some of questionable commercial value, also occur in the basin and will be discussed in this paper.

The largest and perhaps best known deposit is located in the Sunnyside area on the south flank of the Uinta Basin a few miles north of the coal mining community of Sunnyside, Utah (1 on fig. 1). The U. S. Geological Survey has estimated reserves of oil in this deposit to be in excess of 728 million bbl. of 10-12° A.P.I. gravity oil. The second largest deposit is the bituminous sandstone beds of the Asphalt Ridge area four miles west of Vernal, Utah (2 on fig. 1); its proved reserves are 250 million bbl. of oil. The third deposit which has commercial significance is the asphaltic sandstones of the Whiterocks area (3 on fig. 1); its proved reserves exceed 125 million bbl.

Other deposits, whose reserves are unknown but which may have commercial possibilities, are the deposits at the P. R. Springs along the Roan Cliffs, at Chapita Wells, and at Dragon-Asphalt Wash. Other deposits that probably are not commercial for the foreseeable future are in the Deep Creek area, the John Starr Flat area, an area south of Whiterocks, an area northeast of Tabiona, the Lake Fork-Yellowstone area, on Leland and Pariette Benches south of Myton, in the Argyle Creek area, and on Raven Ridge.

Exploitation of these deposits, probably beginning with the largest, will be dependent on the costs of mining and of extracting the bitumen from the rocks. This paper evaluates some of the economic factors to be considered in developing the deposits and describes in some detail the Shell Oil Company’s plan for developing asphalt sand properties in Alberta, Canada.

The Uinta Basin lies in northeastern Utah and northwestern Colorado and is bounded on the north by the east-west trending Uinta Mountains, on the west by the north-south trending Wasatch Mountains, on the south by the Roan and Book Cliffs, the topographic expression of the San Rafael Swell and the Uncompahgre uplift, and on the east by the Douglas Creek arch. The basin is both a topographic and structural basin, resembling an elongated sauce dish. The more steeply dipping north flank of the basin has sedimentary beds with dips ranging from 6 to 60 degrees, while the more gentle south flank has dips which average 4 to 6 degrees. The east-west axis extends from the Utah-Colorado line to the Strawberry Reservoir area, a distance of approximately 160 mi. The north-south dimension of the basin ranges from 40 to more than 120 mi.

The climate of the area is semiarid, except at higher elevations along the mountain front. The topography is extremely varied, ranging from 4,400 ft. along the Green River south of Ouray in the central part of the basin to more than 10,000 ft. on the south flank of the basin near Sunnyside. The area is drained by the Green River, which flows from northeast to southwest across the eastern one-third of the basin. The White River, a tributary to the Green, flows from east to west and joins the Green at Ouray just below the confluence of the Green with the Duchesne River, a river which drains the area north and west of Ouray.

U. S. Highway 40 crosses the north part of the basin in an east-west direction; it is a major transcontinental highway that connects the Uinta Basin with Salt Lake City, Utah, and Denver, Colorado. The bituminous sandstones near Sunnyside are only...
FIGURE 1.—Index map showing the location of the bituminous sandstone deposits of the Uinta Basin as well as the oil and gas fields. The circled number index the deposits, and the formations in which they occur are as follows:

1. Sunnyside (green River & Wasatch)
2. Asphalt Ridge (Duchesne River and Mesaverde)
3. Whiterocks (Navajo Sandstone)
4. PR Springs (Wasatch)
5. Chapita Wells (Uinta)
6. Dragon (Uinta and Green River)
7. Deep Creek (Duchesne River)
8. John Starr Flat (Duchesne River)
9. South Whiterocks (Duchesne River)
10. Tabiona (Currant Creek)
11. Lake Fork-Yellowstone (Uinta)
12. South Myton (Uinta)
13. Argyle Creek (Green River)
14. Raven Ridge (Green River)
about seven miles from a spur of the Denver and Rio Grande Western Railroad Company, but the nearest convenient railheads to the Asphalt Ridge and Whiterocks bituminous sandstone properties are located at Craig, Colorado, 120 mi. to the east on U. S. 40 and at Heber City, Utah 120 mi. to the west.

Rocks in the basin range in age from Precambrian to Quaternary. Most of the bituminous sandstones are in the Wasatch, Green River, Uinta, and Duchesne River Formations of Eocene to Oligocene age, but the principal deposits at Asphalt Ridge occur in Cretaceous rock with minor, noncommercial tar sands in the Eocene rocks, and the deposits at Whiterocks are in the Navajo Sandstone of Triassic (?) -Jurassic age.

For the purpose of this paper the term "material" refers to any asphaltic or bituminous sandstone which is of commercial significance and the term "overburden" refers to noncommercial tar sands or to barren rock. Also, the terms "asphaltic sandstone," "oil sand," "bituminous sandstone" are used interchangeably. For commercial and legal purposes the definition of any deposit of bituminous sandstone should include its location by township, range, and section and its stratigraphic position, such as "lying above the top of the Mancos Shale and below the lowest Cretaceous shales and lignites which lie en top of the Rim Rock Sandstone Member of the Mesaverde."

SUNNYSIDE BITUMINOUS SANDSTONES

The bituminous sandstones of the Sunnyside area are the largest known deposits in the United States. They are on the south flank of the Uinta Basin near the top of the Book Cliffs, a south-facing topographic escarpment. Elevations of the bitumen-bearing beds range from 8,500 to 10,000 ft. The deposits are six miles north of the coal mining community of Sunnyside, Utah, and are seven miles from the spur of the Denver and Rio Grande Western Railroad. The U. S. Geological Survey has estimated that the beds contain 1,600 million cu. yds. of bituminous sandstone of which approximately 50 percent is of commercial grade containing in excess of 9 percent bitumen by weight, the economic cutoff point. The area has been mapped and described in detail (Holmes, et al, 1948). A cubic yard of material which has 9 percent of bitumen by weight contains 38.2 gal. or a little less than one barrel of bitumen. Thus the total reserve for the Sunnyside deposits is about 728 million bbl. of bitumen, which can be divided as follows: 450 million cu. yds. of measured and indicated material and 350 million cu. yds. of inferred material.

The bituminous sands of this deposit are located within beds of the upper part of the Wasatch Formation and the lower part of the Green River Formation. Beds of the Wasatch Formation are primarily fluvial, while beds of the Green River Formation are lacustrine, although considerable intertonguing of the two occurs in a transition zone. The fluvial beds of the Wasatch Formation are extremely discontinuous and lenticular, while the basal Green River beds are more uniform and have greater persistency. The most significant deposits of bitumen occur in the Wasatch beds. The saturated beds range in thickness from a few inches to more than 350 ft. Many of the sandstones occupy broad channels in the underlying shales and limestones. The bituminous sandstones wedge out laterally into shale and are overlain and underlain by shale. Many beds which are highly inspissated with bitumen near the top become lean to barren downward toward the base and often along strike, indicating that there has been insufficient bitumen to occupy all of the available pore space.

Regional dip of the formation is to the north and east at moderate rates, ranging from 6 to 8 degrees. Topographic relief in the south-facing exposed bituminous sandstone beds is extreme. For purposes of mining, especially strip mining, this is a decided advantage, as it eliminates the problem of where to place overburden and waste. Further, aerial tramways can be employed utilizing the force of gravity in lowering the material. Disadvantages are that the material on the steep cliffs will have an overburden to material ratio which will become excessive soon after mining operations commence.

The bituminous sandstones of this deposit are, for the most part, hard and tough and require drilling, blasting, and quarrying. Water for mining operations will have to be obtained from wells or pumped up to the cliff faces, for the country is semiarid and there is little water except during the spring runoff; ponds and earth dams could be constructed to impound these waters. During the period 1930 to 1948 more than 300,000 tons of "rock asphalt" was quarried, crushed, and sold for paving material. All of the bituminous sandstones thus far mentioned have excellent road paving characteristics and are superior to asphalts made from crude oils. This is because the bitumen in the sandstone is "tacky" and tenacious. During hot weather and under weight and pressure it tends...
to be more cohesive and not soften as does that made from crude oil.

The origin of the asphaltic sandstones in the Sunnyside area is closely related to the interfinger- ing of the nonmarine, fluvial beds of the Wasatch Formation downdip with the lacustrine Green River Formation. The oil moved out of the Green River source beds consisting of shales and marlstones soon after burial and before consolidation and induration, and into the adjacent and subjacent sandstones. After uplift of the San Rafael Swell to the south during late Cretaceous-early Eocene time the oil moved updip in the reservoir beds. Erosion stripped off the beds leaving the tilted edges of the oil-bearing sands exposed and permitting the more volatile fractions to escape.

THE ASPHALT RIDGE DEPOSITS

The bituminous sandstones of the Asphalt Ridge area are in a northwest trending ridge whose nearest exposure to Vernal is about three miles southwest of town in the northeastern part of the Uinta Basin (fig. 2). The deposit is named from the prominent topographic ridge of which it is a part (fig. 3). Vernal lies in a valley in Mancos Shale. The more resistant ridge consists of Mesaverde sandstones and shales whose upper part is overlapped unconformably and truncated by less steeply dipping Duchesne River beds of Oligocene age (fig. 4). Formation dips within the Mesaverde are 8 to 12 degrees to the southwest. Bitumen saturation is related to the unconformities along the ridge, especially at the point where the Duchesne River beds unconformably overlap the Rim Rock Sandstone Member of the Mesaverde. The most important deposits are located in sees. 14-17 and 21-24, T. 4 S., R. 20 E., in sees. 19, 29, 30, and 31, T. 4 S., R. 21 E., in sees. 3-11, 13-15, 21-26, 34 and 35, T. 5 S., R. 21 E., and in sees. 31 and 32, T. 5 S., R. 22 E., Salt Lake meridian.

A striking example of the relationship of the asphalt saturation to the Tertiary unconformity can be seen in the county pit just west of Vernal (fig. 5). Here the contact between the Rim Rock Sandstone and the overlapping fluvial Ducnesne River beds is well exposed. The conglomerate and sandstone beds of the Duchesne River Formation, as well as the subjacent Rim Rock Sandstone, are saturated with bitumen. A shale and lignite interval separates the Rim Rock Sandstone from

![FIGURE 3.—View of Asphalt Ridge looking northwest. Southwest dipping Duchesne River beds cap the ridge. Mesaverde Formation crops out in the lower slopes.](image-url)
GEOLOGIC CROSS PROFILE

ASPHALT RIDGE AREA

T.S. S., RSI E.

UINTAH COUNTY, UTAH

FIGURE 4.
the underlying Asphalt Ridge Sandstone. In the county pit area a normal fault, downthrown on the west, delimits the saturation on the east. The Asphalt Ridge Sandstone is upthrown against the lignite-shale interval and is completely barren of any bitumen. Evidently the saturation is post-faulting, since the Asphalt Ridge bituminous sandstones are limited to the downthrown (west) side of the fault.

Along the ridge, well up in the Duchesne River Formation there are important beds of asphalt; all of these are beds which lie along angular unconformities. The degree of saturation within beds of Tertiary or Cretaceous age is a direct function of the proximity of those beds to unconformities and to the porosity and permeability within those beds. The Cretaceous sands are water wet, with the bitumen covering the water-wet grains and filling the pore space, a physical characteristic which gives the sand a decidedly "cool" feeling. The bitumen has a 12° A. P. I. gravity and is extremely low in sulfur. Both the Rim Rock sand (the more important zone) and the Asphalt Ridge sand have tar-water contacts. It is probable that, prior to denudation and exposure of the tar sands, reservoirs of high gravity, paraffin base oils existed along the ridge. The origin of this oil was probably the downdip, basinward highly organic shales and marls of the lacustrine Green River Formation. Tectonic movements which tilted the sedimentary beds of the ridge area and elevated them to a structurally higher position than the lacustrine beds of the Green River Formation were responsible for the upward migration of oil from the source beds into the fluvial and interfingering beds of Wasatch facies at the base of the formation and Uinta facies at the top of the formation. There are well developed, although highly lenticular, sandstones in both of these formations. Farther to the northeast, uplift along the mountain front gave rise to many unconformities and truncated zones within the entire Tertiary sequence. These readjustments in elevation and structural attitude caused movement of the oil updip and along the unconformities into the overlying Duchesne River beds and into the truncated and overlapped Cretaceous basal Mesa-verde sandstones.

The economics of the development of the Asphalt Ridge property are very favorable. The reserves of bituminous sandstone of commercial grade,
computed for all formations for a distance of ten miles along the ridge in a northwest to southeast direction and excluding any reserves which lie more than one mile down-dip from the outcrop is in excess of 475 million cu. yds. of material containing in excess of 9 percent bitumen by weight for a total of approximately 250 million bbl. of bitumen. This figure is about one-fourth of the 1 billion bbl. previously estimated (Spieker, 1930), although the lesser figure applies to proved reserves. Wells drilled more than a mile down-dip from the outcrop have encountered saturated tar sands which could easily more than double the proved reserves. Of the 250 million bbl. reserve of the Asphalt Ridge area, approximately one-half or 125 million bbl. are contained in the Rim Rock Sandstone, and the underlying Asphalt Ridge Sandstone contains 23 million bbl. There are minor reserves in sandstones above the Rim Rock Sandstone in several places along the ridge, especially where small south-west plunging anticlines are developed in the Cretaceous beds. The balance of the reserves is in the Oligocene Duchesne River Formation. At the south end of the ridge, at a point where the Vernal-Naples-Horseshoe Bend road crosses the Duchesne River beds at the base of the dugway, there is a well-developed series of asphaltic sandstone beds which can be easily strip mined.

In the evaluation of the reserves of Asphalt Ridge more than 53 diamond core holes were drilled with total cored footage in excess of 21,000 ft. All cores were analyzed at two-foot intervals. Detailed mapping was done to provide accurate topographic and geologic control on the scale of 1 in. = 200 ft. Isopachs were made of material and overburden. The individual tar sands were also isopached. From these data estimates of mining costs were computed. A discussion of the economics of these costs of extraction and upgrading of liquid bitumen are discussed later in this paper.

**THE WHITEROCKS AREA**

The bituminous sandstones of the Whiterocks area are in T. 2 N., R. 1 E. and R. 1 W., Uintah meridian, approximately 25 mi. northwest of Vernal, along the south flank of the Uinta Mountains. Paleozoic beds are exposed along the mountain front and a pronounced "bowing" of these beds has been named the Whiterocks nose (fig. 6).
Mesozoic beds are also exposed in Whiterocks Canyon; the youngest formation to crop out is the Jurassic Curtis Formation. These beds strike northeast in Whiterocks Canyon and dip about 62° SE (fig. 7).

The Triassic-Jurassic Navajo Sandstone in this area has a total thickness of slightly less than 1,000 ft. Asphalt saturation occurs throughout the entire formation, from top to the base of the sandstone with fairly uniform saturation of bitumen throughout. The formation is well exposed on both flanks of Whiterocks Canyon, although in the canyon itself it is covered by gravels and alluvium (see fig. 8). Whiterocks River, a perennial stream, flows southward across the outcrop. Topographic relief in the area is moderate. From the canyon floor to the beveled contact between the Navajo Sandstone and the Duchesne River beds which lie on top with strong angular unconformity there is about 350 ft. of topographic relief.

Laterally the outcrop is exposed for a distance of 6,000 ft. The sandstone has permeabilities ranging from 10 to 127 millidarcies and porosities which range from 14 to as high as 32 percent. Core analysis shows water saturations which range from 38 to as high as 82 percent and oil saturations ranging from 13 to 33 percent. The bitumen has an A.P.I. gravity of 12° and is low in sulfur. The outcrop appearance is extremely deceiving as the rocks weathers a whittish blue, although the depth of weathering is extremely thin (fig. 9).

A well drilled by the author for Mervin J. Fulton & Associates in the NE4 sec. 24, T. 2 N., R. 1 W., Uintah meridian, spudded in Duchesne River Formation. The unconformity between this formation and the steeply dipping Navajo asphaltic sandstones was encountered at a depth of 470 ft. The well probably penetrated the Navajo in the middle of the section. Saturation was excellent and the base of the sand was reached at approximately 1,200 ft. The following summer a well was drilled in Whiterocks Canyon on fee land by Caldwell and Covington. The well was located in the SE4 sec. 18, T. 2 N., R. 1 E., Uintah meridian. The well spudded in gravels and the Navajo Sandstone was encountered at 54 ft. This well probably entered the steep, southeast dipping beds in the middle of the section. Bitumen saturation was encountered to a depth of 560 ft., below which the sandstone was barren. A correlation of this well with the Fulton and Associates well showed that the base of the saturation drops 375 ft. to the mile to the southwest, along the strike. Subsequent coring has shown that the base of the saturation also drops 1,000 ft. to the mile in a northwest to southeast direction across the outcrop. This reflects the relative amount of uplift which occurred after the bitumen was emplaced.

Along the outcrop on the west side of the canyon there are many tar or "brea" seeps, especially where the roots of trees have fractured the underlying sandstone. In an assessment tunnel which was driven into the side of the hill, tar seeps onto the floor of the tunnel from the walls and roof.

The Navajo Sandstone in the Whiterocks area is cross-bedded, fine-grained, white sandstone with varying degrees of cementation. In general the sandstone is noncalcareous with a white, clay matrix, although locally there are thin beds of sandy, hard, tight limestone. Fracturing within the formation is common and many of the factures are filled with white clay or gypsum. The sand grains are highly frosted and range from rounded to sub-rounded, with sparse large orange and pink grains.
The degree of bitumen saturation is a direct function of porosity and permeability within the saturated interval. Density measurements of the sand range from 2.02 to 2.46, with an average of 2.20. This density corresponds to a weight of 3,707 lbs per cu. yd. or 1.85 tons per cu. yd. The bituminous sand of the Navajo Sandstone averages 24.4 gal per cu. yd. Additional core drilling in the Whiterocks area has indicated the following reserves: 65 million bbl in the proved category, 35 million bbl in the probable category and 25 million bbl in the possible category. This totals 125 million bbl of oil in place for all categories.

It has been proposed in the literature that the Green River Formation was the source for the oil in the Navajo Sandstone. Since the Navajo is believed to be eolian in origin, the oil is certainly not indigenous. The author is of the opinion that the oil originated in Paleozoic beds, probably Permo-Pennsylvanian, and migrated from the Weber Sandstone at a point where the Navajo is faulted against the Weber along the northeast-trending Whiterocks thrust. The movement of oil into the very fine-grained rocks of the Navajo would tend to indicate that the oil was of extremely high gravity. Subsequent uplift and erosion beveled the top of the outcrop, allowing the lighter ends of the oil to escape.

Geologic criteria used in arriving at this premise are the following: (1) There is no evidence of asphalt or tar across the beveled Mesozoic-Paleozoic unconformity, other than the saturation in the Navajo. (2) There is no increase in saturation in the Navajo from the base of the zone of saturation upward to the Navajo-Duchesne River Formation. (3) The Carter Oil Company No. 2 Whiterocks well which was drilled in NE^4 sec. 6, T. 1 N., R 1 E., Uintah meridian, three and one-half miles southward (down dip), encountered almost no shows of oil or gas in the Green River Formation and encountered no dead oil stained sands which might have been the original reservoir rocks from which the oil might have migrated into the Navajo. The highly fossiliferous Curtis Formation has been proposed as a source of the Navajo oil. On the outcrop there is no saturation in the limestone and sandstone beds of the Curtis except at one place adjacent to a small fault. The eastward wedging Thaynes limestone tongue of the Moenkopi Formation could possibly have been a source for the oil. Entrapment may have been due to the shaling out of the limestone updip on the southwest flank of the Whiterocks nose.

Because of the massive nature of the Navajo Sandstone and its relatively uniform saturation, combined with shallow depth and a ratio of overburden to material of 0.26 to 1.0, this deposit is extremely attractive from the standpoint of commercial exploitation. The recoverable reserves, based on a recovery factor of 80 percent, are 132.000 bbls. per acre.

THE P.R. SPRINGS BITUMINOUS SANDSTONES

The bituminous sandstone deposits of the P.R. Springs area are similar to the Sunnyside deposits and lie on the southeast flank of the Uinta Basin along the Roan Cliffs, a south-facing topographic escarpment (4 on fig. 1). The bitumen occurs in beds of Wasatch lithology and all are in the upper portion of the formation. They are exposed in many places throughout an area which embraces Tps. 15 and 16 S., Rs. 23 and 24 E., Salt Lake meridian, Uintah County, Utah. Regional dip is to the northwest, with dips averaging 4 to 8 degrees. The geologic occurrence and origin of the oil in this deposit is the same as that of the Sunnyside deposit. The richest saturation occurs in small northwest-plunging anticlinal nosings or "bowings" and where porosity and permeability is high. Field evidence has shown the thickness of the saturated sandstone beds to range from a few inches to as much as 250 ft., although the latter are not common. The author has no core data on saturations, but from field inspection of several cores there appeared to be a wide range of saturation, varying from extremely lean and dry to very well saturated, tarry cores. The highly lenticular nature of the beds poses problems of reserve estimation. The remoteness of the area, lack of adequate roads for hauling, and extreme shortage of water in the high cliff area, combined with the extremely lenticular character of the reservoir sands will require highly detailed engineering and geologic work to properly evaluate the commercial significance of these deposits.

CHAPITA WELLS BITUMINOUS SANDSTONES

The bituminous sandstones of the Chapita Wells area were first mentioned in the geologic literature in 1963 (Covington, 1963), although they were well known to early settlers and to the Ute Indians. The deposit is located in the Chapita Wells area in the east-central part of the Uinta Basin east of Ouray (5 on fig. 1) and along the north side of the westward flowing White River in the northwest part of T. 9 S., R. 23 E. and in the northeast part of T. 9 S., R. 22 E., Salt Lake meridian, Uintah
County, Utah. The bitumen occurs in the fluvial sandstones of the Uinta Formation. Saturations vary from extremely lean to moderately rich. There are a few thin sandstones which have rare zones of tarry saturation. The individual sandstone beds vary in richness, with lean and rich zones contiguous with each other. Although the degree of saturation is, in part, dependent upon porosity and permeability, it would appear, from field inspection, that the most important consideration was the proximity of the beds to fault and fracture zones from which the gilsonitic, tarry oil could move upward and into the Uinta sandstone reservoirs. The reserves of this deposit are not known definitely, although they are probably not of great commercial significance. Most of the sands could be mined using open-pit methods, although the disposal of overburden and waste will prove to be a problem in any large scale operation.

**DRAGON-ASPHALT WASH BITUMINOUS SANDSTONE**

The Dragon-Asphalt Wash bituminous sandstones are located south and east of the Chapita Wells deposits in \( E_{22} T. 12 S., R. 24 E. \) and \( W_{12} T. 12 S., R. 25 E., \) Salt Lake meridian, Uintah County, Utah (6 on fig. 1). The richest tar sand is located adjacent to and updip from the Black Dragon gilsonite vein. The author believes that the saturation in this sand had its origin in the viscous, tarry hydrocarbon material from the vein before lighter ends were oxidized. This can be demonstrated from the fact that the degree of saturation varies directly with the distance from the vein of gilsonite. At 1,000 ft. updip from the vein the saturation is extremely light and dry. The total thickness of this sand is about 25 ft. The beds in this area which have bitumen saturation are highly lenticular beds of the upper Green River and basal Uinta sandstones. The reserves of this area are not known, and though the beds are fairly extensive, their lack of concentration and continuity probably is a major factor in making them economically unattractive at the present time.

**THE BITUMINOUS SANDSTONES AND CONGLOMERATES OF DEEP CREEK AREA**

Fifteen miles northwest of Vernal in SW14 T. 3 S., R. 19 E., Salt Lake meridian, Uintah County, Utah, a small deposit of tarry sandstones and conglomerates is located. This deposit has no economic significance but is of geologic interest. The deposit is developed in beds of the Duchesne River Formation where they overlap with angular unconformity the Cretaceous Mancos black, marine shales. The origin of the bitumen was probably the lower Green River lacustrine beds. The oil migrated into the fluvial facies of the adjacent, superjacent and subjacent fluvial beds along the edge of the old Green River lake. Later, during regional uplift to the north the Green River and Uinta Formations were tilted rather steeply southward and the Duchesne River Formation was deposited unconformably over their beveled edges. The oil then migrated into the sandstones and conglomerates of the Duchesne River beds when further uplift tilted and folded the Tertiary beds into the Deep Creek south plunging nose. Erosion of the beds down to the present unconformity exposed the reservoir beds, allowing the light ends of the oil in the reservoir to escape and oxidize.

**MISCELLANEOUS LOCALITIES**

There are many other localities of interest within the Uinta Basin, such as the John Starr Flat area in sec. 24 of T. 1 N., R. 3 W., Uintah meridian, Duchesne County, Utah, along the south flank of the Uinta Mountains in beds of Duchesne River age.

A second deposit of interest is a dry, lean bituminous sandstone in the Duchesne River beds in the south Whiterocks area in SE14 sec. 19 of T. 2 N., R. 1 E., Uintah meridian. The thickness of the sand is 15 ft. and lies updip and adjacent to a northeast-trending fault. The Duchesne River beds probably unconformably overlie the Frontier Sandstone of Cretaceous age and it is possible that the source of the bitumen is the underlying Cretaceous sandstones.

Northeast of the town of Tabiona a few miles, another deposit of bituminous sandstone. The saturation occurs primarily in sec. 17, T. 1 S., R. 7 W., Uintah meridian, Duchesne County. The saturation is confined entirely to beds of the Cur-\( \text{C} \) rant Creek Formation and seems to be related to the angular unconformity between the overlying Cur-\( \text{C} \) rant Creek Formation and the underlying Mesa-\( \text{C} \) verde beds. The Cur-\( \text{C} \) rant Creek Formation on the north flank of the basin dips 23° S.

In the Lake Fork-Yellowstone River area along the north flank of the basin near the mountain front where the Uinta and Duchesne River Formations unconformably overlie and overlap older Tertiary beds is a deposit located on the Ute Indian
Reservation land in secs. 5 and 6, T. 1 N., R. 4 W., Uintah meridian. The Uinta Formation dips 4-6° S. in the area. The saturation occurs in beds of this formation on the divide between Lake Fork and the Yellowstone River. There are four sandstones exposed which range in thickness from 15 to 20 ft. Although most of the beds are "lean and dry" there are several areas where there are rich enough zones to form small "brea" tar seeps where the formation has been locally fractured. Some coring was done by the Duchesne County Road Commission in 1958 but the cores were not evaluated. A dispute over title to the land and minerals led to the abandonment of the project. The origin of the oil in the sands is not known. There is another small deposit in sec. 33, T. 2 N., R. 4 W., Uintah meridian, just north of the Uintah and Ouray Indian Reservation line.

South of the town of Myton, Utah, on Leland Bench and Pariette Bench are three deposits of bituminous sandstone in the Uinta Formation, the deposits are all located updip and adjacent to the Duchesne-Myton east-west fault zone. The origin of the oil which saturated these fluvial beds was undoubtedly the lacustrine Green River Formation. The oil moved updip from fractured shale reservoirs in the Green River and up the faults to enter the Uinta sands. Because of the highly lenticular nature of the sands and the fairly lean quality of the beds it is not believed that the deposits are of commercial value.

On the southwest flank of the basin in the Argyle Creek area is an asphaltic sandstone which was once mined and marketed under the trade name of "Argulite." The deposits occur in beds of the basal Green River Formation and contain from 8 to 10 percent bitumen by weight. The beds dip north and east with dips ranging from 4 to 6 degrees; they are well exposed on the divide which separates the drainage of Minnie Maude from the north draining streams which are developed on the dip-slope of the Green River Formation. This deposit has been described (Abraham, 1945). The origin of the oil is probably the result of the interfingering of the lacustrine Green River Beds with the fluvial Uinta Formation.

On the northeast flank of the basin in an area known as Raven Ridge is a deposit of asphaltic sandstones which occur in the deltaic sandstones of the lower Green River. Although much of the deposit consists of lean "dry" bituminous sandstones, local ranchers say that years ago a small "oil seep" was present in the area where live oil spurted from the rocks intermittently with water during the early spring runoffs. They claim the seep had the diameter of a person's small finger. The source of the oil is probably the same as that of the present Red Wash-Walker Hollow oil field. The beds strike southeast and dip 18° SW. Although the reserves are small, the location of these beds in close proximity to the Red Wash oil field is extremely significant.

ECONOMICS OF MINING AND BITUMEN EXTRACTION

General economic considerations which affect a final decision as to the relative merits of an asphaltic sandstone deposit can be brokendown into two major categories. The first is mining costs and the second is the cost of extraction of the bitumen from the rock. Some of the factors which must be considered are: price per barrel of the bitumen extracted, the size and extent of the reserves, local topography and geology, the ratio of overburden to material, the degree of induration or consolidation, state and local taxes, costs of local labor, transportation costs, royalty rates, availability of materials, and the cost of water and fuel.

If open pit or strip mining operation are contemplated, an overburden ratio to material of not more than 0.5 to 1.0 is probably a feasible cutoff point. A large part of the Asphalt Ridge area is amenable to this mining method, while some of the property will undoubtedly have to be developed by thermal or "in situ" mining methods. One of the major problems which would affect the choice of mining methods used is the disposal of overburden and waste, which is a direct function of topography.

A realistic evaluation of any proposed open pit or strip mining operation must include the mining costs. With favorable overburden to material ratios this cost, involving either bulldozers with rippers, scrapers and heavy duty construction equipment or large electric shovels such as those used in the eastern coal fields, should range from 30c to 50c per cu. yd. Capital investment for a 6,400-cu. yd. operation in 1964 is $160,000.

The costs involved in the erection and operation of the separation plant are directly related to the size of the plant and to the method of extraction contemplated. There are many different methods which have been tried on asphalt sands with varying degrees of success. There is a hot-water separation plus fluid coking process, a hot-water and diluent process plus a visbreaking (thermal crack-
ing) unit, the Coulson centrifuging method and separating of oil from the sands by sonic methods.

In retorting the asphaltic sands the process involves preheating the sands with hot gases, followed by burning the oil residue from the sand. The liquid and vapor from this combined operation is cooled and collected. The produced oil has an A.P.I. gravity which ranges from 26 to 28 degrees. The recovery from this method is about 85 percent of the oil in the sands. The capital investment for a retort capable of producing 2,400 bbl. of oil per day would be about $860,000. The equivalent costs to retort a cubic yard of asphaltic sand is 30c. This includes amortization of capital investment, maintenance costs, labor costs, overhead, insurance, and taxes.

The fluid coker and hot water wash separation process involves separating the asphalt and sand from each other by a hot water and chemical wash wash similar to the method proposed by the U. S. Bureau of Mines. The asphalt thus produced is upgraded by a fluid coking process to an oil of about 27° gravity. This method would also produce commercial grade coke as a by-product and could furnish a high-grade silica sand of glass manufacturing quality. Net recovery by this process is 80 percent of the oil in the sands. The capital investment for a 2,400 bbl. per day plant of this type would be $540,000 for a hot water separation unit and $2,231,000 for a fluid coker and auxiliary equipment for a total of $2,771,000. The equivalent cost to separate the oil and the sand and upgrade the oil is 32c per cu. yd. and includes all of the costs included above but does not take into account the value of the coke and glass sands produced as by-products.

The hot water and diluent separation process plus visbreaking (thermal cracking) was tried in the Athabasca tar sand area by a combine of the Imperial Oil Company, Cities Service Oil Company, Richfield Oil Corp., and the Royalite Oil Company. The capital investment and processing costs of this method should be comparable to the fluid coking process.

The recovery of oil from the asphaltic sands using "in situ" or thermal methods has certain advantages and can be successfully utilized when the depth to the sands is sufficiently great so that strip mining operations are not feasible. This method is especially practical where the tar sands are in a massive, homogenous sandstone with fairly uniform porosity and permeability. The bitumen in the Mesaverde sandstones of the Asphalt Ridge area could be recovered by this process with a high degree of success. This is particularly true if a method similar to the steam injection process which the Shell Oil Company plans to use in their Athabasca tar sand lease is utilized, since the water-wet condition of the sands means recoveries ranging from 70 to 80 percent, only slightly less than the mining-retorting methods.

A brief discussion of the Shell Oil Company's plan for the development of their asphaltic sand properties is pertinent to this paper since much of their research data can, and probably will be utilized in the use of extraction of bitumen from asphaltic sands. The Shell Oil Company plans to invest $260 million to recover 100,000 bbl. per day from the Athabasca tar sands. This deposit contains 82,000 bbl. of recoverable oil per acre or 52 million bbl. per sq. mi. over an area of 217 sq. mi. for a total recoverable reserve of 11.4 billion bbl. of oil.

Between 1956 and 1962 the Shell Oil Company of Canada, Limited, conducted exploration and research on the Crown Bituminous Sands Leases in the Province of Alberta, Canada. Their leases consist of 138,000 acres. The bitumen occurs in the McMurray sands. The thickness of the tar-bearing sands ranges from 20 to 120 ft. and rests unconformably on Devonian argillaceous limestones. There are three sands in the Shell area. The sands are good, clean sands with porosities which range from 36 to 42 percent. The tar saturation varies from 40 to 50 percent of pore volume. The bitumen averages 9.3 percent by weight. Average overburden is 1,050 ft. Average sediment density is 137.5 lbs. per cu. ft. and pressure exerted by the overburden ranges from 800 to 1,000 lbs. per sq. in. The original reservoir pressure is 150 psig and reservoir temperature is 65° F.

Shell plans to develop the tar sands by drilling the five spot wells on four-acre spacing and injecting steam at the rate of 100 tons of steam per well per day under an injection pressure of 1,000 psi. Using these parameters, the recovery of bitumen would be 560 bbl. per day for each five-spot pattern. In conjunction with the steam injection will be the use of hot alkaline solutions to increase recovery rates and to help emulsify the tar in place.

The produced emulsion would be gathered, the tar and water will be separated, and the tar thermally converted to yield a low viscosity, synthetic sour crude at the Athabasca site. This crude will be pipelined to Edmonton and hydrotreated to yield a 33° A.P.I. sweet crude. Low gravity
pitch produced from the thermal converters would supply fuel for the Athabasca operation. Sulfur would be produced as a by-product.

Shell planned to commence operations during 1966, with production to reach 100,000 bbl. per day by 1971. The payout on an operation on this scale will be eight years. The payout time increases rapidly as the project size decreases. The Province of Alberta would have realized $300 million in royalties over the first 25-year life of the proposed project. This plan was turned down by the Commission on the grounds that it would disrupt the present market.

One factor which markedly affects the overall economic efficiency of the project is the quantity of heat lost to the underlying and the overlying formations. The heat loss can be corrected by injecting steam at higher rates and decreasing well spacing. This, in turn, is limited by the permeability which can be developed within the formation with the maximum pressure which can be applied without rupturing the zone in a vertical plane. Displacement efficiency in swept zones reaches a value as high as 87 percent. Preliminary tests have shown no channeling or bypassing of injected fluid.

This brief discussion of the Shell Oil Company's project of thermal "in situ" recovery of bitumen from tar sands gives some data with which to compare and evaluate the bituminous sandstone deposits of the Uinta Basin.

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