BITUMINOUS SANDSTONE NEAR VERNAL, UTAH

By E. M. Spieker

ABSTRACT

Asphalt Ridge, a series of low discontinuous hogbacks, 3 to 4 miles southwest of Vernal, Utah, contains beds of bitumen-saturated sandstone, most of which are of Eocene age and belong to the Uinta formation, but a few may belong to the Mesaverde formation, of Cretaceous age. At seven localities along a strip of outcrop about 11½ miles long the thickness of the bituminous beds was measured and their relative richness estimated. Samples collected from one locality were analyzed chemically and mechanically to determine the character and quantity of the bitumen and the distribution and proportion of the various sizes of the sand grains. The analyses showed that the bitumen content of the sandstone ranges from about 8 per cent to a little more than 15 per cent by weight. On the basis of these data and the assumption that the mining can be carried back 1½ miles from the outcrop it is estimated that the whole area examined should contain about 1,175,000,000 cubic yards, or about 1,970,000,000 tons, of bituminous rock. Of this amount 1,030,000,000 tons is in one tract about 2½ miles long at the northwest end of Asphalt Ridge. The bituminous sand has been successfully used as it is mined for paving the streets of Vernal. The bitumen may lend itself to hydrogenation so as to yield motor fuels and related products.

INTRODUCTION

Asphalt Ridge, southwest of Vernal, Utah, has long been known to contain beds of bitumen-bearing sand and sandstone, which, as suggested by the name given to the ridge, have been called asphalt rock. Chemical examination of the material shows that it is not true asphalt but may more properly be designated bituminous sandstone.

In order to determine roughly the amount, availability, and general stratigraphic relations of these beds, the writer made a brief reconnaissance examination of Asphalt Ridge in September, 1926. No detailed map was made, but a number of locations on the outcrop of bituminous sandstone were plotted on the map of the region made in 1907 by Gale.[1] The outcrop of the bituminous sandstone was followed throughout its extent, and detailed sections were measured at several localities.

[1] Gale, H. S., Coal fields of northwestern Colorado and northeastern Utah: U. S. Geol. Survey Bull. 415, pl. 21, 1910.

PHYSICAL FEATURES OF THE AREA

Location.—The area described is in northeastern Utah, west of the mouth of Split Mountain Canyon of the Green River (see fig. 2), south of the Uinta Mountains, in the eastern part of the Uinta

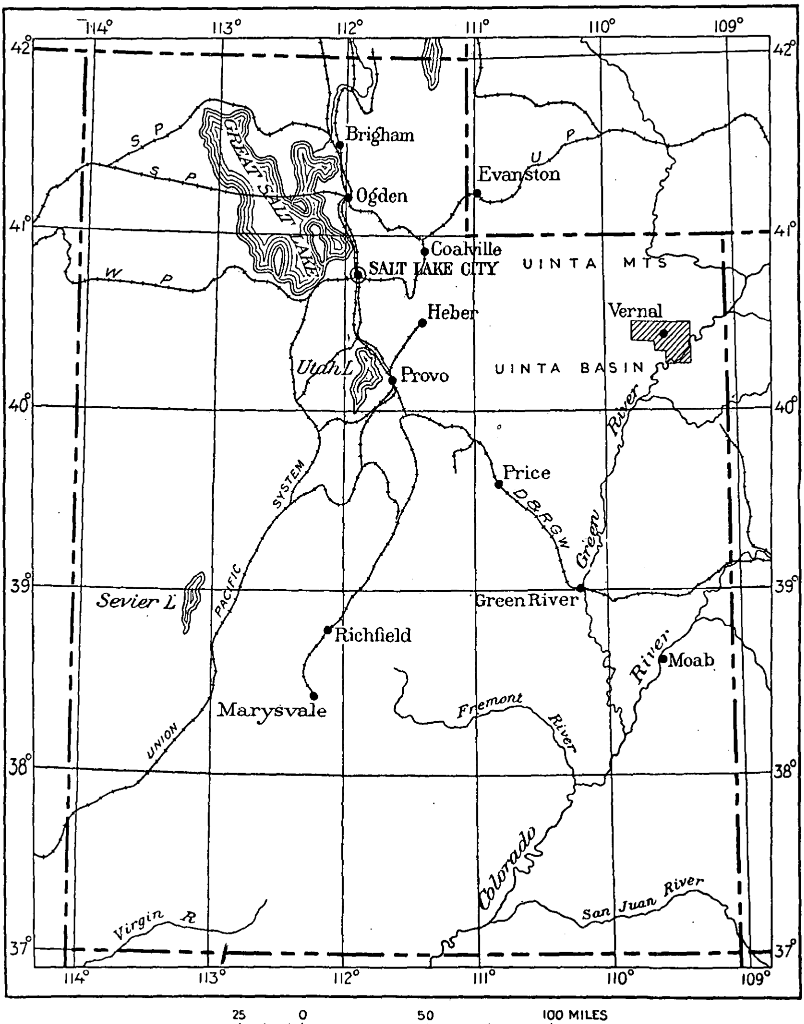


FIGURE 2.—Index map of Utah showing location of Asphalt Ridge

Basin. Asphalt Ridge occupies parts of T. 4 S., Rs. 20 and 21 E., T. 5 S., Rs. 21 and 22 E., and T. 6 S., R. 22 E. Salt Lake meridian, Utah.

Surface features.—Ashley Valley (see fig. 3) is flanked on the southwest by a line of hills and hogbacks, 200 to 900 feet high and about 14 miles long, known as Asphalt Ridge. This ridge, a distinct topographic feature, trends northwest with fair regularity. The front of the ridge facing Ashley Valley is steep and is indented by the short gulches of intermittent tributaries of Ashley Creek; the other side slopes southwestward at moderate angles and is deeply in-

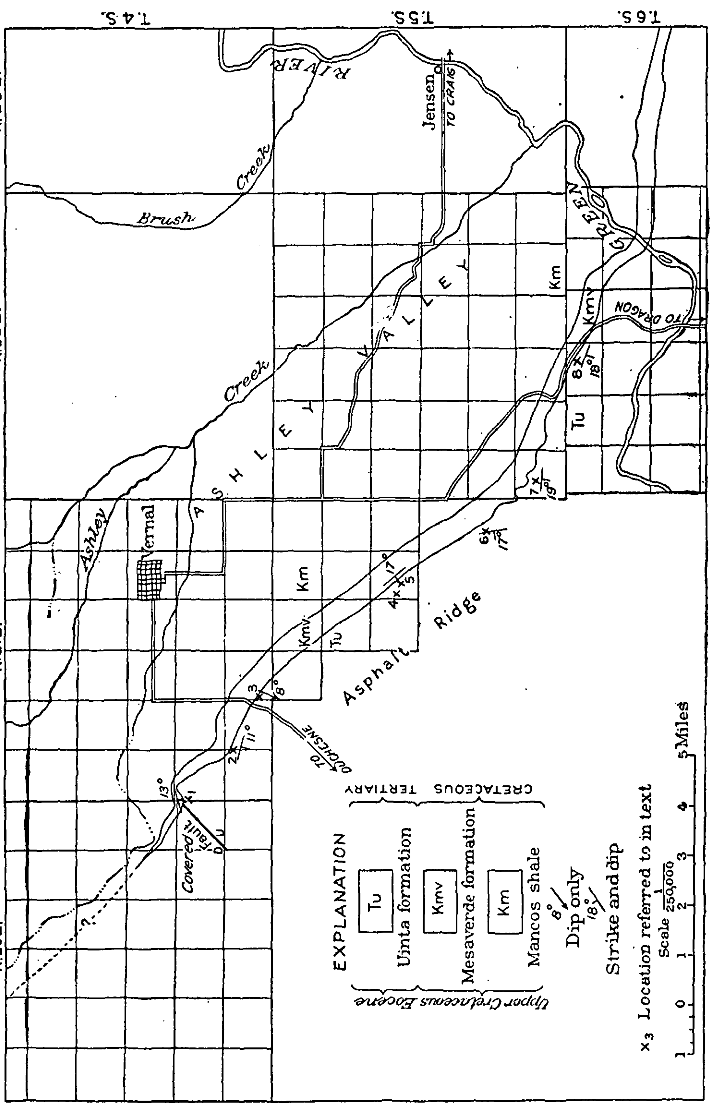


FIGURE 3.—Sketch map of Asphalt Ridge and Ashley Valley, Utah

trenched by long, winding gulches tributary to the Green River below the mouth of Ashley Creek.

The northwestern half of Asphalt Ridge, the highest part, is a prominent landmark. (See pl. 7, *A*.) The southeast half is lower and except for two or three buttes that rise 100 to 200 feet above the main ridge is not a conspicuous surface feature. (See pl. 7, *B*.) Near the southeast end of the ridge the south side slopes off rather steeply toward the Green River, and the gulches there are deep and rough.

Settlement, accessibility, and roads.—Ashley Valley is well populated. The rich valley soil supports many successful ranches. Vernal, whose population in 1920 was 1,309, is the commercial center of the valley and the principal town in the eastern part of the Uinta Basin.

The area is reached by highway, the nearest railroad points being Price, Utah, on the Denver & Rio Grande Western Railroad, about 125 miles by road southwest of Vernal, and Craig, Colo., the terminus of the Denver & Salt Lake Railroad, 137 miles east of Vernal. Salt Lake City is 186 miles west by highway. Roads to all these places are normally good and are being improved in response to the demands of increasing automobile traffic.

Asphalt Ridge is accessible from Vernal by road at several places, but the only good roads that reach it are the Duchesne (Victory) Highway west of Vernal, which crosses the ridge in the northwestern part of T. 5 S., R. 21 E., and the road to Dragon, which crosses it in the northern part of T. 6 S., R. 22 E. A road has been constructed to the "asphalt" quarry (location 2, fig. 3), and in 1926 an automobile could reach the base of the hill beneath the quarry. Other poor roads and trails lead from ranches to "asphalt" and coal prospects.

GEOLOGY

STRATIGRAPHY

Formations exposed.—The geologic formations of Ashley Valley are listed below.

Formations exposed in Ashley Valley and Asphalt Ridge

System	Series	Formation	Character	Thickness (feet)
Tertiary.	Eocene.	Uinta formation.	Varicolored shale, sandstone, and conglomerate; bituminous sand in basal part.	500+
		—Unconformity—		
Cretaceous.	Upper Cretaceous.	Mesaverde formation.	Sandstone, shale, and coal.	1,000±
			Sandstone and shale.	
		Mancos shale.	Gray marine shale and sandstone.	5,000+

Bituminous sandstone occurs in the basal part of the Uinta formation, which in this region is underlain by the Mesaverde formation. The uppermost Mesaverde rocks (which apparently correspond to the Williams Fork formation of northwestern Colorado) are gray to buff sandstones, for the most part medium grained and typical of the formation in the general region. The lower part of the Mesaverde, which consists of sandstone and shale, apparently corresponds to the Iles formation of northwestern Colorado. The characteristic rocks of the Uinta formation are red and cream-colored shale and sandstone and coarse siliceous conglomerate. These are easily distinguishable from the Mesaverde rocks, but the sandstone beds at the base of the Uinta formation are in places much like those in the Mesaverde, and the contact between the formations is at many places difficult to discern.

Uinta formation.—The Uinta formation of this area has been identified by the writer by tracing from the central part of the Uinta Basin, where the typical formation is exposed, and from the western part of the basin, where it definitely overlies the Bridger and Green River formations. Moreover, it shows colors and a lithologic habit which are peculiar to the Uinta formation and which are not exactly duplicated in the Wasatch formation in this general region. The reds of the Uinta formation possess a distinctive orange tint, and the cream colors an indescribable cast, neither of which is characteristic of the Wasatch formation. These rocks in Asphalt Ridge were mapped by Gale as a part of the Wasatch formation, but the Wasatch and Green River formations are absent from this locality.

Most and perhaps all of the bituminous sandstone of the Vernal locality is in the Uinta formation. The detailed sections given elsewhere in this paper show the character of the lower part of the Uinta formation. About 500 feet of the formation is exposed in Asphalt Ridge.

The Uinta formation lies unconformably on the Mesaverde rocks, as the Wasatch, Green River, and Bridger formations are entirely missing and probably also a considerable thickness of Upper Cretaceous rocks. At one place at least the contact appears to show angular unconformity. As noted by Gale, westward the base of the Uinta cuts downward into the Mesaverde sandstones, and at location 1 (see fig. 3) apparently the whole of the upper Mesaverde had been eroded away before deposition of the Uinta beds. The contact between the formations therefore represents an unconformity of considerable magnitude.

STRUCTURE

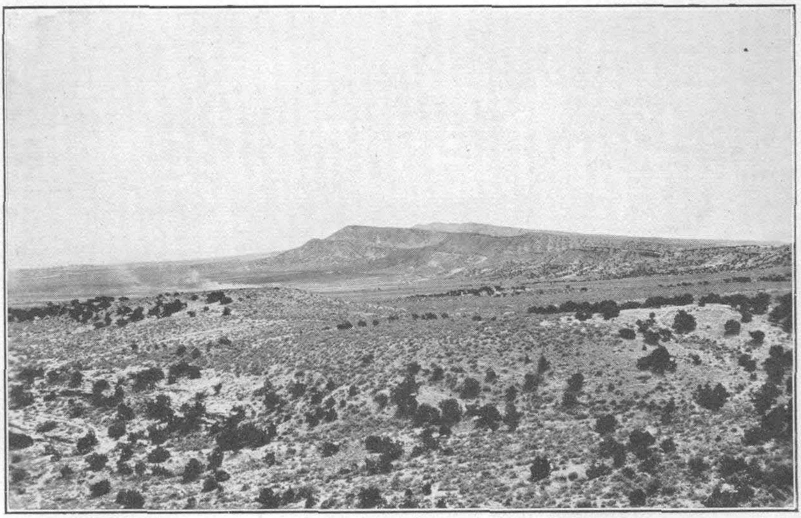
In Asphalt Ridge the strata dip south and southwest at angles ranging from 8° to 30°, and the strike ranges between N. 80° E. and N. 10° W. (See fig. 3.) In the central part of the ridge the strike is generally about N. 40° W., but toward both ends it swings westward, and at the northwest end, near location 1, it curves around to N. 80° E. These trends are broadly reflected in the contacts shown in Figure 3. The rocks here form part of the south flank of the Split Mountain anticline and dip toward the main structural depression of the Uinta Basin. At most places near the contact between the Mesaverde and Uinta formations the rocks appear to dip at about the same angle and in the same direction, but at location 8 the Uinta beds appear to diverge in strike from the underlying Mesaverde in a manner suggestive of angular discordance between the formations. The strike of the Cretaceous beds at this place is about N. 70° W., but that of the Uinta beds is apparently more nearly west, perhaps due west. The Cretaceous beds dip more steeply than the Uinta, suggesting that two stages of tilting occurred, one in pre-Uinta time and one in post-Uinta time.

BITUMINOUS SANDSTONE

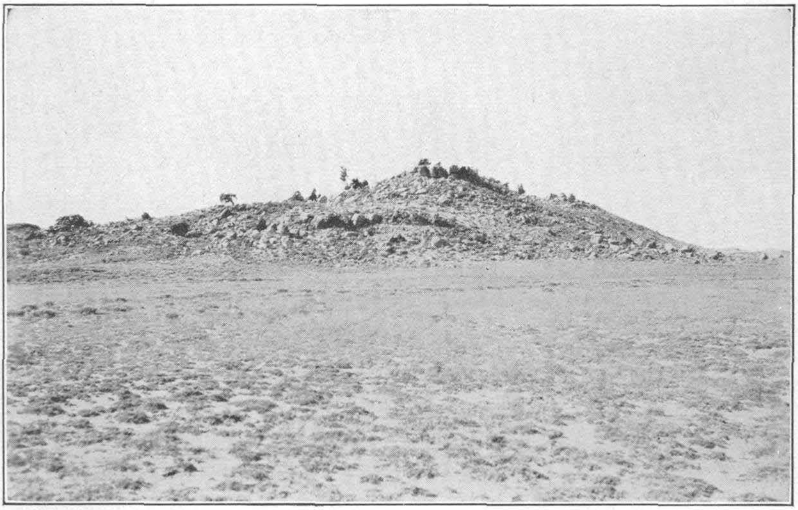
GENERAL CHARACTER

The bituminous rock is sand or sandstone, gray in normal color, ordinarily medium grained but at many places fine grained, impregnated to various degrees with brownish-black bitumen. Much or perhaps all of the rock is simply sand held together by the bitumen, but as most of it is firm and rocklike in character it should be called sandstone. Some of the rock is barely stained brown by the bitumen, but in the richest rock the bitumen occupies more than the normal pore space of the sand. When fresh the rich rock is sticky and tough and yields to hammer blows much as chewing gum would. At a few outcrops the richest rock, heated by the sun, has flowed downhill in pillowy masses resembling lava of the pahoehoe type. The bituminous sandstone weathers to a characteristic blue-gray color. Samples that have been considerably weathered are dark brown in the interior, those that are less weathered are black. The lean and deeply weathered rock breaks like ordinary sandstone, but the fresh rich rock, as exposed in quarries and drift, is gummy and tough.

There are two kinds of bituminous rock. One is pure bituminous sandstone, as described above, and the other is conglomeratic, the pebbles of the conglomerate consisting of cream-colored to white pellets and irregular fragments of silt or very fine grained sand which are not impregnated with bitumen. Seams of this silt run



A. ASPHALT RIDGE, UTAH, AS SEEN FROM THE NORTHWEST



B. FRONT OF ASPHALT RIDGE NEAR SOUTH END

SPECIMENS OF BITUMINOUS SILT-PELLET CONGLOMERATE, SHOWING SHAPE, DISTRIBUTION, AND LACK OF SATURATION OF PELLETS

A, Surface at right angle to bedding, showing flat fragments. *B*, Surface parallel to bedding, showing large rounded pellet and diversely oriented smaller ones. *C*, Surface parallel to bedding, showing range in angularity and orientation of pellets. All four-fifths natural size.

FACE OF QUARRY AT LOCATION 2, ASPHALT RIDGE, UTAH

The black, freshly broken rock is visible on the right, and the dark-gray weathered rock elsewhere in the view. White silt pellets and seamlets are visible on several rock faces.

through some of the bituminous beds, usually along bedding planes. Samples of the conglomeratic rock are shown in Plate 8.

Samples of the rock were taken for analysis and laboratory study, and the results of these examinations are given on pages 88–95, in connection with conclusions that directly follow concerning the amount, availability, and uses of the material.

LOCALITIES AND DETAILED SECTIONS

The locations given on Figure 3 were made as closely as possible by taking compass bearings to physical features recognizable on Gale's map, but they are at best only approximate. The map was prepared by tracing essential features from Gale's map and adding such data as were obtained in the present examination.

Northwest of location 1 the rocks are completely covered, in the rounded hills forming the continuation of Asphalt Ridge as well as in the valley. Near location 1 the bitumen-bearing strata are cut off by a fault, shown on the map, but from the fault southwestward the rocks are fairly well exposed on the steep northeast slope of the ridge.

Location 1 is in the NW. ¼ sec. 30, T. 4 S., R. 21 E., where the following section is exposed:

Section of rocks at location 1

	Feet
1. Conglomerate, gray, siliceous; pebbles, poorly sorted, 6 inches or less in diameter, principally of quartzite	40+
2. Bituminous sandstone, fairly rich	25
3. Concealed (probably bituminous sandstone)	10
4. Bituminous sandstone, like bed 6	22
5. Bituminous sandstone, containing many white pellets (see p. 91) and seams	10
6. Bituminous sandstone, fine grained, moderately impregnated at base, increasing upward in coarseness and content of bitumen; drift on this bed exposes many seamlets of pure bitumen and some seams of white clay	56
7. Sandstone, very fine grained, white, thin bedded to massive; strike N. 80° E., dip 13° S	50–100
Total section	213–263
Total bituminous sandstone	113–123

In this section No. 6 is unquestionably the richest bed, but Nos. 2 to 5 might be profitably worked in a large-scale operation. (See p. 94.) No. 7 of the section is doubtless Cretaceous. The overlying bituminous beds may also be Cretaceous, as, apart from the content of bitumen and the silt pellets, they are lithologically similar to bed 7. The conglomerate may represent the base of the Uinta formation, but this is by no means certain, because at other localities a conglomerate bed which may be an extension of this bed lies some distance above the undoubted base of the Uinta beds.

At location 1 several openings have been made in the principal bituminous bed, one of which is a drift about 150 feet long, and from these workings a moderate amount of bituminous rock has been taken away, apparently several years ago. The place was formerly accessible by a road, which has been largely washed out in the steep slopes near the workings but which in 1926 could be traveled by automobile as far as the base of the hill.

Location 2 is at a quarry in the NE. ¼ sec. 31, T. 4 S., R. 21 E., where a large amount of bituminous rock has recently been taken out for use in paving the streets of Vernal. (See pl. 9.)

Between locations 1 and 2 the bituminous sandstone seems to be fairly uniform, and, as the following section shows, at location 2 it is nearly the same as at location 1.

Section of rocks at location 2

	Feet
1. Red and cream-colored sandstone and siliceous conglomerate of the Uinta formation; thickness present in knobs near quarry	50
Apparent unconformity.	
2. Bituminous sandstone, similar to bed 3 but in places less impregnated	70
3. Bituminous sandstone, very rich, medium grained, containing many seams of fine silt and pebbles or pellets of same material (difficult to measure on account of spread of outcrop, cross-bedding, and dip), about	120
4. Sandstone, fine grained, gray to cream-colored, containing fine-grained layers; at quarry strikes N. 75° W. and dips 11° S	30+
5. Sandstone, medium to coarse, gray, ferruginous in places; at base of hill strikes due east and dips 20° S.	
Total section	270+
Total bituminous sandstone	190

At this locality also it is difficult to determine whether the bituminous rock is Cretaceous or Tertiary. At the quarry the rock seems to be part of the Cretaceous succession, as it rests conformably on beds of undoubted Cretaceous age and has the same general character. The unconformity above bed 2 is suggestive, but it might be merely a local unconformity of the type common in continental beds like those that make up the Uinta formation. Farther up the gulch from the quarry, however, the red beds of the Uinta come down into the bituminous series and appear to be interbedded with it.

The next easily accessible place southeast of location 2 is the point where the Duchesne Highway crosses Asphalt Ridge, and there small amounts of bituminous sandstone are exposed in the road cut, but no satisfactory section is available.

Location 3 is east of the Duchesne Road in the SW. ¼ sec. 33, T. 4 S., R. 21 E., at a gravel pit from which the conglomerate in the Uinta formation has been excavated for use as road metal. Some bituminous material has been quarried from beds below this conglomerate. The section follows:

Section at location 3

	Feet
1. Red and cream-colored sandstone and shale of the Uinta formation; estimated	500±
2. Conglomerate, gray, siliceous, as at location 1	10–15
3. Shale, red and buff, sandy, mainly brick-red	33–35
4. Bituminous sandstone, fine grained, cross-bedded; weathers blue-gray; brown-black when fresh; moderately impregnated (base not exposed)	30+
Total section	573–580±
Total exposed bituminous sandstone	30+

Dip of beds 8° S.; strike approximately N. 70° W.

The section at location 3 does not show the full thickness of the bituminous sandstone, and the rocks beneath the section given are not exposed, but it seems likely that the bed is much thinner than at location 2. Southeast of location 3 the bituminous beds appear to be somewhat irregular, and the bed at location 3 may not be the same as the lower bed at location 4, although it is unquestionably in the same general zone.

Location 4 is in the SW. ¼ sec. 14, T. 5 S., R. 21 E., the steepest part of Asphalt Ridge. The rocks are unusually well exposed. The section measured here follows:

Section at location 4

	Feet
1. Conglomerate, as of other sections, overlain by red shale.	
2. Conglomeratic (silt-pellet) bituminous sandstone	5
3. Sandstone, gray	8
4. Conglomeratic bituminous sandstone	4
5. Shale, drab	5
6. Bituminous sandstone, irregularly impregnated	3
7. Concealed	30±
8. Sandstone; weathers brown	8
9. Bituminous sandstone	5
10. Shale and sandstone, gray, locally bituminous	6±
12. Shale, red and yellow-green, interbedded with gray-buff sandstone	30±
13. Bituminous sandstone	16
14. Sandstone, white, thin bedded	5
15. Bituminous sandstone	4
Base concealed.	
Total section	134±
Total bituminous sandstone	37

Beds 9, 10, and 11 of this section merge northwestward to form a single bed of bituminous sandstone about 15 feet thick, and still farther northwest this bed thickens to as much as 60 feet. About a mile northwest of location 4 the lower bed (13 to 15 of this section) begins to pinch out.

The beds in the foregoing section appear to be about 200 feet above the base of the Uinta formation, and their relation to the beds at locations 1 to 3 is uncertain.

Location 5, in the next gulch southeast of location 4, is also in the SW. ¼ sec. 14, T. 5 S., R. 21 E. Much more bituminous sandstone is exposed in this locality, and the rocks in the Uinta formation show a much greater variability. The thicknesses given in the following section were estimated and thus afford merely a rough measure of the amount of bituminous material present, but they are probably accurate enough for the present purpose.

Section at location 5

	Feet
1. Conglomerate (same as in the preceding sections).	
2. Bituminous zone (mainly bituminous sandstone)	30–50
3. Shale and sandstone (typical Uinta lithology)	150–180
4. Bituminous sandstone	3
5. Concealed interval	15
6. Bituminous sandstone	5
7. Shale	10
8. Bituminous sandstone	15
9. Interval	50
10. Bituminous sandstone (base not exposed)	20–25
Total section	298–353
Approximate total bituminous sandstone	100

Strike N. 40° W.; dip 17° SE.

In the next gulch southeast of location 5 there is exposed a similar fairly rich zone which continues for some distance southeastward but thins considerably before reaching location 6, in the NW. ¼ sec. 25, T. 5 S., R. 21 E., as may be seen in the following section.

Section at location 6

	Feet
1. Shale, etc., of the Uinta formation.	
2. Sandstone, gray, very slightly saturated with bitumen	15
3. Sandstone, gray, slightly saturated	3
4. Conglomerate of bituminous sandstone, moderately saturated	1½
5. Sandstone, gray, slightly saturated (upper Mesaverde).	
	19½

About 500 feet southeast of location 6, across the gulch, considerably more bitumen is present, as may be seen in the following section:

Section 500 feet southeast of location 6

	Feet
1. Conglomerate like that in the section above.	
2. Concealed interval (probably shale)	60–70
3. Bituminous sandstone, evenly impregnated but apparently not very rich (base not exposed)	50–55+
Total section	110–125
Total bituminous sandstone	50–55+

Location 6 is near a wagon road that leads southwestward through a gap that marks the south end of the main part of Asphalt Ridge. Between locations 6 and 7 the topography changes. The beds of Mesaverde sandstone, which northwest of location 6 make a low rough area of discontinuous hogbacks at the base of Asphalt Ridge, form a low ridge that continues past the end of the main part of Asphalt Ridge and might be considered a minor branch of it. The head of a large gulch extends into the southwest side of this Mesaverde ridge in rough, steep-walled canyons. The base of the Uinta formation appears in the upper parts of these canyons, and with it the bitumen zone.

Location 7 is at a narrow place in the bottom of one of these gulches, in the NW. ¼ sec. 31, T. 5 S., R. 22 E. The section measured there follows:

Section at location 7

	Feet
1. Cream-colored and red shale, limestone, and sandstone.	
2. Bituminous sandstone, thin bedded, variable, moderately impregnated at base	3–8
3. Sandstone, gray, thin bedded	9±
4. Bituminous sandstone, rich	1
5. Covered (oil-soaked shaly sandstone)	6
6. Bituminous sandstone (main bed)	6–7
7. Coal, fair to poor	2
Total section	27–33±
Total bituminous sandstone	10–16

Strike N. 85° W.; dip 69° S.

About 100 yards farther west the bituminous zone is overlain by a conglomerate of limestone and quartzite pebbles whose matrix is limestone. The pebbles of Paleozoic limestone and quartzite were doubtless derived from the Uinta Mountains. The bituminous beds are very irregular for a mile or so in either direction and appear to thicken somewhat westward and then to thin again. At location 7 the main bituminous bed seems to be unconformable at both top and base. It is very irregular, and it pinches out against the Cretaceous sandstone on the south side of a big butte in sec. 31, T. 5 S., R. 22 E.

Location 8 is in the NE. ¼ sec. 4, T. 6 S., R. 22 E., about half a mile west of the place where the road to Dragon crosses the base of the Uinta formation. Here the bituminous sandstone appears to be at the base of the Uinta formation, although it might belong in the Cretaceous.

Section at location 8

		Feet
1.	Red, drab, and cream-colored shale.	
2.	Limestone, gray, hard; forms top of low ridge	3±
3.	Shale, cream-colored, calcareous	25±
4.	Sandstone, gray, partly impregnated with bitumen	5
5.	Sandstone, gray, with lenses stained yellow-green	3
6.	Bituminous sandstone	18
7.	Sandstone, gray (upper Mesaverde)	50
	Total section	104±
	Total bituminous sandstone	23

Strike of Cretaceous rocks N. 70° W.; dip 18° S.
Strike of bituminous bed nearly west.

Just east of location 8 the bituminous sandstone pinches out between the shale of the overlying Uinta formation and the sandstone of the underlying Cretaceous formation. On the road to Dragon no bitumen is visible in either Cretaceous or Tertiary rocks.

COLLECTION AND EXAMINATION OF SAMPLES

Samples of the bituminous sandstone were taken near locations 1 and 2 for laboratory study. One sample of the richly impregnated rock from location 2 was submitted to the chemical laboratory of the United States Geological Survey for general chemical analysis, and all the samples were studied by the writer in the sedimentation laboratory at Ohio State University. The samples were analyzed to show the character of the principal kinds of rock.

In the Ohio laboratory a weighed sample was immersed in successive baths of carbon disulphide until the bitumen was extracted. The sand grains apparently were cemented by the bitumen alone, as treatment with the solvent sufficed to free all particles except a few that were cemented by a mineral cement. The remaining sand was dried, weighed, and analyzed mechanically by sieving. Standard sieves were used and the samples were shaken by machine for periods of 10 to 15 minutes. The specific gravity of the sand was determined by the pycnometer method and the rock density [2] of the bituminous rock by weighing a coated sample in water and in air. From these determinations the pore space was calculated, and porosity determinations were made by a modification of the method described by Russell.[3] Aggregates of the sand, as well as the separate fractions

[2] Rock density differs from specific gravity in that rock density takes into consideration the specific gravity of both the pore space and the constituent mineral grains.

[3] Russell, W. L., A quick method for determining porosity: Am. Assoc. Petroleum Geologists Bull., vol. 10, pp. 931–938, 1926.

resulting from mechanical analysis, were examined under the microscope. The specific gravity of the extracted bitumen was ascertained by weighing a sample in absolute alcohol and in air, and by determining with a Westphal balance the density of a solution of alcohol and water in which the bitumen neither sank nor floated.

In order to determine qualitatively the permeability of the silt pellets in the conglomeratic bituminous rock, the writer placed drops of several kinds of crude petroleum on the pellets of several samples and found them highly absorbent.

MECHANICAL ANALYSIS AND MICROSCOPIC EXAMINATION

The mechanical constitution of the sands is shown graphically in Figure 4. Samples 1, 2, and 3 were taken from freshly exposed surfaces in the quarry at location 2 and represent the richly impregnated, soft, gummy rock. Sample 4 was taken from the drift at location 1 and represents finer-grained, harder rock than the average from the quarry. Sample 5 was taken from the weathered outcrop near location 1, to represent the "conglomeratic" type.

The sand in samples 1, 2, and 3 is fairly well sorted. That in sample 1 is finer than the other two, but all three samples show the same general proportions of the constituent grade sizes. The maximum fraction in all three approaches 70 per cent, and most of the remainder is in the size next coarser than the maximum. These are the characteristics of well-sorted sand, such as is deposited by the action of waves or the long-continued flow of slightly varying currents. The sharp drop from the maximum to the next finer grade is a noteworthy characteristic of these sands. In sample 1 the amount in the finer grades is almost negligible, and in samples 2 and 3 it is less than 12 per cent. This condition is most likely to be produced either by waves of fairly constant size or by currents of nearly uniform intensity. Such waves or currents will continually carry away any finer material and wash, rework, and deposit the coarser. In an ideal case the lower limit should be sharply fixed. This consideration is based mainly on theory, which so far as the writer knows has not yet been fully tested but which is borne out by many examples thus far studied by the writer, notably the deposits on the beaches of lakes and the open sea. Shore deposits of large rivers also show this characteristic, although less clearly, as might be expected. The limits on the coarser side are likewise those characteristic of well-worked material. The amounts in the coarser proximate grade[4] doubtless represent material which the waves or currents could move by saltation or rolling but could not carry suspended; this material is much less abundant than the suspended material.

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[4] Udden, Johan, Mechanical composition of clastic sediments: Geol. Soc. America Bull., vol. 25, p. 658, 1914.

Sample 4 is not so well sorted as the first three, but it shows in part the characteristics of well-worked material. The sand is mainly fine, and the maximum grade contains about 60 per cent of the total. The conditions that produced this sand were probably less constant

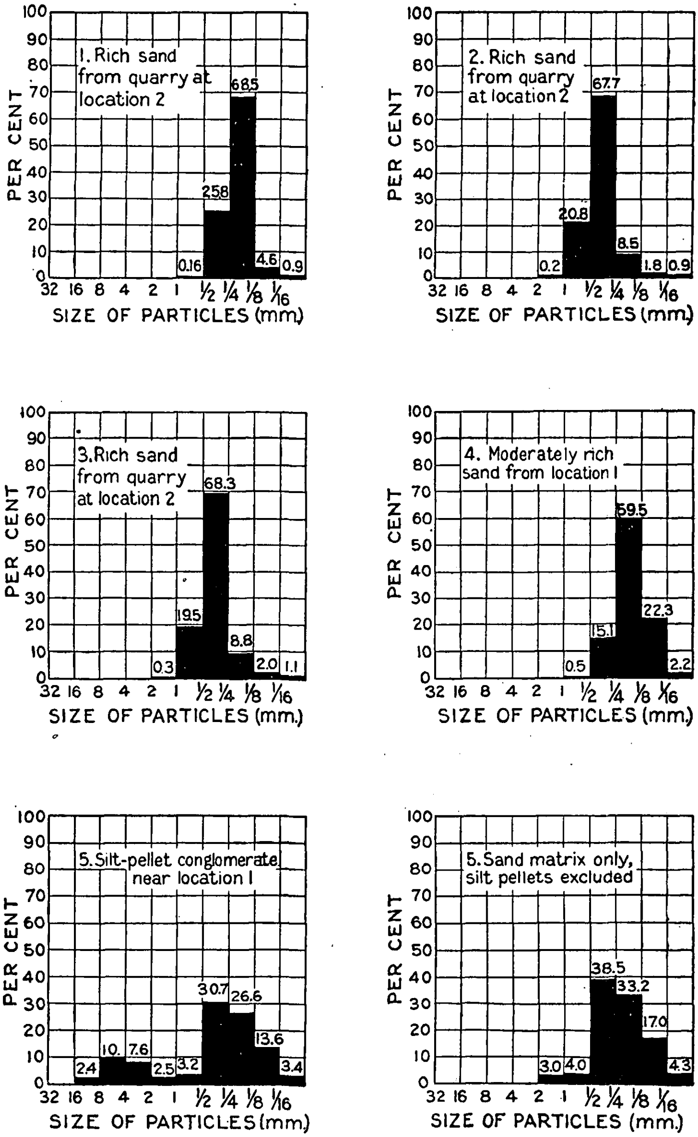

FIGURE 4.—Graphic representation of mechanical analyses of sand residue from bituminous sandstone of Asphalt Ridge, Utah

than those for samples 1, 2, and 3. There is a considerable admixture of material finer than the maximum—nearly 25 per cent—which probably indicates considerable slackening of the water currents with net predominance of silting over washing. This sample, then, represents a modification of the conditions that produced the sand of samples 1, 2, and 3.

The rock represented by sample 5 is in some respects a curiosity. Offhand, it appears to be a typical clay-pellet conglomerate in which the sandy matrix is impregnated with bitumen but the clay pellets are not. These clay pebbles are cream-colored and stand out very clearly against the black background of the bituminous matrix. (See pl. 8.) Microscopic examination of the clay pellets, however, reveals the fact that they are not clay but chiefly very finely divided quartz, of the grade usually termed fine silt. They will therefore be referred to as silt pellets, and the rock as silt-pellet conglomerate.

The bitumen of sample 5 dissolved much more slowly than that of the other samples, digestion in carbon disulphide for two days being necessary to free the individual grains. Samples 1, 2, and 3 disintegrated immediately on soaking in the solvent, and sample 4 after a few hours. The slow solution of sample 5 may be due to the weathered condition of the sample. In the process of soaking and in the subsequent mechanical handling of the material every precaution was taken to preserve the original size and shape of the silt pellets, but doubtless many were chipped and fractured, so that the proportions in the sizes larger than 1 millimeter shown in Figure 4 are not accurate. Furthermore, the sample selected for mechanical analysis did not contain the largest observed silt pellets, which reach a maximum size of 50 by 20 by 5 millimeters in other samples collected by the writer. In the deposits still larger sizes may perhaps be found.

Two graphs are given in Figure 4 for sample 5, one representing the aggregate and the other the sand matrix. This is done because the silt pellets may in a certain sense be considered accidental and the sand matrix the more significant part of the rock for the interpretation of the analysis. The first graphic figure, showing the aggregate, has the general aspect of a river gravel consisting of a matrix of sand with pebbles worked in at times of increased activity of the stream. The sand itself shows the characteristics of poorly sorted material rather typical of stream deposits. There is a sharp drop from the maximum ingredient to the next coarser grade, but a gentler fall of the pyramid on the fine side. This suggests the more irregular conditions characteristic of stream deposition, in which currents commonly vary so greatly that the size being deposited most abundantly differs considerably from time to time. The sharp separation of the silt from the silt pellets, emphasized by the abrupt descent of the curve on the coarse side, shows that the water from which this sand was deposited was more active than that from which the sand of the other samples was deposited and suggests that the silt pellets may have been brought in by some unusual process.

The grains of the sand are mainly clear quartz and dark-gray quartzite, with minor quantities of cream-colored chert, rose quartz, amethyst, and chalcedony. The sand of all the samples is similar. The coarser fractions of all samples contain fragments of sandstone and of the cream-colored siltstone of the silt pellets. The sandstone fragments are firmly cemented by a small quantity of secondary silica. In the medium and coarser fractions (larger than 0.25 millimeter) the dark-gray quartzite is present in sufficient quantity to give these sands a dark color; in the finer fractions it is sparingly present, and these fractions are white to cream-colored. A notable feature of the material is the very small quantity of clay; the finest fractions contain almost exclusively angular grains of clear quartz, with a sprinkling of heavy minerals among which pyrite, magnetite, and muscovite are most abundant. Sample 4 contains a large amount of pyrite.

Most of the individual grains are angular. A count of several microscopic fields of the aggregate of sample 2, covering about 200 grains, showed about 2 per cent well rounded (no flat faces), 1 per cent moderately rounded (flat faces visible), 5 per cent subangular (corners and edges rounded), and 92 per cent angular. Estimates of all other samples gave similar results except for the sandstone fragments of the "conglomerate" (sample 5), which are mentioned below.

The silt pellets of the "conglomerate" show some curious characters. Nearly all are flat and chiplike, and many are angular. All have been indented by the grains of the surrounding sand, and the individual pellets, when freed in the mechanical analysis, are so incrusted by inset sand grains that they look like fragments of sandstone. Doubtless the flattened shape of many of the pellets is due to pressure upon rounded balls of the soft material. The angular fragments, however, appear to have been chipped when fairly firm. Why the pellets should have cohered so well when soft is not easy to see; the apparent amount of clay is small, and the material is highly absorbent and under the microscope appears to be little more than an aggregate of very fine quartz grains.

The sand of the conglomerate differs somewhat from that of the other samples in that the fractions greater than 0.5 millimeter contain many fragments of sandstone in which the grains are on the whole better rounded than the free grains of the sand. Probably half of the grains in the sandstone fragments are at least moderately rounded, and many more are subangular. Very few of the free grains in the sand are rounded. The fractions finer than 0.5 millimeter are similar in character to the sand of the other samples.

The predominance of angular grains does not appear to agree with the sorting of the sand; sand as well sorted as that in samples 1 to 3 would presumably have been considerably worn in the process of transportation and sorting. This evidence can not be evaluated, however, without consideration of the possible sources of the sand. It is obvious that part of the material, or perhaps nearly all of it, has been in sandstone before. However, the nearly exclusive occurrence, in the coarser fractions, of the highly angular grains of dark-gray quartzite suggests that these grains may have come only a comparatively short distance from a fresh body of quartzite and so are not as small nor as much worn as the quartz grains. An abundance of quartzite is present in the Uinta Mountains, from which the sediments may have been derived, but most of it is reported, by those authors who have described it, as red or white. The absence of red quartzite in the sand suggests that the streams which brought in this material had not yet begun to erode the thick series of red quartzite that makes up the main core of the Uinta Mountains. The evidence afforded by the sands considered here seems to point to a complex source, including some fresh quartzite and some fairly well sorted sandstone and siltstone. The few rounded grains probably came from older beds of sandstone, possibly one of the littoral marine sandstones of the Upper Cretaceous. The source was probably not far away, and the process of accumulation probably involved rapid but efficient sorting.

ROCK DENSITY AND PORE SPACE

Two specimens of the the rock from location 2 (sample 2) were found to have a rock density of 2.03. One specimen of sample 4 has a rock density of 1.99. The specific gravity of the sand of sample 2 was found to be 2.63, slightly less than that of pure quartz. The pore space of sample 2, determined from these data, is 38 per cent, and that of sample 3 is 33.7 per cent. The porosities of three other samples from the quarry at location 2, determined by a modification of the method described by W. L. Russell, are 29.5, 37.0, and 37.9. Some of the material, however has much greater pore space than this; that of the sample examined in the laboratory of the Geological Survey was reported to be 47 to 49 per cent. The usual pore space of an aggregate of identical spheres is 47.64 per cent. The samples that show the greatest pore space are of a type in which the writer recognized in the field the presence of bitumen bodies free from sand grains.

BITUMINOUS CONTENT OF SAND

The sample submitted to the chemical laboratory of the Geological Survey was found to contain 12.8 per cent by weight of bitumen soluble in carbon disulphide, and as practically all the bitumen is soluble in carbon disulphide, this represents nearly the total quantity.

Sample 1 was found by the writer to contain 12.4 per cent of bitumen; sample 2, 14.0 per cent; sample 3, 12.0 per cent; sample 4, 8.3 to 9.0 per cent. Six other samples, selected at random from the material at location 2, were found to contain 13.3 to 15.1 per cent of bitumen. The average for the six samples is 14.2 per cent. The content of sample 5 was not determined because it constitutes so small a part of the bituminous strata, and because the percentage varies so greatly with the distribution of the silt pellets that even the average of several determinations might yield a misleading result. The percentages here given are used to determine the amount of bitumen present in the deposit in an estimate given on pages 95–97.

CHEMICAL NATURE OF THE BITUMEN

The sample submitted to the chemical laboratory of the Geological Survey was examined by E. Theodore Erickson, who reports as follows:

Chemical character of bituminous sand from Asphalt Ridge, Utah

	Per cent
Loss (moisture) obtained at 105° C. for 1 hour	0.20
Residue obtained upon ignition	86.45
Total sulphur by the Carius method	.09
Soluble in carbon disulphide	12.8
Fixed carbon in residue from evaporation of carbon disulphide	7.1
Soluble in petroleum ether, specific gravity, 0.644	11
Amount of hydrocarbon material extracted by petroleum ether of chemically saturated nature	65

The bitumen occurring in the sample differs in the following respects from native asphalt: (1) The proportion of solubility in light petroleum ether compared with the solubility in carbon disulphide is somewhat higher than that given by typical asphalt materials. The material designated asphaltenes, which is insoluble in light petroleum ether, may comprise more than one-third of the composition of native asphalt. (2) The yield of fixed carbon is lower. Natural and artificial asphalt materials yield about 15 per cent of fixed carbon. (3) The sulphur content is unusually low. Native asphalts contain from 1.7 to 10 per cent[5] of sulphur.

The bitumen appears to consist of residual material derived from a paraffin-base petroleum or a petroleum containing a high proportion of paraffin series and other saturated hydrocarbons. This conclusion is supported by the high solubility of the bitumen in the sample in light petroleum ether, in which the above-mentioned types of hydrocarbon material are soluble, and by the high proportion of saturation noted in the extracted bitumen.

Further examination of the bitumen by Mr. Erickson shows that it contains a small quantity of paraffin.

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[5] Holde, D., The examination of hydrocarbon oils and of saponifiable fats and waxes, p. 270, New York, 1922.

Thus it appears that the designations "asphalt rock," "asphaltic sand," and others of similar nature which have long been applied to these deposits are not only inexact but misleading and should be abandoned in favor of a more general term such as "bituminous sandstone." The recognition of this material as the residue of a paraffin petroleum rather than a typical asphalt lends added interest to the source and suggests the desirability of further investigation into its origin and history.

The specific gravity of the bitumen, determined by the writer, is 0.980.

WELLS DRILLED TO THE BITUMINOUS SAND

Several wells drilled a short distance southwest of Asphalt Ridge have penetrated the bituminous sandstone beds at moderate depth. Two of these were drilled in 1911 and 1912; one is in sec. 6, T. 5 S., R. 21 E., and the other in sec. 35, T. 4 S., R. 20 E. The well in sec. 6, T. 5 S., R. 21 E., is only about a mile southwest of the outcrop of the bituminous sandstone beds. It is reported that each of these wells contained a small quantity of black oil that was too viscous to be pumped. Recently the Western Venture Corporation has been drilling a well close to one of these old wells near the center of the SE. ¼ sec. 6, T. 5 S., R. 21 E. At a depth of 1,270 feet it penetrated a saturated sandstone bed, and at depths of 1,300 and 1,500 feet it was making a small quantity of gas. The finding of fluid bitumen so close to the outcrop of the bituminous sandstone has a direct bearing on estimates of the reserves of minable bituminous sandstone in Asphalt Ridge.

AMOUNT OF BITUMEN

The data presented on the foregoing pages afford the basis for a rough estimate of the amount of bituminous rock present and available for mining in Asphalt Ridge. For the purpose of making this estimate, the writer has divided the area into three tracts, designated in the following paragraphs, in each of which conditions of occurrence and richness of the rock are sufficiently different to justify separation.

In the section of outcrop between the fault west of location 1 and the Duchesne road, about 2½ miles, the principal bituminous bed is 30 to 120 feet thick and is overlain between locations 1 and 2 by 60 to 70 feet of thinner beds which in places are practically continuous with the main bed. It seems safe to assume that all these beds extend under cover 1½ miles southwestward from the outcrop. The assumption of a greater distance beneath cover for available rock seems unwise, because of uncertainties in the mining and possibly also because of the more [illegible]ly fluid bitumen found in the wells drilled southwest of Asphalt Ridge. A simple calculation, using these linear dimensions and weighted averages for the thicknesses of bituminous rock, shows the total amount present to be about 615,000,000 cubic yards.

The next section of outcrop, from the Duchesne road to a point midway between locations 5 and 6, about 5 miles long, contains thinner beds which are more widely spaced (see sections for locations 5 and 6, p. 86), so that the conditions of mining will be somewhat different from those in the tract above described. Here the main beds appear to have an average thickness of about 11 feet. On the assumption of an extent of 1½ miles from the outcrop, as before, the total amount of bituminous rock appears to be about 435,000,000 cubic yards, of which more than 345,000,000 cubic yards is in the main beds.

The next 1¼ miles of outcrop appears to contain no rock rich enough to consider commercially. Beyond this barren interval the succeeding section of outcrop, which is about 4 miles long, contains leaner rock than that in the two tracts already considered and, owing to changes in topography, presents still different conditions for mining. In this stretch the main beds average 18 feet in thickness and the minor beds about 3 feet. The total amount of bituminous rock present, to a distance of 1½ miles from the outcrop, is probably about 125,000,000 cubic yards. The factors for this estimate are considerably more variable than for the foregoing two, and the possibility of error, in either direction, is accordingly greater. These estimates are probably all conservative.

To summarize the figures given above, it seems that the area should contain as a whole at least 1,175,000,000 cubic yards of bituminous rock. One cubic yard of the kind of rock at location 2 weighs about 1.68 tons, and the amounts named above may be transformed into tonnages by the use of that factor. The total amount is thus about 1,970,000,000 tons, and the amount in the first tract (probably the most promising of all) is about 1,030,000,000 tons.

Translated into barrels of petroleum residue and of original petroleum these amounts yield interesting figures. The rock between locations 1 and 3 contains 9 to 15 per cent by weight of bitumen, and the rock of the first tract above estimated thus contains 93,000,000 to 155,000,000 tons of the bitumen. One barrel of 42 gallons of the bitumen (specific gravity 0.980) weighs 343 pounds, and a ton thus contains 5.831 barrels. The bituminous rock estimated for the first tract therefore contains 542,000,000 to 904,000,000 barrels of bitumen. If, as seems likely, the average richness of the rock in the first or northwestern tract is 13 per cent, the amount is 785,000,000 barrels. For the whole area, on the assumption that the total amount of rock above estimated contains only 10 per cent of bitumen, to allow for the lean rock at the south end, the amount of bitumen is about 1,150,000,000 barrels. The total bitumen in the formation in the area probably exceeds this amount. In the writer's opinion it is nearer 2,000,000,000 barrels than 1,000,000,000 and may be even greater. If the petroleum from which the bitumen was derived contained originally over one-third volatile constituents (gasoline, kerosene), as is likely, then it is fair to assume that the bitumen represents 1,500,000,000 to 3,000,000,000 barrels of petroleum. The original amount of petroleum must have been enormous. The total production of the United States for 1928 was about 898,000,000 barrels, and the total production of the Rocky Mountain fields from 1890 to 1928 has been only 354,000,000 barrels. With due allowances for loss in recovery, the comparison is still striking. It is clear that these bituminous sands represent a large accumulation of petroleum—a lost oil field of notable proportions.

MINING

Underground mining of some sort will be necessary to recover most of the bitumen above estimated; quarrying and steam-shoveling could reach only a small fraction of the total. If underground mining is feasible, the whole amount ought to be at least within reach. At 1½ miles from the outcrop and at a dip of 10° the cover would be about 1,400 feet thick (plus or minus varying amounts up to 500 feet for irregularity of surface relief); at 15°, 2,100 feet; at 20°, 2,900 feet. Difficulties will probably be met in any mining operations, because the rock, though compact, is apparently held together principally by the bitumen and will have a tendency to yield and flow in underground workings. Probably some special methods of mining will have to be devised.

It may be of value to point out the mining possibilities of some of the localities. The most favorable places are obviously those where stripping is easy and open-pit mining or quarrying can be carried on. Unfortunately, the dip of the rocks is so steep that in most places the amount of the overburden becomes excessive as the bed is quarried into the hill. The only places where this is not true are where gulches eroded nearly parallel to the strike of the ridge have laid bare large areas of bituminous rock and separated ridges containing large quantities of the rock overlain by a thin cover. These conditions exist at location 2, where advantage has already been taken of the ease of mining, and the bituminous rock has recently been quarried for use as road metal in paving the streets of Vernal.

At location 7 is a moderately large area which could be stripped, but it is in a very rough gulch and is difficultly accessible. At this place, on the south side of the ridge, the steep stream channels follow the dip of the rocks, thus producing a favorable situation for stripping. However, the quantity and quality of the rock available are probably somewhat low for such operations.

Between location 6 and the southeast end of the outcrop most of the low ridge affords fairly good ground for stripping, but the rock is in most places doubtless too lean for profitable exploitation.

Moderate amounts of rock could be quarried at most places on the outcrop between locations 1 and 5, but probably not enough to justify the installation of much equipment.

USES

The natural sandstone appears to make a good paving material. Pavements laid in 1924 in the town of Vernal, made of the material from Asphalt Ridge without the addition of any other ingredients, were in good condition in 1926 and promised to give excellent service.

The bitumen itself might be profitably amenable to some of the recently developed processes of hydrogenation whereby the lighter hydrocarbons suitable for motor fuel have been synthesized from heavy bituminous residues.

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