GEOLOGY OF THE BITUMINOUS SANDSTONE DEPOSITS NEAR SUNNYSIDE, CARBON COUNTY, UTAH

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The bituminous sandstone deposits near Sunnyside, Carbon County, Utah, the largest known in the United States, were examined by the writers when employed by the Geological Survey, U. S. Department of the Interior, as a collateral part of an investigation of sources of petroleum products. The field work was done by Clifford N. Holmes, Ben M. Page, and Paul Averitt during the summer and fall of 1945. An area of about one square mile enclosing the quarries of the Rock Asphalt Company of Utah was mapped by plane table on a scale of 400 feet to the inch, using as a base enlarged aerial mosaics of the Soil Conservation Service. These maps are shown in figures 1 and 2 respectively.

Conservatively estimated, the Sunnyside deposits contain 1,600,000,000 cubic yards of measured, indicated and inferred bituminous sandstone, half of which is believed to contain at least 9 per cent bitumen by weight. The bituminous beds occur in beds ranging from 10 feet to 350 feet in thickness within a zone about 1,000 feet thick in the upper part of the Wasatch formation and in the lower part of the Green River formation. The beds lie at elevations between 9,000 and 10,000 feet near the top of the Book Cliffs, a southwest-facing escarpment carved in gentle north- to northwest-dipping rocks on the southern margin of the Uinta Basin. Because of the presence of the resistant bituminous sandstone beds, this escarpment near Sunnyside is steep and rugged and overlooks a wide belt of mountainous terrain carved in less resistant rocks in the lower part of the Wasatch formation. North and northeast of the crest of the escarpment the terrain is essentially a broad, somewhat dissected plateau formed on a gentle dip slope of Green River shale, which overlies the Wasatch formation. The bituminous deposits can be reached by a 7-mile drive on a dirt road from the coal-mining town of Sunnyside, the terminal point on a spur of the Denver and Rio Grande Western Railroad.

The bituminous deposits near Sunnyside were first opened at the small quarry near station D on figure 1 in 1892, and operated for a year or longer, during which time about 1,000 tons was removed. This material was used for street paving in Salt Lake City, Utah. The quarry was next operated in 1902-03 when an additional 1,000 tons was mined. A new quarry site, now the largest quarry shown on figure 1, was opened by the Utah Asphalt Company in 1915, and about 3,000 tons was removed before it shut down in 1916 or '17. This quarry was reopened by the Utah Rock Asphalt Corporation in 1927 and worked until 1931; during this period about 25,000 to 30,000 tons were mined. In 1931 the ownership of the quarry passed to the Rock Asphalt Company of Utah, and it has been worked more or less continuously since that date. The production from 1931 through 1945 totaled approximately 300,000 tons, making an all-time total of about 335,000 tons. The yearly output in 1945 was about 20,000 to 30,000 tons, all of which is crushed and used without further treatment for paving streets, highways, airplane landing strips, tennis courts, and the like. Although the material is consumed mostly in Utah and Colorado, small shipments are made to Kansas, Nebraska, Nevada, and Wyoming.

Previous Work.—Although before 1945 the bituminous rock quarries near Sunnyside had been visited by
FIGURE 1

GEOLOGIC MAP
AND
CROSS SECTION
OF
BITUMINOUS
SANDSTONE
DEPOSITS
NEAR QUARRIES
OF THE
ROCK ASPHALT CO.
OF UTAH

EXPLANATION

- Surficial deposits
- Green River formation
- Wasatch formation
- Bituminous sandstone
  Fine shingle indicates nearly saturated beds
- Dolomite limestone beds
  with oyster beds

Scale

Contour interval 100 feet
many geologists and engineers, the deposits had never before been surveyed, and only casual descriptions of them appeared in the geologic literature. The topography of the region is shown on a scale of about 1 inch to the mile on the Sunnyside quadrangle of the U. S. Geological Survey, and on a similar scale on photographic mosaic quadrangle No. 163 of the Soil Conservation Service. The regional geology is discussed in a report on coal resources of the Castlegate, Wellington, and Sunnyside quadrangles by Clark (1928), and the bituminous sandstone occurrence is described in two short paragraphs in a report by Bard and Ball (1944), which is cited because it contains a comprehensive bibliography on the solid hydrocarbons of the Uinta Basin.

**STRATIGRAPHY**

The rocks in the area here described form a continuous depositional sequence made up of non-marine sandstone and shale of Eocene age. This sequence is divided on the basis of lithology and mode of deposition, into two units, the Wasatch and Green River formations. The lower part of the section, which is chiefly fluviatile, is assigned to the Wasatch formation, and the upper part, which is chiefly lacustrine, is assigned to the Green River formation. The transition between these two units, however, is gradational throughout an interval of several hundred feet. The writers place the boundary at the approximate plane where dominantly fluviatile strata below gave way to dominantly lacustrine sediments above, but each of the formations contain beds characteristic of the other. The stream deposited beds tend to be lenticular, and of limited lateral extent. Moreover, they exhibit marked changes in facies, and many local disconformities. The lacustrine beds, on the other hand, are strikingly uniform and persistent.

**Wasatch Formation**

The Wasatch formation, of Lower Eocene age, contains the bulk of the bituminous sandstone deposits, and makes up most of the steep face of the Book Cliffs. According to Clark (1928) the formation is 3,750 feet thick in the Sunnyside quadrangle, but only the uppermost one-third, in which all of the bituminous sandstone beds contained in the formation are concentrated, was examined during the course of the present survey. The lithology, however, is typical of the entire formation, which consists predominantly of sandstone interbedded with shale and to a minor extent with beds of this limestone.

Both bituminous and non-bituminous sandstone beds are fine- to medium-grained, thin- to massive-bedded, and lenticular. Commonly they exhibit cross-bedding and are underlain by a local 1- to 2-foot intraformational conglomerate in which angular pebbles and cobbles of white shale and yellow-weathering limestone are prominent. These conglomerates, and to a lesser extent the overlying sandstone, locally contain fragments of bones and teeth, as well as black, polished plates of gar pike (Lepisosteus). The constituent mineral grains are principally sub-rounded quartz, orthoclase, microcline, and plagioclase, with subordinate amounts of muscovite and chalcedony. Ferromagnesian minerals are rare. A small amount of interstitial calcite is present in some specimens. In weathered outcrops the barren sandstone beds are light buff in color.

Intervening between the sandstone beds in the upper one-third of the formation are many varieties of shale and mudstone. These include pale gray shale; hard, brittle blue-green clay shale; brittle, greenish-gray silty shale; and brittle mudstone members lacking shaly cleavage. The mudstone beds range in color from maroon to brick-red and purple red, and are, therefore, very conspicuous. The shale beds contain fragments of leaves and plant stems, but these fossils are uncommon in the mudstone.

In addition to the argillaceous sediments, the upper part of the Wasatch contains several thin calcareous beds Ms to 5 feet thick. These include beds of hard, dense, white-weathering limestone, ostracode beds resembling oolitic limestone, and yellow-weathering, sandy beds containing ostracodes. All three varieties of calcareous beds are locally somewhat bituminous.

Fossils occurring in the upper part of the Wasatch formation consist principally of bone and plant fragments, fish scales, and small gastropods. Several different forms that have been identified are: gar pike or Lepisosteus cuneatus Cope, Knightia atta (Leidy), crocodile or Mioplosus cf. abbreviatatus Cope, turtle (?), the fresh-water gastropods "Planorbis" spectabilis Meek, Physa aff. P. pteromatis White, Goniodosis tenea Hall, and Physa aff. P. bridenterensis Meek, as well as fresh-water ostracodes, algae, and leaves of plants related to the Eucalyptus. The invertebrates are without exception forms that are widespread in the lower Eocene, but whose limit of range upward is not well known. Most of those found are pond and lake dwellers whereas a more fluviatile environment is suggested by the gar pike and crocodile.

**Green River Formation**

The Green River formation, of Middle Eocene age, is in gradational contact with the underlying Wasatch, and forms the crest and dip slope of the Book Cliffs. The basal 450 feet of the formation, which is all that is exposed in the area mapped, is composed largely of pale greenish-gray mudstone and thin-bedded shale of lacustrine origin, interbedded with sandstone of fluviatile origin. Contained in the shale are many thin, calcareous layers, some of which are marlstone, and some of which are limestone. These beds are % to 5 feet thick, and are mostly white-weathering, dense, and hard. Many are dark and bituminous on fresh surfaces. The limestone
layers occasionally show small, rough, concentric hemispheres of algal colonies, and very rarely, large biscuit-shaped algal masses 2 or 3 feet long. In the area shown on figure 1 the formation contains two or three strikingly continuous 1-foot beds of varved oil shale, which are black on fresh surfaces, but which weather into very thin white sheets. Fragmental fish remains are numerous in the oil shale, and rare in other parts of the formation. Fossil leaves and other plant remains are present throughout the formation.

The sandstone beds contained in the lower part of the Green River formation are similar in appearance and origin to those in the underlying Wasatch. In the area shown on figure 1 these beds are bituminous. They range from 1 to 55 feet in thickness, but most are less than 12 feet, and, in general, they are not of economic importance.

**Surficial Deposits**

In common with other areas in north-central Utah, the lower reaches of all streams in the Sunnyside region were extensively alluviated during Pleistocene time, and are now being reexcavated. In the area shown on figure 1, all of which is above 8,000 feet in elevation, this valley filling was accomplished mainly by mud flows and landslides, and in part by deposition in streams behind such obstructions. The surficial accumulation is composed exclusively of debris from the Wasatch and Green River formations. It contains fragments of all sizes and shapes, with rudimentary or no stratification. Since the climatic or physiographic change that permitted the resumption of normal stream erosion took place, the streams in the area shown on figure 1 have cut through at least 150 feet of this material, leaving local remnants as terraces along the valley slides.

**STRUCTURE**

In the area shown on the accompanying maps the structure is essentially homoclinal; the rocks dip 3 to 10 degrees northeast into the Uinta Basin. Toward the northwest end of the mapped area and beyond, however, the strike of the beds changes gradually westward in an arcuate pattern, essentially parallel to the Cretaceous rim rock of the San Rafael Swell, a large eroded dome whose center lies about 50 miles to the south.

Several minor vertical faults with displacements ranging from 1 to about 150 feet are present, and locally, as in the sandstone promontories in the amphitheatre at the head of Water Canyon, systems of vertical joints may be observed. No reversals of dip are present.

**BITUMINOUS SANDSTONE DEPOSITS**

The bituminous sandstone deposits, known locally as "rock asphalt," consist of numerous beds individually ranging from 10 to 350 feet thick, which individually may extend several thousand feet along the strike. Collectively, the beds occur throughout a vertical stratigraphic interval of 1,000 feet, and extend about 9 miles along the strike.

The accompanying maps show the outcrops of all bituminous beds of possible economic importance along the Book Cliffs front. Thin bituminous beds continue, northwestern, however, beyond the limits of the area shown on the maps. Similarly, bituminous beds are exposed in valleys on the dip slope northeast of the Book Cliffs, particularly in the headwaters of Dry and Range Creeks. In the time available to the writers it was not possible to map the beds northeast of the crest of the Book Cliffs, but several reconnaissance visits in the deeply incised Middle and South Forks of Dry Creek revealed that the bituminous section there has been cut by the streams. In the South Fork of Dry Creek the bituminous beds were somewhat thinner, but otherwise comparable to those on the face of the cliffs.

The bituminous beds on the front of the Book Cliffs are very resistant and crop out conspicuously on the steeper slopes. Typically they are battle-sharp gray, or infrequently, light buff on weathered surfaces. When freshly broken, however, the rock is generally black, and the bleached exterior is seen to be less than 1/16 inch thick. Beds that are only slightly bituminous are frequently light to medium-brown throughout.

The bituminous sandstone beds generally are well stratified and medium bedded. Cross bedding is commonplace, and in a few outcrops, the sandstone is thin-bedded, weathering into plates 1 to 4 inches thick. In the richer beds where the pore space appears to be entirely filled, no stratification of any kind is visible. All of the beds are lenticular, and many of them clearly occupy broad channels cut into the underlying fluvialite shale thin lacustrine limestone. Most of the bituminous beds are underlain and overlain by shale, and wedge out laterally in shale, the bitumen clearly being bounded by the impervious layers. Less frequently, the bituminous sandstone gives way to barren sandstone downward or along the strike, as though there had been insufficient bitumen to invade all of the host rock. At contacts between the impregnated material and barren sandstone, the change is very gradual in some localities and abrupt in others. In both types of occurrence the contacts between bituminous and barren parts of the beds are generally highly irregular, unlike the smooth, level contact that might be expected to result at an oil-water interface.

As shown in the tables below the porosity of the bituminous sandstone ranges between 25 and 30 percent by volume, and the permeability, based on four determinations, ranges between 154 and 677 millidarcies. Little or no water is present in the interstitial space.

On the whole the bituminous sandstone is quite hard, tough, and tenaceous requiring drilling and blasting in quarrying. In hot weather, however, the outer
FIGURE 2.
MAP SHOWING DISTRIBUTION OF BITUMINOUS SANDSTONE DEPOSITS NEAR SUNNYSIDE, CARBON COUNTY, UTAH
surface of the bituminous beds soften slightly, and on sunlit surfaces ooze asphalt in pencil-sized seeps, the rate of flow being almost imperceptible. No large seepages are known in the district.

Grade and Nature of Bitumen

The bituminous content of the beds in the district ranges from few to a little more than 13 per cent by weight. The tables below give the results of analyses by the Oil and Gas Laboratory of the Geological Survey at Casper, Wyoming of samples collected during the course of field work from localities shown on the accompanying maps. Most of these were taken from weathered outcrops and slightly weathered surfaces in abandoned quarries and prospect pits, and, therefore, are not representative of fresh material. On the basis of visual comparison between weathered and unweathered bituminous rock in the operating quarry, and weathered rock elsewhere in the district, it is likely that at least half of the material shown on the accompanying maps, particularly in the thicker beds in the central half of the reconnaissance map (figure 2) is comparable to that in the operating quarry.

The accompanying tables also show the results of analyses of the extracted bitumen, and include the data on the porosity and permeability of a few selected samples.

Reserves

The reserves of bituminous sandstone in the area mapped (figure 2) total 1,600,000,000 cubic yards of which 900,000,000 cubic yards is either measured or indicated by geologic evidence, and 700,000,000 cubic yards is inferred. These results were obtained by combining detailed measurements of 32 small sub-areas classified according to the total thickness of bituminous sandstone. On the steep face of the Book Cliffs, where most of the bituminous beds crop out, the reserves grouped in one class as measured and indicated were arbitrarily terminated 1,000 feet or less down dip from the crest of the ridge. The reserves classed as inferred, all of which are under cover, were computed on the conservative assumption that the bituminous sandstone beds, in toto, thinned down dip below the first class of reserves to an assumed zero line. The reserves contained between the down-dip boundary of the first class of reserves, and the assumed zero line form a belt 4,000 feet wide at the center of the deposits tapering to 1,000 feet at the ends. Slightly bituminous beds and all beds less than 10 feet thick were excluded in preparing the estimates.

In the area of the detailed map, figure 1, the reserves were recalculated bed by bed, and the results obtained were in close accord with those obtained in the comparable sub-area on the small-scale map. In the area of the detailed map, the measured and indicated reserves are 226,000,000 cubic yards, and additional inferred reserves are 46,500,000 cubic yards. These amounts are included in the totals above.

From the data available on the grade of material, it is reasonable to assume that one half of the total reserves contains at least 9 percent bitumen by weight. Material of this grade, therefore, totals 450,000,000 cubic yards of measured and indicated bituminous sandstone,

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Bitumen content, water content, porosity and permeability of samples from the bituminous sandstone deposits near Sunnyside, Carbon County, Utah

Properties of extracted asphalt from the bituminous sandstone deposits near Sunnyside, Carbon County, Utah
and 350,000,000 cubic yards of inferred bituminous sandstone. The bitumen in the Sunnyside deposits has a specific gravity of 1.0. Assuming that the bituminous sandstone has a specific gravity of 2.1 and a bitumen content of 9 percent by weight, a cubic yard of bituminous sandstone weighs 1.77 tons and contains 38.2 gallons of bitumen. On this basis the measured and indicated bituminous sandstone contains at least 409,500,000 barrels of bitumen, and the inferred material contains 318,500,000 barrels. This makes a total of 728,000,000 barrels, exclusive of material assumed to contain less than 9 percent bitumen.

**METHODS OF QUARRYING AND EXTRACTION**

The present operators are removing material from two adjoining quarries (see figure 1) in a thick bituminous sandstone bed near the base of the bituminous zone. These quarries lie at an elevation of about 9,000 feet on the steep front of the Book Cliffs. To simplify haulage down the mountain front, the operators employ a 3-mile aerial tram, which functions by gravity. From the foot of the tram at an elevation of 7,250 feet, the bituminous sandstone is taken by truck to the crushing plant at Sunnyside where the finished product is subsequently loaded into railroad cars for shipment.

As the bituminous bed being quarried is overlain by a thick overburden, like most of those in the district, and as the quarry walls on the mountain side are steep and high, it is likely that the present operations will be extended laterally along the outcrop where the overburden is less. New operations will also be started for the most part in the zone of outcrop. It will be noted that although 335,000 tons have been removed from the two large quarries shown on figure 1, this small area alone offers many comparable sites for such operations.

Several small areas in the district offer possibilities for strip mining that might be investigated by those interested in a more economical method of extracting the material. Among these are the long ridge that forms the western boundary of the area shown on figure 1; the saddle northwest of Bruin Point between Bruin Creek and South Fork of Dry Creek (figure 2); and the area of broad outcrops on the divide between the heads of Left Fork and Slide Fork of Right Fork (figure 2). As it is possible that the grade of material in the last named locality is lower than it is in and near the present quarries, a careful sampling program should precede operations in this area.

Although the bituminous sandstone in the Sunnyside area is now used only for surfacing material, it offers possibilities as a source of extracted bitumen. This, in turn, might be converted to fuel oil and other petroleum products. It might also be used as a source of organic chemicals. The deposits near Sunnyside have several natural advantages as a source of extracted bitumen that should be emphasized. First, the reserves are adequate for large scale operations. Second, the deposits occur in an area of high relief where disposal of the residual sand would present no serious problem. Third, the extracted bitumen or secondary products could be moved by gravity to the railroad terminal at Sunnyside.

Although no systematic attempts have been made to extract the bitumen from the Sunnyside bituminous sandstone beds, experimental work of this nature has been carried out by the U. S. Bureau of Mines and several independent companies on similar bituminous sandstone deposits in California (Moore, personal communication) and at Athabaska, Alberta, Canada (Ells, 1926), and there is little doubt but that workable and economically feasible processes will be developed.

A variation of the usual attempts of extraction is suggested by the fact that the bituminous sandstone beds, which dip gently northeastward, are underlain by impervious shale beds, and are cut locally on the dip slope northeast of the Book Cliffs crest line by tributaries of Dry and Range Creeks. In the previously mentioned saddle between Bruin Creek and South Fork of Dry Fork, for example, the prominent, thick bed of bituminous sandstone just below the saddle crops out both in Bruin Creek on the Book Cliffs front, and in the headwaters of South Fork or Dry Fork on the opposite side of the Roan Cliffs divide. The horizontal distance through the sharp divide between these two opposite flowing streams at the top of the, thick bituminous sandstone bed is less than 1,000 feet. By using the methods of horizontal drilling employed by Ranney (1939) it should be possible to drill sloping holes entirely in bituminous sandstone from Bruin Creek side of the Roan Cliffs divide to the South Fork of Dry Fork side. Then, by introducing heat in the holes, and by arranging a system of collecting channels and gutters at the base of the sandstone on the cleared-off outcrop on the lower side, it should be possible to extract part of the bitumen without moving the enclosing sand.

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JAMES A. PETERSON, Editor

SEVENTH ANNUAL FIELD CONFERENCE

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