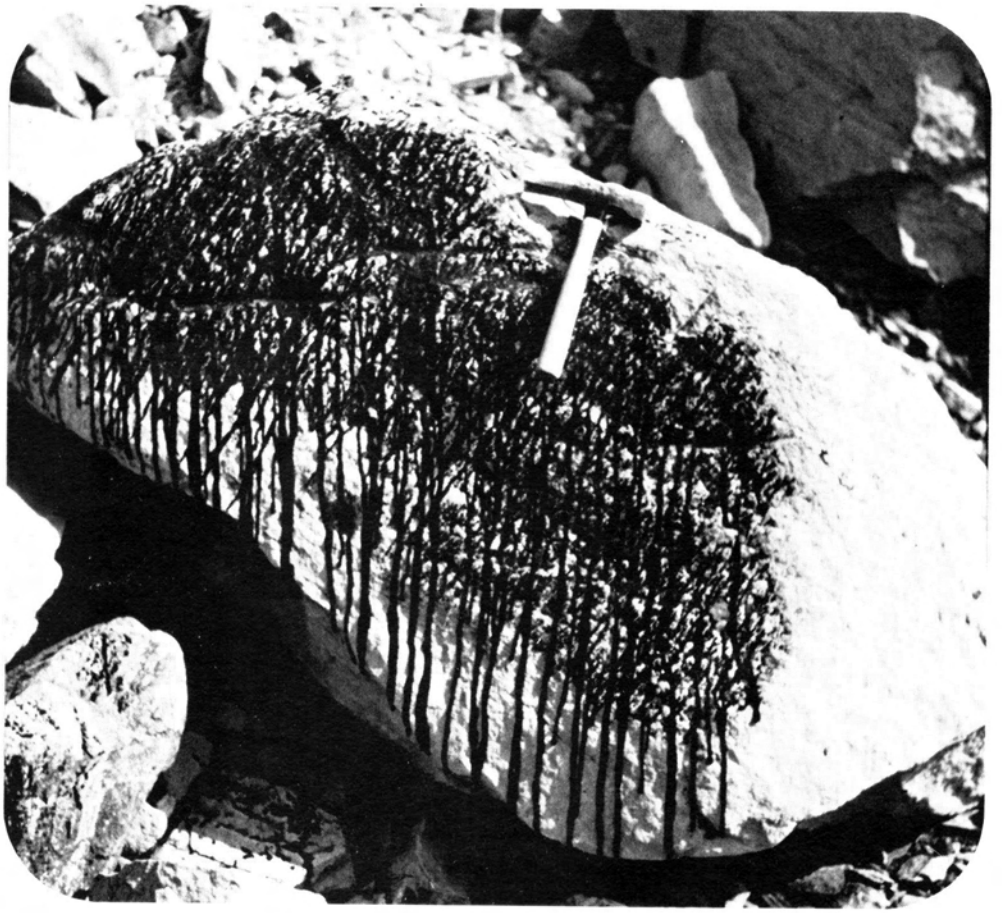
KENTUCKY GEOLOGICAL SURVEY
UNIVERSITY OF KENTUCKY, LEXINGTON
SERIES X, 1976
Wallace W. Hagan, Director and State Geologist

TAR SANDS (ROCK ASPHALT) OF KENTUCKY— A REVIEW

Preston McGrain



REPORT OF INVESTIGATIONS 19

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LETTER OF TRANSMITTAL

November 5, 1976

Dr. Wimberly C. Royster
Dean of Graduate School
and Coordinator of Research
University of Kentucky

Dear Dean Royster:

Today's growing energy shortage and the need to re-evaluate all potential sources of energy materials have prompted the preparation of this report on the tar sand (rock asphalt) resources of Kentucky.

This is primarily a literature review. Since most of the older geological maps and reports pertaining to these deposits are out of print, this report will serve as an orientation summary for those interested in exploration for or development of Kentucky tar sands.

Sincerely,

Wallace W. Hagan

Wallace W. Hagan
Director and State Geologist
Kentucky Geological Survey

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TAR SANDS (ROCK ASPHALT) OF KENTUCKY—A REVIEW

Preston McGrain

ABSTRACT

Deposits of bitumen-bearing Late Mississippian and Early Pennsylvanian sandstones are present in western Kentucky along the eastern and southeastern rim of the Eastern Interior basin in Breckinridge, Hardin, Grayson, Hart, Edmonson, Butler, Warren, and Logan Counties. A minor deposit has been reported near the Rough Creek fault system in McLean County in the interior of the Western Kentucky coal field.

In northeastern Kentucky, small tar sand deposits are present in Early Pennsylvanian sandstones in the Soldier area of Carter and Rowan Counties at the edge of the Appalachian basin, and on the Paint Creek uplift near the junction of Johnson, Magoffin, and Morgan Counties.

Development of the Kentucky deposits has been almost exclusively for use as paving materials. Since reserves of the western Kentucky deposits have been estimated at more than 500 million tons of strippable tar sands, having equivalent bitumen content of 10 to 15 gallons per ton, these tar sands should be considered a potential future source of energy raw material.

INTRODUCTION

Today's growing energy shortage and the need to re-evaluate all potential sources of energy materials have prompted the preparation of this compilation on the tar sands (rock asphalt) of Kentucky. This is primarily a review of reports dealing with various aspects of the surface and near-surface bitumen-bearing rocks of the State. In addition, the present writer has attempted to incorporate some observations resulting from a quarter of a century of geological work in the Commonwealth. In view of the fact that most of the older geological maps and reports pertaining to these deposits are out of print, it is hoped that this review will serve as an orientation summary for those interested in exploration for or development of Kentucky tar sands. The writer gratefully acknowledges the contribution of Dr. Benjamin Gildersleeve, U.S. Geological Survey, for his counsel during the preparation of this report and for reviewing the manuscript.

The Kentucky deposits have been referred to not only as tar sands but also as oil sands, bitumen-bearing rocks, petroleum-bearing rocks, rock asphalt, and natural rock asphalt. Where it naturally occurs in outcrop, it has been called "black rock" by some Kentucky natives, and this descriptive term found its way into some of the geological literature of 60 years ago. At one time its use as a surfacing material was so widespread that it went under the commercialized or trade name, "Kentucky rock asphalt." When exposed to air and sunlight for extended periods, the surface of the asphaltic rock bleaches to a light gray. When completely saturated, the rock may "bleed," particularly during hot weather (Fig. 1). Some of the sites where these bleeding sandstones are present have been designated locally as "tar springs."

Tar sands have long been recognized as a potentially significant mineral resource in Kentucky. The earliest reports of the Kentucky Geological Survey, more than a century ago, noted their existence in the State. David Dale Owen, the first state geologist of Kentucky, recorded the presence of tarry oozes in northern Edmonson County and wrote that the inhabitants of the area used the crude material, when freed from earthy impurities, for greasing wagons, pitching boats, and other such purposes (Owen, 1856, p. 166-167). Owen (1856,

Figure 1. Block of bleeding and bleached bitumen-bearing Pennsylvanian sandstone, Edmonson County. Heat from the sun lowers the viscosity of the asphalt-like material so that it will seep from within the rock. Sunlight also bleaches the outer surfaces of the rock to a light gray, making evaluation of weathered deposits difficult.

p. 166) presented the following analysis of material obtained from a seep near the mouth of Dismal Creek:

Moisture	0.0%
Volatile combustible matter	59.7%
Fixed carbon	14.3%
Ashes	26.0%

The following year, Owen (1857, p. 87) wrote of observing springs of a thick oily fluid issuing from the base of the Tar Springs Sandstone along the Ohio River in Breckinridge County near the Hancock County line, reporting that on one property 10 barrels were collected in a year. Owen observed that the material accumulated more rapidly in wet weather than dry, suggesting that rain water filtering through the porous sandstone carried the oil with it to the base of the rock. This was probably the first geological account of a "waterflood" of an oil sand in Kentucky.

Since Owen's 1856 and 1857 reports, there have been numerous observations and investigations relative to the tar sands of the State. They have been recognized in both eastern and western Kentucky (Fig. 2), and considerable geologic information has been published about them. One of the earliest unified reports on Kentucky deposits is that of Eldridge in 1901. More recently, significant compilations have been made by U.S. Army, Corps of Engineers (1951) and Ball Associates, Ltd. (1965). Widely scattered occurrences were recorded on the State geologic map of Jillson (1929); Russell (1933, Fig. 1) outlined the principal areas of occurrence in western Kentucky, and Schwalb and others (1971) showed locations of rock asphalt quarries and prospects in western Kentucky. In addition, there is much descriptive literature of general and local nature, and several 1:24,000-scale geologic quadrangle maps denote specific occurrences. Numerous informative and pertinent references which were useful in the compilation of this report are cited later in the text.

Kentucky's bitumen-bearing rocks have been utilized primarily as paving material for roads, drives, parking areas, and similar surfaces (Table 1). The naturally occurring asphaltic rock required very little treatment other than crushing and mixing before being applied. Its skid-resistant character is considered its outstanding property. In recent years, the product of portable hot-mix asphalt plants has virtually replaced the use of the State's naturally occurring tar sands. However, the Kentucky deposits constitute a substantial reserve of hydrocarbons and should be considered a potential future source of fossil-fuel energy. *Their development will depend upon economic conditions, technology, and a variety of geologic factors.*

Table 1.—Production of Kentucky Rock Asphalt, 1923-1931. All of the production apparently came from western Kentucky deposits, and the material was used primarily for paving purposes. (Production data from U.S. Bureau of Mines [1926-1933], Mineral Resources of the United States, 1923-1931.)

Year	Tons	Value
1923	184,300	$1,468,396
1924	274,743	2,386,557
1925	286,850	2,403,360
1926	320,430	2,530,480
1927	344,220	3,156,700
1928	318,548	2,757,547
1929	340,346	2,785,772
1930	305,024	2,374,834
1931	161,202	1,197,620
Total	2,535,663	$21,061,266

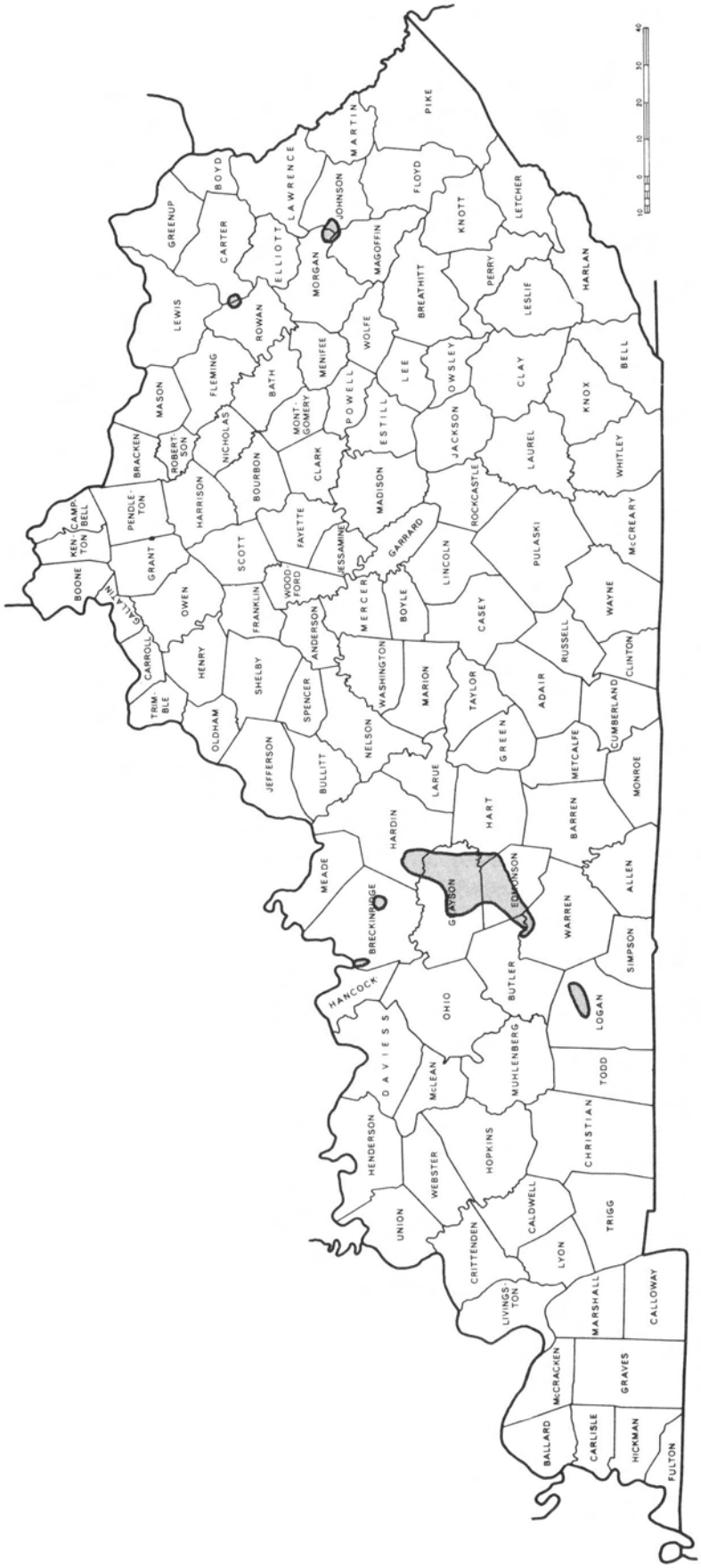

Figure 2. Principal areas of occurrence of tar sands in Kentucky.

Tar sands in Kentucky are mineral aggregates composed of natural mixtures of sandstone and residues of petroleum. Texturally, they range from fine-grained sandstone to conglomeratic sandstone with pebbles up to 0.5 inch in diameter. The predominant component is quartz in the form of angular, subangular, or rounded particles. Silica generally constitutes 80 to 90 percent, or more, of the weight of the rock. The bitumen impregnation is not homogeneous; bitumen content ranges from nothing to approximately 15 percent by weight. The crude hydrocarbon material occurs principally as disseminated deposits in small pore spaces of the sandstone. Occurrences have also been recognized in fractures and other openings, with concentrations at irregular intervals. They appear to represent the residual material of oil sands whose lighter and more volatile constituents have dissipated due to proximity to the surface or direct exposure to the atmosphere. The bitumen is highly viscous and is not recoverable in its natural state by conventional oil-field methods. However, many deposits are sufficiently close to the surface of the ground to make quarrying or mining by open-face or open-pit methods feasible.

Geologically, Kentucky tar sands are present in Late Mississippian sandstones and sandstones and conglomeratic sandstones of Early Pennsylvanian age. They are not restricted to any particular formation in a district, nor are they restricted to a particular stratigraphic zone within a formation. Outcrop thicknesses of the asphaltic beds generally range from a few inches to 30 feet, though greater thicknesses have been reported. Variations in thickness of impregnated rock and in concentration of bitumen characterize the deposits. Although highly petroliferous at a number of localities, the sandstones are not consistently so, and barren areas may be present within the bounds of a designated asphaltic rock area. In many places the Pennsylvanian sandstones, including conglomeratic sandstones, are complexly crossbedded. There has been cementation locally by iron oxide, silica, or calcium carbonate along both horizontal bedding planes and the plane of crossbedding, thus restricting movement by hydrocarbons through the rock and causing irregularities in the extent of impregnated zones. In numerous instances there is no apparent change in porosity, either horizontally or vertically, and it appears that lack of pressure prevented further impregnation. The Mississippian sandstones are thin bedded to massive, are crossbedded in places, and exhibit similar irregular patterns of hydrocarbon impregnation. These erratic variations are unpredictable and make it difficult to evaluate deposits. Bleaching of the outcrop, surface staining, and soil and vegetation cover further complicate the problem. The best places to inspect the tar sands of Kentucky are in the man-made prospects, pits, quarries, and roadcuts. More than 60 years ago, Crump (1913, p. 1062) estimated that there were more than 100 openings in Edmonson and Grayson Counties alone. In the final analysis, however, core drilling should prove to be the most useful and reliable tool for locating and evaluating deposits in Kentucky.

WESTERN KENTUCKY

The largest and best known tar sand deposits in Kentucky occur along the southeastern rim of the Eastern Interior basin. This is where the Mississippian Plateaus meet the Western Kentucky coal field. The area in which the deposits occur extends from Breckinridge County on the Ohio River, south and southwest around the rim of the basin, to Logan County. Russell (1933, p. 581) estimated that the western Kentucky asphalt-bearing area contained one billion barrels of oil before erosion and the loss of its lighter constituents.

The structure of the area is essentially a homocline, and the strata dip approximately 30 feet to the mile to the north, northwest, and west into the Eastern Interior basin. The regional structure is modified locally by a few low-amplitude folds and east-west trending faults.

Stratigraphically, the asphalt-bearing rocks of western Kentucky are principally the Kyrock and Bee Spring sandstones of Early Pennsylvanian age and the Big Clifty (Cypress of many earlier writers), Hardinsburg, and Tar Springs sandstones of Chesterian (Late Mississippian) age (Fig. 3). Thick-bedded sandstones generally appear to be richer in bitumen than thin-bedded ones. The largest deposits have been found in the Big Clifty, Kyrock, and Bee Spring. All of these sandstones have been recognized by the petroleum industry as potential reservoir rocks for oil and natural gas and have been productive in a number of localities downdip from their outcrop.

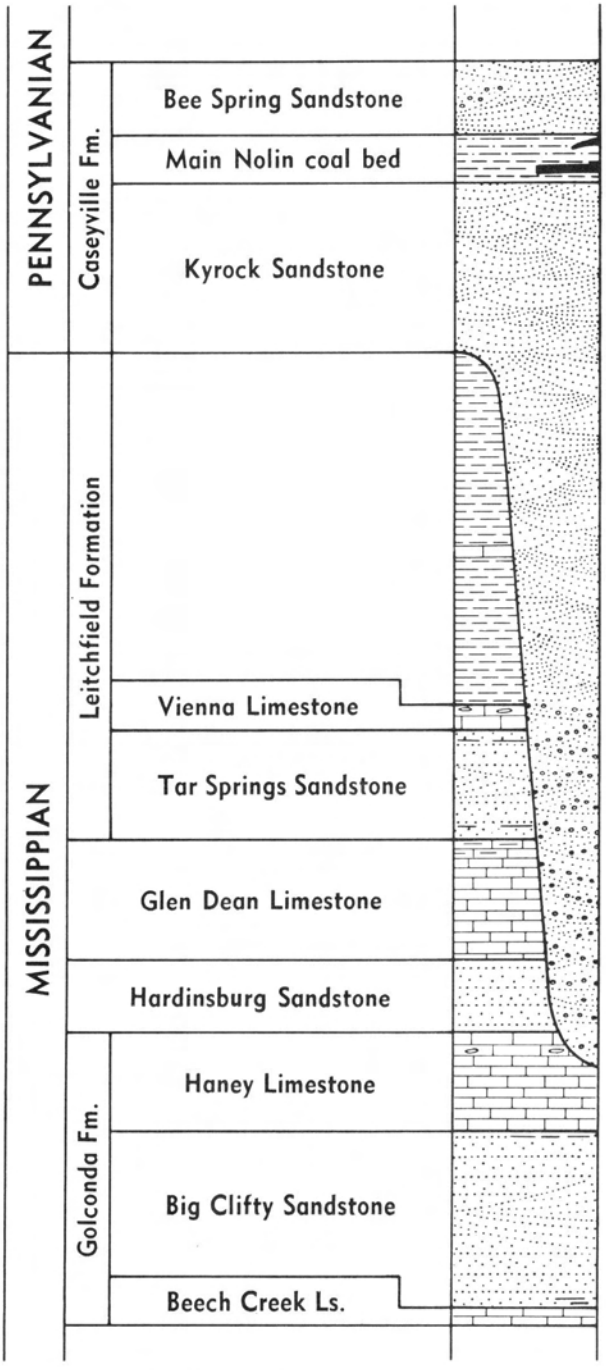

Figure 3. Generalized geologic section for the Western Kentucky rock asphalt district. The Bee Spring, Kyrock, and Big Clifty sandstones are the principal sources of bitumen-bearing rock in the district.

Topographically, the region is a dissected upland plateau. Most of the hills and ridges are capped with sandstones, and the valleys along the eastern edge of the area are commonly bottomed in limestone formations. Local relief of 200 feet or more is common. Maximum elevation rarely exceeds 900 feet above sea level. The sandstones are generally resistant to erosion, forming flat-topped ridges and local tablelands, or, where dissected by stream erosion, rugged, precipitous cliffs.

Bryant (1914), in a study of the economic geology of portions of Edmonson and Grayson Counties, outlined an area of about 80 square miles which incorporates the principal area of asphalt-bearing sandstones in that two-county region. It included some acreage in which asphaltic rocks had not been observed but might be proven by prospecting. This area is interpreted to be restricted largely to Pennsylvanian outcrop.

Jillson summarized the occurrences of Kentucky rock asphalt in two reports (Jillson, 1921a, 1927) and concluded that the deposits with greatest economic potential were in the Pottsville (Pennsylvanian) and Cypress (now called Big Clifty) (Mississippian) sandstones. Six analyses of sandstones from the Cypress (Big Clifty) in Hardin, Grayson, and Logan Counties had a bitumen content of 6.82 to 9.96 percent, and six analyses of Pottsville conglomeratic sandstone from Edmonson County ranged from 6.83 to 8.98 percent bitumen (Jillson, 1927, p. 101).

Weller (1927), in a comprehensive description of the geology of Edmonson County, recognized bitumen-bearing sandstones of both Mississippian and Pennsylvanian ages. The Pennsylvanian rocks were the principal source of raw material supporting a then-active rock asphalt industry which produced material for paving purposes. He wrote that the rock asphalt beds, although of wide extent, were quite erratic as to local development. The deposits pinch and swell and thicken and thin without apparent reason. The separation between commercial and waste rock was observed to occur abruptly along an even line which in some cases revealed no suggestion of bedding (Weller, 1927, p. 203). More specific observations as to the geographic and geologic distribution of the Edmonson County deposits are summarized in subsequent portions of this report.

In 1942 the U.S. Department of the Interior, as part of its broad program of synthetic-liquid-fuels research, requested the Department of the Army to assist in the development of a liquid-fuels program. The contract called for a survey of 37 states and Alaska. A report on Kentucky, which was prepared

by Ford, Bacon & Davis, Inc. (U.S. Army, Corps of Engineers, 1951), included a survey of strippable oil-impregnated deposits. Fourteen Kentucky counties were listed as containing oil-impregnated sandstone deposits. The largest deposits located were in Edmonson and Logan Counties of western Kentucky; these counties had an estimated 434 million tons of oil-impregnated material in place or 347 million tons recoverable, occurring in zones 15 to 35 feet thick with less than an equal footage of overburden. These deposits have equivalent bitumen content of 10 to 15 gallons per ton. Of the 347 million tons recoverable, 196 million were within an area of 4,220 acres in Edmonson County; the remainder covered 2,253 acres in Logan County. No other deposits of such material were found meeting the minimum requirements of this survey, which specified deposits at least 15 feet thick, under no more than their own thickness of overburden, and averaging not less than 10 gallons of oil per ton (U.S. Army, Corps of Engineers, 1951, p. 5-6).

Ball Associates, Ltd. (1965) estimated Kentucky reserves at more than 500 million tons of asphaltic material (equivalent bitumen content of 10 to 15 gallons per ton) recoverable from zones 15 to 30 feet thick which are covered with approximately 15 feet of overburden. Most of this is indicated to be in western Kentucky. This estimate was the result of a survey conducted in 1964 by Ball Associates, Ltd., Denver, Colorado, on behalf of the Joint Committee on Petroleum-Impregnated Rocks (also called the "Tar Sands Committee") of the Interstate Oil Compact Commission and the Bureau of Mines and Geological Survey, U.S. Department of the Interior.

Breckinridge County

In Breckinridge County, tar sand deposits have been recognized in the Big Clifty Sandstone near Garfield (Amos, 1976; Eldridge, 1901; Foerste, 1910; Jillson, 1927) and near Harned (Eldridge, 1901). Oil or tar seeps from the Tar Springs Sandstone have been reported south of Cloverport (Eldridge, 1901; Foerste, 1910; Jillson, 1927), west of Cloverport (Ball Associates, Ltd., 1965; Owen, 1857), and near Mattingly (Clark and Crittenden, 1965).

Although there has been some mining of bituminous sandstone in the Big Clifty near Garfield and Harned, all deposits in Breckinridge County appear small, and there are large areas of barren rock. The impregnated zone at Garfield attains a thickness of 14 feet with a bitumen content of 6 to 10 percent in the lower 7 or 8 feet (Eldridge, 1901, p. 248). Prospecting in the area southeast of Harned disclosed only 3 or 4 feet of bitumen-impregnated sandstone. The overburden near both Garfield and Harned was generally less than 20 feet.

Jillson (1927, p. 99) did not regard the Tar Springs Sandstone to be of commercial importance as a rock asphalt source due to the fact that its bituminous content was high in volatiles and relatively low in asphalt base. In the vicinity of the type locality of the Tar Springs Sandstone, which is named for a tar seep or spring approximately 2.5 miles south of Cloverport, 11 wells penetrated oil-saturated Tar Springs Sandstone at an average depth of 120 feet. The best part of the "pay" was about 20 feet thick and the oil was very viscous; reservoir pressure was nil, and the operators had no primary production (Geological Society of Kentucky, 1966).

Butler County

The southeastern part of Butler County generally has been considered to be in the belt of bitumen-bearing sandstones of Early Pennsylvanian age, but little has been recorded about specific deposits.

Jillson (1928, p. 42) reported asphaltic sandstones in the southeastern part of the county adjacent to Green River, and Ford, Bacon & Davis, Inc. (U.S. Army, Corps of Engineers, 1951, p. 139-140) reported bituminous Pennsylvanian sandstone to be present east of Reedyville in southeastern Butler County.

Shawe (1966) wrote that logs of drill holes southwest of Roundhill, east of Threlkel, and southwest of Reedyville show rock asphalt variously in the Glen Dean Limestone, Hardinsburg Sandstone, and Haney Limestone and Big Clifty Sandstone Members of the Golconda Formation.

In a recent report, Schwalb (1975, p. 16) noted that large quantities of heavy (low gravity) oil appear to be present in the tar sands of Butler County, the most important of which is the Big Clifty Sandstone. He (Schwalb, 1975) stated that as much as 40 feet of Big Clifty saturated with heavy oil has been reported, and the lateral extent

of this sandstone suggests that the amount of hydrocarbon at depth in Butler County is enormous.

Edmonson County

Edmonson County has been the site of the greatest commercial development of natural rock asphalt in Kentucky and appears to contain the largest reserves of strippable deposits. If larger deposits are present in the State, they have not been disclosed in public records. Inferred and indicated reserves, based on 104 core holes, outcrop measurements, and available geologic and topographic maps, have been calculated at 195.55 million tons of strippable bitumen-impregnated rock containing 10 to 15 gallons per ton, or the equivalent bitumen content of 50 million barrels (U.S. Army, Corps of Engineers, 1951, and Table 2 of the present report).

Table 2.—Reserves of Strippable Tar Sand Deposits in Edmonson County. (Adapted from U. S. Army, Corps of Engineers, 1951, p. 5.)

Area	4,220 acres
Thickness of deposit	15-30 feet
Thickness of overburden	15-30 feet
Bitumen content	10-15 gallons/ton
Indicated tertiary reserves	125,885,000 tons
Inferred secondary reserves	21,648,000 tons
Inferred tertiary reserves	48,018,000 tons
Total inferred and indicated reserves	195,551,000 tons
Equivalent bitumen content	50,000,000 barrels

Ball Associates, Ltd. (1965, p. 142-145) listed four Edmonson County deposits that contain inferred reserves of more than one million barrels of bitumen each.

Area	Millions of Barrels
Kyrock	18.4
Davis-Dismal Creeks	7.5-11.3
Bee Spring	7.6
Ollie	7.4

In addition, it has been estimated that the area in the vicinity of the community of Asphalt, west-central Edmonson County, contains in excess of 200 million tons of asphaltic Pennsylvanian sandstone on 7,000 acres (Ball Associates, Ltd., 1965, p. 146).

Rock asphalt deposits are found mainly in the northern part of Edmonson County, in the area bounded by Nolin River on the east, Green River on the south, and Bear Creek on the west. Weller (1927, p. 202-203), in his comprehensive description of the geology of Edmonson County, reported that rock asphalt deposits are present on the west side of Bear Creek, south of Green River, and east of Nolin River but are generally limited in size except near Ollie in the northeastern part of the county where core drilling encountered an important deposit.

The Kyrock and Bee Spring Sandstones, both Early Pennsylvanian in age, are the principal exposed bitumen-bearing rocks in the county. The two sandstones are generally separated by a shaly zone containing one or more thin coal beds referred to as Nolin coals. The thickest and most persistent is the Main Nolin coal which has been mined or prospected at several places within the rock asphalt district.

Sandstone strata above the Bee Spring Sandstone are locally impregnated with bitumen, but they have been considered too thin, too lean, or of too limited extent to be of any economic importance ((Weller, 1927, p. 202).

Outcrops of Big Clifty (Cypress) Sandstone on First, Second, and Bylew Creeks and outcrops of Hardinsburg Sandstone in the valley of Crooked Creek are asphaltic, but Weller (1927, p. 201) did not consider them important sources of rock asphalt because of their low elevation and thick overburden. Asphaltic Big Clifty Sandstone was also reported by Klemic (1963) in the Rhoda area, and asphaltic Big Clifty and Hardinsburg Sandstones were reported by Gildersleeve (1965) in the Brownsville area. Results of industry-directed test drilling to these formations in the subsurface have not been disclosed.

The largest rock asphalt quarries, all in Pennsylvanian strata, which operated in Kentucky are in the areas covered by the Brownsville and Bee Spring quadrangles (Gildersleeve, 1965, 1968b). Impregnated zones 10 to 30 feet thick are common. Table 3 contains core analyses of surface samples. Gildersleeve (1965, 1968b) reported more than half of the State's production during the record-high period of 1925-1930 (Table 1 of this report) came from quarries in the Bee Spring quadrangle and that more than one million tons had been mined from deposits in the Brownsville quadrangle since operations first began. Production has

Table 3.—Core Analyses of Surface Samples of Bitumen-Impregnated Pennsylvanian Sandstones from Edmonson County. (Analyses courtesy of an industrial source.)

Location	Permeability (millidarcys)		Percent porosity		Oil saturation
General area	Before extraction	After extraction	Before extraction	After extraction	% pore
Davis-Dismal Cks.	376	870	17.0	19.4	29.9
Do.	239	1789	13.3	23.8	26.3
Do.	< 0.1	1316	18.5	22.7	78.8
Beaverdam Creek	522	1842	20.5	26.6	36.6
Do.	2.3	1228	22.9	23.6	56.9
Do.	137	1438	21.0	24.8	34.8
New Liberty Ch.	1.2	401	25.3	25.3	63.6
Do.	180	424	22.0	29.1	14.5
Do.	0.6	4.1	16.4	17.2	30.4
Do.	208	684	20.0	25.7	17.0
Do.	12	2709	14.0	24.3	57.8

continued during recent years but on a very limited scale. Highway Safety Materials Inc., Brownsville, is currently the only operator producing road-surfacing materials from Kentucky natural rock asphalt. Gildersleeve also reported an asphalt prospect near Pine Grove Church in the Bristow quadrangle (1963) and outcrops of asphaltic Caseyville in the Nolin Reservoir quadrangle (1971). Shawe (1966) wrote that rock asphalt had been mined from the Caseyville near Segal (Reedyville quadrangle). Bryant (1914) listed a number of pits and outcrops where "black rock" was exposed. The highwalls of these quarries and pits, all of which are in Pennsylvanian sandstones, are good places to study the deposits—the grain size and other lithologic characteristics of the rock, sedimentary structures, and the idiosyncrasies of bitumen impregnation (Fig. 4).

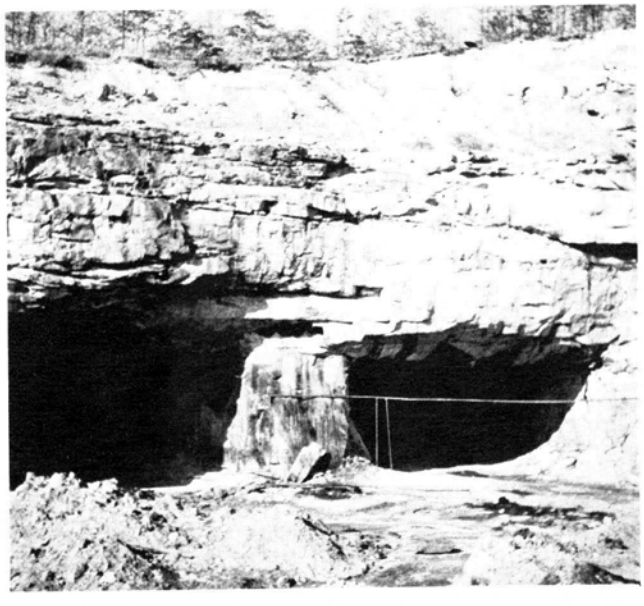

Figure 4. Rock asphalt quarry and mine in Pennsylvanian Kyrock Sandstone near the head of Indian Creek south of Sweeden, Edmonson County.

Bitumen occurrences in Edmonson County, as in the remainder of the Western Kentucky rock asphalt district, are erratic, thicken and thin abruptly, and vary in viscosity; rich deposits are separated by lean or barren sandstone. Rock asphalt of commercial grade ranges in thickness from 10 to 90 feet (Gildersleeve, 1965). The thickest deposits appear to be associated with a sandstone-filled paleovalley which traverses northwestern Edmonson County in the vicinity of Dismal Rock and Nolin Dam (Weller, 1927; Sedimentation Seminar, 1974).

Since the mid-1950's private industry has engaged periodically in research and experimental work on extractive techniques for oil recovery from the asphaltic sandstones. The results of these endeavors, which were concentrated in the area between Davis and Dismal Creeks 1 mile southeast of Broadway, northern Edmonson County, have not been made public.

Grayson County

Asphaltic Caseyville (Pennsylvanian) sandstones continue northward from Edmonson County into Grayson County, extending to near Caneyville, Leitchfield, Grayson Springs, and Millerstown. In

the area of the Millerstown quadrangle, asphaltic zones are found at or near the base of the Caseyville (Moore, 1965), whereas near the Edmonson County line bituminous outcrops appear to be associated with the stratigraphically higher Bee Spring Sandstone. Throughout much of this area the terrain is highly dissected and the asphaltic strata occur as small, isolated patches. In the Church-Shrewsbury area, deposits are more continuous and occur over a larger area (U.S. Army, Corps of Engineers, 1951, p. 138-139).

Asphaltic sandstone in the Church area has an average thickness of 9 feet, with one reported thickness of 32 feet. Bitumen content is 7.1 to 7.4 percent (Ball Associates, Ltd., 1965, p. 138-139). Two small pits were opened here (Gildersleeve, in press).

One mile south of Peonia, on the C. J. Huffman farm, bitumen-impregnated Pennsylvanian sandstone was reported in eight core holes at depths of 11 to 46 feet; thicknesses ranged from 2 to 26 feet, and average bitumen content was 3.60 to 4.77 percent (Hagan, 1942, p. 241-243).

Several outcrops of asphaltic Caseyville conglomeratic sandstone have been reported in the area between Rock and Conoloway Creeks. Hagan (1942, p. 240) suggested that the area may contain asphalt of commercial importance. Thicknesses of impregnated zones vary from 4 to 30 feet, and bitumen content ranges from 6.2 to 9.0 percent (Ball Associates, Ltd., 1965, p. 139-140).

In the northern part of the county, the Big Clifty Sandstone (Mississippian) is the principal host rock for the bitumen. Deposits are numerous but large areas of barren sandstone are present.

Hagan (1942, p. 239) reported asphalt content of Cypress (Big Clifty) sandstone near the headwaters of Rocky Creek (Fragrant community) to be 2.05 percent.

Ball Associates, Ltd. (1965, p. 135-137) reported 10 feet of impregnated Big Clifty Sandstone with bitumen content of 7 percent near Tar Hill, and 5 feet of Big Clifty with 6 percent bitumen near the community of Big Clifty; occurrences were also mentioned in nearby Crow Hollow.

Table 4 contains analyses of surface samples from the Big Clifty and Tar Hill areas.

Grayson County has a long history of asphalt mining but all the operations were small. Weller (1927, p. 208) reported that a plant was built near Grayson Springs in 1891 to extract bitumen from sandstone but shut down after about 80 barrels had been separated. (According to Hagan [1942, p. 60], the source of material may have been Kyrock conglomeratic sandstone from a pit on Hunting Creek east of Snap.) Pits have been reported also in the Big Clifty Sandstone near Big Clifty and Tar Hill (Swadley, 1962), and in sandstones of the Caseyville Formation at Buzzard Ridge (Moore, 1965), near Meridith (Glick, 1963), and near St. James Church (Hagan, 1942, p. 240).

Hancock County

U.S. Army, Corps of Engineers (1951, p. 139-140) reported that bituminous Cypress (Big Clifty) sandstone crops out in Hancock County east of Patesville. Since the Glen Dean Limestone is the oldest formation known to be exposed in Hancock County (McGrain and others, 1970, p. 2), the locality is possibly somewhere in adjacent Breckin-

Table 4.—Core Analyses of Surface Samples of Bitumen-Impregnated Big Clifty Sandstone from Grayson County. (Analyses courtesy of an industrial source.)

Location	Permeability (millidarcys)		Percent porosity		Oil saturation
General area	Before extraction	After extraction	Before extraction	After extraction	% pore
Big Clifty	18	697	16.9	20.7	27.7
Tar Hill	2.5	446	15.1	21.7	50.3
Do.	0.8	1241	16.3	21.4	59.5
Do.	<0.1	303	19.5	20.1	78.0
Do.	71	83	19.2	20.5	17.7
Do.	0.6	1112	22.7	25.0	59.4
Do.	16	386	18.5	20.5	31.3

ridge County. However, it is possible that bitumen-impregnated sandstones of Chesterian age may be present beneath the surface at comparatively shallow depths in Hancock County.

Hardin County

Bitumen-bearing Big Clifty Sandstone extends eastward from Grayson County into western Hardin County. Jillson (1928, p. 143-144) indicated that there were many undeveloped deposits of rock asphalt in this area, and particularly noted deposits on Big and Little Meeting Creeks. He (Jillson, 1928, p. 143) stated that the Sample Sandstone is also somewhat asphaltic in the western part of Hardin County.

Rock asphalt has been quarried from the Big Clifty Sandstone on either side of Lost Branch southwest of Summit (Moore, 1964). The bituminous zone averages 6 feet in thickness and has a bitumen content of 7 to 8 percent (Ball Associates, Ltd., 1965, p. 134-135).

Table 5 contains core analyses of surface samples of Big Clifty Sandstone from the Summit area.

Ball Associates, Ltd. (1965, p. 134) reported scattered outcrops of asphaltic Big Clifty southeast and southwest of Solway.

Hart County

Bituminous Pennsylvanian sandstone extends into northwestern Hart County from Grayson County, but there has been little commercial interest in the development of rock asphalt in the area (U.S. Army, Corps of Engineers, 1951, p. 139-140).

Analyses of samples of asphaltic Kyrock conglomeratic sandstone from an area near the mouth of Little Dog Creek varied from 2.37 to 9.86 percent bitumen (Hagan, 1942, p. 240).

Eight core holes on the B. F. and George Thompson farms near Big Windy encountered asphaltic Pennsylvanian sandstone at an average depth of about 20 feet. Thicknesses of the impregnated sandstone zones ranged from 5 to 19 feet, and the average bitumen content ranged from 1.64 to 6.57 percent (Hagan, 1942, p. 244-245).

Jillson (1928, p. 155) published a photograph of a cliff of asphaltic Pennsylvanian conglomeratic sandstone on Dog Creek in western Hart County.

Logan County

A large reserve of natural rock asphalt is present in Logan County. Although this county was the site of the first rock asphalt mining in the State for paving material (1894), the deposits have not experienced extensive commercial development (Weller, 1927, p. 208). Inferred and indicated reserves, based primarily on approximately 47 core holes, have been calculated at 151.26 million tons of strippable impregnated rock containing 10 to 14.4 gallons of bitumen per ton (U.S. Army, Corps of Engineers, 1951; and Table 6 of the present report). Detailed geologic and topographic maps of the area did not exist when this estimate was made.

Table 6.—Reserves of Strippable Tar Sand Deposits in Logan County. (Adapted from U.S. Army, Corps of Engineers, 1951, P. 5.)

Area	2,253 acres
Thickness of deposit	20-35 feet
Thickness of overburden	15-35 feet
Bitumen content	10-14.4 gallons/ton
Indicated tertiary reserves	27,752,000 tons
Inferred tertiary reserves	123,508,000 tons
Total inferred and indicated reserves	151,260,000 tons
Equivalent bitumen content	37,000,000 barrels

The principal area of occurrence is in the vicinity of Homer in the central part of the county, approximately 4 or 5 miles northeast of Russellville. The Big Clifty Sandstone (Cypress Sandstone of some earlier workers) is the most important stratigraphic unit. The sandstone is fine to medium

Table 5.—Core Analyses of Surface Samples of Bitumen-Impregnated Big Clifty Sandstone from the Summit Area, Hardin County. (Analyses courtesy of an industrial source.)

Location	Permeability (millidarcys)		Percent porosity		Oil saturation
General area	Before extraction	After extraction	Before extraction	After extraction	% pore
Summit	8.3	2193	21.6	28.2	17.1
Do.	1.3	985	21.5	25.1	61.8
Do.	770	1368	25.1	28.1	15.2
Do.	1.5	175	24.1	27.1	48.5
Do.	21	2280	21.0	28.4	53.4

grained and thin to thick bedded. In the Homer and Quality quadrangles the asphaltic deposits on outcrop are erratic, ranging from a few inches to 20 feet in thickness and varying from traces of bitumen to complete saturation (Gildersleeve, 1966, 1968a). The impregnated stone is found mainly on the north (upthrown) side of an east-west trending fault system; its occurrence is comparatively rare on the south (downthrown) side (Gildersleeve, 1966; Russell, 1933, p. 579).

Asphaltic Big Clifty Sandstone has been reported also in the west-central part of Logan County in the Olmstead quadrangle (Ulrich, 1966).

The tar spring from which Tar Springs School (now destroyed) received its name is located about 2 miles northeast of Homer. The spring is near the base of the Hardinsburg Sandstone and is the only reported occurrence of bitumen in this formation in the Homer area (Gildersleeve, 1966).

McLean County

Russell (1933, p. 579) stated that a small outcrop of asphalt occurs near a large fault (part of the Rough Creek fault system) on the uplift south of Beech Grove. No other information has been published on the deposit.

Warren County

U.S. Army, Corps of Engineers (1951, p. 138) reported bitumen-bearing Pennsylvanian sandstone in the area bordering Green River in northern Warren County but concluded that even though the deposits were of high quality and had been worked commercially in the past (possibly before 1900) they did not constitute a reserve as defined by their study. Two rock asphalt quarries in Pennsylvanian conglomeratic sandstone at Youngs Ferry (near Cherrys Chapel) appeared to Eldridge (1901, p. 256) to be no more than prospects. Maximum thickness of asphaltic stone observed was 10 feet, and the richest zones contained 7 percent bitumen (Eldridge, 1901, p. 257-258).

Shawe (1966, 1968) observed asphaltic Pennsylvanian sandstone and Mississippian Hardinsburg Sandstone in the Cherrys Chapel and Fallover Bend areas of northern Warren County. He (Shawe, 1966) noted that the deposits near Cherrys Chapel seem to be associated with a fault that has cut a small dome-like structure in Mississippian rocks.

The Glenmore oil pool in northeastern Warren County was the site of an experimental steamflood project which was later converted to a fireflood process. The closely spaced wells were drilled to the Big Clifty Sandstone, a depth of approximately 300 feet. Apparently very little success was obtained from the project (McGrain and Sutton, 1973, p. 8, 12, 13).

EASTERN KENTUCKY

In eastern Kentucky, tar sand deposits have been noted principally in two areas: (1) the Soldier area of Carter and Rowan Counties at the edge of the Appalachian basin in the northeastern part of the State and (2) on the Paint Creek uplift near the junction of Johnson, Magoffin, and Morgan Counties. In both areas the host rock for the bitumen is a sandstone or conglomeratic sandstone of Early Pennsylvanian age, referred to in the geologic literature as Lee or Pottsville (Fig. 5).

Carter and Rowan Counties

Asphaltic Lee (Early Pennsylvanian) sandstones are present in the headwater areas of Mocabee and Soldier Creeks near the community of Soldier in extreme western Carter County. Several prospect pits and outcrops were reported by Eldridge (1901, p. 244-246), Crider (1913, p. 683), and Jillson (1921a, p. 43-44). The asphaltic zones are thin, ranging from a few inches to a maximum of 10 feet, and are characteristically irregular in degree of impregnation. Eldridge (1901, p. 245-246) reported the amount of bitumen in the better rock to vary from 4 to 6 percent, but locally to carry as high as 9 or 10 percent.

The area of asphalt occurrence is small; it was estimated by Jillson (1921a, p. 43) to have a diameter of less than 3 miles, possibly extending a short distance into Rowan County. A quarry in the asphaltic stone was opened on the J. P. Danner farm, but it never became commercial (Jillson, 1921a, p. 43-44).

Johnson, Magoffin, and Morgan Counties

Asphaltic or oil-impregnated Lee sandstones have also been reported on the Paint Creek uplift near the junction of Johnson, Magoffin, and Morgan Counties in northeastern Kentucky. Jillson (1921a, p. 44) studied asphalt-impregnated sandstone in the gorge of Paint Creek near Low Gap Branch and other tributaries and concluded that

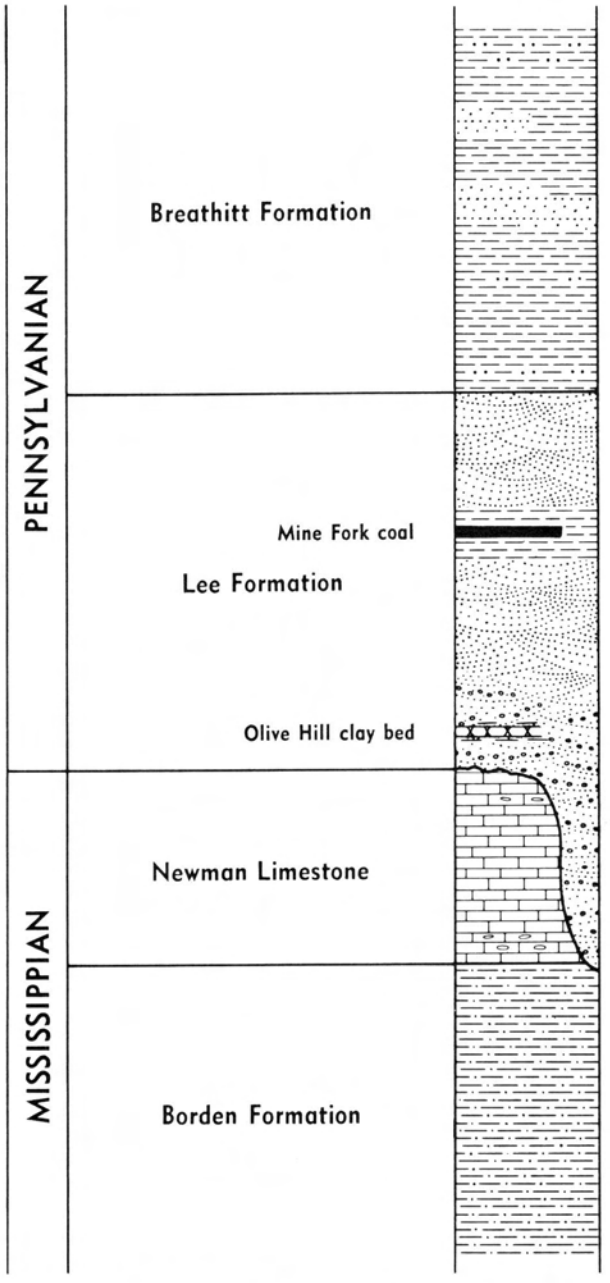

Figure 5. Generalized geologic section for the tar sand areas of eastern Kentucky. Lee sandstone is the principal host rock for the asphaltic material.

the deposits were either not thick enough or not favorably situated from a mining-engineering standpoint to merit commercial consideration.

Hauser (1953, Pl. 2) also observed asphaltic sandstones in Lower Pennsylvanian strata along Paint Creek and recorded the location of seven prospect entries in Johnson County, all on the north (upthrown) side of the Irvine-Paint Creek fault. He (Hauser, 1953, p. 69) reported that zones of asphaltic rock, ranging from 4 to 12 feet in thickness, are found 50 to 75 feet below the top of the Lee Formation. Thicknesses as great as 90 feet in oil and gas tests had been reported to him, but he was not able to confirm these reports (Hauser, 1953). An analysis of one deposit indicated a bitumen content of 9.87 percent.

Outerbridge (1967) wrote that the sandstone member of the Lee Formation in the Oil Springs quadrangle locally is saturated to a thickness of as much as 15 feet and that on hot days fresh cuts in the sandstone may bleed oil.

MISCELLANEOUS OCCURRENCES OF OIL-IMPREGNATED ROCKS

Several bituminous accumulations other than impregnated sandstones have been reported in Kentucky. All are thought to be small and primarily of academic interest.

In the vicinity of Soldier, Carter County, oily material found its way into pockets of fire clay (Olive Hill clay bed). Crider (1913, p. 683) and Jillson (1921a, p. 43-44) reported an asphaltic seep from the J. D. Patton clay mine. The material was caught and used locally as a lubricant and for domestic purposes.

Weller (1927, p. 206, 221) reported bituminous material in fractures and bedding planes of the Main Nolin coal east of Bee Spring and near Nolin School, both in Edmonson County.

Jillson (1921b, p. 149) described an experimental project at Ravenna, Estill County, where an attempt was made to "mine" oil by a shaft sunk 130 feet to a petroliferous limestone of Devonian age. The venture yielded only 2 or 3 barrels of oil per day. Laboratory tests indicated that the deposit may contain 5 to 10 gallons of oil per ton of limestone (Jillson, 1921b, p. 150-151). According to Kentucky Geological Survey records, petroleum has been produced by conventional methods from the Ravenna area since about 1901.

Small deposits of asphalt-impregnated limestone reportedly crop out in Nelson, Madison, Marion, and Bell Counties (U.S. Army, Corps of Engineers, 1951, p. 140). In western Nelson County small outcrops of asphalt-impregnated limestone of Devonian age have been observed on the right fork of Snake Run. The asphaltic zone is about 6 feet thick; the quantity available is considered too small

for commercial operations (Ball Associates, Ltd., 1965, p. 131). Jillson (1928, p. 294) published a photograph of the Nelson County deposit.

In describing the lithology of the Bisher Limestone (Middle Silurian) in the Manchester Islands quadrangle area of Lewis County, Peck and Pierce (1966) stated that petroleum residue is common in more porous beds, and oil slicks are present locally in springs at the base of the formation.

Outerbridge (1967) reported that the Newman Limestone (Mississippian) in the aggregate mine on Big Mine Fork, Magoffin County, is petroliferous.

The building-stone facies of the Girkin Limestone (Chesterian) in Warren County may be petroliferous locally. Where observed by the writer, the petroliferous material is a light-colored oil rather than a dark, viscous, tarry material.

SUMMARY

Geologic observations for more than a century have disclosed numerous tar sand deposits in Kentucky. Tar seeps and springs and outcrops of "black rock" have indicated the presence of deposits, but drilling or excavation have been necessary to determine whether an exposure represented a local patch or a potentially commercial deposit.

The largest and greatest number of deposits have been found in the Big Clifty Sandstone (Late Mississippian) and Early Pennsylvanian sandstones (Bee Spring and Kyrock of western Kentucky and Lee of eastern Kentucky). The deposits are lenticular in shape, and erratic in distribution and concentration of bituminous materials. The Western Kentucky rock asphalt district appears to offer the best opportunities for future commercialization of the Kentucky deposits.

Past geological investigations (U.S. Army, Corps of Engineers, 1951; Ball Associates, Ltd., 1965) indicate and infer approximately 500 million tons of strippable bitumen-impregnated rock, having equivalent of 10 to 15 gallons per ton, in the Western Kentucky district. Unknown to date is the quantity of heavy oils present in these same sandstones where they are buried below surface-mining depths. It is not unreasonable to assume that an equal or greater amount of heavy oil could be recovered from this part of Kentucky whenever in-situ methods can be demonstrated to be commercially feasible.

A majority of those who have written on the tar sands of Kentucky refer to the bitumen-impregnated deposits as fossil oil fields. However, W. O. BeMent, University of Cincinnati, in a paper at the 1975 annual meeting of the Kentucky Oil and Gas Association, proposed that the absence of asphaltic limestones in the area of the tar sand deposits suggests that the tar sands do not represent exhumed pools (fossil oil fields), but rather the direct migration of hydrocarbons through unsealed reservoirs to the surface.

No single geological environment will explain the localization of the Kentucky deposits. In the Homer area of Logan County, northern Warren County, McLean County, Johnson County, northern Grayson County, and elsewhere, the proximity of deposits to known faults suggests structural control and orientation. Locations of the larger pits in Edmonson County appear to be related to a deep sand-filled paleovalley. Other deposits can be explained only as stratigraphic traps or local porous zones in the enclosing rock.

Naturally occurring asphaltic materials cannot be mapped from outcrop in Kentucky. Soil and vegetation cover, iron oxide stain on weathered surfaces, and bleaching make identification and evaluation of surface deposits extremely difficult. Geologic maps showing the outcrop pattern of sandstones known to be bitumen bearing are guides, not answers, to exploration programs. As stated by McFarlan (1943, p. 384), ". . . the mapping of the particular sandstone in which a deposit is known to occur is not a mapping of the asphalt deposit." However, published geologic quadrangle maps showing specific sites of asphalt mines, pits, prospects, and outcrops (Fig. 6) are of inestimable value to one entering the district for the first time.

An exploration program to ascertain basic geologic data about one of Kentucky's tar sands or a particular deposit would require: surface and subsurface mapping, core drilling (including testing sandstones under known deposits), sampling, and analyses of materials. Geologic literature for more than 75 years has made reference to core-drilling activities associated with tar sand investigations in the State. The preponderance of these test holes were under the direction of private capital, and the data gathered therefrom have not been made public. These data have been discarded, lost, or are in private files. Unless these data, together with ade-

Figure 6. Map of portion of western Kentucky showing geologic quadrangle maps recording sites of rock asphalt mines, outcrops, pits, or prospects. Quadrangles with numbers have been published and are available at the time of this report.

quate locations and analyses, can be retrieved, a company, individual, or agency contemplating a qualitative and quantitative program to explore a known deposit, a specific area, or a complete evaluation of Kentucky's tar sands would be faced with initiating a completely new project and a repetition of earlier exploratory activities.

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