OKLAHOMA GEOLOGICAL SURVEY
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CIRCULAR NO. 5.

ROCK ASPHALTS OF OKLAHOMA AND THEIR USE IN PAVING.

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NORMAN
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INTRODUCTION.

This circular consists principally of two papers previously published in technical journals. The papers are "Rock Asphalt Deposits of Oklahoma" published in the *Mining and Engineering World* of March 22, 1913, and "Rock Asphalts of Oklahoma and their use in Paving" published in *Good Roads* of March 1, 1913. These journals have permitted the use of the articles for this circular. Some few paragraphs have been added to both articles. Further acknowledgment is due the *Mining and Engineering World* for the use of cuts for figs. 1, 2, 3, 5, and 6. H. I. Jones, (formerly of the Muskogee High School, now Professor of Chemistry of Dakota Wesleyan University, Mitchell, S. D.) made the analyses of the sheet and rock asphalt pavements and furnished a large share of the notes on the comparison of the rock asphalt and sheet asphalt pavements.

The most complete description of the asphalt deposits of the State so far published is contained in Bulletin No. 2 of this Survey. The edition of this bulletin is almost exhausted and this circular is issued as a source of information concerning the deposits until a final report can be prepared.

BRIEF DESCRIPTION OF THE DEPOSITS.

The asphalts of Oklahma with one or two exceptions, occur in the southern one-third of the state, from the Arkansas line westward nearly the length of the State, the westernmost occurrence being in the northwestern part of the Wichita Mountains. For convenience the area will be divided into districts beginning at the west as follows: The Wichita Mountains, Stephens and Jefferson counties, Ardmore district, Arbuckle Mountains, Ouachita Mountains, and Red River district.

The commercial deposits of asphalts of the Wichita Mountains occur in the vicinity of Lawton. They consist of sandstones saturated with asphaltic bitumen. One quarry near Elgin was worked for material for paving in Lawton some years ago, and has recently been reopened. Several other exposures are known, but they have not been sufficiently prospected to give anything definite as to the exact area, thickness or nature of the material. The Wichita district cannot, at present, be classed as important in the asphalt resources of the state in point of production but the amount of material is sufficient to make it of at least local importance.

Jefferson and Stephens counties contain considerable deposits of sandstone asphalt. In the northeastern part of Jefferson County 160 acres of segregated asphalt land is underlaid by a ledge of asphaltic sandstone 25 feet thick. This material has been shipped from Comanche and used for paving. Two other outcrops of similar material occur in the vicinity and may be part of the same bed. The Stephens County deposits are in the southeastern part of the county. In one instance at least, the asphalt appears to have work-

ed up along a fault and to have impregnated the sandstone on either side. All the deposits are at some distance from transportation and have not been utilized, although there are large amounts of the material present.

The Ardmore district in Carter County is an important one, both in respect to the amount of asphalt present and to the amount of development. The asphalts occur in the Glenn formation of Pennsylvanian age, and those worked are impregnations of sandstone by asphaltic bitumen of varying consistency. The rocks are folded and the deposits of asphaltic sandstone usually dip very steeply, and in some cases are almost perpendicular. The amount of asphaltic sandstone in the district is impossible to estimate, and the known deposits number about 15. Brief descriptions of the four principal deposits are given below.

The Consolidated Sand quarry is located 5 miles south and 2 west of Ardmore, and 2 miles north and 1 west of Overbrook. The ledge is 25 feet thick and dips at an angle of 20°. The outcrop is one-half mile long. It is underlaid by blue shale and has an overburden of soil. The sandstone is massive, but shows lighter colored streaks due to variations in the percentage of bitumen. There are occasional nodules of clay through the deposit. The asphalt is used to give the solid pitch to paving mixtures. The material shows a fairly sharp, fine sand carrying about 10% of semi-solid sticky, ductile bitumen.[1]

The examination of this material gave the following results:

Locality	Ardmore.	
Material	Rock Asphalt.	
Bitumen soluble in CS_2	9.97	%
Character of bitumen—Semi-solid, sticky, ductile.		
Analysis of bitumen:		
Specific gravity 25°C/25°C	1.032	
Penetration 100 g. 5 sec. 25°C	54.	
Loss at 163° C. 5 hours	4.11	%
Consistency of residue, penetration as above	22.	
Bitumen insoluble in 86° B. paraffin naphtha	22.44	%
Fixed carbon	10.22	%
Mineral matter	1.78	%
Grading of mineral aggregate:		
Retained on 50-mesh sieve	0.0	%
Retained on 80-mesh sieve	4.4	%
Retained on 100-mesh sieve	14.0	%
Retained on 200-mesh sieve	57.5	%
Passing 200-mesh sieve	24.1	%
	100.0	%

Character of mineral aggregate—a fairly sharp, fine sand.

[1]The tests upon the asphalts were made by the U. S. Office of Public Roads, at Washington, D. C.

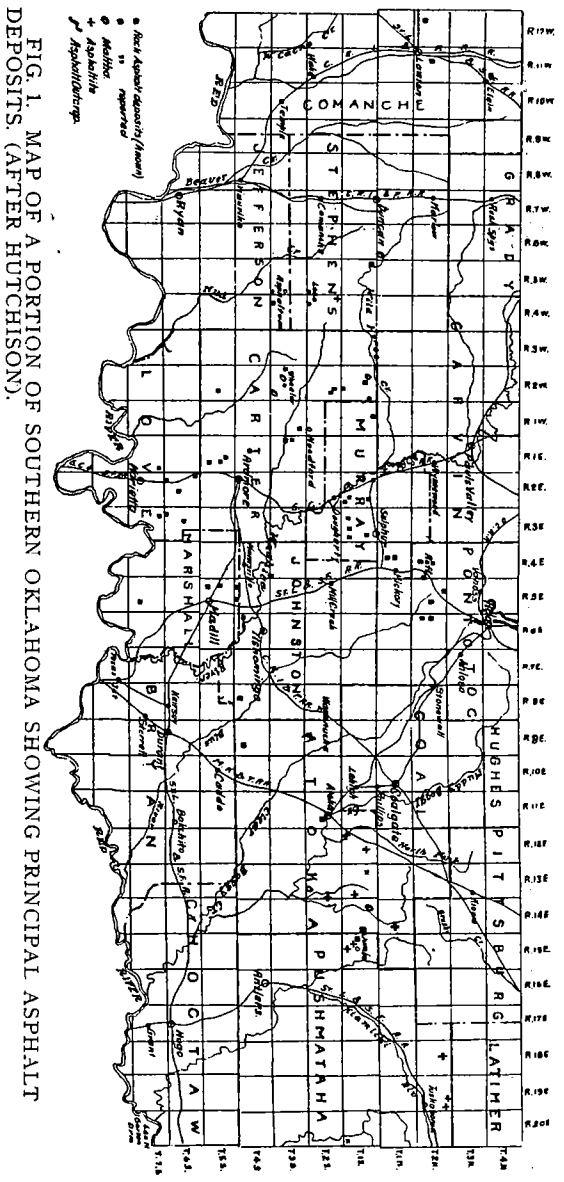

FIG. 1. MAP OF A PORTION OF SOUTHERN OKLAHOMA SHOWING PRINCIPAL ASPHALT DEPOSITS. (AFTER HUTCHISON).

Another deposit of consolidated sand lies 2 miles north of the one described. This ledge stands practically perpendicular, and is about 25 feet thick. The trend of the ledge is NW-SE. On the east side there is a wall rock of limestone 2 feet thick, and on the west a bed of conglomerate. There are occasional "horses" of clay and conglomerate which must be thrown out when the material is worked. The material is similar to that last described, and is reported to average 10 per cent bitumen. The product of both the consolidated sand mines is hauled to a spur track on the Gulf, Colorado & Santa Fe railway, about 2 miles distant.

The Aleck mine is located 12 miles northwest of Ardmore. A perpendicular ledge of 65 feet in thickness is separated from a second perpendicular ledge by a bed of shale. The deposit is broken occasionally by streaks of clay. The sand carries about 12% of heavy, viscous bitumen. The extent of the deposit is not known, but the ledge is exposed at intervals for one-fourth mile, and the material in sight may be said to be inexhaustible. A pit 60 by 60 feet has been opened without reaching the limit of the bed. The product is elevated by horse power cranes and is hauled by wagon to Ardmore. It is used as the flux in the paving mixtures.

Near Woodford, 9 miles west and 11 north of Ardmore, is an area of 1280 acres of segregated[1] land. The asphalt-bearing rock is a sandstone which contains an impregnated zone about 45 feet wide. The rocks stand almost vertically, and the impregnated zone outcrops for a distance of about a mile, and may extend much farther. The depth to which the asphaltic rock extends is unknown. This deposit has been worked to a considerable extent. The nature of the deposit and the workings are shown in the accompanying illustration showing the east end of the pit (fig. 2). The amount of material present is practically inexhaustible.

In the Arbuckle Mountain district, Murray, Johnston and Pontotoc counties contain commercial deposits of asphalt.

The deposits of Murray County are principally rock asphalts, and are impregnations of limestone and sandstone of Ordovician age. The deposits are confined to a relatively small area lying east of Dougherty and south of Sulphur. The area is divided into two districts, the Buckhorn and the Brunswick. Each of these districts contains several known deposits of which only a few will be mentioned.

The Moss quarry in the Buckhorn district is about 400 feet long and has been worked back about 300 feet from the outcrop. The material is a sandstone about 8 feet thick which carries 7 to 10 per cent. bitumen. The cover varies from 20 to 40 feet. Probably less than half of the deposit has been removed.

[1]Segregated land is that which on account of its containing coal or asphalt deposits was set aside at the time of the allotment of the Indian tribes, and which remains the property of the Choctaw and Chickasaw tribes.

One of the most important quarries in this district is the No. 4 of the Gilsonite Paving & Roofing Company. Here the asphalt impregnates a portion of the Viola limestone of Ordovician age, which dips steeply to the south. The impregnated zone is about 130 feet thick and consists principally of a granular, crystalline limestone carrying 3 to 6 per cent bitumen. The quarry face is 15 to 75 feet high and about 400 feet long. The product is hauled by wagon to Dougherty.

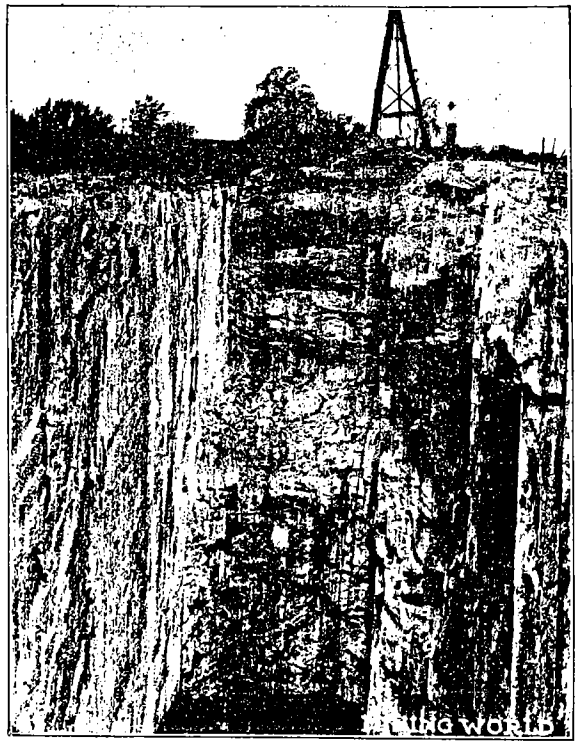

FIG. 2. PORTION OF WOODFORD ASPHALT PIT.

The number of quarries and prospects in this district is about 20. The majority of them are in the sandstones of the Simpson formation of Ordovician age, but some are in the overlying Viola limestone.

The Brunswick district lies about 3 miles west and a little south

of the Buckhorn district. The area is much smaller than the Buckhorn and contains fewer deposits. The principal quarries are the Brunswick Rock, Nos. 2 and 3 sand quarries.

The Brunswick rock is an asphaltic limestone which occurs about 4 miles northeast of Dougherty. A large quarry has been developed with a face 25 to 35 feet high. It is located on a hill side that seems to consist entirely of the bituminous limestone. The

FIG. 3. PORTION OF BRUNSWICK ROCK QUARRY.

surface outcrop shows an area of at least one-fourth square mile. The face of the quarry as well as the product shows crystalline limestone carrying from 5 to 8 per cent heavy maltha. Some of the crystalline portions are free from bitumen. The material is probably of as much value in paving on account of its mineral matter and structure as on account of its bitumen. A portion of the quarry is shown in fig. 3.

The report of the test of this material is as follows:

Locality	Murray County.	
Material	Bituminous limestone.	
Specific gravity	2.50	
Weight per cubic foot	156.	pounds.
Water absorbed per cubic foot	0.86	pounds.
Per cent. of wear	4.2	
French coefficient of wear	9.6	

Hardness—Not suitable for these tests.
Toughness—Not suitable for these tests.
Cementing value—Excellent.

Remarks: A rock of medium resistance to wear and excellent cementing value. Would probably make a very good road building material.

The No. 2 sand quarry is located on Rock Creek about a mile east of the limestone quarry just described. The development consists of a large circular pit, 35 feet deep, on the banks of the creek. The depth is reported to have been explored by the drill to 90 feet. The deposit is probably horizontal and has an overburden of 2 feet 10 feet of conglomerate and varying thickness of soil. The product consists of sub-angular grains of sand cemented by solid asphalt pitch having the penetration of ordinary asphalt cement. The product is hauled to Dougherty. It is used to furnish the solid pitch for paving mixtures.

The report of the tests on this material follows:

Locality	Dougherty.	
Material	Rock Asphalt.	
Bitumen soluble in CS_2	7.80	%

Character of bitumen—Semi-solid, sticky, ductile.

Analysis of bitumen:

Specific gravity 25° C/25° C	1.017	
Penetration 100 g. 5 sec. 25°C	61.	
Loss at 163° C. 5 hours	3.48	%
Consistency of residue, penetration as above	29.	
Bitumen insoluble in 86° B. paraffin naphtha	22.44	%
Fixed carbon	10.36	%
Mineral matter	4.93	%

Grading of mineral aggregate:

Retained on 50-mesh sieve	0.2	%
Retained on 80-mesh sieve	9.8	%
Retained on 100-mesh sieve	14.3	%
Retained on 200-mesh sieve	45.1	%
Passing 200-mesh sieve	30.6	%
	100.0	%

Character of mineral aggregate—very fine sand with rounded grains.

The No. 3 sand quarry is also located along Rock Creek in the Brunswick district. The layer is about 15 feet thick, lies horizontally, is underlaid with blue clay and has an overburden of soil from 5 to 20 feet in thickness. The area is not known. The aggregate is of angular to sub-angular grains of sand cemented loosely with a soft maltha. The product is hauled to Dougherty. It is used as the softening agent or flux for the harder pitches.

The examination of this sample gave the following results:

Locality	Dougherty.
Material	Rock Asphalt.
Bitumen soluble in CS_2	6.77 %

Character of bitumen—sticky, viscous fluid.

Analysis of bitumen:

Specific gravity 25° C/25° C	0.991%
Loss at 163° C. 5 hours	6.13 %

Consistency of residue—Too soft for penetration.

Bitumen insoluble in 86° B. paraffin naptha	11.15 %
Fixed carbon	6.95 %
Mineral matter	.81 %

Grading of mineral aggregate:

Retained on 30-mesh sieve	0.0 %
Retained on 50-mesh sieve	1.3 %
Retained on 80-mesh sieve	40.0 %
Retained on 100-mesh sieve	39.5 %
Retained on 200-mesh sieve	18.6 %
Passing 200-mesh sieve	.6 %
	100.0 %

In Pontotoc County, asphalt deposits are known at or reported from near Fitzhugh, Ahloso, Franks, Ada, and Roff. Of these deposits only the last two named have been developed. The quarry at Ada is 1½ miles west of Ada on the side of a hill which has an area of about 100 acres. Prospect drilling shows the entire hill to be underlaid with the asphaltic rock to a depth of 80 feet. The material is a fairly coarse calcareous sand, which lies nearly level, carrying about 7½ per cent of a sticky, semi-solid bitumen. The product is quarried in hillside quarries and is hauled by wagon to Ada. A small portion of one of the quarries is shown in fig. 4, and the opening of a new quarry in fig. 5. Pavements have been constructed from this material in Ada, Lawton, Tulsa, Holdenville and Hugo, Oklahoma; and Sherman and Paris, Texas, with marked success. The property described is only a portion of an extensive deposit in this vicinity and the total amount available is very great.

The results of the examination are as follows:

Locality	Ada.
Material	Rock Asphalt.
Bitumen soluble in CS_2	7.45 %

Character of bitumen—semi-solid, sticky, ductile.

Analysis of bitumen:

Specific gravity 25° C/25° C	1.019
Penetration 100 g. 5 sec. 25°C	81.
Loss at 163° C. 5 hours	4.69 %
Consistency of residue, penetration as above	31.
Bitumen insoluble in 86° B. paraffin naphtha	21.90 %
Fixed carbon	11.52 %
Mineral matter	.79 %

Grading of mineral aggregate:

Retained on 30-mesh sieve	0.0 %
Retained on 50-mesh sieve	6.3 %
Retained on 80-mesh sieve	36.0 %
Retained on 100-mesh sieve	18.3 %
Retained on 200-mesh sieve	25.7 %
Passing 200-mesh sieve	13.7 %
	100.0 %

Character of mineral aggregate—a calcareous sand with fairly sharp grains.

FIG. 4. PORTION OF ASPHALT QUARRY NEAR ADA.

In the neighborhood of Roff there are several occurrences of asphaltic rock, but only one has been developed. This is a rich sandstone asphalt about 10 feet thick, and dipping to the west.

Only a small quarry has been opened. Near Franks, 480 acres of land containing limestone, shale and sandstone asphalts, some of them very rich in bitumen, have been segregated. The distance from transportation has prevented development.

FIG. 5. OPENING AN ASPHALT QUARRY NEAR ADA.

Johnston County has only one deposit of asphalt in the Arbuckle Mountain region. This is at Ravia. A portion of the quarry is shown in fig. 6. The asphalt is a limestone, 5 to 6 feet thick, unevenly impregnated with bitumen. The material has been used in paving, but the quarry is not worked at present.

The asphalts of the Red River district occur principally in the Trinity sand, the basal formation of the Lower Cretaceous system. The rocks all dip very gently to the southeast and have remained practically unaltered since deposition. The sands of the Trinity are usually unconsolidated except where cemented by bituminous materials. The deposits of the Red River district are not so well developed nor so well known as those of the Ardmore and Arbuckle Mountain districts, and although they are of considerable importance can receive only brief notice here.

In Love County there are seven reported occurrences of asphaltic material, partly in the Trinity sand and partly in the Glenn formation. The only deposit which has been worked is southeast of Overbrook in the Glenn formation. Marshall County has seven reported occurrences, principally lenticular bodies in the sand. The deposits in the extreme southern portion of Johnston County seem to be quite extensive. One of these, a mile south and 2 east of Russet, is a layer near the top of the Trinity sand about 12 feet in

thickness. The hill has an area of about 50 acres. The asphalt is overlaid by 10 to 20 feet of barren sandstone and 2 to 3 feet of limestone. The conditions of outcrop are shown in fig. 7. A similar deposit is found 3½ miles south, and 1½ miles west of Tishomingo. Bryan County contains some deposits of sand asphalt northeast of Durant, but nothing definite is known of their extent or character. One deposit in the Trinity sand occurs on the bank of Little River, near Idabel in McCurtain County, east of the area shown in the accompanying map. In general these asphalts are soft and seem to contain considerable paraffin. Their use in paving is questionable at present.

In the Ouachita Mountain region the only deposits of rock asphalt known are a few in Atoka County, and one in LeFlore County, which have not been prospected sufficiently to make any statements regarding their extent or value. The deposits of pure asphalt, grahamite at Jumbo near Antlers, and at Paige near Poteau, and gilsonite near Tuskahoma, are also in this region. The pure asphalts occur in veins, usually along fault lines. Some of these could be used for paving but they are more valuable for other purposes.

FIG. 6. PORTION OF ASPHALT QUARRY NEAR RAVIA.

THE USE OF THE OKLAHOMA ASPHALTS IN PAVING.

In spite of the abundant supply of raw material, the Oklahoma asphalts have not been used to any great extent for paving purposes and the idea seems to prevail that these asphalts are not suited for paving. It is well known that the asphalts used in paving in Europe are rock asphalts, the Seyssel limestone asphalt probably being the

best known, but the Oklahoma asphalts are usually considered as belonging to an entirely different type.

The ideas in vogue concerning the Oklahoma asphalts are probably derived in large measure from the opinions expressed by Clifford Richardson in his book, "The Modern Asphalt Pavement." In chapter XII of this book he describes some of the deposits of Oklahoma and arrives at the following conclusions: "That the deposits, though large in amount are individually small, and moreover far from being uniform in their character, they contain too little bitumen and this bitumen is not sufficiently asphaltic in its character."

In speaking of the deposits of the Buckhorn district he says:

"Although fairly satisfactory pavements have been made with these materials it is not probable that they will prove of any importance in the paving industry as the supply as turned out is too small to permit of obtaining a requisite quantity of uniform quality and because the greatest skill is necessary in so handling the material as to make it possible to put it down with the bitumen in a proper state of consistency, as this changes very readily on being heated in the slightest degree to too high a temperature."

The points as given by Richardson, then, may be summarized as follows:

1. The small size of the individual deposits.
2. The lack of uniformity in character.
3. Small amount of bitumen content.
4. Non-asphaltic character of the bitumen.
5. Skill required to lay the pavement.

Since Richardson's work appeared the material has been used to a greater extent than before and the results seem to be at variance with his conclusions. In the following paragraphs the objections made by Richardson are considered in turn in the light of experience with the material in pavements.

In regard to the first point, two things must be considered, (1) That many of the individual deposits are much larger than any of those described by Richardson; (2) that, for use in paving, the products of two or more mines may be mixed together to form the surface mixture. One of the deposits of the Ardmore district is 45 feet wide, is known to be 1½ miles long and 100 feet deep. (See fig. 2). Both the depth and length may be, and the depth certainly is, much greater than this. Estimated on the basis of the known length and depth, this deposit contains about 2¼ million tons. Three other deposits in the same district contain together at least twice as much more and probably several times as much. A very conservative estimate of the known deposit at Ada (fig. 3) gives 13½ million tons. One of the limestone asphalt deposits is sufficiently large to supply any demands that may be made up on it for many years to come.

The smaller deposits are in clusters or districts and in many cases their products can be combined so that they are in all respects

equal to a smaller number of larger deposits. It is true that up to the present the output has been small but this is due to financial and other conditions affecting development and not to the lack of material or conditons of occurrence. Capital and demand for the material are the factors required to produce a great development of the industry.

In regard to the uniformity of the deposits, it may be said that they do vary widely in percentage of bitumen within small distances, and that small samples collected from the same quarry or from different quarries show widely different percentages of bitumen. In quarrying, transportation, and preparation for the street, however, the material is so mixed that a very uniform percentage of

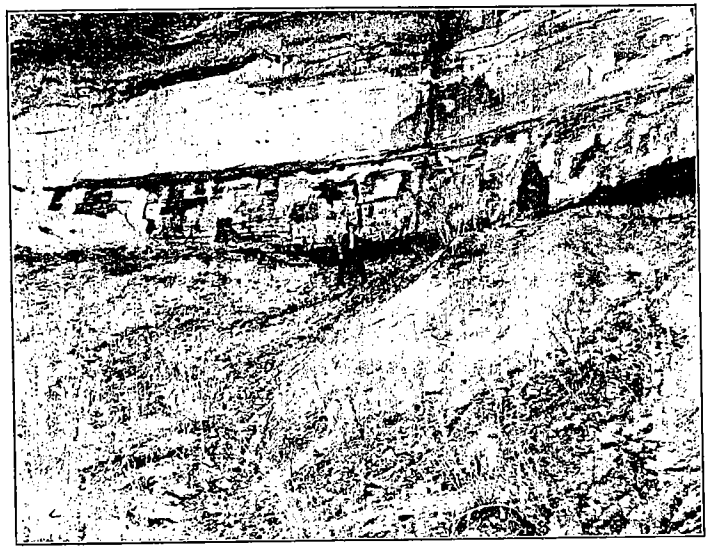

FIG. 7. OUTCROP OF ASPHALTIC LAYER IN TRINITY SAND NEAR RUSSETT.

bitumen results. The sand remaining after the extraction of the bitument from the sand asphalts is just as uniform, as well or better graded and is much cleaner than the sand usually utilized in the manufacture of the sheet asphalts.

The percentage of bitumen carried by the Oklahoma rock asphalt is not usually as great as that of the finished sheet asphalt pavement. However, the physical characteristics of the rock asphalts and the artificial mixture used for sheet asphalt are so different that it seems that comparisons should be made, not with the

artificial mixtures, but with other rock asphalts which are known to have given good service in pavements.

The bitumen in the Seyssel (French) rock varies from 6 to 8 per cent, the Val de Travers (Swiss) rock will average about 10 per cent and the Mons about 9 per cent. The Sicilian asphalts run as high as 12 per cent bitumen. They are not used alone but are diluted with the less bituminous rock of Seyssel, Val de Travers or Mons. The situation in Oklahoma, then, is similar to that in Europe in that we have rock asphalts of varying bitumen content, some of which may be used alone while others are mixed to produce a pavement of the proper bitumen content.

As to the character of the bitumen it may be said that it is usually softer and more viscous than the Trinidad or Bermudez asphalts and shows a greater penetration than do those asphalts. However, it must be remembered that in the paving mixture the Trinidad and Bermudez asphalts are fluxed with residuum so that the penetration of the bitumen from the finished pavement is not very different from that from the hard pitch Oklahoma rock asphalt.

In any event, the uniformity of composition and physical character of the finished pavement is of vastly more importance than that of any single constitutent and in this respect the rock asphalts compare more than favorably with the artificial sheet asphalts. The sheet asphalt pavement samples in the following table were taken from one street and its crossings in the distance of four blocks while the rock asphalt samples were taken from pavements in four different cities and represent material from several quarries:

[1]**Analyses of Sheet Asphalt Pavement Samples.**

		Total Bitumen.	Asphaltene.	Petrolene.
I.	Muskogee	13.5	9.9	90.1
II.	Muskogee	11.0	38.2	61.8
III.	Muskogee	11.5	17.8	82.2
IV.	Muskogee	10.5	24.6	75.4
V.	Muskogee	12.0	29.8	70.2
VI.	Muskogee	11.0	21.9	78.1
VII.	Muskogee	9.1	32.9	67.1
VIII.	Muskogee	11.5	24.8	75.2
IX.	Muskogee	10.2	21.6	78.4
X.	Muskogee	9.7	28.5	71.5

[1]**Analyses of Rock Asphalt Pavement Samples.**

		Total Bitumen.	Asphaltene.	Petrolene.
I.	Ardmore	8.53	22.40	77.60
II.	Ardmore	7.85	21.19	78.81
III.	Ardmore	8.05	21.90	78.10
IV.	Ada	9.97	22.45	77.55
V.	Sulphur	10.10	27.35	72.65
VI.	Sulphur	9.80	29.39	70.61
VII.	Oklahoma City	9.95	25.21	74.79

[1]Analyses by H. I. Jones.

The results show that the rock asphalt pavement has a lower but far more uniform bitumen content, and that while the average composition of the bitumen is about the same, the composition of the bitumen from the rock asphalt is far more uniform.

The relative penetration of the finished pavements is shown by several facts. In any of the sheet asphalt pavements of Oklahoma City or Muskogee a knife blade can be easily thrust through the surface coat on a hot day and the sheets are marked by horses' hoofs, wheels of vehicles or even by the heels of pedestrians. Some of the samples from Muskogee were pulled from the street with the fingers. On days of as equally high temperature the rock asphalt streets of Ardmore and Sulphur cannot be penetrated by a knife. At Ardmore a loaded freight car was pushed from the end of a stub track across the side walk, asphalt pavement, second side walk and on to the earth on the opposite side of the street. The car in passing off of the ends of the rails bent them into the ground. Both concrete sidewalks were crushed, but the only damage to the asphalt pavement was a slight marking by the flanges of the wheels. In Lawton heavy circus parades have passed over the streets in warm weather and in one instance a heavy steam ditching machine passed over the whole length of a recently completed street with no sign of damage to the pavement. The rock asphalt pavements in the cities mentioned do not become unduly hard in the winter and do not crack or grind up.

It appears, then, that although the percentage of bitumen in the Oklahoma rock asphalt pavements is less than that in the sheet asphalt pavements, it is as great as that of the rock asphalt pavements of Europe which have given satisfaction for years. The bitumen is as asphaltic in character as that of the sheet asphalt and while the bitumen of the rock asphalt has a higher penetration than the Trinidad asphalt, the finished rock asphalt streets are much more impenetrable than the sheet asphalt streets.

The manner of laying the pavement is very simple. The concrete foundation is generally used, and is laid in the same manner as for a sheet asphalt street. The asphalt is delivered to the plant in pieces easily handled by one man. These pieces are pulverized in a hammer crusher, screened through a 3/8 inch screen and fed into a drum which is heated to the required temperature (about 225° F.). Paddles force the asphalt through the drum and at the same time mix it thoroughly. From the drum the heated asphalt is dropped into wagons and hauled onto the concrete foundation, spread by raking, and rolled with a light roller, 2½ tons, afterwards with a heavier roller. The wearing coat is two inches thick after rolling. While cooling the pavement is swept with Portland cement or limestone dust and after cooling is open to traffic. Where more than one asphalt is used, pieces from piles of the different varieties are fed into the crusher in rotation. Some of the most successful pavements have been made of a mixture of equal portions of a bit-

uminous sandstone containing a hard pitch, and a bituminous standstone containing a soft pitch and a bituminous limestone. These are from the deposits of the Ardmore, Buckhorn, and Brunswick districts. The Ada asphalt has been used alone in Ada, Lawton, and other places. It is a calcareous sand asphalt. In Lawton, instead of using the concrete base, the earth base was well compacted and then a foundation was made of the poorer portion (stripping) of the asphalt from the Ada quarry, containing 4 to 7 per cent bitumen and broken to pass a 2½ inch ring, with sufficient fine material to fill the voids. This was laid cold and rolled in two courses of 2 inches each, making a base four inches in thickness. This pavement has been in use 4 years and the city engineer reports the base to be very satisfactory, only one small crack appearing in the surface coat of three miles of pavement.

The danger of over heating in the rock asphalts is very slight. Since each rock particle is already coated with bitumen only a moderately high temperature is required to soften it for mixing and for rolling. The rock asphalt is heated to about 225° F. in the heater while Richardson recommends that the Trinidad and Bermudez surface mixtures reach the street at temperatures of from 280° to 340° F. It is manifestly necessary to heat the artificial mixtures to a higher temperature to insure perfect mixing than it is the natural mixtures where each particle is already coated with bitumen.

The price of sheet asphalt pavement in Oklahoma is about $2.25 to $2.50 per square yard. The Oklahoma rock asphalt pavement can be laid anywhere in the state for less than $2.00 per square yard. The price in Kansas City has never exceeded $2.15. The fact that the entire surface mixture must be transported from the mines or quarries in the case of the rock asphalt, while for the artificial pavements only the bitumen need be imported from a distance and the mineral aggregate can be obtained from near at hand, handicaps the rock in competition with the sheet asphalt at a great distance from the mines. At present the rock can compete with the sheet pavements within a radius of 500 miles or so of the mines. When the mines and quarries are developed on a larger scale this radius will be increased on account of the less cost per ton of production of the rock. Judging from the qualities of the pavement already laid, the area in which the rock can successfully compete with the sheet asphalt will be greatly increased by the recognition of the greater value of the natural rock pavement.

Up to the present the Oklahoma rock asphalt has been used for paving in several cities in Oklahoma and Texas and in a few other cities. A partial list of the places in which the material has been used includes Kansas City, Kansas; Kansas City, and Sedalia, Missouri; Fort Worth, Paris, and Sherman, Texas; Ardmore, Lawton, Hugo, Oklahoma City, Muskogee, Tulsa, Holdenville, Norman, and Sulphur, Oklahoma.

In the following paragraphs a few statements from city engineers and others acquainted with the pavements of the Oklahoma asphalts are given.

S. F. Peckham, in his book, "Solid Bitumens," (page 287) says: "In Ardmore, a number of streets have been laid in a manner more nearly approaching the method pursued in Europe. The materials used were taken from quarries a few miles south of Ardmore, and were thoroughly mixed after being softened by heat. The material was spread on a concrete foundation without a binder and rolled until cold. When I inspected this street on one of hottest days in August, it was as solid as a rock. I know of no such streets in an Atlantic or Pacific coast city. They are the product of the intelligent application of sound principles of technology to the manipulation of the best materials for the construction of solid bituminous streets yet found on the American Continents."

Dr. C. N. Gould, former director of this survey, in an address makes the following statement: "Within the last year I have been very much interested in the subject of good pavements and have taken occasion to examine the asphalt streets in a number of northern and eastern cities, Baltimore, Washington, Pittsburg, Chicago, Kansas City, St. Louis and places nearer home, and I think I am safe in making the statement that Ardmore has at the present time the best paved streets in America."

Equally as good streets have been laid in Sulphur, Oklahoma. Some cracks have appeared running entirely across the streets in these pavements, but they seem to be due to the settling of the foundation as the same cracks continue through the cement sidewalks. The asphalt surface along these cracks does not disintegrate but on the contrary seems to be "healing over."

The city engineer of Kansas City, Kansas, in a statement of May 25, 1909, says: "We have some of this pavement that has been down over fifteen years and with the exception of a few places where water has not been properly drawn off and allowed to stand, it has stood heavy traffic and is still in a good state of preservation.

"We have fifteen miles of other asphalt which has had to be repaired a great deal, while this pavement, except for plumbers' cuts, gas company's and water company's cuts, has had no repair at all.

"Some of the streets of Kansas City, Mo., have been paved with this material and they are in better condition than some sheet asphalt streets that have been paved later, after being down fifteen years.

"Last season there were laid in this city 22,000 square yards of rock asphalt and this year there is being laid and petitioned for about twice as much more, which ought to show that it is giving satisfaction here."

Lawton, Oklahoma, has three miles of this pavement with both base and surface of the Ada asphalt, laid in 1909 and 1910. Four miles are under construction or contracted for. The city engineer reports as follows (Jan. 6, 1913):

"This pavement has stood all the demands of traffic and shows no wear except in places along the gutters where horses have stamped repeatedly and a few places where faulty material crept in.

"While our traffic is not what would be called heavy in a city, quite large frame buildings have been moved over it on wheels not over twelve inches wide and large circus parades have been over it with no apparent settlement; on one occasion a large steam ditching machine was run the whole length of one street shortly after completion with no permanent sign of damage to the pavement.

"With this base there is no tendency of the wearing surface to crack and I know of but one small crack in the three miles of pavement.

"Our present contract is being constructed the same way except that the greater part of the material for base is obtained from a mine within two miles of this city."

Sedalia, Missouri, has used no asphalt for paving for the last fourteen years but of the old asphalt pavement, the city engineer reports the natural rock as being in a great deal the better condition.

These are only a few of the statements at hand but they are sufficient to show that the pavements constructed of the Oklahoma asphalts are successful and that these asphalts are, at least, worthy of consideration as a paving material.