OKLAHOMA GEOLOGICAL SURVEY

Governor Lee Cruce, State Superintendent R. H. Wilson,
President A. Grant Evans, Commission

Chas. N. Gould, Director
L. C. Snider, Assistant Director

BULLETIN No. 8

PRELIMINARY REPORT
ON THE
ROAD MATERIALS
AND
ROAD CONDITIONS
OF
OKLAHOMA

By L. C. SNIDER

NORMAN
August, 1911

SCIENTIFIC STAFF

PERMANENT STAFF

Chas. N. Gould ..... Director
L. C. Snider ..... Assistant Director
Frank Buttram ..... Chemist

CO-OPERATING GEOLOGISTS IN CHARGE OF SPECIAL INVESTIGATIONS

D. W. Ohern ..... Stratigraphy and Paleontology of the Oil and Gas Fields
Chas. H. Taylor ..... Igneous Rocks
Chester A. Reeds ..... Stratigraphy and Paleontology of Arbuckle Mountains
J. W. Beede ..... Stratigraphy and Paleontology of the Permian Area

OKLAHOMA BANK AND OFFICE SUPPLY CO., GUTHRIE

ACKNOWLEDGMENT

The writer's thanks are due to the Board of Park Commissioners of Oklahoma City and to the Officers of Public Roads at Washington, D. C., through whose co-operation most of the quarries of the State were visited and samples collected and tested. Many valuable suggestions were received from Mr. Jas. T. Voshell, highway Engineer of the Office of Public Roads, who accompanied the writer on the visits to the quarries.

Cuts for this report loaned as follows:

Figs. 2, 3 and 4 are used from Roads and Pavements by permission of I. O. Baker.

Figs. 5 and 6 by the Merillat Culvert Core Company, Winfield, Iowa.

Figs. 7 and 8 by the Illinois Concrete Machinery Company, Buda, Illinois.

Fig. 9 by the Municipal Engineering and Contracting Company, Chicago, Illinois.

Figs. 10 to 13 by the Sidney Steel Scraper Company, Sidney, Ohio.

Figs. 14 to 17, 21 and 22 by the Austin-Western Company, Chicago, Illinois.

Fig. 23 by the T. L. Smith Company, Milwaukee, Wisconsin.

Figs. 24 and 25 by the Kelly-Springfield Road Roller Company, Springfield, Ohio.

CONTENTS

LIST OF ILLUSTRATIONS

CHAPTER I.

HISTORY OF ROAD BUILDING AND VALUE OF GOOD ROADS

HISTORY OF ROAD BUILDING.

Trails and tracks between objective points are common to races of all stages of civilization. It is, however, only the more highly civilized peoples that have established permanent roadways and have improved them by surfacing them with resistant materials. Among the ancient nations the Egyptians, Assyrians, Greeks, Carthaginians and Romans recognized the value of improved highways and they constructed roads which have become famous in history and of which some remains exist to the present. Most of these roads were built for military purposes i. e. to render possible the rapid transfers of troops and supplies which were necessary to keep the widely separated portions of the empires in subjection.

THE ROMAN ROADS.

The greatest and the most important of these ancient highways were the Roman roads. These radiated from Rome into the outer portions of the empire and later they were an important factor in the long-continued military supremacy of the Romans and still later became the avenues of commerce between the different sections of Europe.

The Roman roads were built in straight lines regardless of obstacles. They were from 8 to 20 feet in width and from 18 inches to 3 feet in thickness. [1]"Two shallow trenches, called sulci, were first dug parallel to each other, marking the width of the road. The space between them was excavated to solid ground; in this the road materials were placed, arranged in four layers, having a total thickness of about three feet. (1) The *stratumen* consisting of two courses of large, flat stones laid in lime-mortar; (2) The *rudus*, composed of broken stones mixed with one-third their quantity of lime, and well consolidated by ramming; (3) The *Nucleus*, a mixture of broken brick, potsherds, tiles and lime; (4) The *Summa crusta* or *pavementum*, composed of large

1. Byrne, Austin T., Highway Construction, p. XXXV.

irregular shaped stones about 6 inches thick, closely jointed and fitted with the utmost nicety."

The cost of these roads probably averaged $50,000 per mile. They were extremely durable, lasting for centuries, and still form the foundation or, in some instances, the surfaces for modern highways. They were on the other hand rough surfaced or soon became so and were needlessly expensive on account of their great thickness.

TRESAGUET ROAD.

After the fall of the Roman Empire little or nothing was done in the way of highway construction and the roads already built were neglected. It was not until the time of Napoleon I, when the extent of his empire and the demand for rapid movement of troops and supplies made the construction of highways a necessity, that interest in road-making was revived. The roads were built after a plan proposed by Tresaguet, a French engineer of the First Empire, in 1874. He adopted the plan of the Roman road, but greatly lessened the thickness, and used two layers of stone. The lower layer, which was several inches in thickness, was composed of large pieces of rock and the upper layer was of small broken stones such as are used in modern macadam construction. In the preparation of the roadway, the clay was left higher in the middle to give an arched form to the road.

TELFORD AND MACADAM ROADS.

Other countries soon followed the example of France and, especially in Great Britain, miles of improved road were built. These English and Scotch roads were constructed after the plans of one or the other of two Scotch engineers, Thomas Telford, and John L. Macadam.

Telford's plan differed from that of Tresaguet, principally in giving the arch or crown to the road by making the layer of finer stone thicker in the middle instead of making the arch in the clay foundation. He also applied the finer stone in two courses, first one of four inches which was compacted by rolling or by traffic, the second, two inches of slightly smaller stone which was also rolled to smoothness.

Macadam was the first to realize that the heavy stone foundation was unnecessary, and constructed his roads only a few inches thick of crushed stone, none of the pieces of which were over two inches in diameter. He placed great emphasis on the proper grading and compacting of the earth foundation so as to bring about good drainage. He saw that if the earth foundation was properly made, the layer of

crushed stone, when compacted, would prevent water from passing into the foundation and thus insure a permanent, firm roadway.

Other engineers at first regarded his plan as impractical, but after test roads in France demonstrated its merits, it was generally adopted and at present is almost universally followed. It has proved to be just as durable as the Telford or Tresaguet road and is much cheaper. However, it requires a firm earth foundation, and where the ground is swampy or mucky the Telford road is preferable and is still used to some extent. The relative thickness and structure of the types of roads and the decrease in thickness from the Roman to the modern macadam road is shown in fig. 1.

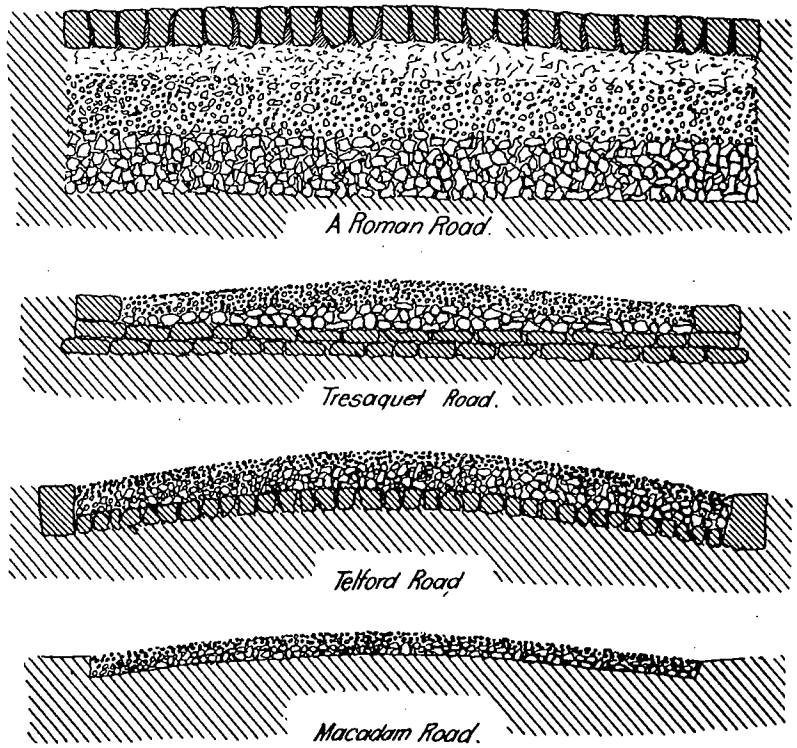

Fig. 1. Sections of Roads showing change from Roman to Modern type.

EARLY ROADS IN THE UNITED STATES.

In the United States, very little was done toward road improvement in Colonial times and no paved roads were built until several years after the close of the Revolutionary War. Probably the chief

cause of this condition was the fact that the principal settlements were along the water courses and could easily be reached from the coast. Later, as the population increased and settlements were formed away from the water courses, the need for roads became evident. However, in the early years of settlement the population was too sparse to permit of the building of improved roads.

The National Road. Washington was a strong advocate of improved roads and assisted in having laws passed giving government aid for this purpose. The principal road thus built was known as the "National Road." The first money for its construction was appropriated in 1806. It was started at Cumberland, Maryland, and gradually pushed westward through Pennsylvania, West Virginia, Ohio, and Indiana and into Illinois. The roadway was sixty feet wide, thirty feet of which was macadamized through Maryland and Pennsylvania. The road was maintained by the general government for several years but in 1830 was finally turned over to the states through which it passed. For many years it was the principal overland route from the coast to the interior and it had a great influence in the settlement and development of the Northwest Territory.

Turnpikes. Previous to and during the time of the construction of the National Road, many turnpike companies were organized. These companies constructed roads upon which toll was charged. Many miles of road were built in this way in the different states. Since the Civil War, however, all of the states have passed laws which enabled the state, county, or township to purchase these roads and to maintain them at public expense. There are at present very few toll roads in any of the states, and the matter of road construction and maintenance is left to the state or to the local government.

THE ADVANTAGES OF GOOD ROADS.

The advantages of good roads may be divided into two classes, financial and social. These are, of course, very closely related and cannot be entirely separated in a discussion of this kind. Any added social advantage to a community has an appreciable effect on the price of real estate and its products and any increase in the price of land or its products causes a betterment in social conditions. However, in this report the two advantages will be considered as independently as possible.

FINANCIAL ADVANTAGES OF GOOD ROADS.

INTRODUCTION.

The advantages of good roads are classified under four heads, by W. C. Latta:

1. Good roads lessen the time and force in transportation to and from the market.
2. Good roads enable the products and farm supplies to be delivered at all seasons of the year.
3. Good roads diminish the wear and tear on vehicles, harness and horses.
4. Good roads increase the value of real estate.

These points will be considered in turn.

LESSENING OF TIME AND FORCE REQUIRED FOR TRANSPORTATION

The time and force necessary to transport goods to and from market, other things being equal, will depend upon the nature of the road bed. In this connection the following points must be considered: (1) the nature of the road bed; (2) velocity with which load is moved; (3) inclination or grade of road.

Nature of the road bed. The following table gives the tractive force or power required to draw a load of 2240 lbs. at a speed of 3 miles per hour over level roads of different character.

TABLE 1.

Kind of road	Tractive force.
Loose sand	448 lbs.
Loose gravel (deep)	320 lbs.
Loose gravel (4")	222 lbs.
Good gravel road	88 lbs.
Hard gravel road	75 lbs.
Ordinary dirt road	224 lbs.
Hard clay	112 lbs.
Bad macadam	160 lbs.
Common macadam	64 lbs.
Very hard and smooth macadam	46 lbs.
Wood blocks	54 to 26 lbs.
Stone blocks	90 to 45 lbs.
Asphalt	17 lbs.
Iron railway	11½ to 8 lbs.

Velocity with which load is moved. The following table gives the tractive force which the average horse, pulling on the level and working 10 hours can exert at different speeds:

TABLE 2.

Miles per hour.	Tractive force.	Miles per hour.	Tractive force.
¾	333.33	2¼	111.11
1	250.00	2½	100.00
1¼	200.00	2¾	90.91
1¼	166.66	3	83.33
1¾	142.86	3½	71.43
2	125.00	4	62.50

Grade of road. Where the road bed inclines the tractive force required to draw a fixed load is greatly increased as is shown in the following table. These results were secured on good macadam roads, and show the tractive force required to draw a load of one ton over roads of different inclination and the equivalent length of each mile of grade in miles of level road:

TABLE 3.

Rate of inclination.	Angle with the Level.			Tractive force.	Equivalent length of Road in Miles.
Level	0°	00′	00″	38	1.00
1 in 500	0	06	53	42	1.10
1 in 100	0	34	23	58	1.52
1 in 80	0	42	58	63	1.66
1 in 60	0	57	18	71	1.87
1 in 50	1	08	16	78	2.05
1 in 40	1	25	57	88	2.30
1 in 30	1	54	37	104	2.73
1 in 25	2	17	26	118	3.10
1 in 20	2	51	21	138	3.63
1 in 15	3	48	51	171	4.50
1 in 10	5	42	58	238	6.26

Some examples may bring out the points of the above tables.

A horse traveling for 10 consecutive hours exerts a tractive force of 83.33 pounds. This is sufficient to draw a load of about 2 tons a distance of 30 miles over the best macadam roads, but only one-fifth of that amount the same distance over loose sand or one-third that amount over ordinary dirt roads (dry). If the speed instead of the load be changed, the average horse can draw one ton a distance of 30 miles in 10 hours over good gravel road but can draw the same load only 11 or 12 miles over ordinary dry dirt road.

From the third table it may be seen that while a horse can move 2 tons a distance of 30 miles over good macadam roads on the level, he can draw the same load only one-half as far on the same road having a grade of 1 in 50 or only one-sixth as far in a road having a grade of 1 in 10.

All these tests and comparisons are for ordinary, dry dirt road. If the conditions as they exist in large portions of Oklahoma in wet seasons of the year were taken into consideration, it could be shown, as many people have proved to their own satisfaction, that one horse can draw a very light load only a very short distance.

There is no doubt that in the majority of localities in Oklahoma, the estimate of 1500 pounds as a load for one horse for 30 miles in 10 hours is far too high, indeed, over much of the State, 1500 pounds would be a large load for two horses for that distance, while over good macadamized roads with moderate grades, two horses should draw 2 or 3 tons the 30 miles in 10 hours.

PERMIT MARKEING AT ALL SEASONS.

Through certain seasons of the year the majority of the unimproved roads become impassable for anything like heavy traffic, and traveling even in light vehicles is at least very unpleasant. During these seasons hauling is practically stopped and the teams and men who might be profitably engaged are thrown into idleness.

The production of vast quantities of fruit and vegetables would be possible in Oklahoma were it not for the difficulty in getting the produce to market in reasonable time and at reasonable expense. Even of the amount produced a large percentage is allowed to go to waste on account of the impossibility of marketing during the short time in which the produce is in marketable conditions.

While this fact is more noticeable in connection with perishable products, it often affects the value of the staple products in equal measure. Corn, cotton and wheat often deteriorate and fall off in value because they cannot be marketed at just the right time.

DIMINISH WEAR AND TEAR.

This item is very hard to estimate in dollars and cents but is one of great importance. The great difference between the general appearance of vehicles, harness and horses in a region of good roads and in one of bad roads is sufficient to impress the importance of this factor upon the mind of anyone.

INCREASE THE VALUE OF REAL ESTATE.

From an investigation on this subject in Indiana, some years ago, Professor W. C. Latta,[2] of Purdue University, arrived at the following results:

"1. The average estimated increase in the selling price of land due to existing improved highways is $6.48 per acre. The estimates from which this average is made refer in most cases to lands near the improved roads; but in few instances they apply to all the lands of the county. The average increase, therefore, of $6.48 is lower than was intended for the lands near the improved roads.

"2. The estimated average increase per acre that would result from improving all the public roads is $9.00 per acre.

"3. The estimated average cost of converting the common public roads into improved highways, is $1,146 per mile."

The land area of Oklahoma is 69,417 square miles. Estimating that the value of land would be increased only three dollars per acre by the improvement of the highways, (which is a very low estimate, and only one-third of the estimate of the increase for land in Indiana), the increase in value would be $133,300,000 or enough to improve 67,000 miles of road at an average cost of $2,000 per mile.

It should be understood that such an estimate as this makes little pretension to accuracy. It does, however, show something of the nature of the increase of real estate value caused by road improvement. Some writers have added the increased price of land to the saving from the other items mentioned to obtain the total value of improved roads. This seems to be an error since the increased price of land is the result of the improved conditions in the other items and the increase represents the sum of the saving in the other items.

EXCESSIVE ESTIMATES OF VALUES OF GOOD ROADS.

By assigning values to some of the factors which have been mentioned and carrying the calculations through for certain regions, stupendous results showing the values of good roads have been obtained. In many cases these results have been of such magnitude as to produce a doubt in the mind of the average reader as to whether the whole matter of the advantages of good roads has not been grossly exaggerated. One of the best known of these calculations is given below. Holmes[3] makes the following estimate as to the loss to the farmers of North Carolina from this cause:

"These 134,000 country horses and mules, credited to the middle and western counties, cannot be used during four weeks of the year on account of bad roads. The cost of feeding them per day at twenty cents each, is $26,800, which for the four weeks amounts to $750,400. Now, let us add to this item the loss of time for these animals. Putting this at twenty-five cents per day, (twenty-four days), we see another source of loss, amounting to $804,000. These two items give us a total of $1,554,000 per annum, which may be charged against the impassable public roads. Let us add to this the cost of the following items which will amount in the aggregate to certainly not less than $50,000: (1) Value of the services of ox teams and the cost of feeding them, during the four weeks; (2) and the loss farmers sustain by not being able to carry farm produce, tobacco, cotton, etc., to markets at times when prices are highest; and the result presents at a reasonable estimate a total loss of more than $1,600,000 per annum, to be charged against excessively bad public roads in North Carolina, during these four weeks."

This calculation is manifestly in error on account of the fact that of the 134,000 country horses and mules mentioned, only a very small proportion, probably less than 5 per cent., would be engaged in hauling upon the roads at wet seasons of the year, even if the roads were in excellent condition. In almost the whole territory of the United States the wet season comes at a time when there is comparatively little hauling to be done by farmers. Also the number of horses required for raising the crops are much larger than the number required for marketing them.

There is no doubt as to the validity of the charges against bad roads on account of their rendering marketing impossible at times when it might be advantageous, but the charges estimated for the keeping of horses off the road seem to be far too large.

Circular 19, of the Road Inquiry Office of the United States De-

2. Circular 23. Office of Road Inquiry, U. S. Dept. of Agr.

3. Holmes, Prof. J. A., N. Car. Geol. Survey, Bull. No. 4, Road Materials and Road Construction in North Carolina.

partment of Agriculture[4], gives data concerning the cost of bad roads. This data was obtained as the result of 10,000 letters of inquiry distributed over the country. Replies were received from 1,061 counties. The following table gives the results for the different sections of the country:

TABLE 4.

LOCALITY	Average distance hauled	Average load	Av. cost per ton mile	Total cost from farm to market per ton
Eastern States	5.9	1.108	$.32	$1.89
Northern States	6.9	.....	.27	1.86
Middle Southern States	8.8	.....	.31	2.72
Cotton States	12.6	0.688	.25	3.05
Prairie States	8.8	1.204	.22	1.94
Pacific Coast and Mountain States	23.3	1.098	.22	5.12
Whole United States	12.1	1.001	.25	3.02

By comparing these results with results from a similar investigation regarding the cost of wagon transportation in Europe, the Office of Road Inquiry arrived at the conclusion that the annual saving produced by the improvement of all the roads would be $628,000,000.

I. O. Baker[5] discusses this bulletin and its conclusions very fully and maintains that the results are from five to six times too large. His arguments may be summarized as follows:

1. The data is not respresentative of the entire country as only one county in thirty is represented in the replies; too few to give a true average of the conditions.

2. The average haul, as given in the table, is too large. A distinction should be made between average haul and average distance hauled as there are always many more loads hauled from the farms lying nearer a market than from those farther away owing to the gardening and truck farming nearer the cities. In Illinois, which is represented in the table by replies from 56 counties and in which the average haul is given 5.5 miles, a later inquiry with 316 replies from 72 counties gave the average haul at 3.2 miles.

3. The cost per ton-mile is too great as a large part of the hauling is done when the men and teams would not be otherwise engaged. In the inquiry referred to in Illinois, the actual cost per ton-mile was

4. April, 1896.
5. Roads and Pavements, pp. 11-20.

given at about one-third of that given for Illinois in the table in Circular 19.

4. The $628,000,000 represents 26 per cent. of the value of the crops raised in the country. If it really cost so much to market the crops, the land farthest from market should be valued 25 per cent. lower than that near market. Investigations have shown that the average difference is about 5 per cent. The rental values for lands near to and remote from market also show only a small difference.

5. The average for the United States is not correct as no account has been taken of the amount of traffic in the different states. Iowa, with its 5.4 miles haul and 25,000,000 tons traffic counts for no more in the mean than Arizona with a haul eleven times as great and a traffic only one one-hundredth as great; no difference is made between Illinois with 72 per cent. tillable land and Wyoming with 1 per cent., or between Delaware with an area of 2,050 square miles and Texas with an area of 265,780 square miles.

Blatchley[6] calls attention to the millions of dollars spent by railroad companies, not in building new roads, but in making more solid road beds and embankments, straightening curves, reducing grades, etc., in order to economize time, motive power, and wear and tear on rolling stock. The great railroad companies act upon the principle that the *best* railroad is the cheapest.

The same principle applies to a certain extent to public roads and highways, but it should be noted that such extensive improvements are not undertaken until the traffic carried by the road is sufficient to bear the expense and still return a fair income on the investment. In other words, the kind of construction and the expense incurred is adjusted to the conditions and to the return on the investment.

From the financial standpoint and without reference to the social advantages, the same criterion must hold in public road building. There is no general rule to tell whether a given road will pay for expensive improvements. All depends on the amount of traffic and the nature of the road. Strictly speaking, the amount of traffic i. e. number of ton-miles hauled over the road, and the average saving per ton-mile with improved roads, determines whether or not the improvement of the road will pay.

It must be kept in mind, however, that when the road is improved

6. Blatchley, W. S. 30th. Ann. Rept., Ind. Dept. of Geol. and Nat. Resources, 1905.

that the amount of hauling will be considerably increased due to the improved social conditions, greater ease of marketing, etc. This should always be considered in determining whether the improvement of a road will produce a sufficient return on the investment.

SOCIAL ADVANTAGES OF GOOD ROADS.

The social advantages of good roads are certainly as important as the financial advantages and probably have as great an effect on the general progress and welfare of a community. The great difference in the comfort and convenience of living in the city and country is primarily a difference in ease of transportation.

The bad roads are responsible for the poor social condition of the country through portions of the year. During the wet seasons the attendance in the country schools is greatly reduced. A similar condition exists in the churches and all social activities are at a standstill. Several writers have given this lack of social life in the country as the principal cause of the movement of the younger generation from the country to the towns, and the consequent overcrowding of other trades and professions and the attendant evil results. The rural free delivery which has been established by the United States Post Office Department is one of the greatest modern advantages to the rural population. This depends entirely upon good highways and routes are not assigned to communities where the roads are likely to be impassable during any season of the year.

Many northern farmers have visited Oklahoma, with the purpose of buying land and making their homes in the New State, but on account of the condition of the roads have decided not to change locations. This is especially true of the middle-aged or older men. As one man expressed it, "I have put in a great deal of time and money in helping to build roads and bridges in my home state, so that I could go where I wanted when I wanted to. I do not feel that it would pay me to go back to the old condition of mud roads and fords even if I can get more land for the same money or can make a few more dollars a year. The comfort and convenience of good roads are worth more than the difference."

It is this class of men, too, i. e., those that intend to make their homes here and to become a part of the community in which they purchase land, that will be of the greatest advantage to Oklahoma. It seems to the writer that probably the greatest loss of all those chargeable to bad roads in Oklahoma, is the great numbers of men of moderate means and of middle age who are prevented from becoming citizens of

our state by their unwillingness to return to conditions of transportation and of social life which they have already passed in older states. A man who buys a small farm in Oklahoma, who settles upon it and becomes a part of the community, is worth much more to the State in the long run than one who buys a large tract for speculation and rents it merely to make as much as possible from it until he can sell it for a large profit.

CHAPTER II.

ROAD MATERIALS AND THEIR PROPERTIES

CLASSIFICATION OF ROAD MATERIALS.

In this chapter the nature of the different road materials is considered, while the discussion of their distribution in Oklahoma is left to another chapter.

The materials, which have been used in the construction of roads, and which occur in Oklahoma may be classified as follows:

TABLE 5.

1. Sand and sandstone.
2. Clay and clay products.
3. Gravel.
4. Asphalt and bitumens.
5. Clinker from burned culm heaps of coal mines.
6. Rock for macadam roads.
   a. Igneous rocks.
   b. Sedimentary rocks.
   c. Metamorphic rocks.

SAND AND SANDSTONE.

Ordinary sand consists of small particles of quartz or silica, and sandstone is merely sand which has been cemented together, usually by infiltration of silica, lime or iron oxides and by subsequent pressure.

As road materials, sand and sandstone are usually worthless or worse than worthless. The only exception to this rule for sand is in the case of extremely plastic or sticky clay roads. Such roads may be improved by adding a proper proportion of sand and mixing it thoroughly with the clay. This will be discussed more fully under sand-clay roads.

The poor quality of sand and sandstones as road material is due

to the lack of bonding or cementing material. The quartz grains are very hard and even the finest dust does not cement when wet and dried again. Consequently the sand road remains a mass of loose material, which rolls about under the traffic, and thus causes the highest tractive force of any road material in the dry condition. Sandstone when placed under traffic soon grinds down into sand and becomes a sand road. While this process is going on the fine sand works to the bottom and leaves the surface covered with the larger pieces of sandstone, thus producing a rough and "jolty" roadway. The writer has seen roads surfaced with crushed sandstone at considerable expense which after one or two years were much worse than the natural clay road before the sandstone was placed upon it. Sand roads are better when wet than when dry as the water fills the voids in the sand and prevents the grains from moving over each other.

CLAYS AND CLAY PRODUCTS.

Clays are the decomposition products of other rocks. They possess the peculiar property of plasticity, i. e. of being molded into any shape when wet and retaining that shape with considerable strength when dry. It is this property which renders them of value in the clay working industries, but which renders them objectionable as road materials.

The majority of natural road ways are of clay, or of soil in which clay is the principal constituent. In dry weather the clay roads are hard and, if properly graded, very satisfactory. When wet, however, they become very soft and sticky and often impassable. Clays containing a considerable proportion of sand do not become so soft and sticky. Clay roads may be greatly improved by the addition of sand.

The only place in which clay may be used to advantage as a material for improved roads is in the case of very sandy roads where its addition causes the sand to pack instead of rolling around under traffic.

Shales, which are simply consolidated clays, are often very hard when freshly quarried, and in many places have been used to surface roads. However, they weather down into soft, plastic clay in one or two seasons so that they are valueless for road materials and should not be used except, in some cases, on sand roads.

Vitrified Brick. When clays are heated above a certain temperature they lose their plastic properties and become hard and firm. This property is taken advantage of in burning brick and other clay wares. Vitrified brick, which are simply brick burned at a sufficiently high temperature to cause the clay to begin to melt, are widely used as a street

paving material and in some of the older states for country highways. They make very satisfactory roads in every way, but are quite expensive. At present they can scarcely be considered as available material for country roads in Oklahoma, but as the population becomes more dense and as land values become higher, they will undoubtedly come into use in some sections of the State. Their properties will be considered more fully in connection with the construction of brick pavements.

GRAVEL.

Gravels are composed of fragments of rock, the nature of which depends on the rock from which they are derived.

Three kinds of gravel occur in Oklahoma: granite, quartz and limestone gravels. The granite gravels are derived from the weathering of the granite rocks of the Arbuckle and Wichita Mountains and are composed of small pieces of granite and separate crystals of feldspar and quartz. The quartz gravels are derived from the weathering of sedimentary rocks, principally conglomerates, chert and sandstone. Limestone gravels are of small extent and are derived from limestones or from limestone conglomerate.

The granite gravels have only fair wearing qualities, but have good cementing value and form a smooth, hard surface. Although quartz itself has little or no cementing value, the quartz and chert gravels usually contain sufficient limestone pebbles and other impurities to cause them to cement.

In the glaciated portions of the United States there are immense beds of gravel which furnish the principal road material in large areas. There is no glacial gravel in Oklahoma and the occurrences of gravel are in stream beds. The use of gravel for roads in Oklahoma will be almost entirely confined to the localities in which it occurs for when it is shipped by rail it is almost as expensive as crushed rock, while the latter is generally a much better road material.

Conglomerate may be regarded as a cemented gravel. At first thought it would seem to be very suitable for road material, but is is usually very difficult to prepare for the roads. The principal conglomerate in Oklahoma occurs around the Arbuckle Mountains and is composed of limestone and some granite pebbles of varying sizes.

ASPHALT AND BITUMENS.

These materials have been fully discussed in a previous publication[7] of this Survey so they will receive only a brief notice here.

The asphalts are generally regarded as the residuum of asphaltic petroleum from which the lighter oils have escaped. They are viscous substances whose principal use in a road or pavement surface is to act as a binder or cement for mineral particles which furnish the resistance to the wear of traffic.

To bind this mineral aggregate properly the asphalt must be sufficiently viscous to coat each mineral particle and yet sufficiently hard not to soften appreciably under the sun's heat. This result is attained by mixing a stiff pitch-like asphalt with a softer asphalt or an asphaltic oil, and with sand and limestone dust. This mixture is heated, spread on the street and compacted. In time the lighter oils from the soft asphalt or asphaltic oil will escape leaving the heavy pitch as the binder for the mineral aggregate.

The asphalts of Oklahoma occur pure, as gilsonite or grahamite, and also as impregnations of sandstone, limestone and shale. The asphalt impregnating the sandstones and limestones varies in nature in different deposits, some of it being of a hard, pitch-like consistency and some of it being soft and oily. Very successful pavements have been laid by combining two or three of these natural rock asphalts, e. g. a lime asphalt, a sand asphalt containing a soft pitch, and a sand asphalt containing a hard pitch. This combination furnishes all the necessary ingredients for the asphalt pavement surface, i. e. the mineral aggregate (sand and limestone), the hard pitch and the soft pitch or heavy oil.

Asphaltic oils for dust prevention. In recent years heavy asphaltic oils have been used to spray or to mix with the surface of earth, clay or macadam roads. This process naturally does not give the firm hard surface of true asphalt pavement, but it is comparatively cheap and is a great improvement on the ordinary earth or clay road. Probably the most valuable result from this treatment is the prevention of dust.

The oils of the great oil fields of northeastern Oklahoma have a paraffin base and are not suitable for this purpse. The oil from the Wheeler field is much more promising and the soft asphalts of the southern parts of the State may be used similarly.

7. Hutchison, L. L., Bulletin No. 2, Okla. Geol. Survey, 1911.

CLINKER FROM BURNED CULM HEAPS OF COAL MINES.

In the mining of coal immense heaps of waste, consisting of slack coal and shale accumulate. In Oklahoma the coal and shale contains considerable iron pyrite or iron sulphide. When the heaps become moist this iron sulphide ($Fe\ S_2$) is oxidized to the sulphate ($Fe\ SO_4$) and enough heat is generated to ignite the coal, thus causing spontaneous combustion. The piles burn very slowly and for considerable length of time. The coal is either burned out or coked, and the shale clinkered so that all its plastic properties are destroyed.

This burned or clinkered material has been used to some extent on the roads near the coal mines. It is a rather soft material and is not suited to heavy traffic. It does not become muddy when wet, but is very dusty in dry weather. Even under light traffic it will probably have to be renewed every few years to keep the road in good condition.

It cannot be regarded as a good road material, but still is an improvement on an earth road and is very cheap. It is also available in regions where good material is scarce so that it will probably be used to considerable extent in the immediate vicinity of the coal mines.

ROCKS FOR MACADAM ROADS.

The following general classification[8] of rocks is the one adopted by the Office of Public Roads of the Department of Agriculture:

TABLE 6.

Class	*Type*	*Family.*
I. Igneous	1. Intrusive (Plutonic)	a. Granite
		b. Syenite
		c. Diorite
		d. Gabbro
		e. Peridotite
	2. Extrusive (Volcanic)	a. Rhyolite
		b. Trachyte
		c. Andesite
		d. Basalt and Diabase

8. Lord, Edwin C. E., Bull. No. 31, Dept. of Agriculture, Office of Public Roads, 1907.

II. Sedimentary	1. Calcareous	a. Limestone	
		b. Dolomite	
	2. Siliceous	a. Shale	
		b. Sandstone	
		c. Chert (Flint)	
III. Metamorphic	1. Foliated	a. Slate	
		b. Schist	
		c. Amphibolite	
	2. Nonfoliated	a. Slate	
		b. Quartzite	
		c. Eclogite	
		d. Marble	

THE IGNEOUS ROCKS.

The igneous rocks have been formed by cooling from a molten mass. The intrusive rocks are supposed to have cooled slowly at some distance below the surface, so that opportunity was given for the formation of large crystals. The distinction between the different families of the same type is based on mineralogical composition, granites and syenites containing essentially quartz, orthoclase, feldspar and hornblende, while diorite and gabbro contain, in order, less quartz, (gabbro may have no quartz) less orthoclase and more plagioclase feldspar, and more augite and hornblende. Peridotite contains no quartz or feldspar, its essential minerals being augite, magnetite, olivine, and hypersthene. The color changes through the series from the gray or pink of the granites and syenites to the black of the peridotite.

The extrusive or volcanic rocks are those which were poured out on the surface or pushed up into narrow dikes or thin sills so that the cooling was rapid and the crystals formed were very small. If the cooling was rapid enough a glassy structure without crystallization resulted as in obsidian. Any of the volcanic rocks may contain small percentages of this rock glass. The mineralogical composition varies from rhyolite to diabase in something the same way that the intrusive type does from granite to peridotite, rhyolite containing more of the acidic minerals and diabase more of the basic. The same change in color from light to dark is also noticed.

Porphyry. From the nature of the formation of the plutonic and volcanic types, it can be seen that they must grade into each other. The term porphyry is used to designate rocks in which the ground mass is

glassy or very finely crystalline while large crystals or phenocrysts of some of the minerals are developed.

Qualities of igneous rocks. Of the two types, the volcanic is usually the better for road materials. This is due to the smaller size of the crystals and the fact that the crystals are curiously interlocked with each other producing what is known as "ophitic" structure. Diabase and basalt usually have this structure well developed and on account of their wide distribution are much used as road materials.

Secondary minerals. Practically all of the minerals of igneous rocks may be altered and broken down by weathering. The resulting minerals are called secondary minerals. They are usually softer than the original, and have much less power of resisting wear. Consequently an igneous rock which has been exposed to the action of the weather is much softer, less tough, and less resistant than fresh rock. This exposed or "altered" rock, however, usually has a higher cementing value.

The principal secondary minerals with their composition and percentage by volume in which they occur in the average rocks used for road making is given in the following table[9]:

TABLE 7.

Name	*Chemical Composition*	*Volumetric Percentages.*
Chlorite	Hydrous silicate of magnesia, iron and alumina	3.5
Kaolin	Hydrous silicate of alumina	2.4
Epidote	Hydrous silicate of lime, iron and alumina	2.2
Calcite	Carbonate of lime	1.4
Limonite	Hydrated oxide of iron	0.9
Serpentine	Hydrous silicate of magnesia and alumina	0.3
Opal	Hydrated silica	0.2
Scolecite	Hydrous silicate of alumina and lime	0.1
Natrolite	Hydrous silicate of alumina and soda	0.1

In Oklahoma the igneous rocks occur in the Arbuckle and Wichita Mountains. The nature of these rocks and an account of their areas and exposures will be given in relation to the distribution of road materials.

SEDIMENTARY ROCKS.

Siliceous. Of these rocks, clay and shale are not fitted for macadam roads, and have been discussed in a previous section of this chapter.

9. Lord, Edwin C. E., Op. Cit. Page 21.

Chert or flint is impure quartz, the average analysis giving about 94 per cent. silica. The impurities are usually limonite, calcite and kaolin, with, occasionally, organic matter. These impurities usually give sufficient cementing value for the material to be used for macadam roads. Part of the cementing value of chert is probably due to its having been deposited by chemical precipitation in the form of colloidal silica, which resumes this form when ground under traffic, while wet. Chert is very hard, but only moderately tough. It has high resistance to wear, and breaks easily into angular fragments.

Calcareous. The calcareous sedimentary rocks are limestone, which is the carbonate of calcium, and dolomite, a mixture or compound of the carbonates of lime and magnesia. In physical properties they are very similar, but can be easily distinguished by their action with dilute hydrochloric or nitric acids. The limestone will effervesce actively in the cold acid while the dolomite is only slightly affected, but both effervesce actively in warm acid.

Either limestone or dolomite may occur in crystalline or amorphous (powdery) forms. Of these the crystalline form is the better road material unless the crystals are too large. The best limestones for roads are those in which the crystal forms are too small to be visible to the naked eye. These are called compact limestones.

Limestones are usually the result of the deposition of the remains of sea animals, whose shells were composed of calcium carbonate. Many limestones show these fossil shells very plainly, while in others the fossils have been destroyed. Some limestones, however, as well as some dolomites seem to have been formed by chemical precipitation.

Limestones and dolomites are usually white or buff in color, but sometimes grade through light to dark blue and black on account of various percentages of ferrous iron or organic matter. They are usually fairly hard and tough and possess medium resistance to wear. They show high cementing values, which are probably due to the fact that calcium and magnesium carbonates are slightly soluble in water. When the material is wet a portion of it dissolves and, as the water drys out, it recrystallizes and the crystals interlock.

Owing to their wide distribution and the ease with which they are quarried, and crushed, limestones will probably be the principal macadam road material of Oklahoma.

Gypsum. Although not given in the table, gypsum is a sedimentary rock which should be taken into consideration in this connection. It is the hydrated sulphate of calcium, $CaSO_4 . 2H_2O$. It is a very soft

substance, being easily scratched by the finger nail. It has very low toughness and wearing qualities. It shows very high in cementing value, due to its solubility in water and then recrystallizing on drying as was described under limestones and dolomites.

Several newspapers and magazine articles have recently appeared which speak of gypsum as a good road material, but in view of its qualities which have been enumerated, it cannot be regarded in this light. It grinds to pieces easily under traffic and gives large quantities of very disagreeable dust. It mashes down and "mushes" badly in very wet weather. It has been used as the base or foundation for roads surfaced with limestone or dolomite, but even in this way its use can be regarded only as a makeshift, which is made permissible by the lack of better material. It is possible that on residence streets in cities, where the traffic is very light, and where the street could be sprinkled every day that gypsum would be fairly satisfactory, but otherwise it cannot be recommended as a road material. Good results have been had by the use of gypsiferous clay in the building of sand-clay roads.

METAMORPHIC ROCKS.

These are rocks which have been derived from either igneous or sedimentary rocks by heat and pressure usually aided by moisture. The foliated types such as gneiss and schist have been subjected to such pressure as to result in a sort of parallel arrangement of the crystals. In the nonfoliated types the structure and mineralogical character is not changed. For example, clay may pass into shale and the shale into slate with no change except the hardening and some development of cleavage. Quartzite may be regarded as a very pure and extremely hard sandstone, and marble as an entirely crystallized limestone.

The gneisses, schists, and amphibolites are good road materials and are widely used in some states, but do not occur in Oklahoma. Slate is of very little or no value as it gradually grinds down into clay. Quartzite is very hard and resistant, but has practically no cementing value, so it has to be mixed with some cementing substance to form a road surface. Marble occurs in one locality in eastern Oklahoma. Its behavior on roads is that of any hard, crystalline limestone.

PROPERTIES OF ROAD MATERIALS.

In many localities the idea seems to be prevalent that almost any sort of material is good enough to use for road building. One often hears the expression, "That rock isn't good enough for building stone, but would be all right for roads." This may be true in a few instances,

i. e. where a rock material is firm and sound in its finer structure, but so broken by joints and bedding planes that sound pieces large enough for building material cannot be obtained. But as a general rule road materials are subjected to much severer usage than is ever required of a building stone and must be more resistant in their nature.

FORCES TENDING TO DESTROY ROADS.

In a consideration of the physical properties of road materials, it seems necessary to consider first the factors of wear and decay to which they are subjected in order to understand the properties which resist these factors.

The factors tending to destroy the roads may be divided into two classes, (1) wear and tear of travel, (2) natural or weathering forces.

Wear and tear of travel. Reid[10] divided the ways in which roads may be injured by travel as follows: "(1) by the blows of horses' feet; (2) by the blows of the wheels, for no road is so smooth that the wheels do not at time strike against, and at time fall from, slight projections and thus produce blows against the road; (3) by the action of the horses' feet in pulling or holding back, tending to pull the stones out of place; (4) by the friction of the wheels especially when brakes are used; and (5) by the pressure on the road due to the weight of vehicles and of the horses. It is evident that some of these causes (3, 4) tend to destroy the general cohesion of the road and to break up the pieces of stones themselves into smaller particles and to grind them into dust; the effect of pressure (5) is probably beneficial to a well made stone road, as it tends to consolidate it; but a soft road, or one with too thin a stone covering, is terribly cut up by the pressure of the wheels."

Wear due to natural causes. The natural or weathering factors which tend to destroy roads may be classified as follows:

(1) The chemical action of water and air tends to destroy the stones by altering them to softer materials. This factor is, however, of comparatively little importance.

(2) Sudden changes in temperature and freezing and thawing tend to disintegrate the stone and cause it to crumble. This action is not so great in Oklahoma as in the more nothern states.

(3) Rain water softens the road bed making it more likely to be cut through. If in sufficient quantity it may cause streams to flow down the road, washing deep ruts and gutters.

10. Reid, Maryland Geological Survey, Vol. III, p. 317, 1899.

(4) Winds blow the protective covering of dust from the road as fast as it is formed, which results in continual exposure of the wearing surface and consequent rapid wear, and also allows the water to penetrate more readily into the road surface.

The resistance which a road offers to some elements of destruction, depends almost entirely upon the nature of the surface material while to others it depends more upon the construction, drainage, etc., of the road, but usually both factors are related.

PHYSICAL PROPERTIES OF ROAD MATERIALS.

The properties which affect the value of a stone as a road material are per cent. of wear, hardness, toughness, cementing value, and specific gravity. As the tests for this report were made by the Office of Public Roads of the Department of Agriculture the following discussion of these qualities and descriptions of the tests is condensed from their reports[11]:

The per cent. of wear represents the amount of material under 0.16 cm. in diameter lost by abrasion from a weighed quantity of rock fragments of definite size. It is determined in the following manner: The rock sample is broken into pieces that will pass through a 2.4 inch ring but not through a 1.2 inch ring, and after being thoroughly cleansed, dried and cooled, 5 kg. are[12] weighed and placed in a cast-iron cylinder (34 cm. deep by 20 cm. in diam.) closed at one end and having a tight fitting iron cover at the other. This cylinder is one of four attached to a shaft so that the axis of each is inclined at an angle of 30° with that of the shaft. These cylinders are revolved for five hours at the rate of 2,000 revolutions per hour, during which the stone fragments are thrown from one end of the cylinder to the other twice in each revolution. At the end of the fifth hour the machine is stopped, the cylinders opened, and their contents placed on a sieve of 0.16 cm. mesh and the material which passes through is again sifted through a sieve of 0.025 cm. mesh. Both sieves and the fragments of rock remaining on them are held under running water until all adhering dust is washed off. After the fragments have been dried in a hot air bath at 100°C. and cooled in a desiccator they are weighed and their

11. U. S. Dept. Agr., Office of Pub. Roads, Bull. No. 31, pp. 23-24. This is condensed from a more detailed discussion in U. S. Dept. Agr., Bureau of Chemistry, Bull. No. 79.

12. For the convenience of those not accustomed to the metric system the following approximate equivalents are given; 1 meter (m.) equals 1 yard 3 inches; 1 gram (gr.) equals 1-32 ounce; 1 centimeter (cm.) equals .4 inch; 1 kilogram (kg.) equals 3.2 pounds.

weight subtracted from the original 5 kg. The difference is the weight of detritus under 0.16 cm. worn off in the test. By dividing this weight by the original weight of 5 kg. the *per cent of wear* reported is obtained.

Hardness is the resistance which a material offers to the displacement of its particles by friction and varies inversely as the loss in weight by grinding with a standard abrasive agent. The test is made in the following manner: The test piece in the form of a cylinder about 3 inches in length by 1 inch in diameter is prepared by an annular core drill and placed in the grinding machine in such a manner that the base of the cylinder rests on the upper surface of a circular grinding disc of cast iron, which is rotated in a horizontal plane by a crank movement. The specimen is weighted so as to exert a pressure of 250 grams per square centimeter against the disk which is fed from a funnel with sand of about 1½ mm. in diameter. After 1,000 revolutions the loss in weight is determined and the coefficient of wear obtained by deducting one-third of this loss from 20.

Toughness, as here understood, is the power possessed by a material to resist fracture by impact. The test piece is a cylindrical rock core similar to that used in determining hardness, and the test is made with an impact machine constructed on the principle of a pile driver. The blow is delivered by a hammer weighing 2 kg. (4.4 lbs.) which is raised by a sprocket chain and released automatically by a concentric electro-magnet. The test consists of a 1 cm. (.4 in.) fall of the hammer for the first blow and an increased fall of 1 cm. for each succeeding blow until failure of the test piece occurs. The number of blows required to cause this failure represents the toughness.

The cementing value, or binding power of a road material, is the property possessed by a rock dust to act as a cement on the coarser fragments comprising crushed stone or gravel roads. This property is a very important one and is determined as follows: One kg. (2.2 lbs.) of the rock to be tested is broken sufficiently small to pass through a 6 mm. but not a 1 mm. screen. It is then moistened with a sufficient amount of water and placed in an iron ball mill containing two chilled iron balls weighing 25 lbs. each and revolved at the rate of 2,000 revolutions per hour for two and a half hours, or until all the material has been reduced to a thick dough, the particles of which are not above 0.25 mm. in diameter. About 25 grams of this dough is then placed in a cylindrical metal die, 25 mm. in diameter and by means of a specially designed hydraulic press, known as a briquette machine, is subjected to a momentary pressure of 100 kg. per square centimeter. Five

of the resulting briquettes, measuring exactly 25 mm. in height are taken out and allowed to dry 12 hours in air and 12 hours in a hot oven at 100°C. After cooling in a desiccator they are tested by impact in a machine especially constructed for the purpose. This machine is somewhat similar to that used in determining the hardness, and the blow is about the same, excepting that it is given by a 1 kg. hammer and the distance of drop does not exceed 10 cm.

The standard fall of the hammer is 1 cm. and the average number of blows required to destroy the bond of cementation in the five briquettes determines the cementing value.

The specific gravity is the weight of the material compared with that of an equal volume of water, and is obtained by dividing the weight in air of a rock fragment by the difference of its weight in air and water. Given the specific gravity the weight per cubic foot of the rock is obtained by multiplying this value by 62.5 pounds, the weight of a cubic foot of water.

THE MINERALOGICAL COMPOSITION.

Besides the examination of physical properties, the mineralogical composition of the rocks is determined. The rocks consisting essentially of the carbonates of lime and magnesia, (limestones and dolomites) as well as fine-grained shales and unconsolidated materials such as sands and gravels are subjected to chemical analysis where necessary, while the igneous rocks are examined microscopically or megascopically (by the eye aided only by a hand lens).

The megascopic form of analysis is used where the rock is sufficiently coarse grained to allow the different mineral constituents to be made out with the unaided eye. The approximate amounts of the minerals present can be determined by obtaining a smooth face on the rock and laying over it a transparent celluloid scale divided into 100 equal squares. The number of squares of this scale covered by a mineral represents approximately the volume percentage in which it occurs in the rock.

The microscopic examination is made with a polarizing microscope by means of which the different minerals may be determined. The method of determining the volumetric percentages of the minerals is similar to the one described above except that the cross line field is supplied by a special eyepiece designed by Mr. L. W. Page, director of the Office of Public Roads.

The chemical composition of the rock may be closely approximated

by the following method: first obtain the relative masses of the minerals present by multiplying the percentages found, by the specific gravities of the minerals and reducing the whole to 100, and then multiplying the products obtained by the percentages of the chemical components, reckoned as oxides, belonging to each of the minerals. This simple rule applies only when the minerals present have a definite composition. With minerals having a variable composition the matter is more complicated and need not be gone into here.

The results of the mineralogical analysis are reported in the following manner: on a blank form especially prepared for the purpose, the geologic character, name and location of the rock are indicated and the minerals classed according to the microscopic determination, as essential [13], accessory, and secondary and their general composition and volumetric percentages given. Finally the color, texture, and other properties likely to be of value to road engineers are noted.

Relation of mineralogical composition and structure to physical properties.

Lonegrove[14] performed experiments which showed that the loss by attrition or per cent. of wear is dependent to large extent upon the mineral composition, texture and freshness of the minerals. He found that in general the hardest and toughest stones are those combining an abundance of quartz, (hardness 7) with a dense fine-grained texture. The value of the interlocking or ophitic structure has already been mentioned. Porosity induced by the fracture of the rock in place, insufficient cementing power, and the presence of secondary minerals in appreciable quantities condemn the material.

The effect of structure upon the hardness, and toughness is shown by the tests of the intrusive rocks as granite, syenite and gabbro as compared with their extrusive equivalents, rhyolite, andesite and basalt. The former are coarser grained and more fully crystalline than the latter and as a rule show greater hardness but less toughness. The altered varieties of all of these rocks show less hardness and toughness, and higher per cent. of wear and cementing value than the fresh rocks, due to the formation of soft semi-crystalline minerals such as chlorite and kaolin.

In the sedimentary rocks, the limestones and dolomites, composed

13. Minerals are classed as essential when their presence is necessary to the classification of the rock, as accessory when they may or may not occur in the rock without altering its classification, and as secondary when they are derived by weathering or other changes from original constituents.

14. Surveyor, 1905, 28, Nos. 721-729.

largely of calcite, are inferior in hardness, toughness and wearing qualities to the sandstones and cherts which are composed principally of silica, but show higher cementing value than the siliceous rocks.

The non-foliated metamorphic rocks are more durable road material than the foliated varieties. The foliation of the latter permits of fracture along the planes of foliation resulting in flat or wedge shaped fragments instead of angular fragments of equal dimensions. Chlorite or mica schists show very high per cent. of wear on account of softness of the materials and also on account of the foliated structure.

CHAPTER III.

CONSTRUCTION AND MAINTENANCE OF EARTH, SAND AND CLAY ROADS

In this chapter the methods of road location, construction and maintenance with reference to natural roadways are considered. Since for many years the majority of the roads of Oklahoma will be earth roads, and since the building of any other type of road requires the construction of an earth road as a foundation, these matters receive rather full consideration.

LOCATION.

The state law of Oklahoma declares the section lines roadways, and in so doing, locates the major portion of the roads. However, provision is made in Sec. 4 (See page 86) for the location of roadways along the most practicable lines where there is a public necessity therefor, and in these cases it may be well to consider what is meant by the most practicable lines.

In the level portions of the state the section lines probably represent the most practicable routes for almost all of the roads. Roads laid out in this way may not give the shortest distance between objective points, but on the other hand the advantages of through, straight roads in the cardinal directions, and the division of the farming land into rectangular blocks instead of other shapes overcomes the disadvantage of not being able to cross the country at an angle to the principal directions.

In the more hilly regions the section lines do not often represent the most practicable routes, and in locating roads in these portions, the following points should be taken into consideration:

1. Distance.
2. Grade.
3. Expense of construction.
4. Purpose of road (i. e. for light or heavy traffic).
5. Convenience and comfort.

Distance. The grade remaining equal, the shortest line between objective points is the most practicable roadway. Unnecessary length causes extra cost for construction, extra cost of maintenance, and loss of time and labor traveling over it. However, the problem of grades bears an important relation to distance and must always be taken into consideration. The increase of distance caused by a curved or bent road is often overestimated.

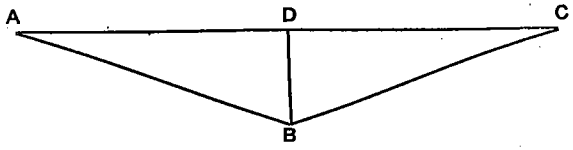

Fig. 2. Relative Length of Straight and Curved Roads.

"In figure 2[15] if A B equals B C equals 1 mile and B D equals 300 feet, the line A B C is only 17 feet longer than A D C. Very often a road is built over a steep hill instead of going around it because it is supposed to be much shorter. In many cases the curvature over the hill is as great as that around the hill and the road is just as long with the disadvantage of steep grades."

Grades. In the consideration of grades two factors must be taken into consideration, (1) *the rise and fall* or total vertical height through which a load must be lifted in passing over the road in one direction, and (2) *the steepness or per cent. of grade.* The rise and fall increases the cost of transportation and also of road maintenance. Steep grades do both of these and also limit the size of the loads which may be hauled over the road.

Expense of construction. The expense of construction per unit length will depend upon the several factors. The grades; the curves; cuts and fills; the nature of the soil as affecting drainage, removal from cuts, etc.; the price of land through which the road passes; and many other local conditions will have a pronounced effect on the total expense.

Purpose of road. The road for light traffic may take steeper grades and need not be so straight as a road for heavy traffic. The beauty of a road should always be considered, but is more important for roads intended for light traffic or for driving.

Conclusion. Other things being equal the road should, of course, be located to give the best possible service to the greatest number of people. From what has been said it may be seen that many factors enter into the location of a road. All of these factors vary in each locality and make the location of each road a problem in itself. In general, it may be said, that the location of a road, especially of an improved road upon which much expense is to be put, should be left to a *competent* civil engineer. The probable saving of distance or grade or both, and the added convenience and beauty of the road is worth many times the initial expense of the services of such a survey.

15. Baker, I.O., Roads and Pavements, p. 46.

DRAINAGE.

The matter of drainage is the most important point to be considered in the building of earth roads, as no road can be good without it. The difference between a good and bad earth road is usually a difference in drainage. Water attacks a road in two ways, (1) by softening the loam or clay, and (2) by its mechanical action in washing gutters. When the loam or clay becomes wet it is kneaded under the horses' feet and under the wheels to a soft dough-like mass. Each succeeding horse and vehicle works a little deeper into the road bed until the result is a mass of soft mud which may be deep enough to render the road impassable. When this mass freeezs, the surface is extremely rough and is almost as bad as the mud. The effect of running water is to carry away the soil, leaving deep trenches and gutters. These may become so bad as to cause the road to be abandoned. In some places in Oklahoma, the writer has seen as many as four or five tracks successively abandoned on account of the gutters. While the country is new and thinly settled, this procedure of driving around a bad piece of road is possible, but as land values increase and the population becomes thicker, some steps must be taken toward making one roadway which shall be permanent.

UNDER-DRAINAGE.

The object of under-drainage is both to remove the surface water and to lower the water level in the soil. Of the two the latter is more important, as the wind and sun will rapidly dry the surface if the subsoil be well drained. This lowering of the water level makes the subsoil dry and firm, so that it will support the weight of traffic; it causes the road to dry quickly after a freeze as the water released by thawing is immediately carried away. It also prevents the "heaving" of the road in freezing, as this is due to the expansion of the water in the pores of the soil. The freezing of a road is harmless when it is perfectly dry.

Tile drainage. Formerly various materials were used to construct the drains, but since the use of ordinary farm drain tile has become common, other materials have fallen largely into disuse. The best

practice for draining roads is to lay a line of this tile three or four feet deep on one or both sides of the road. The tile should be of uniform diameter, perfectly straight, smooth inside and with square cut ends.

The *diameter* of the tile required will vary with the amount of water to be carried, but it has not been found practicable to use tile of less than four or five inches in diameter. The *fall* or *slope* is an important item. Usually two and one-half or three inches per 100 feet is considered to be the least fall which will insure good tile drainage, but drains have given good results where the fall is not greater than one inch per 100 feet. There is no danger of the fall being too great. If the fall is very slight, tile of larger diameter must be used than where the fall is greater. The *depth* to which the tile should be laid, depends to some extent upon the conditions. Other things being equal, the deeper the tile, the better the drainage. Three to four feet has been found to be satisfactory in almost all cases. The tile must be laid on a true grade as a sag will cause deposition of mud and silt. If a drain sags by an amount equal to the diameter of the tile, the drain is almost certain to become closed. The lower end of the tile should be protected by masonry or by a box. A good practice is to have the last few lengths of tile of vitrified sewer pipe instead of the porous tile. The upper end should be securely closed or protected by an inflow box, provided with screens to keep out foreign material that might clog the drain. If the line of tile is very long silt boxes (fig. 4A) should be installed to lessen the danger of the tile becoming stopped. These should be cleaned out every season.

One or two lines of tiles. In most cases one line of tile 3 feet deep at one side of the road will give sufficient drainage under almost all conditions. However, in some cases as where there is an impervious layer of clay at a slight depth beneath the surface, the tile must be laid near the surface and two lines are necessary.

The following figure[16] shows the relation of the curves of saturation (water level) with one and with two lines of tile.

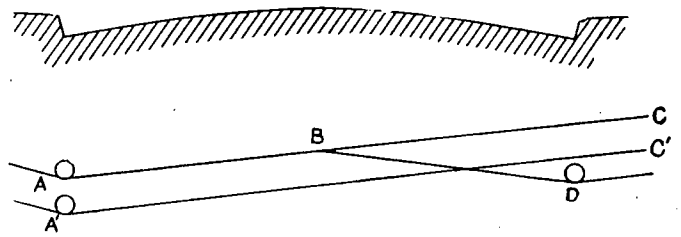

Fig. 3. Water level with one and with two lines of tile.

"If A represents the first line of tile, the surface of the ground water is represented by the lines A B C. If a second line of tile, D, is laid, the water surface will be A B D, and the second line will drain only a comparatively small portion, C B D. The diagram shows that a single line well below the surface is far better than two shallow ones. For example, lowering the tile A, 6 inches, lowers the water surface to A^1 C^1, which represents better drainage than the line A B D with two lines of tile."

Location of tile. The single line of tile may be placed along one side or in the center of the road. The latter location is often recommended, but it has several disadvantages. It does not bring the water level appreciably lower; the dirt in the trench tends to settle forming a depression and mud holes; if the tile should become clogged its removal injures the road and interferes with traffic. If one side of a road is higher than the other the line of tile should be placed on the higher side to intercept the ground water flowing down the slope below the surface.

Cost of tiling: The following table[17] shows the approximate cost, weight and number in carloads of the various sizes of drain tile:

TABLE 8.

Inside-diameter	Price per 1000 f. o. b. factory.	Weight per ft.	No. of feet in carload.
3 inches	$ 10.00	5 lb.	7000
4 inches	15.00	7 lb.	6500
5 inches	20.00	9 lb.	5000
6 inches	27.00	12 lb.	4000
7 inches	35.00	14 lb.	3000
8 inches	45.00	18 lb.	2500
9 inches	55.00	21 lb.	1800
10 inches	65.00	25 lb.	1600
12 inches	90.00	33 lb.	1000
14 inches	120.00	43 lb.	800
16 inches	150.00	50 lb.	600
18 inches	240.00	70 lb.	400
20 inches	300.00	83 lb.	330
24 inches	360.00	112 lb.	300

The average cost of laying 5-inch tile in ordinary loam with clay

16. Baker, I. O., Op. Cit., page 79.
17. Baker, I. O., Op. Cit., p. 75.

subsoil is 10 cents per rod for each foot of depth, with an increase of one cent for each additional inch of diameter.

The cost of laying one mile of 5-inch drain tile, 3 feet deep would be as follows:

Price of tile at factory.

5280 feet at $20.00 per 1000 feet	$105.60
Digging trench 3 feet deep and 320 rods long and laying tile, etc., 3x320x10 cents	96.00
	$201.60

To this must be added the freight on one carload of tile from factory to delivery point and the expense of hauling from delivery point to roadside. These charges, of course, will depend entirely on the location of the road.

Substitutes for drain tile. The clay industries of Oklahom are as yet in their infancy and in some parts of the state the distance, which drain tile must be shipped, will almost prohibit their use. This condition can certainly not last many years, but in the meantime it may be well to notice what may be used as a substitute for the tile.

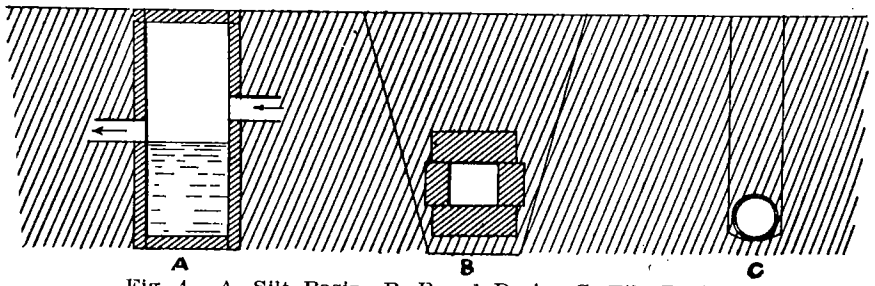

Fig. 4. A. Silt Basin—B. Board Drain—C. Tile Drain.

Board drains may be constructed of heavy plank built into a rectangular box (Fig. 4, B) the size depending on the amount of water to be carried. Brick or flat stones may be used in similar fashion, i. e. the brick or stone laid lengthwise across the bottom of the ditch, then other bricks or stone laid on edge across the ends of the bricks on the bottom, and finally a course laid on top of these parallel to the first or bottom row. The ditch may be partially filled with poles or with large stone. None of these are nearly as satisfactory as tile drains and are seldom as cheap in the long run. They are not to be recommended where tile can be procured at anything approaching a reasonable price.

SURFACE DRAINAGE.

The surface drainage of the road is a distinct problem from the under drainage which has been discussed. The water which falls on the surface of the road can reach the tile drains only by soaking down through the soil and thus softening it, so some arrangement must be made to allow this to run off rapidly. This is accomplished by giving an arch or crown to the road and by constructing side ditches.

The crown. The slope of the crown of a road should be merely sufficient to carry the water quickly to the side ditches. The crown is usually built with scrapers or the scraping grader, the dirt removed from the side ditches being used to build the crown.

The crown may easily be made too high. If the slope is too steep the water may run from it fast enough to wash badly and carry considerable quantities of the road bed into the side ditches. The steep crown also tends to throw all of the traffic to the center of the road and this wears the road hollow on top, permitting the water to stand on it. When the crown is very steep the top of the wheels of vehicles are farther from the center of the road than the bottom, and mud picked up by the wheels will be carried to the top of the revolution and dropped farther from the center than it was. Each vehicle then acts as a sort of plow moving the earth from the center to the side of the road.

The crown should be steeper on steep grades than on level portions of the road since on these grades the shortest line from the center of the road to the side ditch is not at right angles to the length of the road, and the water tends to travel obliquely down the road. When water begins to run down the road on a steep grade it soon washes deep gutters and ruins the road. Catch waters or water breaks are often built on steep grades to stop the longitudinal flow of the water and the consequent washing effects. These catch-waters are shallow trenches or low ridges built at an angle across the road so as to deflect the water to one of the side ditches. The water can be deflected to both side ditches if the catch water is built in the shape of an obtuse angle with the apex in the center of the road and pointing up hill. There is little to choose between the ridge or trench form except that the latter may be paved with cobble stones. Neither the trenches nor the ridge form need to be steep enough to interfere greatly with traffic. Catch-water trenches should also be constructed in depressions; these should be built directly across the road to carry the water that collects in the depres-

sion to the side ditches. The bottom of the trench should be paved with cobble stones or gravel.

Side ditches. Side ditches are made to carry away the water from the crown of the road and to intercept that which may flow in from side hills. They need not necessarily be very deep and should have a gentle slope toward the crown so as to prevent accidents when vehicles are forcd near the edge of the embankment. The bank on the outer side should not be steep enough to make them likely to cave. This sort of side ditch may be easily made with the scraping grader and is much better than a deep ditch with steep sides, as the latter is apt to cave in. Side ditches on very steep slopes may require to be paved with cobble stones or gravel to prevent washing.

BRIDGES AND CULVERTS.

The matter of bridges and culverts is too technical to be considered fully in a report of this nature. Large bridges should be and usually are, constructed only under the direction of a competent engineer. Culverts and small bridges on the other hand are usually built by township or road district authorities and should receive some notice in this connection.

SIZE OF CULVERTS.

The opening of a culvert should be of sufficient size to carry the run-off from the catchment basin during the heaviest rainfall. The calculation of the proper area of the cross section of the culvert is too complicated to consider in this connection. Too small culverts are liable to cause washouts, while those larger than necessary to carry the run-off entail needless expense of construction. In case of doubt it is better to err on the side of too large rather than too small culverts as the extra expense of construction is small compared to the possible expense and discomforts of washouts.

MATERIALS AND METHODS OF CONSTRUCTION.

The principal materials which have been used for culverts are as follows: wood, stone, vitrified sewer-pipe, cement pipe, cast iron pipe, corrugated steel pipe, and concrete.

Wooden planks are often used for culverts since the first cost is small and the culverts are easily constructed. However, they are very short-lived, lasting on an average less than 5 years, and it is hard to protect the ends of the culverts so that the water will not channel under them or along their sides. Their use is to be considered permissible

only where wood is very plentiful and where other material is hard to obtain.

Stone, when it occurs at hand and is of a resistant nature makes a good culvert, but the expense of getting the stone out in blocks of convenient size and shape is often prohibitive.

Vitrified sewer pipe and cement pipe are excellent materials for the construction of small culverts, but the initial cost is high, and they are liable to breakage in handling and installing. Culverts of either material should have the ends protected by brick or concrete masonry since otherwise the wheels of vehicles are almost certain to slip down on the ends of the pipes and crush them.

Cast iron pipe is sometimes used for very small culverts where other material is hard to obtain. There is probably no reason for its use in Oklahoma.

Corrugated steel pipe is being used very largely for culverts in Oklahoma at present, but not always with satisfaction. The initial cost is moderate and the pipes are light and easily handled. On the other hand they are usually very short-lived and they cannot be considered economical in the long run.

The principal objection to the usual manner of installing any form of pipe culverts is that they are not buried deep enough. The top of the culvert is often above the level of the roadway and is covered by making a "bump" in the road. This is rapidly worn down by traffic and by the washing of water so that the wheels of vehicles break through the culvert. Instances of this kind are common in almost all parts of Oklahoma. The laying of the culvert to the proper depth often makes necessary the deepening of the side ditches, especially on the outlet side, but this can always be done with less expense and trouble than that caused by allowing the culvert to be damaged by laying it at an insufficient depth.

Concrete is coming rapidly to the front as a material for culverts and in regions where gravel or crushed stone can be obtained without too great difficulty, bids fair to replace other materials. Its advantages are low initial cost, ease of handling and practical indestructibility when properly mixed.

The principal objection to the use of concrete in the past has been the difficulty of preparing circular or semi-circular wooden forms for small culverts. This seems to have been overcome by the introduction of collapsible steel forms. Some of these are constructed that they may

be adjusted for any size culvert from 20 inches to 4 feet in diameter. Wing and end walls should always be built with these culverts and for these wooden forms are required. However, the same lumber can be used for several forms so that the added expense is not excessive. These forms have been used extensively in Kansas and Nebraska and are reported to give excellent satisfaction. One type of these collapsible forms is shown in fig. 5, and the same form collapsed for removal from a completed culvert in fig. 6.

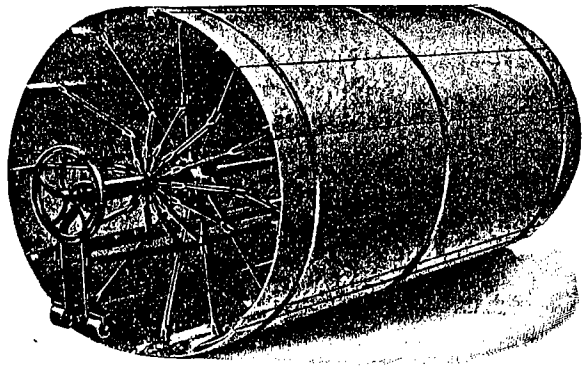

Fig. 5. Adjustable Core for Concrete Culverts.

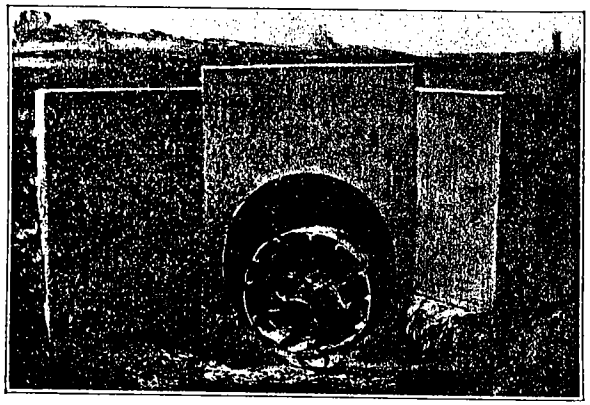

Fig. 6. Core Collapsed for Removal from Completed Culvert.

For bridges up to 50 or 60 foot span built-up forms are manufactured. These have been used on Grand Boulevard at Oklahoma City and are reported by R. E. Brownell, the Park Board Engineer, to have given excellent results. The forms in use on one of these bridges are shown in fig. 7, and the completed bridge in fig. 8.

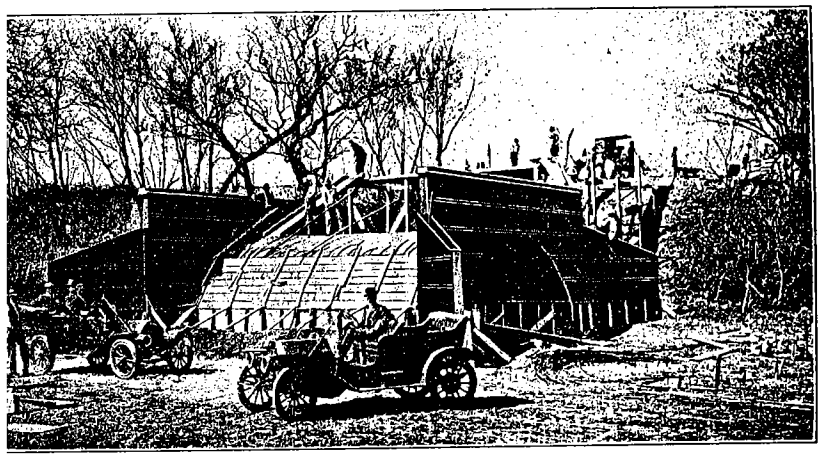

Fig. 7. Steel Forms for Concrete Bridge at Oklahoma City.

Fig. 8. Completed Concrete Bridge at Oklahoma City

For work where any considerable quantity of concrete is required, a mechanical mixer is a necessity. These are made in many designs and sizes so that any township or road district can secure one suitable for their needs. A large size mixer to be driven by steam power is shown in fig. 9. The smallest sizes are driven by a crank operated by hand.

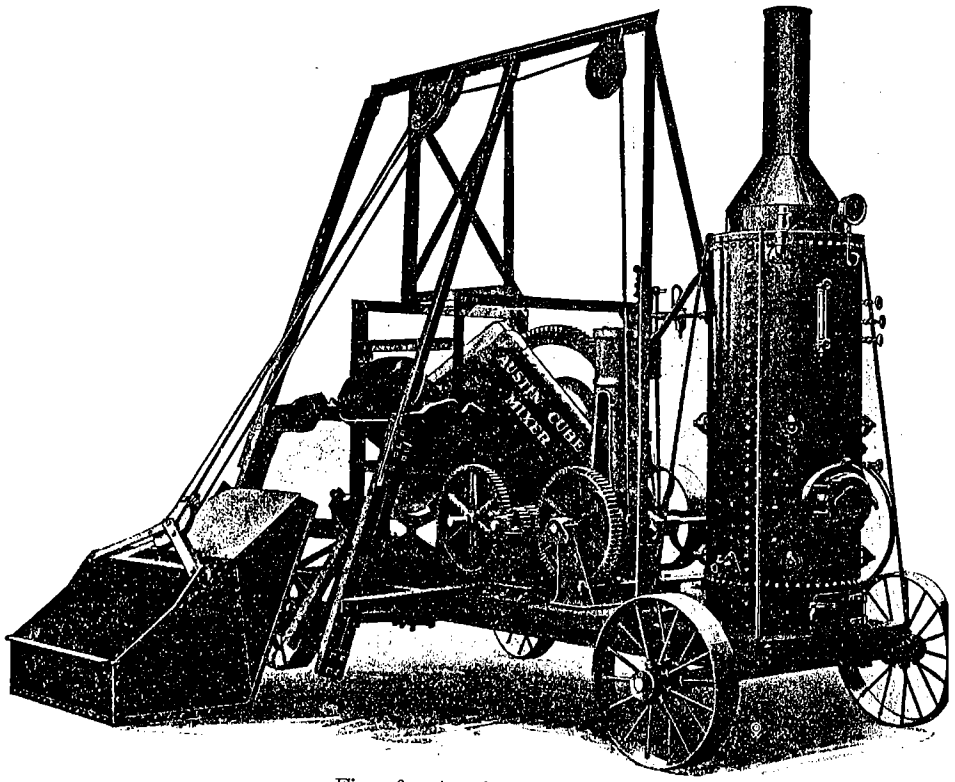

Fig. 9. Austin Cube Mixer.

CONCLUSION.

The item of culverts and small bridges is, at the present stage of development, one of the most important in the construction of good roads in this state. We cannot hope to have good roadways until the matter of the major drainage is attended to. Only a small advance can be made as long as merely temporary culverts and small bridges are installed as the expense of maintenance prevents the undertaking of other improvements. In many sections of the State little consideration is given to the selection of materials or proper installation of culverts. In the vicinity of the Arbuckle and Wichita mountains the writer has seen many corrugated steel culverts installed at considerable expense which in less than a year were broken through by wagon wheels. In many instances, good concrete gravel could have been obtained at hand and the initial expense of a permanent concrete culvert would have been less than for the pipe. These are extreme cases, but there are few neighborhoods where a thorough consideration of the materials to be

used and the best method of installation would not result in the saving of large sums and would make possible the turning of a greater share of attention to grading and other improvements.

CUTS AND FILLS.

The cuts and fills on a roadway should be as nearly balanced as possible in order that the dirt removed from the cuts may make the fills. The angle of the slopes of the sides of cuts and fills will depend upon the nature of the soil and is too complicated a matter to consider in detail here. Any good text on highway or railway engineering will give this information together with rules for allowing for the expansion or contraction of embankments, and other important details.

ROAD BUILDING MACHINERY.

The principal machines used in road construction are as follows: scrapers, scraping graders or road machines and elevating graders.

SCRAPERS.

The scrapers are of four kinds: the drag scoop, the tongue scraper, buck scraper and wheeled scraper. These are shown in the accompanying cuts.

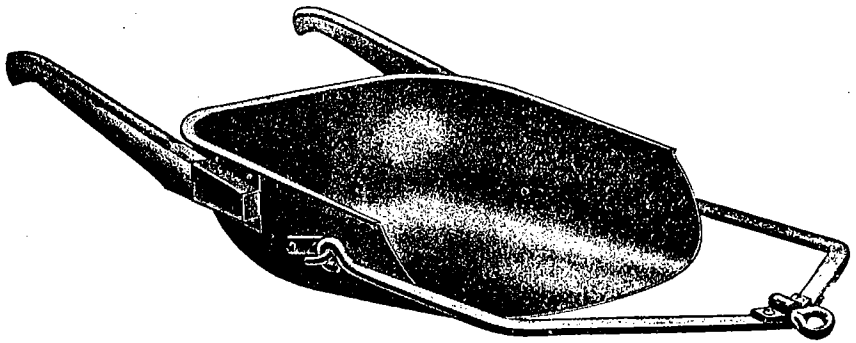

Fig. 10. Drag Scoop Scraper.

The drag scrapers or drag scoops (fig. 10) are simple in construction and easy to operate. They are economical for short hauls, but should not be used where the dirt is to be moved to any considerable distance. They are often used in making the crown of roads or in finishing the surface fills. Their use in this connection is questionable as they leave the surface a succession of humps and hollows, very trying to drive over when dry and very apt to form mud holes when wet. Drag scrapers are made in three sizes, 3, 5, and 7 cubic feet in capacity.

The prices average about $6.00, $6.50, and $7.00 for the respective sizes at the factory. The addition of runners adds about 50 cents to the price, and the double bottom about $1.00. The drag scoops cannot be depended upon to handle their full capacity as their shape makes them difficult to fill completely, and considerable dirt will lose from the front especially on down grade hauls.

The tongue scraper is used for leveling the road surface, in excavations and in constructing the subgrade for pavements. It is made in two sizes, 36 and 48 inches wide, which cost about $6.00 and $7.00 respectively at the factory.

The buck or Fresno scraper (fig. 11) has the following advantages over the drag scoop[17]: (1) The proportions of the buck scraper are such that it is more readily loaded to its full capacity. (2) It distributes the earth on the bank better, as it can be adjusted to deliver in layers from 1 to 12 inches thick. (3) The runners make it more durable. (4) It is more easily loaded. (5) It will follow up a steep bank without dumping and hence run ways are not required.

Buck scrapers are made in three sizes, the cutting edges being 3½ feet, 4 feet and 5 feet; and their respective capacity is 8, 10, and 12 cubic feet. The cost is usually about $17.00, $18.00 and $19.00 respectively.

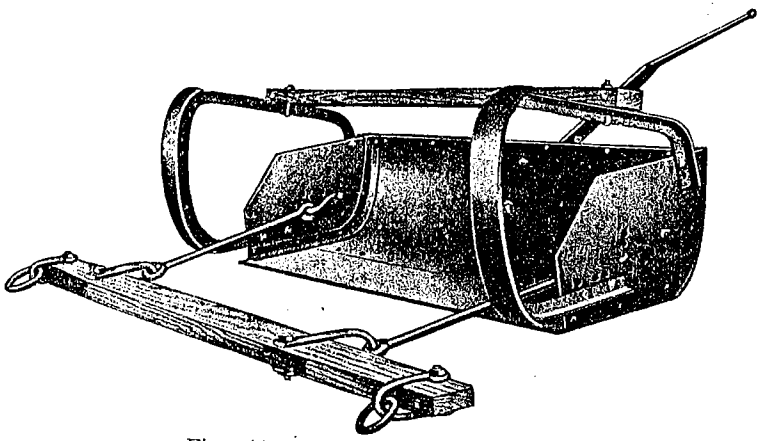

Fig. 11. Buck or Fresno Scraper.

The wheeled scraper (figs. 13 and 14) consists of a steel box mounted on wheels and provided with levers for raising, lowering and dumping. All the movements may be made without stopping the team. The

17. Baker, I. O., Op. Cit., page 98.

wheeled scrapers are made in three sizes, 9, 12, and 16 cubic feet, of which the price is about $25.00, $30.00 and $40.00 respectively.

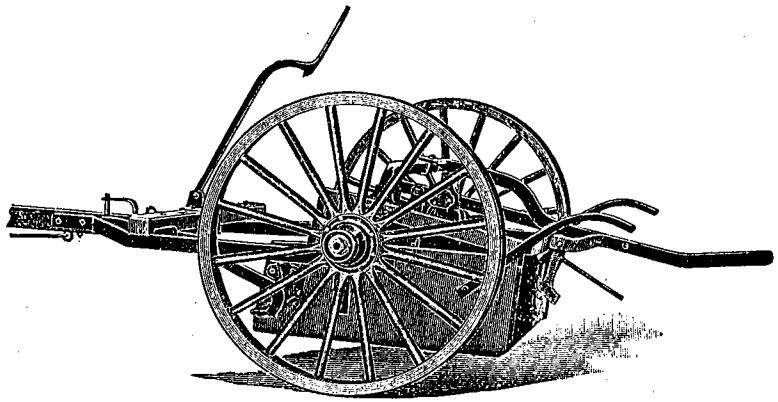

Fig. 12. Wheeled Scraper, carrying.

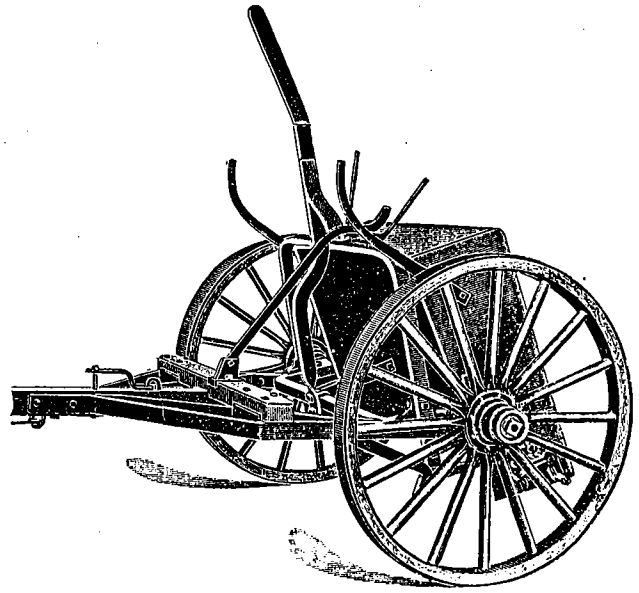

Fig. 13. Wheeled Scraper, dumped.

THE SCRAPING GRADER OR ROAD MACHINE.

The machine known by various names, as scraping grader, road scraper, road grader or road machine, (fig. 14) is the most important of the various tools used in road construction or maintenance. It consists

of an adjustable scraper blade suspended from a frame which is carried on four wheels. The blade can be adjusted at any height or at any angle with the direction of draft, and can be tilted forward or backward. The front end of the blade is used to plow a furrow, while the rear end pushes the dirt to the center of the road or distributes it uniformly over the surface.

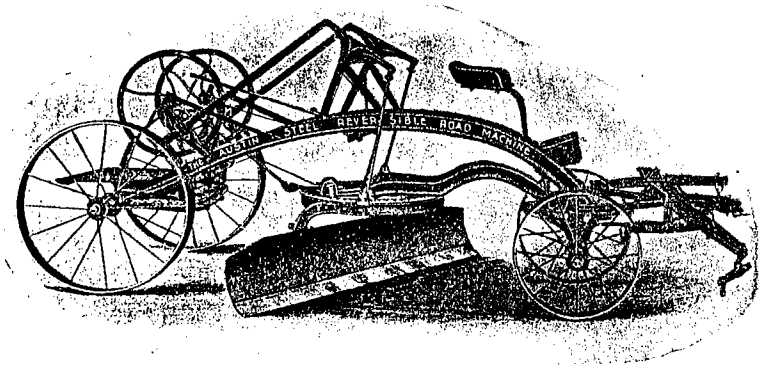

Fig. 14. Scraping Grader or Road Machine.

The rear axle is arranged so that the machine may be thrown to one side or the other to compensate for the side thrust due to the resistance of the earth to being pushed sidewise. In some forms either rear wheel can be shifted independently. In other machines the same result is secured by having the wheels set at an inclination which can be adjusted by a hand wheel.

Use of the scraping grader. In building a road with the scraping grader, on the first round a light furrow should be plowed where the outside of the ditch is to be. To do this, especially in hard or stony ground requires that the blade be set at an angle and that the rear end be considerably elevated.

On the second round the rear end of the blade is somewhat lowered and the furrow is broadened and deepened. On the third round (fig. 15) the dirt previously plowed loose is moved toward the center of the road. The rear end of the blade is left somewhat elevated in order to distribute the dirt over the surface instead of heaping it up in a ridge at the center of the road. This process is repeated until the ditches are of the desired depth and the road has the required crown. A ridge should never be left in the center of the road as it forces the traffic to the sides of the road and this soon destroys the symmetry of the crown. The proper handling of the grader will usually prevent

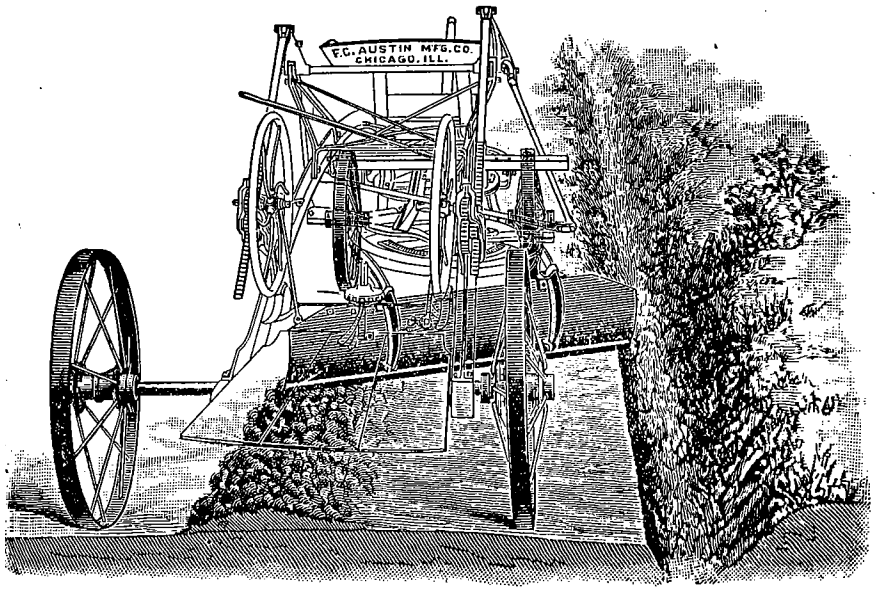

Fig. 15. Scraping Grader Making First Round.

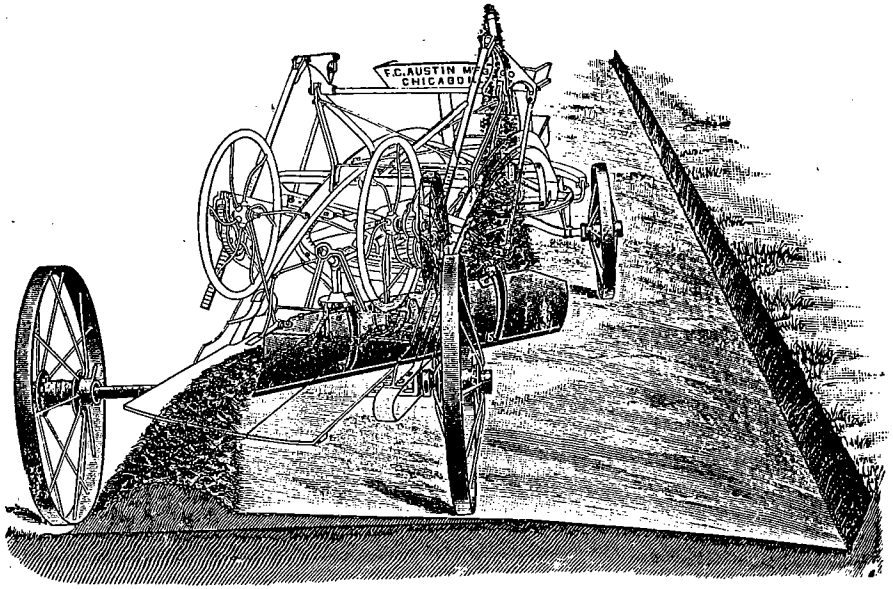

Fig. 16. Scraping Grader Making Third Round.

the formation of ridge, but if the road is very rough there may be a ridge in some places. If the ridge is formed it can be removed by setting the blade of the grader level, and square across the road, and low enough to catch the top of the ridge. With most machines the blade can be entirely reversed and the center ridge smoothed down by using the back of the blade.

Grass, weeds and brush should be removed from the ground before grading by mowing and by burning. Not more than 4 to 6 inches of fresh earth should be placed on a road at one time as that is all that can be thoroughly compacted by traffic. If it is necessary to move a greater thickness of earth, the road should lie until the first coat is thoroughly compacted and then be gone over with the grader again, or each layer may be compacted by a heavy roller.

Cost of earth roads built with scraping graders. In general it may be said that the scraping grader is usually the most economical and by far the most satisfactory means of constructing earth roads. It is better adapted for use in a level or rolling country than in a hilly one, but even in hilly districts there are always long stretches of road which can be built entirely with this grader. The different uses to which the grader may be put are illustrated in the accompanying cuts.

The average cost of the scraping grader is $225.00 to $250.00 at the factory. The cost per mile of ordinary prairie road, with a width of 30 to 35 feet between the ditches and with a 6-inch crown should be about $30.00 to $40.00, counting team and driver at $3.50 per day and operator at $1.50 per day. This estimate does not include the wear and tear of the machine or interest on the money invested in the machine. Two or three teams are required according to their strength and to the nature of the ground to be worked. Traction engines are sometimes employed and usually give cheaper and more satisfactory power than horses.

THE ELEVATING GRADER.

The elevating grader (fig. 17) consists of a frame resting upon four wheels, from which is suspended a plow and a frame carrying a wide traveling belt. The plow throws the dirt on to this belt which elevates it and drops it on the embankment or into wagons.

The machine is made in two sizes. Eight horses are required to draw the smaller which will place 1,000 cubic yards of earth on an embankment or 600 cubic yards in wagons per day of 10 hours.

This is a very effective machine and is of great value in road building. However, the price ($1200 for the smaller machine at the factory)

will hinder its use in Oklahoma especially under the present organization with the township as the road unit. The cost of constructing roads with this machine is somewhat less than with the scraping grader.

BEAUTIFYING THE ROADWAY.

This side of road construction is usually neglected, but must be regarded as of value. The most common practice is to plant trees, but this should be practiced in moderation. Too many trees will shade the roadway so as to keep it moist which is extremely detrimental to earth roads. The trees should be planted near the outer edge of the right of way instead of near the roadbed. Almost any of the common forest trees are suitable for road ornamentation, however, trees such as willows, cottonwoods, or Carolina poplars should never be planted

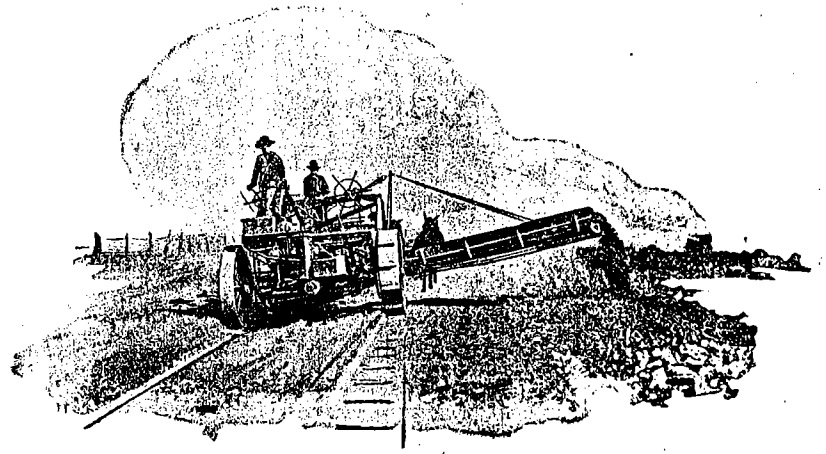

Fig. 17. Elevating Grader at Work.

along roads as their small roots are certain to enter the drains and will finally close them entirely. The fences are important factors of the appearance of a road, but they are usually the property of the adjoining landowner and are out of the jurisdiction of the road builder or supervisor.

SAND ROADS.

Sand roads may be considered as a kind of earth road and will be considered in this connection. As sand roads are better while wet and clay roads are better while dry the methods of construction and maintaining the former will be directly opposite to those of the latter. There should be as little drainage as possible and efforts should be made to

retain all the moisture. They do not need to be graded, but the traveled surface should be merely leveled off.

The roadway should be shaded as much as possible by trees, and grass and shrubs should be allowed to grow as near the edge of the way as possible on account of the binding power of the roots and of the leaves which fall on the roadway. Covering the surface of the road with straw, leaves, shavings, etc., will afford temporary improvement.

THE SAND-CLAY ROAD.

Since the properties of sand and clay as road materials are almost the direct opposite of each other it follows that either one may be used to improve a road which consists entirely of the other. Such mixtures of sand and clay are known as sand-clay roads. They may be natural, i. e. the soil may contain the proportions of sand and clay to make a good road, or they may be made by mixing sand and clay in the proper proportions.

Several roads of this type have been built under the Office of Public Roads in the southern states and as they have proved very successful the method of their construction will be given in full[18]:

The bad properties of sand as a road material are due to the fact that it possesses no cementing material and the particles are free to move about over each other. Clay has the bad quality of forming a plastic, sticky mass when wet. Every one has noticed the fact that when there is an excess of water in sand that it is soft and "quick," but that when there is just sufficient water to fill the voids or open spaces between the sand grains that it is quite firm. The object of the sand-clay road is to bring about a condition similar to the latter, in which the place of the water is taken by clay. The two materials, then, should be mixed in such proportions that there is just enough clay to fill the voids in the sand, leaving the corners of the grains touching each other. The clay then prevents the sand grains from moving freely over each other when the mixture is dry, and the sand grains being braced against each other prevent the mixture from becoming soft and plastic when wet. If too much sand is present, the clay cannot keep the grains separate and the mass will have more of the characteristics of sand when it is dry and if there is too much clay the sand grains become entirely separated and cannot reinforce each other so as to keep the mass from becoming plastic when wet. This proportion is difficult to ascertain

18. U. S. Dept. Agr., Farmer's Bull. No. 331, or U. S. Dept. Agr., Office of Public Roads, Bull. No. 27.

in the case of a given sand and clay, and is usually determined by the action of the mixture under traffic as is described later.

In the building of a sand-clay road two distinct conditions are met with, (1) where the subsoil is of sand, and clay must be added and (2) where the subsoil is of clay, and sand must be added. There is a radical difference in the construction in the two cases so they will be taken up separately.

SAND CLAY CONSTRUCTION UPON A SAND SUBSOIL.

The remarks already made concerning drainage apply to the sand-clay roads. When the drainage has been properly provided, the roadbed should be brought to a crown. It has been found more economical to crown first a section of the road nearest the source of the clay. The

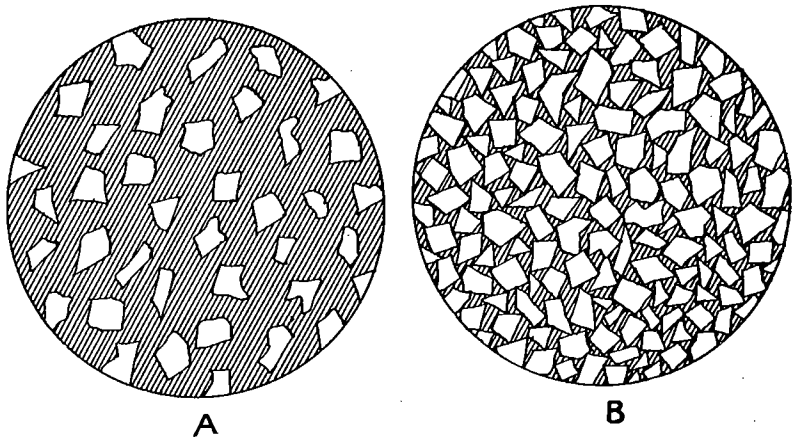

Fig. 18. A. Sand-clay Mixture Containing Excess of Clay. P.—Sand-clay Mixture Containing Proper Proportions of Sand and Clay.

first load of clay is dumped on this prepared section at the point nearest the clay bed, each succeeding load thus being hauled over the preceding. Care should be taken to spread each separately and evenly as soon as it has been deposited and before it has been driven over.

After spreading the clay it should be covered with a layer of clean sand. When the road has been opened to traffic a sufficient amount of sand should be added from time to time to keep the surface smooth and prevent the formation of mud. Both the thickness and the width of the layer of clay are determined by the volume and character of traffic which the road is to sustain. If a narrow, single-track roadway is to be built, it has been found best to spread the clay to a width of

about 12 feet and to a depth of 3 to 8 inches, tapering the layer to a thin edge at the sides. In some cases it may be necessary to modify these directions to accord with the quality of the clay and the amount of sand which it contains. The "leaner" or more sandy the clay, the greater will be the amount required. After the clay layer is complete and covered with sand as already stated, if the clay is of plastic and lumpy character, it will probably be necessary to plow and harrow it alternately until the lumps are thoroughly disintegrated. Advantage should be taken of rains in order to puddle the road surface with a harrow. As long as the surface shows a tendency to "ball" or cake, more sand must be added until this trouble is overcome. If, on the other hand, the surface loosens in dry weather, it is due to an insufficient quantity of clay or else because the clay lacks bonding power. It must be borne in mind that the construction of a sand-clay road is not a quick operation, but a process of rather slow development. In the course of the work there is time to determine what proportions of the two materials will finally lead to the best results.

If the materials are specially adapted to the purpose it is possible to construct very excellent sand-clay roads without the use of plow, harrow or roller. The mixing can be left, after the materials have been properly spread, entirely to the action of traffic. In all construction, however, the best results are hastened by the use of plow and harrow. In all cases it is advisable to use a scraping grader to shape the surface, after which a light coat of sand may be added.

The quantity of clay required to build a mile of road will vary, of course, with the width and depth of the clay layer. A roadway 12 feet wide with an average depth of 6 inches of clay will require a cubic yard to cover four and one-half feet of road length; that is to say, each cubic yard of clay will make one and one-half "running" yards of clay roads. Since there are 1,760 yards to the mile, it will be seen that 1,174 cubic yards of clay will be required for 1 mile of construction.

The cost of sand-clay roads upon sand can be readily calculated, when the rate of wages and the distance of haul is known. The average load has been found to be about two-thirds to three-fourths of a cubic yard, when the hauling is done over sand, and about 1 cubic yard when the hauling is done over a dry clay road.

SAND-CLAY CONSTRUCTION UPON A CLAY SUBSOIL.

After proper drainage has been provided the roadbed should be first crowned as nearly as possible to the form desired in the finished road. The road surface should slope from the center to the sides at

least one-half inch per foot. It should be noted that it is much more important to form this foundation crown first where the subsoil is of clay than it is with a sandy subsoil.

The foundation having been properly prepared, the surface should be plowed and harrowed to a depth of about 4 inches until it is pulverized as completely as possible. It is then covered with 6 to 8 inches of clean angular sand. The sand should be spread so the layer is thickest at the center of the road, following in general the same plan as was outlined for spreading clay upon a sandy foundation. The materials should then be mixed while they are in a comparatively dry state, contrary to the usual practice of doing the entire mixing and puddling when the materials are wet. It has been found that the clay foundation can be more evenly disintegrated when comparatively dry, and it is also a difficult matter to mix the sand evenly with the clay if the latter is soft and cut into ruts by travel. This preliminary mixing should be done if possible, but often conditions do not allow it and the sand has to be mixed on the wet clay road. After this first mixing has been finished the road is finally puddled after a rain. In case an excess of clay works to the surface and tends to make the surface sticky, sand should be applied until this trouble is overcome.

Upon the completion of the mixing and puddling, the road should be shaped while it is still soft enough to be properly finished with a scraping grader and at the same time stiff enough to pack well under the roller or under the action of traffic. In case it is impossible to obtain the proper consistency of the surface material, it is better to shape the road when somewhat too wet than when it is too dry, even if it is necessary to stop traffic upon it for a few days. The road should be opened to traffic as soon as practicable after completion, as travel will be found to be the best conditioning factor.

VALUE OF SAND-CLAY ROADS.

The sand-clay road is of recent development and its value is not well understood over the country. Its cheapness makes it desirable as its original cost is only from one-fourth to one-half as much as that of a macadam road. It is easily kept up and is easily renewed if necessary. The materials are widely distributed and are usually to be obtained where material for macadam or other roads is lacking or at so great a distance as to render the cost of transportation prohibitive. The construction is able to support any sort of country traffic, loads of six bales of cotton having been hauled over it without damaging it. It is very solid and only slightly dusty in dry weather and never very

muddy in wet weather. The presence of the sand in the clay prevents the excessive expansion of the clay in freezing. This type of road will undoubtedly be of great value in Oklahoma, especially in most portions of the western half of the State. This matter will be discussed more fully in connection with the road conditions in the part of the State mentioned.

BURNT CLAY ROADS.

These roads are used in some parts of the country where all other road materials are lacking and where the soil is a stiff, "buckshot" clay. They are made by laying wood in rows along the side of the roadway and in trenches across the road and covering it with a layer of clay so that there may be sufficient draft to cause the wood to burn when fires are started along the side of the road. This burning destroys the sticky properties of the clay and the result is a roadway that is a great improvement over the unburned clay. It cannot, however, be called a first-class road and is not recommended where any other road materials are available. In the greater part of Oklahoma the cost of wood will render this construction impossible and it will probably not be used unless it be locally in the southeastern part of the State.

MAINTENANCE OF EARTH ROADS.

IMPORTANCE OF ROAD MAINTENANCE.

The subject of the maintenance of earth roads is of as much importance as their construction. No matter how well a road may be constructed, if it is left a few seasons without the proper care, it will deteriorate until it is in as bad condition as before improvement. The principal factors of road destruction have already been noticed so they will only be mentioned here and the methods of their prevention will be taken up.

The effects of water in softening the road bed and in washing and gullying it have been discussed[19]. This is one of the principal factors in the decay of roads and if this action is guarded against most of the other factors will take care of themselves.

NARROW VS. WIDE TIRES.

Another thing which may injure the road is the use of narrow tires. This is important, but is often overestimated. The tractive force required to draw a load must be taken into consideration as well as the

19. See Page 23 and 24.

effects on the road. This is well shown by Shaler in his book on "American Highways."[20]

"First, as to the width (diameter)of wheels. Where these are small, i. e., of less diameter than, say, thirty inches their effect is to push bits of loose stone before them, particularly when the vehicle is heavy laden, in such a manner that the fragments plow up the road until they have worn out or glanced aside. A wheel thirty inches to three feet in diameter or less will do this when one four feet across will ride over the obstructing bit, crushing it or driving it down into the bed. If it were possible (it is obviously not so) to have wheels limited in diameter to four feet, good roads could be more easily maintained in order. Fortunately, there is a tendency toward the general adoption of large-wheeled vehicles wherever the roads are made good. There are, indeed, several mechanical reasons why this should be the case. Moreover, in this country, where the carriages are as much better as the roads are worse than those of the Old World, it is the custom to avoid the road-destroying, small fore-wheels of farm wagons which are so commonly used in Europe.

"While the diameter of wheels has been but little considered, the matter of the width of tires has been made the subject of much remark. There has, indeed, been no end of idle talk concerning this matter, much of it directed to the point that our American wagon-builders have shown a lack of judgment in building with narrow tires, while they should provide their vehicles with broad tires such are in use in Europe. The fact is that in this as in many other ways in which our people have departed from ancient and old-world customs, they have been led by wisdom and not by folly. This will on a little consideration be made evident. Where, as in ninety-nine hundredths of the mileage of American roads, there is no definite pavement the wheels have in muddy weather to descend into the earth until they find a firm foundation on which to rest. In so doing they have to cleave sticky mud which often has a depth of a foot or more. If these wheels were broad-tired the spokes would also have to be thick and the fellies wide, so that the aggregate holding power of the mud upon the vehicle would be perhaps twice what it is at present. It is usless to talk about the advantages of a broader tread to the wheels of our wagons until we have a thoroughly good system of roads which they are intended to traverse. Any laws looking to this end would be destroyed because of private needs so general that would amount to a public necessity. When the roads of a district are made good only as regards the main lines of communication, the side roads still demand the peculiar advantages afforded by

20. Pages 163-164.

the narrow tread. It is thus only when the good ways are developed to a complete system that the people can be justly required, or even expected, to adopt the proposed broad tires.

"While it is clearly injurious to a road paved with broken stone to have heavy-burdened wagons with narrow tires pass over it, there is no reason to anticipate that such vehicles will continue to be used when the general conditions of wagoning are such as will make it practicable to use wheels of a broader-tread except, perhaps, in cities, where there may be some advantage arising from narrow-rimmed wheels for the reason that they fit into the tramway track. The greater strength of the wide-framed wheel, with the resulting broad tire, is certain to commend it to general favor. We have here a natural influence which is likely to prove far more effective than any statute."

The wisdom of Professor Shaler's conclusions is borne out by the fact that where all the roads of a section or district have been improved, the use of the narrow-tired wheels has been abandoned.

Other features of the mechanical wear of traffic on earth roads are the wear due to the use of brakes and especially the locking of wheels on steep grades. The blows of horses' feet, especially when they are shod with shoes with calks, are probably greater agents of wear than are the wheels. This is especially true on macadam roads.

THE CARE OF THE SURFACE.

The maintenance of an earth road practically resolves itself into the keeping up of proper drainage, and the retention of a smooth, well crowned surface. To insure the first, it is necessary to see that the side ditches are cleaned out in the spring and fall, and to open the tile drains at any time when they show evidence of being clogged. The smooth crown can be maintained by dragging or by the use of the scraping grader. If the road becomes softened and rutted in the winter, a thorough dragging with a piece of railroad iron or a split-log drag will greatly improve it. In the spring the road should be harrowed with an ordinary farm harrow and dragged with the railroad iron or split-log drag. If this is not sufficient to restore a smooth surface and to fill the ruts, the scraping grader should be used.

In using the scraping grader for this work the blade should be set almost at right angles with the road and the rear end elevated only slightly above the front end. This adjustment causes considerable dirt to be pushed ahead of the blade and this fills up the ruts and depressions. The work should be done at a time when the road is moist and soft. It can well be done in the early spring before the soil is

dry enough for plowing. This time has several advantages; the farmers are not busy as they are later in the season; the road being soft permits of more rapid work with the grader as well as requiring less power; the loose dirt left by the scraper will compact and unite with the solid part of the road bed much better when it is moist. As in the construction of the road, there should be no ridge in the middle of the road and no "shoulders" should be left inside the side ditches. If the work is left until the road is dry, it is very difficult to smooth the surface with the grader and it may be necessary to have a man follow the grader and smooth down the bumps and fill in the depressions with a shovel. The depressions should be filled a little higher than the solid portions to allow for the packing of the loose dirt. A few days after the road has been graded it is well to go over it with the split-log or railroad drag to level up the small depressions caused by traffic on the soft dirt which the grader left in the old ruts.

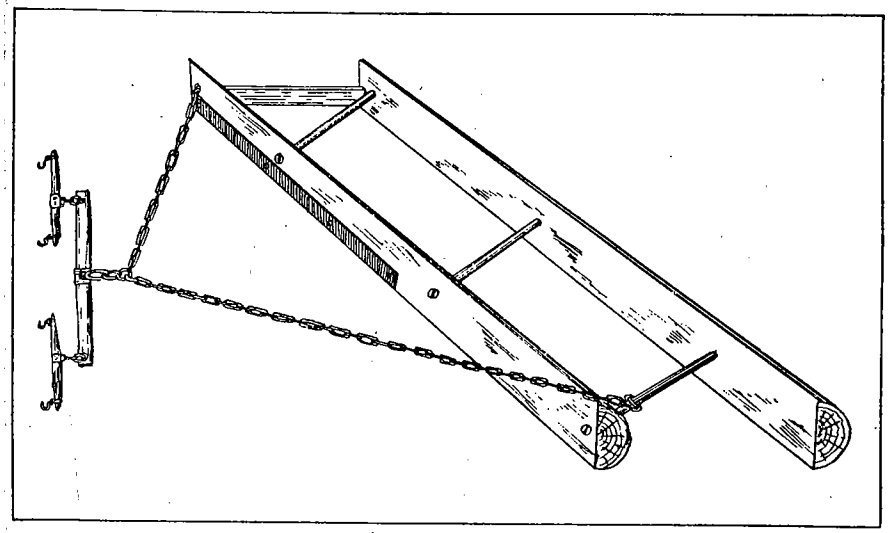

Fig. 19. Split-log Drag.

The Split-log Drag. This implement has already been mentioned and as it gives a very satisfactory means of maintaining earth roads, is very cheap, and is easy to construct and operate, a short description of it may be of value.[21]

The log should be seven or eight feet long and about twelve inches in diameter, and carefully split down the middle. The best slab should

21. King, D. Ward, U. S. Dept. Agr., Farmer's Bull., No. 321.

be selected for the front. The two slabs should be fastened together, with the flat sides to the front as shown in the illustration (fig. 19 and 20). They should be placed so that the end of the back slab will lay 16 inches nearer the center of the road than the front one, giving what is known as "set back." The two slabs should be held 30 inches apart by three cross stakes, which are fitted into holes in the slabs and held by wedges. A strip of iron about three and one-half feet long, 3 or 4 inches wide and one-fourth inch thick may be used for the blade. This should be attached to the front slab, so that it will be one-half inch

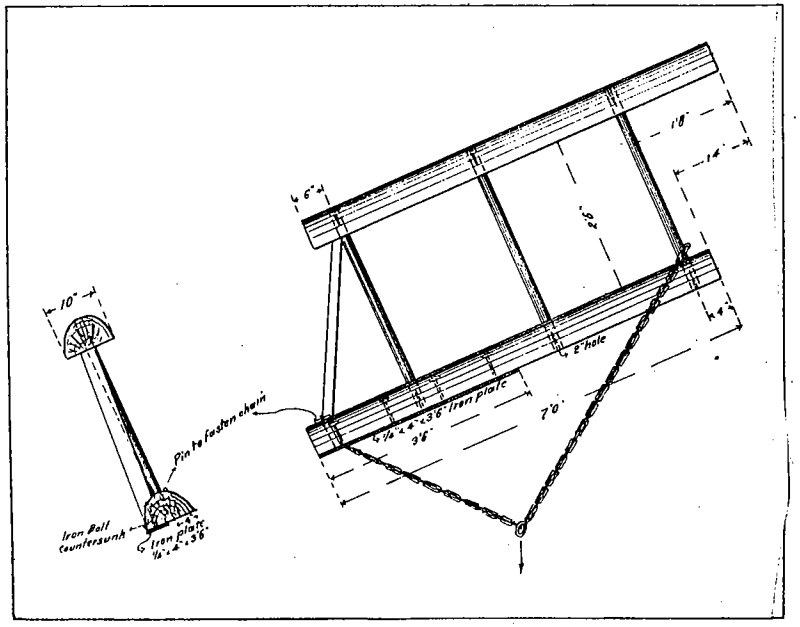

Fig. 20. Plan of Split-log Drag.

below the lower edge of the slab at the ditch end, while the end of the iron toward the middle of the road should be flush with the edge of the slab. The bolts holding the blade in place should have flat heads and the holes to receive them should be countersunk. If the face of the front slab stands plumb it is well to wedge out the lower edge of the blade with a three-cornered piece of wood to give it a set like the bit of a plane. A platform of boards should be made to fit across the top of the drag upon which the driver may stand. This should be made of narrow boards and they should be spaced so that any dirt that is thrown up over the front slab may sift back on the road.

An ordinary trace chain is strong enough to draw the drag if the clevis is not fastened through a link. The hitch should be made nearer the ditch end of the drag so that the unloaded drag will follow the team at an angle of about 45 degrees. This will cause the dirt to move smoothly along the face of the drag toward the center of the road. The driver should stand in the line of draft. The depth of cutting is regulated by the distance from the drag at which the team is hitched. Shortening the chain tends to lift the drag from the ground, and lengthening it causes the blade to cut more deeply. The blades should be sharpened occasionally. Side ditches may be cleaned with the drag by hitching near the outer end and having the driver rest most of his weight on the extreme outer end of the front slab. The expense of maintaining roads with this drag is very slight and the results obtained by its use are very valuable.

THE PREVENTION OF DUST.

This has become an especially important feature of road maintenance since the introduction of the automobile. The rapid movement of the broad rubber tires over the road creates a suction which lifts great clouds of dust into the air. The slightest wind will carry this dust from the road and distribute it over the surrounding country. The effect is to continually remove the layer of dust which acts as a wearing surface over the road bed and to leave the solid bed exposed to the wear of traffic. Added to the effect on the road, the unpleasantness of the dust clouds to travelers and to those living near the highways makes the prevention of this condition of great importance.

The usual preventives fall into two classes: (1) Those which are temporary in their effect and (2) those which are permanent. The temporary preventives simply hold the dust on the roadway while the permanent ones prevent the formation of dust. Any substance whose effect lasts for one season or longer is classed as permanent.

The principal substances used as temporary dust preventives are water and water containing various salts, while the permanent ones are coal tars and coal tar pitch, crude oil, and residual oils.

Water and water with soluble salts. The sprinkling of streets with water is the oldest method of dust prevention. The effect is of very short duration on account of the rapid evaporation of the water. It is very expensive when the short time it lasts is taken into consideration. The effect of sprinkling is lengthened by adding to the water such salts as common salt, sea salt, magnesium chloride and calcium chloride. These salts are hygroscopic, i. e. they can take water from a moist at-

mosphere and hold it tenaciously. This addition of these salts to the water used in sprinkling causes the streets to remain moist much longer than when the water is used alone. The process is expensive and the effect does not last a great length of time as the salts are washed out of the streets by heavy rains.

Coal tar and oils. Coal tar, and crude oil and residuum from oil refineries have been used extensively during the last few years as dust preventives. They are heated and applied to the street or road by sprinkling. The coal tar and oils with an asphaltic base are permanent in their effects while oil with a paraffin base does not last long and also makes a greasy muck when wet that is very harmful to the paint on vehicles and to clothing. The best results have been obtained by the use of asphaltic base oil (principally California oil) on sandy loam. Oil should not be used on plastic clay roads as it "balls up" and will not mix. Alkali soils break up the oils and the effect is very short. If a heavy asphaltic oil is used and mixed thoroughly with the soil to to the depth of 3 or 4 inches and rolled, the resulting surface resembles an asphalt pavement. It is free from dust and is fairly lasting. Many miles of these "oiled earth" roads have been built under such names as bitulithic and petrolithic. In many cases they have not been altogether satisfactory and in California where they were first introduced they are being largely replaced with macadam at a cost of several times that of the oiled earth roads.

The writer believes that a saticfactory oiled or bituminous earth road can be made by the use of the soft sand asphalts of the Cretaceous area (southern part) of Oklahoma. If the earth or sand roads should be plowed and loosened to the depth of 3 or 4 inches and a thin layer of the heated sand asphalt applied and thoroughly mixed with this loosened surface by harrowing or raking and the mixture consolidated by rolling, a surface should result which would be dustless and at the same time have fair wearing qualities. It is hoped that some experiments with this material will be made in the near future.

CHAPTER IV.

PAVED ROADS AND STREETS

MACADAM ROADS.

DEFINITION AND USE.

A macadam road is one whose surface or wearing coat is composed of broken or crushed stone, none of the pieces of which are over two and one-half inches in diameter and which has no binding material other than stone screenings. It is a valuable form of road for those country highways which are main thoroughfares and for residence streets in cities. Its cost is usually prohibitive for neighborhood or little traveled country roads and its wearing qualities are not sufficient for streets subjected to heavy traffic.

MATERIAL FOR MACADAM ROADS.

The nature of the material and its availability are of prime importance in a macadam road. The various rocks differ greatly in their wearing qualities and in the ease with which they are quarried and crushed. A macadam road should not be built until the relative merits as well as the cost of the different available materials have been considered. It is often more economical in the long run to import a good stone from some distance than to use an inferior stone which is near at hand. The excessive cost of maintaining a road constructed of poor material will more than equalize the difference in first cost.

CRUSHING THE STONE.

Formerly the stone for macadam roads was broken by hand and this custom is still followed to some extent in Europe. In this country the high price of labor and short working hours make this method unfeasible. The stone can be broken much faster and to more uniform sizes by the power crushers. These are of two kinds, the portable and the stationary. Either of these may be of two types, the oscillating or jaw crusher, and the rotary, or gyratory crusher. The portable crushers are usually of the first type and the stationary of the second.

The Blake or jaw crusher (fig. 21) consists of a heavy frame having a movable jaw at one end, set at an angle to the frame. By a toggle point and eccentric the jaw is successively pushed toward and drawn away from the frame. As it is drawn away the stone drops down into the opening between the frame and the jaw. Then as the jaw is pushed

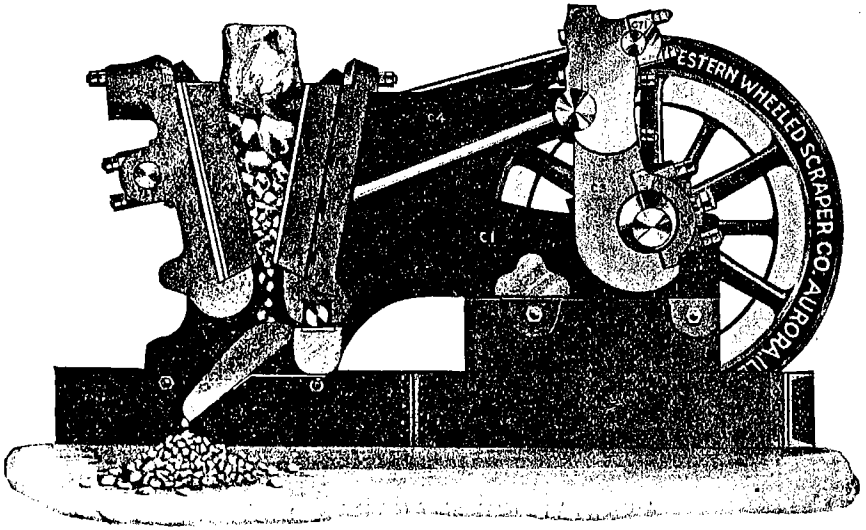

Fig. 21. Sectional View of Jaw Crusher.

toward the frame the stone is crushed, and on the withdrawal of the jaw drops farther down toward the apex of the angle and when fine enough, out of the small opening between the bottom of the jaw and the frame.

The Gates or gyratory crusher (fig. 22) consists of a solid, conical, iron shaft mounted within a heavy iron frame, shaped like an inverted bell. An eccentric gives a rocking and rotary motion to the shaft so that each point on its surface is alternately brought nearer to and removed farther from the inner surface of the frame, crushing the stone that is fed in from above.

The Crusher Plant. If a portable crusher is used it should be located as near the road which is to be surfaced as possible, and at the same time beside the ledge of the rock which is to be used. Water is essential for the engine furnishing the power, so that the presence or absence of water will often decide between two possible locations. The crusher should be installed with its top or mouth, as nearly level as possible with the floor, the stone can then be hauled in carts or wheel

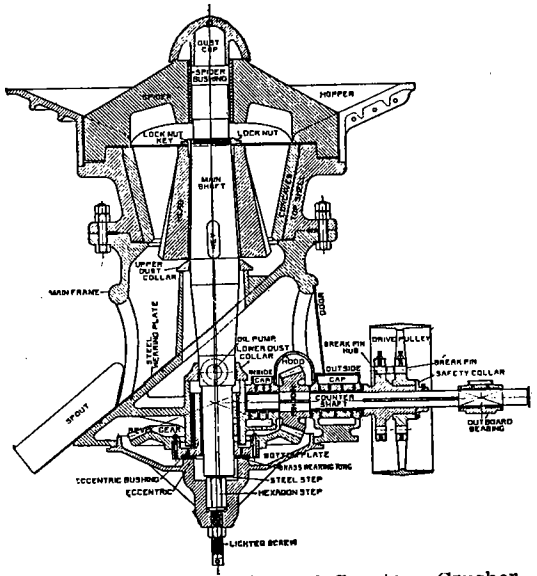

Fig. 22. Sectional View of Gyratory Crusher.

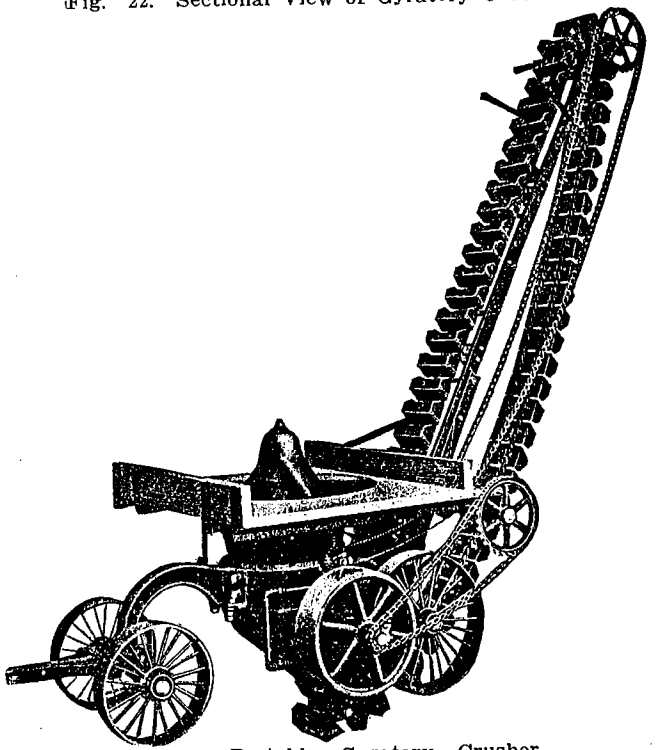

Fig. 23. Portable Gyratory Crusher.

barrows and dumped on a platform at the mouth of the crusher. From this platform it can be fed into the crusher without further handling. From the crusher the stone drops upon a bucket elevator belt. This elevator carries the stone to the screens, which are usually of the rotary type and are driven by the same power as the crusher. The rotary screens are cylindrical in shape. The stone is fed into the end nearer the crusher, which is higher than the other and which has the smallest perforations. The smallest pieces drop through these holes and as the stone moves down the screen successively larger pieces drop through the openings and fall into the proper bins or into wagons. The pieces which are too large to pass through the largest perforations fall out at the end of the screen and are returned to the crusher. The stone may be run directly into wagons, but storage bins should be provided to receive the crushed stone when the road is too muddy for hauling. A

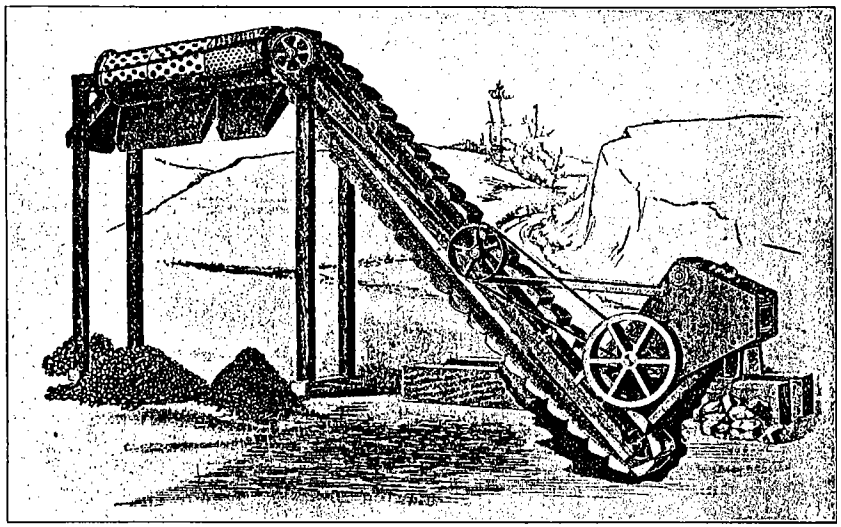

Fig. 24. Portable Jaw Crusher, with Screens.

portable gyratory crusher is shown in fig. 23 and a portable jaw crusher and screens in fig. 24. The power for the portable plants is often furnished by traction engines. The total expense for a plant of this kind will run from $1,500 to $2,500.

CONSTRUCTION OF THE ROAD.

Preparation of Foundation. The drainage and foundation should be provided as discussed in the chapter on Earth Roads. Any good,

well drained earth road makes a suitable foundation for macadam. The surface should be thoroughly compacted by rolling so that the broken stone may not be pushed down into it.

First Course. On the foundation is placed a layer of broken stone. This is usually hauled to the road in wagons and dumped. It is then spread to an even thickness by raking. A heavy horse roller or steam roller (fig. 25) is then used until the stone layer is thoroughly compacted. Better results are had by adding the stone in courses and rolling each course separately. The size of the stone varies with its nature.

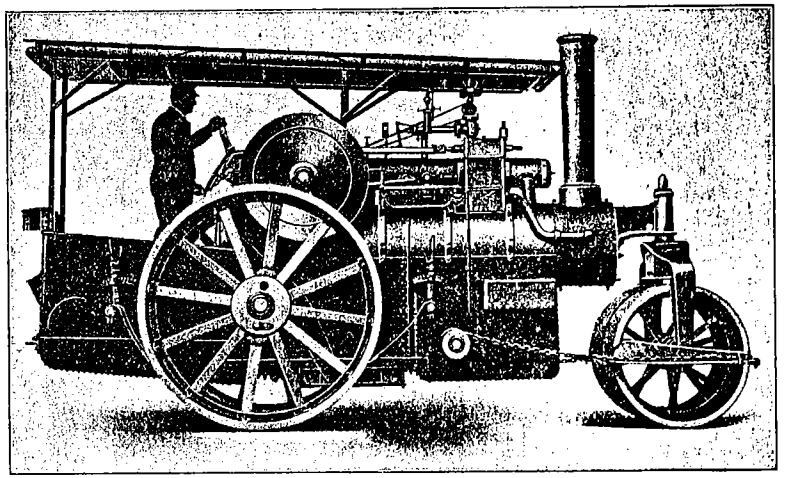

Fig. 25. Steam Roller for Macadam or Earth Roads.

The harder and tougher the stone, the smaller the pieces, as they are not broken so badly under the roller. With very soft stones, the lower courses are sometimes of fragments two or three inches in diameter. In any case the top courses are of finer material, usually one inch to one and one-half inches in diameter. The thickness of the finished road will depend upon the use to which it is to be put. Formerly twelve inches was considered the minimum thickness of a road for ordinary traffic, but the prevailing tendency is toward thinner roads, six or eight inches having been proved sufficient to support anything but very heavy traffic. The stone shrinks when rolled, the amount of shrinkage depending on the nature of the stone and the size of the fragments. About 20 per cent. is an average shrinkage, so, for an eight-inch road about 10 inches of loose stone must be applied. The width of country roadways need not be more than 12 to 15 feet.

The Binder. This usually consists of the screenings from the crushed rock of which the road is built. Some road builders add a thin coat of the binder to each course of stone and roll it in before the next course is applied, while others add it only to the top of the road. The object of the binder is to fill the voids between the stones and to cement the larger pieces together. It is applied as a coat from one-half to one inch in thickness, thoroughly sprinkled and rolled into the surface. Clay and sand are sometimes used as binders, but are not, as a rule, satisfactory.

COST OF THE MACADAM ROAD.

The cost of macadam roads varies so greatly with the nature of the road, kind of material, distance which material must be hauled, size of contract, labor conditions, etc., that only general statements can be made. Where the stone can be obtained near the road to be built, macadam roads should be constructed for from $2,000 to $5,000 per mile. Where stone must be bought and then shipped some distance the cost is greatly increased.

MAINTENANCE OF THE MACADAM ROAD.

The maintenance of the macadam road is governed by the same factors as that of the earth road. The drainage must be kept in good condition, and the crown must be kept in shape.

Periodic Maintenance. With the periodic system of maintenance the entire road is permitted to wear to thinness and then an entire new surface is added. It is not to be understood that no repairs are made under this system, for ruts and gullies are filled up occasionally and any portions of the road that wears much more rapidly than the rest are patched, but no attempt is made to keep the surfacing up to its original thickness. This system is followed in this country.

Continuous maintenance. In Europe, however, as soon as any spot shows evidence of wear, fresh stone is added so that the road maintains its original thickness. The continuous system requires that men shall be constantly employed in the repair of the roads and is practically prohibited in this country by the high price of labor.

"Raveling." The greatest wear upon macadam roads comes in long continued dry spells. The drying out destroys the cementing value of the stone and the pieces tend to work loose from each other. This is called "raveling" and is best checked by heavy sprinkling of the road and rolling while wet. A thin layer of coarse sand also prevents raveling.

Ruts. The formation of ruts is due to too heavy loads, to inferior binding material, or to continuous traffic along the same track. When ruts are formed the only way to repair them is to fill them with new material or to pick down the sides of the ruts. If new material is used it should be the same stone as the rest of the road to prevent unequal wear.

Freezing. Freezing loosens the bond between the pieces of stone, so that the roads are easily cut through while soft in the spring. This may be prevented by rolling the road as soon as it is dry enough to support the weight of a moderately heavy roller.

Patching. If depressions appear in the road surface they should be repaired by patching. The patch should be thin and of smaller pieces of stone than were used in the road. The continuous method repair is practically a constant and systematic patching.

Regrading. If the road becomes extremely rough while there is still sufficient macadam material to form a good wearing surface, it may be regraded. To accomplish this the surface is loosened by plowing or by going over it with a steam roller whose rear wheels are provided with spikes. The latter method is the better. After being thoroughly loosened, the surface is leveled by raking and is then sprinkled and rolled as in the construction of the road.

Resurfacing. When a macadam road is worn very thin it should be resurfaced. All the dust and dirt is removed. If the old surface is very hard it is loosened with picks, to the depth of one-half to one inch. The new material is added, rolled, and the binder applied as in constructing a new road.

GRAVEL MACADAM.

Where there are large deposits of gravel, this forms a convenient and cheap material for macadam roads. The method of construction of the road does not vary greatly from that used with crushed stone. A thicker coat of gravel is required than of crushed stone. The compacting is usually left to traffic, but much better results are secured by sprinkling and rolling. The scraping grader may be used to restore the shape to the crown and to fill up ruts when the surface becomes worn. The road must be resurfaced every two to four years, depending upon the traffic and upon the nature of the gravel.

In some of the states gravel macadam forms the greater part of the improved roads, but this will not be the case in Oklahoma. The gravel macadam will be restricted to the regions of the Arbuckle and

Wichita Mountains where granite gravel occurs in the stream beds, and to the extreme northeastern portion where there are deposits of chert gravel or "chats" in the streams. Some deposits of gravel have been reported from the streams of the northwest portion. These have not been investigated fully but some of them are probably large enough to be of local importance for road material.

BRICK STREETS AND ROADS.

ADVANTAGES AND USE OF BRICK FOR PAVING.

The advantages of brick pavements are given as follows:[22]

1. Ease of traction.
2. Good foothold for horses.
3. Not disagreeably noisy.
4. Yields but little dust and mud.
5. Adapted to all grades.
6. Easily repaired.
7. Easily cleaned.
8. But slightly absorbent.
9. Pleasing to the eye.
10. Expeditiously laid.
11. Durable under moderate traffic

The use of brick for paving is of comparatively recent introduction. The first brick pavements were laid in Charleston, W. Va., in 1872. Since that time their use has increased very rapidly until at present there is probably as much pavement being constructed of brick as of asphalt, stone block and wood block combined. The brick streets have been universally successful for residence streets and for moderately heavy business traffic, where the proper care was used in selection of the material and the construction of the streets.

DEFECTS.

The failures of brick pavement usually result from the use of poor brick, i. e. those which are not uniformly burned, or those which are made from clay not adapted to their manufacture; or to improper construction in the foundation or cushion coat.

22. Byrne, A. T., Treatise on Highway Construction, p. 258.

THE BRICK.

MANUFACTURE.

Paving brick may be made from surface clays, shales, or impure fire clays. As a rule the surface clays vitrify at too low a temperature and too rapidly to make good pavers, while the fire clays require so high a temperature as to make the burning very expensive. Consequently the majority of paving brick are made from shales whose properties are intermediate between the surface clays and the fire clays. All paving brick are made by the stiff mud process. The shale or clay is ground, made to a stiff, plastic mass with water and thoroughly "pugged" or mixed. It is then pushed through a die by an auger machine. The column of clay as it comes from the machine is cut into sections approximately the size and shape of the brick by automatic wire cutters and the pieces are repressed. This gives the brick the exact shape desired; however, the green brick must be large enough to allow for shrinkage in drying and burning. In repressing, lettering or lugs are formed on one or more surfaces. These are of advantage in keeping the brick slightly separated in the pavement to permit the introduction of joint filler. The corners are often rounded to lessen chipping under traffic. Grooves are sometimes made on the surface, which is to be used as the top, to provide a better foothold for horses.

After having been repressed, the bricks are thoroughly dried and burned. The burning is usually conducted in downdraft kilns, the temperature being carried to the point of vitrification or about 1800° to 2300° Fahrenheit for most shales. By vitrification is meant the condition in which the constituents of the clay begin to fuse together to form a homogeneous body. It is the first stage of the melting of the clay. The value of clays for paving brick depends upon the "vitrification range," or the slowness with which the clay melts. As already mentioned surface clays melt very rapidly so that if the kiln is raised to the heat necessary for vitrification many of the bricks will get too hot and melt out of shape. Complete vitrification of clay is marked by the formation of a homogeneous body (i. e. the different constituents are melted together) by a conchoidal fracture, by absence of pores, and by more or less of a glassy lustre. A vitrified brick is practically an artificial crystalline rock.

After heating to vitrification the kiln is slowly cooled to prevent cracking and checking of the brick which occurs in rapid change of temperature. About two weeks is usually required for setting and burning a kiln and allowing it to cool down.

PROPERTIES OF PAVING BRICK.

Paving brick should be regular and uniform in size and shape. They should fit closely together in the pavement. They should be uniform in hardness, (i. e. must not be over nor under-burned) and this hardness must be sufficient to resist the action of traffic. Each brick should be homogeneous in texture and free from laminations and seams.

TESTING PAVING BRICK.

The general appearance gives an idea of the quality of the brick from the same plant, but does not give a basis for comparison of brick from different plants or clays. The edges of the brick should be reasonably straight and smooth and should not be easily chipped by light blows of a hammer. The *sides* should be flat and the *corners* round. The *size* should be uniform in brick from the same plant, as large brick may indicate under-burning and small brick denote over-burning. The *color* should be uniform in brick from the same plant, as lighter colored brick are usually under-burned and soft, while the darker colored are over-burned and harder than the average. The color cannot be used in comparing bricks made by different processes or from different clays, but only in comparing bricks in the same lot. The surface color is often misleading on account of the sand which has been used in setting the brick in the kiln or from the effect of sulphur in the coal or other causes. Color comparisons should be made on freshly chipped surfaces. The *interior* of the brick should be uniform in texture and color. It should not show either unfused or glassy spots as these indicate poor mixing of the materials of the brick. There should be no lumps unless the boundaries are well fused in the rest of the brick. Lumps of lime are very detrimental as they slake when they become wet and are apt to disrupt the brick. The fresh surfaces should have a vitreous or glassy lustre.

The physical tests which have been used for paving brick are: crushing-strength test, absorption test, transverse strength test, and rattler tests.

The crushing-strength test, if made under uniform conditions would be useful to compare the qualities of different brick, but otherwise is of little value and has been generally abandoned. Brick are very unlikely to fail from lack of crushing strength as very ordinary brick will show a strength of 6000 to 8000 pounds per square inch and they are very seldom subjected to a load of over 2000 pounds per square inch.

The transverse-strength test is made by resting the ends of the brick upon knife edges and applying pressure upon a third knife edge in the middle of the brick until failure takes place. As in the case of the crushing strength test this furnishes a means of comparing different brick but is of little value in determining the properties of a given brick, as bricks in pavements are never known to fail in this way until they are worn almost through.

The absorption test. This test is of value in showing the measure of the vitrification which has taken place. Under-burned brick are very porous. Over-burned brick may be somewhat porous due to the formation of bubbles in melting. Brick properly vitrified have no pore space and consequently will not absorb water.

To make the test, five brick are dried carefully and weighed, then placed in water, the upper surface of the brick being level with or slightly above the surface of the liquid, and left for forty-eight hours. The surface is then dried by wiping with a cloth and the brick is re-weighed. The per cent. of absorption is obtained by calculating the gain in weight as per cent. of the weight of the dry bricks. Good paving brick may show absorptions of from five-tenths to two per cent.

The rattler test. This test is supposed to give a measure of the resisting power of the brick to wear by impact and abrasion. As usually performed the test is as follows:

A charge of given number of brick (usually 10) is placed in a drum, 28 inches in diameter and 20 inches in length which has cast iron heads and is enclosed by 14 cast iron staves. Small spaces between the staves permit the escape of the fine material worn from the brick. A charge of 300 pounds of cast-iron shot of two sizes is introduced with the brick. One-fourth or 75 pounds of the shot is of the larger size, each shot weighing about seven and a half pounds and being two and one-half by two and one-half by four inches in dimensions and having the corners rounded. The remaining 225 pounds is of one and a half inch cubes, weighing about seven-eighths pounds each, and with square corners and edges.

After being securely closed, the drum is rotated 1800 times at the rate of 30 revolutions per minute. At the end of the test, the brick are removed from the drum and weighed. The rattler loss is calculated by obtaining the loss in weight as per cent. of the original weight. The loss of standard paving brick runs from 15 to 20 per cent. as a general rule, although different brick which give satisfactory results in paving may vary somewhat widely.

CONSTRUCTION OF THE PAVEMENT.

The foundation of the brick pavement is usually a 6-inch layer of Portland cement concrete. Upon this is spread the "cushion coat" which consists of 1 inch of fine, clean sand. This is rounded into the exact form of the crown desired in the finished pavement by the use of a template. The brick are then laid on the cushion coat. They are usually delivered by wagons into piles along the curbs and are then hauled to the layers in wheel-barrows. They are laid in courses with the long direction perpendicular to the curb, except at street crossings, where the bricks are set diagonally. Every other course is started at the curb with half a brick so as to alternate the joints in the courses. After the pavement is laid it is rolled with a steam roller of from 4 to 6 tons in weight. Brick around manholes, etc., that cannot be reached with the roller should be thoroughly rammed.

When the pavement has been rolled, the joints between the bricks should be filled in order to keep the bricks in the proper position and to render the pavement impervious to water. The three materials commonly used for this purpose are sand, tar, and cement.

Sand is most commonly employed as a filler. It should be shoveled onto the street and thoroughly swept into the joints. After being swept, the street is covered with a layer of sand one-fourth to one-half inch in thickness and opened to traffic. The advantages of a sand filler are:[23] "(1) It is cheap, usually costing about two cents per square yard. (2) The pavement may be opened to traffic as soon as the brick are laid. (3) The pavement may be taken up easily and without breaking of the brick. (4) It is practically watertight, particularly after being in service a short time. The disadvantages of a sand filler are: (1) It does not protect the edges from chipping. (2) It may be washed out on steep slopes. (3) It is removed from the tops of the joints by street sweepers."

Tar or asphalt or a mixture of the two are sometimes used as fillers. They are heated and poured into the joints. Either of these materials is somewhat more expensive than sand, but makes a perfectly water-tight joint; and tends to make the pavement less noisy. The principal objection to their use is that they are likely to melt and run out of the joints in hot weathed and to become brittle and chip out in cold weather.

Portland cement grouting is made by mixing one part of cement with one part of fine sand and making up to the consistency of thin

23. Baker, I. O., Roads and Pavements, p. 507.

cream with water. It is poured onto the surface of the street and swept into the joints. The street should then be covered with a thin layer of fine sand and closed to traffic until the cement sets. The cement joint protects the edge of the bricks from chipping but does not take up the expansion of the pavement in hot weather as the sand or tar joints will do. It also makes it difficult to take up the pavement without breaking the brick.

Rumbling. The rumbling noise often produced by a brick pavement especially in hot weather is due to the expansion of the pavement by heat which causes the crown to arch up away from the cushion coat. It can be prevented by placing an inch board along the curb when the brick are laid, removing this after the pavement is completed and filling the joint which is left with pitch. For the expansion in the direction of the length of the street it is well to have rather wide (one-half to one inch) joints at intervals filled with pitch.

MAINTENANCE OF THE BRICK PAVEMENT.

The maintenance of the brick pavement consists in keeping the surface absolutely even. If any holes or depressions arise from the rapid wearing of a soft brick, or the settling of a brick into the cushion coat, the continual hammering from the wheels dropping into the depression rapidly wears away the surrounding bricks and increases the hole. In such cases the soft brick should be removed and replaced by a good one, or sand should be added to the cushion coat and rammed and the brick replaced on a level with the others.

Where properly laid and composed of good brick of uniform quality, brick pavements have proved very durable. Many pavements are still in good condition after fifteen to twenty years use under moderate traffic.

COST OF THE BRICK PAVEMENT.

The cost of brick pavements varies with the locality, with distance which brick must be hauled from factory to town where used and from cars on switch to street, with labor conditions, etc. Where pavers are made within a reasonable distance the cost usually ranges from $1.50 to $2.00 per square yard. Where the concrete foundation can be dispensed with the cost is reduced one-fourth to one-third.

USE OF BRICK FOR COUNTRY HIGHWAYS.

So far, the initial cost of brick roads has prevented their general use, but during the last few years several miles of country highway

have been built of brick, especially in Ohio and Pennsylvania. They are proving very satisfactory and it is generally conceded that the difference in initial cost between the brick and other kinds of material is more than made up by the excellence of the roads, by the ease of maintenance and by the difference in the costs of repairs. At present there are not enough paving brick made in Oklahoma for them to be considered as an available country road material. This condition, however, cannot endure as the immense beds of shale in the eastern part of the State combined with the advantages of the same section in the way of fuel and transportation will make this region a great center for the manufacture of clay products, paving brick among others. The increase of population and of land values in the same region will soon bring about a demand for permanent highways and brick will become not only an available, but an advisable road material.

COBBLESTONE AND STONE BLOCK PAVEMENTS.

Cobblestones or small bowlders were formerly used very extensively for paving owing to their cheapness. They produce a very uneven surface, are very noisy and are difficult to keep clean. With the decrease in cost of brick and asphalt streets they have almost gone out of use and very few new pavements of cobblestones are being laid.

The use of stone blocks as pavements is very common in the larger cities where they are used on streets of heavy traffic. Sandstone, limestone, granite and trap blocks are utilized. The sizes vary, the range in dimensions in American cities being as follows: width, 3 inches to 5 inches; length, 6 inches to 14 inches, and depth, 5 inches to 8 inches. The construction of the stone block pavement is the same as that of the brick pavement with such minor changes as the difference in size and shape of the material make necessary. The edges of the blocks rapidly chip off and make a rough surface. This, however, gives good footing for horses so that the stone blocks can be used on steeper grades than brick or asphalt pavements. They are very noisy and it is difficult to keep such pavements clean.

WOOD BLOCK PAVEMENTS.

Wood blocks, either circular or square have been used extensively for pavements. The circular blocks wear round on top and have been generally discarded for the square blocks. The principal objection to the use of wood blocks is the rapidity with which they decay. This may be overcome in some measure by treating the wood with creosote; but this volatilizes and washes out so that it retards, but does not entirely

prevent decay. Kreodone-creosote and Creo-resinate are substances obtained by adding other ingredients to creosote to prolong and increase the preservative action. Wood blocks are laid in the same manner as brick pavements. They expand considerably on becoming wet and the pavement will heave unless the expansion is taken up by tar joints as explained under the discussion of "rumbling" of brick pavements. The chief merit of the wood block (rectangular) is its quietness; its defects are its slipperiness, its lack of durability when untreated and the expense when treated. They are also very absorbent and are considered unsanitary on this account. The cost of rectangular wood block pavements will be generally somewhat higher than that of paving brick.

THE ASPHALT PAVEMENT.

The nature of asphalt and its properties have been discussed briefly in Chapter III of this report and more fully by Hutchison in Bulletin No. 2, of this Survey.

The use of asphalt for paving purposes in this country has increased very rapidly. The growth of the industry is shown by the following statistics:

In 1880 there were 300,000 square yards of sheet asphalt pavement; in 1885, 1,800,000; in 1890, 8,100,000; in 1895, 21,500,000; in 1900, 38,000,000. By far the greater portion of the asphalt pavements of the United States are made from the Trinidad or Bermudez Asphalts, the native rock asphalts being used for only a small per cent. In Europe, which in 1900 had 3,000,000 square yards of asphalt pavements, rock asphalt is used almost exclusively.

ADVANTAGES AND DEFECTS.

The advantages of the asphalt pavement as given by Richardson[24] are as follows:

"1. It does not disintegrate under impact or attrition, and consequently produces neither dust or mud.

"2. It can be kept perfectly clean if the proper efforts are made to do so.

"3. It has an impervious surface and does not absorb filthy liquids, as is the case with wood blocks.

"4. It affords the best foothold for horses except under occasional conditions.

24. Richardson, Clifford, The Modern Asphalt Pavement, p. 355.

"5. Traction on such a surface can be carried on with a smaller expenditure of force than on any other form of pavement.

"6. Its wearing qualities compare more than favorably with granite and exceed those of any other form of pavement under heavy traffic.

"7. Deterioration in a standard asphalt pavement is of a kind that can be readily and economically met owing to the simplicity of making repairs, something that cannot be done satisfactorily with any other form of pavement.

"8. Cuts in the pavement for underground work can be replaced in a manner which makes the repairs undistinguishable from the original surface, where they are quite evident in the case of other pavements.

"9. It increases the actual and rental value of all real estate abutting on streets where it is laid to a larger extent than any other form of pavement."

In the above Richardson has made the best possible case for the asphalt pavement. These points may all be true for the properly constructed or perfect asphalt pavements, but from the writer's observation the great majority of pavements of this type fall far short of perfection. The proper construction of the pavement and the mixing of the surface coat require much skill and patience. This is probably the principal objection to the use of asphalt. *As usually* laid the pavement is open to the following objections:

1. It is not very resistant to heavy traffic, in the majority of cases proving inferior to brick pavements in this respect.

2. In wet or sloppy weather it becomes very slippery and affords poor foothold for horses.

3. The expense for maintenance is very high.

4. In making cuts for underground work, the surface is very seldom put into as good condition as before cutting.

5. Patched places seldom wear well and can usually be easily told from the original surface.

6. The first cost is high.

7. It softens and is easily worn through in hot weather and is liable to chip or crack in extremely cold seasons.

CONSTRUCTION OF THE ASPHALT PAVEMENT.

The construction of the base or foundation of the asphalt pavement does not differ materially from that of a good macadam pavement. The subsoil should be properly graded and drained by side

ditches, and in the case of wet or swampy soils by cross trenches. The method of construction and materials for the drains will depend very largely upon the soil and climatic conditions and cannot be gone into fully in this connection. Especial care should be taken in swampy soil or in places where fills have been made to secure a firm foundation. Cracks often result in asphalt pavements on account of the settling of the foundation after the pavement has been laid. The subsoil should, of course, be compacted by rolling.

THE FOUNDATION.

Foundations of various sorts have been used for asphalt pavements. The old surfaces of granite blocks, macadam streets, asphalt blocks, or brick streets and foundations of natural or Portland cement have been used.

Old Pavements. The use of old pavements as foundations is usually from a motive of economy. They are usually satisfactory if conditioned to the traffic that they are to receive. Old macadam and brick streets possess the advantage of being well compacted. It is difficult to alter the grade or crown of old pavements and in replacing the pavements it becomes less firm. Granite block pavement proves to be a satisfactory foundation where the subsoil is firm and where they are not reset.

The bituminous foundation possesses few advantages. It consists of 6 inches or more of crushed stone passing a two and one-half inch ring and not containing any particles passing a one and one-half inch ring. To the top part of this some bitumen is added to serve as a binder.

The objections to this foundation are that the stone of this size possess about forty per cent. of voids which cannot be filled by rolling. If enough bitumen is added to fill the voids it will be drawn to the surface by the sun's heat and soften the asphalt. The foundation possesses no stability or rigidity and responds to any settling of the subsoil. The porous structure permits the free passage of water and gases. The binder and surface cannot be removed without destroying the foundation.

A novel form of the bituminous foundation has been used on the pavements at Lawton, Oklahoma. The pavements are laid of native rock asphalt and the foundation is made of the poorer asphaltic rock which is removed from the pit as stripping. The material is broken into pieces of varying sizes and spread on the street and compacted by rolling. The plan has not been fully tested, but it does not seem

to promise well. The rock is rather soft and contains widely varying percentages of asphalt. The voids are by no means all filled by rolling and in spite of the asphalt it contains the foundation is porous. The varying hardness of the rock makes it very difficult to roll to a smooth surface. As the material must be shipped considerable distances as well as be hauled to the cars from the quarry in wagons, it is hard to see how it can be built much cheaper than a concrete foundation especially where crushed stone can be obtained in the near vicinity. While it may prove satisfactory on trial it seems to the writer that there is a strong probability that where the foundation is very rich in asphalt that it will be drawn to the surface and soften the surface sheet. This foundation cannot be an improvement on the concrete foundation and stands a chance to be much less satisfactory and its use seems questionable to say the least.

The Concrete Foundation. This is composed of natural or Portland cement concrete. The method of preparing the concrete varies, but is usually approximately as follows: The mixture consists of one part of cement, three parts of sand, two or three parts of gravel and four or five parts of broken stone. The stone usually is of such a size as to pass in any direction through a two and one-half inch ring and be retained on a one inch screen. The gravel is to fill the voids of the stone as stone and sand alone is found to bridge and resist compaction. If gravel is hard to obtain, as good, or even better, results may be had by using graded sizes of stone instead of the more uniform size. The sand should be sharp and angular and free from clay or loam. Crusher screenings have been used for sand with good results. Both natural and Portland cements have been used, but the latter gives more uniform results and is to be preferred. The natural cement is not uniform, is liable to expand after setting and is also likely to fail to set in cold weather.

THE LATERAL SUPPORT.

The lateral support is as essential to the success of an asphalt pavement as the foundation. The practice of putting in cement sidewalks and curbs before the pavement is laid usually gives a firm support, but it is liable to be weak about manholes, water and gas-boxes, against headers where the surface ends and against rails. Vibrations about manholes, and boxes can be avoided by using heavy castings and setting them on a concrete base which is allowed to set firmly before the foundation is laid. The prevention of vibrations next to car tracks is more difficult. The use of a very heavy girder rail laid on ties, both being imbedded in concrete to the level of the adjoining foundation, has

proved best. The cement should set firmly before traffic is allowed over the rails.

THE BINDER COURSE.

This course consists of broken stone, passing a one and one-fourth inch screen and a limited amount of fine material. This is coated with coal tar pitch or asphaltic cement and rolled to smoothness before the surface mixture is applied. The asphaltic cement should be just sufficient to give each piece of stone a coating. An excess is liable to collect in pools and soften the surface sheet. The amount of fine material should be sufficient to fill the voids of the crushed stone. The binder course is used to reduce the thickness of the surface coat and to prevent its displacement. The binder should not be allowed to become too cold before the surface coat is laid as this prevents the formation of a strong bond between the two coats. To lessen the cost of construction the binder coat is sometimes omitted and a coat of asphaltic paint is applied to the surface of the concrete foundation and the surface coat laid directly on this.

THE SURFACE MIXTURE.

This consists of asphaltic cement, sand and dust or filler. The amounts of these different materials that have been used in asphalt pavements vary widely, but Richardson[25] after a wide experience gives the following as a standard mixture:

TABLE 9.

Bitumen	10.5%
Mineral aggregate:	
Passing 200 mesh sieve (filler)	13.0%
Passing 100 mesh (sand)	13.0%
Passing 80 mesh (sand)	13.0%
Passing 50 mesh (sand)	23.5%
Passing 40 mesh (sand)	11.0%
Passing 30 mesh (sand)	8.0%
Passing 20 mesh (sand)	5.0%
Passing 10 mesh (sand)	3.0%

In this table the sand given as passing a given mesh sieve is understood as remaining on the sieve of next finer mesh.

Few sands occurring in nature give the grading required for the surface mixture, and it is usually necessary to mix two or more sands

25. Op. Cit. p. 332.

to get the proper grading. A large per cent. of the material passing the 200 mesh sieve should be an impalpable dust. Finely ground limestone dust has been used for this dust or filler with good results. The different grades of sand are mixed and heated and then mixed with the hot asphalt. The asphalt is usually the Trinidad or Bermudez solid pitch asphalts with sufficient residual oil to "cut" the pitch, that is to render it easily melted and of a more fluid nature.

The full description of the methods and machinery used in mixing and laying the surface mixture is too long and too technical to have a place in this report. For the complete discussion of these points the reader is referred to the book by Clifford Richardson, The Modern Asphalt Pavement[26] which has been previously cited.

THE USE OF THE OKLAHOMA ROCK ASPHALTS IN STREET PAVING.

As previously stated the asphalts of Oklahoma occur principally as impregnations of sandstone, limestone and shale. From what has been said concerning shale as a road material it will be seen that the shale asphalts are not suitable for use in pavements. The sand and lime asphalts have been used for this purpose to some extent. The usual practice is to use a surface mixture of equal parts of a sand asphalt containing a soft pitch or maltha, a sand asphalt with hard pitch and a lime asphalt.

METHODS OF CONSTRUCTION.

The construction of the foundation of concrete is the same as for the artificial sheet asphalt. No binder coat is used. The following specifications give the method of mixing and applying the surface coat or wearing surface.

"This wearing surface shall be constructed after the Standard Rock Asphalt Specifications: Viz., a mixture of, (1) Asphaltic Carbonate (Lime Rock Asphalt), (2) Asphalt Silica, containing soft bitumen, and (3) Asphalt Consolidated Silica, containing solid bitumen, but no mixture shall be used that does not contain at least 25 per cent. of Asphaltic Carbonate.

PREPARATION.

"The rock asphalt shall be pulverized in a hinged hammer pulverizer until no particle is larger than will pass a three-eighths-inch screen. When the material shall have been pulverized and mixed, it shall be

26. Published by John Wiley and Sons, N. Y. City.

heated to about 325 degrees Fahrenheit in a rotary mixer, and the hot asphalt carted to the street and dumped upon the concrete.

MANNER OF LAYING.

"The asphalt shall then be raked to a uniform thickness, after which it shall be compressed with a steam self-propelling roller (fig 26) having a weight of at least two tons, and not to exceed five tons, and the street shall be rolled and cross-rolled until a smooth and uni-

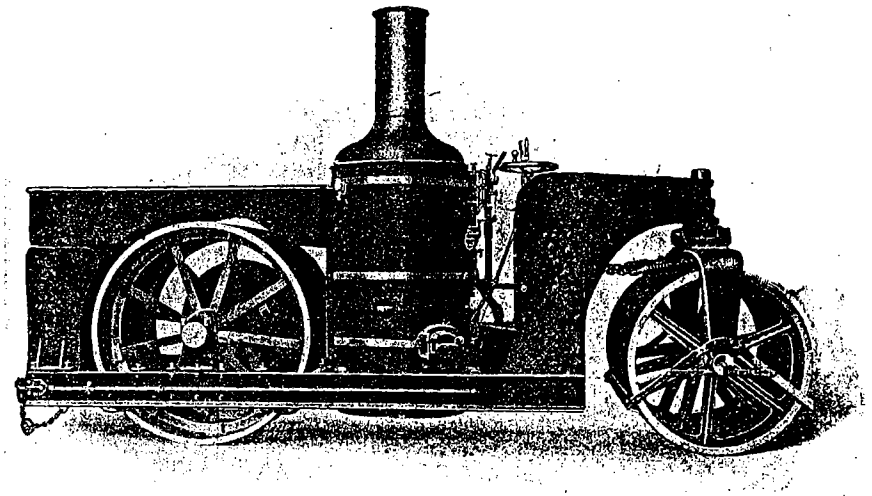

Fig. 26. Tandem Road-Roller.

form surface has been obtained. The wearing surface of the pavement must be not less than two inches thick after being rolled.

"During the process of cooling, the finished pavement shall be swept with Portland cement, so that it may have an agreeable color and appearance, then, after cooling, the pavement shall be turned over to traffic.

BITUMEN PERCENTAGE.

"As the amount of bitumen necessary in any rock asphalt depends upon the voids, or spaces, existing between the grains of mineral matter after the grains are adjusted to one another, no arbitrary percentage will be required in the case of tried material of which the quality has been demonstrated, and is attested by the affidavit of some city official establishing that it has stood two (2) years' satisfactory trial under traffic conditions. All samples of material shall be judged upon prev-

ious practical experience with said materials, and in the event of new, untried materials, the contractor shall file an analysis showing the following, viz.:

1. Grading of the silica in each specimen of bituminous silica.
2. Penetration of the saturating asphalt.
3. General analysis of each rock asphalt submitted.
4. Component rocks entering into the mixture.
5. Nature of the structure of the Lime Rock Asphalt.
6. Average voids in the mineral aggregate.

"The amount of bitumen necessary in any mixture depends upon the voids in the mineral aggregate, so no approximate percentage of bitumen will be required until the nature of the mineral aggregate is known and practical tests are made by the engineer."

A portion of the asphaltic limestone is not pulverized and enters the paving mixture in pieces that will pass a three-fourth inch mesh. These pieces cement firmly in the paving mixture because they have asphaltic surfaces. They reinforce the wearing surface mechanically and give the pavement a mottled appearance, very pleasing to the eye. They allow the use of a softer asphalt cement than could be used without their reinforcing qualities, and prevent cracking and brittleness, which are among the cardinal faults of asphalt pavement.

MERITS OF THE OKLAHOMA ASPHALT.

In his work previously cited, Richardson discusses the Oklahoma asphalt deposits and arrives at the conclusion that they are not fitted for use in the paving industry.

On page 230 he says "Deposits of bitumen in various forms are found widely scattered over this state. Among them are several which consist of bituminous sands. Although none of them are of any great value in the paving industry, it will be of interest here to show what their composition is in order that vain attempts may not be made to utilize them at great financial loss.

"Limestones saturated with bitumen are also found in the immediate neighborhood of the bituminous sands and as attempts have been made to utilize these in conjunction with the sands they will be described at the same time."

In discussing a bituminous sand from the Buckhorn district he says (page 231), "The material has been combined with the limestone, a description of which follows, and fairly successful pavements have resulted from the combination in Kansas City, Mo."

In his conclusion he says (page 240), "From what has been said in our descriptions of the Oklahoma bituminous deposits it is evident that the only conclusion that can be drawn in regard to them is that they are of little industrial interest with the possible exception of the grahamite. The deposits, although large in amount, taken as a whole, 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 reply to his criticisms it may be said that the pavements of Oklahoma asphalt are giving excellent results and are being used more extensively now than ever before. They have been used in Kansas City, Kansas and Kansas City, Mo. The following opinion of the city engineer of Kansas City, Kansas, sets forth the results of their use in that city. In a statement dated May 25, 1909, he says: "We have some of this pavement that has been down over ten 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 Co. and Water Co'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 fiifteen 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.

"When the wearing surface is first put down it is sometimes disappointing to the inexperienced as it appears much more granular than the ordinary asphalt and has surface cracks after being rolled, but with a little traffic over it the cracks disappear and the whole cements together into one solid sheet, without becoming too hard or slippery. After the cement or lime dust has worn off the surface the particles of lime rock show white, giving a pleasing 'mosiac effect.'

"The material used in this city comes from Ardmore, Oklahoma."

(Signed) R. L. McAlpine.

The streets of Ardmore, Oklahoma, are paved with this material

and are the best asphalt streets which have been observed by the writer. They have been laid six years and show practically no signs of deterioration although exposed to moderately heavy traffic. They were laid without cement gutters and even along the sidewalks where the dirt of the street collects there is no disintegration. The surface is still firm and very little affected along the street car tracks.

Concerning the Ardmore pavements Mr. S. F. Peckham, Chemist to the Department of Finance of New York City, in his book on Solid Bitumens[27] 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 the hottest days in August, it was 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, 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."

Of this mixture, the following pavements have been laid:

In Kansas City, Mo.	About 15 miles.
In Kansas City, Kansas	About 15 miles.
Sedalia, Mo.	West Seventh St.
Paris, Texas	1 mile.
Ardmore, Oklahoma	3 miles.
Sulphur, Oklahoma	½ mile.

27 Page 287.

There are under construction or contract in:

Kansas City, Kansas	100,000 sq. yards.
Norman, Oklahoma	28,000 sq. yards.
Ardmore, Oklahoma	22,000 sq. yards.
Ft. Worth, Texas	41,000 sq. yards.

The streets of Lawton, Oklahoma, are paved with a natural rock asphalt from Ada, Oklahoma, which is giving good satisfaction. This is not a mixture but one asphalt rock which seems to fulfill the requirements.

The amount available of these asphalt rocks, which are suitable for paving, while not unlimited, are much larger than one would suppose from reading Richardson's work and is sufficient for all demands likely to be made upon them for many years.

In view of these facts it seems to the writer that Richardson is unfair to the Oklahoma product and that he is not justified in his statement when he says that they are not of value in the paving industry and that they are of little industrial interest.

ASPHALT NOT SUITABLE FOR PAVING.

While it has been shown that many of the asphalts of Oklahoma are suitable for paving material, some are not and a word of caution concerning their use and exploitation may not be out of place. Some of the asphaltic deposits, especially the sands of the younger rocks in the southern part of the State are too soft and contain too much paraffin to be used as paving materials. The "asphalts" of the Trinity sands especially are more akin to paraffin than to true asphalts. Many of them soften and run in the sun's heat and when handled or pressed into a ball, merely "grease" the hands instead of sticking to them. Such materials are totally unfit to enter into the composition of a paving mixture and attempts to develop such deposits will do more harm than good to the asphalt industry of the State. Some of the deposits of this southern region possess sufficient true asphalt to be used as the "soft sand," i. e. to supply the maltha or soft pitch, in a paving mixture but none have been observed by the writer which contain the hard pitch necessary to the street surface mixture. In another connection (page 58) the use of these softer asphaltic sands in the preparation of what may be called oiled or bituminous earth roads, is suggested.

Even for this purpose those asphalts which contain much paraffin will be of little value and those deposits which contain an *asphaltic* oil, or maltha should be used.

Large deposits of pure bitumen of the nature of grahamite and gilsonite occur in veins in the Ouachita Mountains in the vicinity of Tuskhoma, Page and Antlers. These solid black substances containing a large percentage of fixed carbon. They have not been used in paving.

CHAPTER V.

D LAWS AND ROAD ADMINISTRATION

INTRODUCTION.

As the nature and amount of road improvement depends very largely on the road administration and road organiaztion and these upon the road laws of the State, the road law of Oklahoma is given in full.

ROAD LAWS OF OKLAHOMA.

Special Committee Substitute for House Bill No. 39-96 by Putnam of Oklahoma and Smith of Caddo, as amended by the Senate.

AN ACT

DECLARING SECTION LINES, PUBLIC HIGHWAYS AND PRESCRIBING METHOD OF OPENING HIGHWAYS FOR PUBLIC USE, MAKING TOWNSHIP BOARDS, BOARD OF HIGHWAY COMMISSIONERS; AND PRESCRIBING THEIR POWERS AND DUTIES; PROVIDING FOR THE APPOINTMENT OF ROAD SUPERVISORS AND DEFINING THEIR POWERS AND DUTIES; PROVIDING FOR ROAD DUTY, AND FOR LEVYING TAX FOR ROAD AND BRIDGE PURPOSES; PROVIDING FOR WORKING COUNTY AND STATE CONVICTS UPON THE PUBLIC HIGHWAYS; PROVIDING FOR THE VOLUNTARY FORMATION OF ROAD DISTRICTS, FOR THE CONSTRUCTION OF IMPROVED HIGHWAYS; AUTHORIZING COUNTIES AND TOWNSHIPS TO ISSUE BONDS FOR ROAD AND BRIDGE PURPOSES; PROVIDING FOR THE APPONITMENT OF A COUNTY ENGINEER AND PRESCRIBING HIS POWERS AND DUTIES; REPEALING ALL LAWS CONFLICTING WITH THE PROVISIONS OF THIS ACT, AND DECLARING AN EMERGENCY.

Be it Enacted by the People of the State of Oklahoma:

Section 1. All section lines in the State of Oklahoma are hereby declared public highways. The public highways shall not be less than thirty-three feet nor more than sixty-six feet in width.

Section 2. The township boards shall have power and authority upon their own motion to open and establish public roads on section lines only in their township, where the right-of-way can be obtained

only by amicable settlement, and pay for such right-of-way shall be made out of township funds.

Section 3. The County Commissioners shall have power and authority upon their own motion to open and establish public roads on section lines anywhere in the county and obtain the right-of-way therefor, either by amicable settlement or condemnation proceedings as provided by law.

Section 4. Whenever there is public necessity therefor, the county commissioners shall, upon the petition of the township board or upon the petition of the resident freeholders of the township, open and establish any public road in such township along the most practicable lines, with due regard to the distance between objective points, cost of construction and maintenance and cost of right-of-way. The county commissioners shall, in any manner they deem proper, determine the public necessity for such road; provided, however, that whenever a majority of the resident freeholders of any municipal township, who are legal voters, shall petition the county commissioners to open and establish any public road in said township, they shall do so by any lawful method, and such petition shall be conclusive evidence of the public necessity therefor.

Section 5. Whenever a public road is to be opened and established the County Commissioners shall always have power and authority to obtain the right-of-way by amicable settlement. But before any such settlement shall be concluded the terms thereof shall be published in the regular way in general proceedings of the county commissioners. Should as many as five taxpayers of the township wherein such right-of-way lies within ten days after such publication, present in writing a remonstrance objecting to the price to be paid for right-of-way, then the County Commissioners shall certify such fact to the County Judge, who shall appraise such right-of-way and make return thereof under oath at the next meeting of the County Commissioners. Thereafter the County Commissioners shall have full power and authority to conclude the settlement for such right-of-way, but shall pay no higher price than the appraisement thereof.

Section 6. The right-of-way for any public road shall be paid for by the township in which such right-of-way lies; provided, where such right-of-way runs along municipal township lines the cost shall be borne equally by each township. The County Commissioners shall certify to the Township Board the price of such right-of-way, whether same is fixed by amicable settlement or condemnation proceedings, and upon receipt of such certificate the Township Board shall draw warrants on the proper officers for a sufficient amount to cover such price. The cost incident to any proceedings to obtain right-of-way, except the price of the land and damages, shall be paid by the county.

Section 7. Any petition of the County Commissioners to open and establish any public road, shall definitely state where such road is desired, and the width desired.

Section 8. The County Commissioners shall at the time of establishing public roads make an order fixing the width thereof, not less than thirty-three feet nor more than sixty-six feet, and definitely describing such roads.

Section 9. The County Clerk shall make and keep a record of all public roads in the county, showing the location and width thereof and when same was officially established.

Section 10. By virtue of their office the Township Board of each municipal township in this State shall be and are hereby made highway commissioners for such township, and shall have supervision and control over all roads and highways within their respective Township, and a majority vote of such highway commission shall govern in all proceedings, and the Township Trustee shall be chairman of the Board of Highway Commissioners.

Section 11. Each member of the Board of Highway Commissioners shall receive as compensation for his services relating to roads and highways two dollars per day for each day actually and necessarily engaged in work not to exceed ten days in any one year, which shall be paid out of the road and bridge fund of such township in general township warrants drawn on the proper officer by the Township Board.

Section 12. Said Board of Highway Commissioners shall have power, and it is hereby made their duty, to divide their township into a sufficient and convenient number of road districts to consist of not less than four square miles each, and shall cause a record to be made accurately defining the boundaries and number of each road district as well as all alterations made in any of such districts.

Section 13. By virtue of his office the Township Clerk of each Township is hereby made clerk of the Board of Highway Commissioners of such Township and shall keep a true record of the proceedings of all meetings of such Board of Highway Commissioners and shall keep a correct account of all moneys and property belonging to each road district in his Township and all amounts expended for road work therein, and a true account of all funds received and disbursed by said Board in and for each road district within his Township and said records shall be open to inspection by any resident taxpayer of said Township at any meeting of said Board.

Section 14. On the first Monday in January of each year the Board of Highway Commissioners shall appoint one road supervisor for each road district within their respective Townships, who shall hold his office for one year and until his successor is appointed and qualified, unless sooner removed by said Board of Highway Commissioners.

Section 15. Each road supervisor so appointed shall be a resident taxpayer of the road district in which he is appointed and before entering the discharge of the duties of his office shall take an oath for the faithful performance of his duty as such supervisor, and shall execute a bond to the Township in which he is appointed, in a sum not less than double the amount of money that will probably come into his hands at any time during his term of office, with two or more sureties, the amount and sufficiency of the bond to be approved by the Highway Commissioners, conditioned for the faithful discharge of the duties of his office, and the accounting for all funds coming into his hands as such supervisor, which bond shall be by him forthwith caused to be filed in the office of the clerk of said Highway Commissioners. The approval of such bond shall be indorsed thereon by the Chairman of the Highway Commissioners. The Highway Commissioners shall have power to fill by appointment any vacancy in the office of road supervisor within their township.

Section 16. Each road supervisor so appointed shall perform all duties required by law and carry out the orders and instuctions of the Board of Highway Commissioners of said Township, and shall receive as compensation for his services as such supervisor the sum of two dollars ($2.00) for each day actually and necessarily engaged in such road work, not to exceed forty days in any one year, which shall be paid out of the road and bridge fund in general township warrants drawn upon the proper officer of Township Board. Provided, that no sum shall be allowed any road supervisor for services rendered until he has filed with the Board of Highway Commissioners a statement, verified by his affidavit, showing the days upon which such work was performed. Provided, further, that such supervisor shall not be entitled to charge or receive any compensation whatever for a number of days equal to the number required of other persons of his road district liable to road duty.

Section 17. Every male citizen of this State between the ages of twenty-one and fifty years who shall have resided in this State thirty days, and who is not a county or township charge and who has not performed road duty elsewhere in the State in that year shall be subjected to road duty of four days of eight hours in each year: Provided, that any person of whom any road duty is required may furnish a substitute satisfactory to the road supervisor to work out said duty and one day's work of man and team shall be equivalent to two days' work of man alone; provided, further, that any person liable for road duty may, in lieu of said labor on the roads, pay at the time he is warned to work in cash at the rate of one dollar and a quarter ($1.25) per day in lieu of said duty required of him. The road supervisor shall have authority to refuse to accept any substitute sent to work in the place of any person warned to work when such substitute is unsatisfactory to him, and to discharge any person warned to work or any substitute sent in lieu of such person when he fails to perform reasonable services and obey the instructions of the road supervisor.

Section 18. It shall be the duty of each road supervisor immediately after his appointment, and on the first day of January and July of each year thereafter, to prepare a list, alphabetically arranged, of all persons in his road district subject to road duty, and who resides therein, and he shall file said list with the Township Clerk of his Township. Immediately after the preparation and filing of such list the Clerk of the Township Board shall arrange such names in a book to be kept for that purpose, of all names turned in by such road supervisor. All persons, corporations and individuals are hereby required, upon application of the road supervisor to furnish to said supervisor the number of persons in his, her, its or their employment who are subject to road duty under the provision of this Act, and in the event of a wilfull refusal, failure or neglect so to do within ten days after such demand in writing shall be guilty of a misdemeanor.

Section 19. Said supervisor shall call out all able bodied male persons not insane, idiotic, deaf, dumb or blind, who are residents of such district, subject to road duty between the first day of January and the thirty-first day of December of each year. The supervisor shall require such persons to work on the highways of such district eight hours each day and to furnish in such labor any tool that the supervisor may direct if the demand therefor be reasonable. Any person able to perform an ordinary day's labor shall be deemed able bodied within the meaning of this Act, although the person may be in some respects disabled.

Section 20. Such supervisor may require any person liable to road duty who is the owner of a team, plow or wagon to furnish the same and a driver in such labor on such highways and such person shall receive credit for two days' labor for each day's service by such driver and team and shall be given a receipt by such supervisor accordingly.

Section 20A. Any road supervisor who shall issue and deliver to any person his receipt giving credit for work done on highways in his district when such person to whom or for whom such receipt is issued has not actually worked or caused work to be done for the full time that such receipt gives credit for at the rate of eight hours for one day's work, or has not paid the commutation money as provided by law, shall be deemed guilty of a misdemeanor and on conviction therefor fined not less than ten nor more than fifty dollars for each such receipt so issued.

Section 21. Such supervisor shall notify each person in his road district subject to road duty of the time and place of working on such highways at least three days prior to the time designated for such work. Such notice shall be in writing and may be delivered per-

sonally to the person served or left at his usual place of residence. A copy of such notice shall be retained by the supervisor and may be admitted as presumptive evidence of such notice in any court within the county in which such road district is located.

Section 22. If any such person, or his substitute, after appearing, shall remain idle or not work faithfully, or shall hinder others from working, such offender shall for every such offense forfeit the sum of $1.25 to be collected from such person as other fines and forfeitures herein specified and such person or his substitute shall be discharged by the supervisor without credit for any part of the work he may have done.

Section 23. Any person liable to road duty who shall fail, neglect or refuse to appear, after having been notified as provided in Section twenty-one of this Act, shall be deemed guilty of a misdemeanor and upon conviction shall be fined in a sum not less than ten dollars ($10.00) nor more than fifty dollars ($50.00) or by confinement in the county jail not less than ten (10) days nor more than thirty (30) days or by both such fine and imprisonment in the discretion of the Court, but such prosecution shall not relieve the defendant from further road duty.

Section 24. On application to the Board of Highway Commissioners of any Township any person liable to road duty may be exempt therefrom if it be shown that he is unable from bodily infirmities to work thereon, and that he is too poor to pay the commutation therefor; Provided, that before any person shall be excused by the provisions of this section, he shall make the statement provided herein under oath.

Section 25. It is hereby made the duty of the Board of Highway Commissioners to require the road supervisor of any road district to work out upon the public highways of the district, fifty per cent. of the road duty of any district before the first day of July of each year and the remaining fifty per cent. before the first day of January following.

Section 26. It is hereby made the duty of the Board of Highway Commissioners of each township to furnish the supervisors of such township with sufficient and necessary papers, books, notices, receipts, etc., to carry out and put into force the provisions of this Act.

Section 27. It shall be the duty of the road supervisor of each road district to cause to be removed or destroyed all noxious weeds before same mature seed, and cut all brush, growing on the public highway.

Section 28. The Board of Highway Commissioners shall hold regular meetings on the first Monday of January and July of each year and on such other days not exceeding eight, in any one year, as the board may deem necessary for the proper conduct of their office.

Section 29. The township board of any township in this State shall levy a general road and bridge tax on all taxable property within their respective townships not to exceed five mills on the dollar of such taxable property, and such taxes shall be collected in the same manner as other taxes are now collected by law, and the funds to the credit of any township shall be turned over to the Township Treasurer and shall be expended as the Board of Highway Commissioners may in their discretion provide.

Section 30. Whenever it becomes necessary to remove fences or other property located on the right-of-way of public highways for the purpose of opening and improving the same, the road supervisor shall give thirty days' notice in writing to the owner of such property or the occupant thereof, to remove the same, and if not removed within the specified time, he shall proceed to remove the said property.

Section 31. That all bridges, culverts and roads shall be at least fourteen feet wide, and all bridges and culverts not more than twenty feet in length shall be under the control and supervision of the Board of Highway Commissioners of such township and the road supervisor in whose district such bridge or culvert is situated, and all bridges more than twenty feet long shall be under the control and supervision of the Board of County Commissioners. Said bridges to be built by the County Commissioners at such places as may be necessary for the public convenience. In addition to the compensation already allowed by law, the County Commissioners shall receive three dollars for each day actually and necessarily spent in overseeing bridge work. Provided, that no Commissioners shall receive pay for such work for more than sixty days in any one year.

Section 32. Nothing in this Act shall prevent the Board of Highway Commissioners in any township from letting any piece of road or bridge work by contract to the lowest responsible bidder or bidders, and for this purpose they may cause notice to be posted in three of the most public places in such township, or by publication in some newspaper printed in such county for at least two weeks next before the date when such contract will be let, and the proposals or bids may be received under such regulations as they may prescribe at a time and place to be designated by them in such notices for the improvement or repair of any of the highways or bridges in such township, and in all such cases such Board of Highway Commissioners shall adopt such regulations as to extent of improvement or repairs, the terms of payment and the time of commencement and completion thereof, as they may deem proper, and such Highway Commissioners may reject any or all bids. Such work shall be under the supervision of the Board of Highway Commissioners of such township, who shall make payments on such contract according to the terms thereof out of the road and bridge fund of their respective townships.

Section 33. The Board of County Commissioners of each county in this State are hereby authorized and empowered to appoint a Highway Engineer within their respective counties at the first meeting of such Commissioners after the passage and approval of this Act and at the first meeting of such Commissioners after the first day of January of each year thereafter, and said County Engineer so appointed shall serve until the first day of January following his appointment and until his successor is appointed and qualified; Provided, that where competent and not otherwise incapable of performing the duties of County Engineer, the person so appointed shall be the County Surveyor.

Section 34. Before entering upon the performance of his duties, the County Engineer shall execute and deliver to the County Commissioners a bond in such sum as may be fixed by the Commissioners, with sufficient surety to be approved by them, conditioned upon the faithful performance of his duty as such highway engineer, and that he will account for and deliver to his successors in office at the expiration of his term, all books, papers and other property belonging to the county road districts thereof.

Section 35. The County Engineer shall receive such compensation as may be fixed by order of the County Commissioners of his respective county, not to exceed five dollars per day for each day actually and necessarily spent in conducting the affairs of his office.

Section 36. The County Highway Engineer shall be a resident of the State of Oklahoma, and shall reside in the county in which he is appointed, and shall maintain his office at the county seat of such county, and shall have a practical knowledge of civil engineering. He may be removed from office by the County Commissioners upon the grounds of incompetency, neglect of duty or for any other good and sufficient cause.

Section 37. The County Highway Engineer shall, when requested by the County Commissioners or the Board of Highway Commissioners or Road Supervisor within his respective county, give such instructions or advice with reference to the construction, building or repairing of any roads or bridges in his respective counties, and shall not receive compensation for any such instructions or advice.

Section 38. When requested by the County Commissioners or the Board of Highway Commissioners of any township, said Engineer shall personally inspect the condition of any of the roads, culverts and bridges within his county, and shall upon their request make such surveys and perform such other duties in connection with his office as may be required as herein provided, and such County Engineer shall, if required, make his report of such examination in writing, together with such recommendations as he may offer relative to the construction, repairing or building of any such road or bridge. And the township in which

such services are rendered shall pay to the county the amount due for said Engineer's services out of the road and bridge fund of such township.

Section 39. Any person subject to road duty may be exempt therefrom by paying to the supervisor of his road district one and 25-100 dollars for each day he is liable to work thereon, and in that case he shall receive a receipt therefor from the supervisor. Said supervisor shall be authorized to employ some person or persons to work out such money at a rate not exceeding One Dollar and Fifty Cents per day on the roads of his district, or failing so to do he shall pay over all such money into the township treasury for the benefit of the road district, such money to be paid over at the first meeting of said board after the first day of January and July of each year.

Section 40. The Board of County Commissioners of any county in this State shall have authority to purchase such teams, vehicles, machinery, tools, portable lock-ups, and such other equipment as may be necessary for the employment of convicts or other labor upon the public roads; and pay for same from either the court or road and bridge fund.

Section 41. They shall have authority to work all convicts confined in the county jail upon the public highways in such county and to employ such guards and other assistants as may be required.

It shall be the duty of the sheriff to deliver upon the order of the County Commissioners to any person authorized to receive them, any person sentenced to and confined in the county jail either as punishment for crime or in lieu of payment of a fine and costs imposed.

Section 42. Any person working upon the public road in lieu of payment of fine and costs shall be allowed a credit of one dollar ($1.00) per day on such fine and costs.

Section 43. The Board of County Commissioners shall have authority to receive by agreement with the city council, the prisoners of any city who have been sentenced by city prison for a crime committed or in lieu of payment of fine and costs; provided, the Commissioners shall not pay for the services of such persons, except the cost of their maintenance.

Section 44. The Board of County Commissioners shall purchase supplies for feeding and maintaining county convicts while at work to the lowest and best bidder, after reasonable public notice shall have been given. No contract for furnishing supplies at a higher price than the ordinary selling price of the articles furnished shall be valid.

Section 45. The Board of County Commissioners shall furnish wholesome food in sufficient quantity and variety to all convicts working upon the public roads to maintain them in good health and vigor, and shall furnish medical attention when required.

Section 46. Any of the convicts, whether male or female, mentioned in this Act, may be required to perform service in or around the county jail or other place of confinement, or at any camp or commissary where convicts are kept or fed.

Section 47. The Township Board of any township is hereby authorized and empowered to issue bonds not to exceed three per cent. of the taxable property of said township as ascertained by the last assessment for county purposes for the purpose of securing right-of-way and for improvement by draining, grading, graveling, or macadamizing. Said bonds shall bear interest at the rate of not exceeding six per cent. per annum, payable semi-annually, principal and interest to be payable at such place as the Township Board shall direct. Such bonds shall be made payable in twenty-five years, and redeemable in not less than ten years, and be issued in amounts not less than five hundred ($500) dollars nor more than one thousand ($1000) dollars as the Township Board may direct, and shall be sold at such times and in such amounts, as in the opinion of the Township Board seems best; provided, that none of such bonds shall be sold or disposed of for less than par value. Said bonds shall be issued by the Township Board, and signed by the President, and attested by the Clerk thereof.

Section 48. The Township Board is hereby authorized and required annually, after said bonds are issued to levy, in addition to all other taxes authorized by law, a tax on all taxable property in said township sufficient to create a sinking fund to provide for the payment of said bonds, and the interest, as the same respectively mature, which tax shall be certified to the County Clerk of the county and collected the same as other taxes and when so collected shall be turned over to the Township Treasurer of said township for the purposes above set forth.

Section 49. Before any bonds mentioned in this act shall be issued the Township Board shall submit the question of issuing bonds to the qualified electors of said township, thirty days' notice of which shall have been given by the posting notice, in writing, in ten public places in such township. The election shall be held at the usual places for holding elections in such township and all electors favoring the issuing of bonds shall have written or printed on their ballots "Issue of bonds for road improvements" "Yes"? and those opposed to issuing the bonds shall have written or printed on their ballots "Issue of bonds for road improvements" "No"? and should three-fifths of the electors voting on said proposition vote "yes" then such township board shall be authorized to issue bonds and not otherwise.

Section 50. The Board of Prison Control is hereby authorized to provide transportation and all necessary stockades, guards, portable prisons, implements, conveyances, teams, tools, tents and all other equipment necessary for working convicts on the public roads of this State;

Provided, that said convicts shall be equally distributed as near as practicable among the supreme court judicial districts of the State, and shall be worked among the various counties therein as provided in this Act.

Section 51. Said work shall be performed on such roads as are designated by the County Commissioners of the county in which the work is done, and the work shall be of such kind and character as may be determined by the Board of County Commissioners; Provided, that the county shall bear all expense of the costs of material for road improvement done within their respective counties.

Provided, further, that the State convicts assigned to work upon such roads shall be divided into groups of not exceeding one hundred men in each group, and only one group shall be worked in one county at the same time, and that no group shall be permitted to work in any one county for a longer period than five months in any one year, nor shall any two groups be worked in any county until all counties of this State making application for the same shall have received their proportion of work from said convicts.

Section 52. Road improvement districts consisting of not less than eighteen square miles in area may be created in any county upon a written petition signed by fifteen per cent. of the qualified electors of the proposed road improvement district being filed with the county clerk of the county in which said road improvement district is sought to be created, and seventy-five per cent. of the costs of improving any road within such district shall be borne by said district, and twenty-five per cent. by the county; provided, that should any county refuse to vote bonds to pay its portion of costs of improving roads in road districts as provided in this Act nothing herein contained shall prevent any road district in such county from paying the entire amount of costs of such improvement.

Section 53. For the purpose of raising funds with which to meet the county's portion of improving roads in improvement road districts as provided in this Act, and before any improvement road districts are formed in the county, the several counties upon petition of twenty-five per cent. of the qualified voters of the county, as shown by the last general election held in said county, may by a vote of three-fifths of the votes cast upon the proposition, issue bonds not in excess of two per cent. of the assessed valuation of such county. The maximum amount of bonds provided for may be authorized by vote at any one time and issued from time to time as funds are needed to pay the county's portion of such cost of construction; provided, that the life of such bonds shall run from the date of their issuance, permanent record of which shall be kept in the office of the County Clerk.

Section 54. Immediately upon filing a petition for the creation of

a road improvement district the County Clerk shall notify the County Commissioners of such petition, and the County Commissioners shall meet within ten days, and shall by order create the district as prayed for in the petition, and each district shall be numbered consecutively in the order of its creation. The function of the Board of County Commissioners in the creation of road districts is limited to the investigation of the number and qualification of the signers of said petition, and if they are in compliance with the provisions of this Act, then the County Commissioners shall enter the order establishing and creating such road improvement district, and shall order an election to be held for the purpose of issuing bonds to pay the road district's portion of the expense, which in no case shall be in excess of five per cent. of the total valuation of the taxable property in said district; they shall designate the place and time of holding such election, appoint the necessary election officers, and pass all orders and resolutions necessary for the holding of such election and upon the report of the commissioners thereof, shall declare the results, and if a three-fifths majority of all the votes cast at such election shall favor the issuance of such bonds, the Board of County Commissioners shall issue the same with the full endorsement and authority of the county, and shall provide for the levy and collection of such taxes from such road improvement districts as may be necessary to meet the interest and principal installments of the bonds provided for, and if said bonds shall fail to receive three-fifths of all the votes cast at said election, then the road improvement district shall thereby be dissolved. The question shall be submitted in the following form: "Shall the Board of County Commissioners of ..... county be authorized to issue bonds running for twenty-five years and bearing interest at five per cent. per annum in a sum to pay three-fourths of the cost of road improvement in ..... road improvement district number ..... Such sum to be the amount actually necessary and not in excess of five per cent. of the said valuation of all the property in said road improvement district."

Section 55. Upon any road improvement district voting bonds as provided herein, the Board of County Commissioners shall direct the County Engineer to make a preliminary survey of the established roadway to be improved in said road improvement district. Said engineer shall file with the County Clerk in a formal report preliminary estimates of the cost of improvement of said highway with the notes of the surveys thereof within ten days from the time of his appointment for such work where the surveys and estimates cover not more than eighteen miles of highway and within a proportionate time for greater mileage. When in the judgment of the Engineer or Surveyor and the Board of County Commissioners it is best to divert any roadway from the previously established line, they may change the same and condemn as provided by law such land as is necessary. On the filing of said Engineer's report the County Clerk shall by application once in some

newspaper published in the county seat of such county give notice that a preliminary estimate of the cost of said proposed road improvement has been filed, and that the Board will receive offers of contribution toward the cost of constructing or improving said highway from the sources hereinafter designated for a period of ten days from and after the date of said publication. If any city or town through its proper officer shall within ten days represent to the Board of County Commissioners that such city or town will vote upon the proposition of making a donation of not less than ten per centum of the estimated costs of the construction of road improvement as heretofore provided, then the time for receiving offers of contribution shall be extended pending such election, which shall be held at the earliest possible date under the law.

Section 56. Donations may be given and received for any road in this State. Cash contributions may be received from any source; any incorporated town or city may contribute not less than ten per cent. of the total cost of any roadway in any district out of any available fund or may issue bonds therefor; any owner of real estate in any county in which a permanent highway is proposed to be constructed or improved may contribute (in addition to other contributions he may offer) any amount not in excess of fifteen per cent. of the last assessed valuation of such real estate and have the same divided into ten equal annual tax installments on any parcel or parcels of real estate owned in said County, by filing with the County Clerk of the County such pledge of contributions in the following form, and all such donations accepted shall be paid by the County out of the good road fund, and when collected shall be returned to said fund.

To the Honorable Board of County Commissioners of ..... County. For the purpose of aiding in the construction and improvement of the proposed road (here giving full description of proposed improvement) in Road District No. ....., to be constructed along the following lines:

I hereby contribute ..... Dollars, to be divided into ten equal payments, each payment bearing interest at the rate of five per cent. per annum, payable annually, from date until paid, to be paid to the County of ....., and to be collected by the County Treasurer at the same time and in the same manner that the taxes on the following described real estate in the State of Oklahoma, County of ....., to-wit: (describing property fully) are collected, and in the event that said roadway is improved as above designated you are hereby authorized to assess each annual installment with the annual interest due against the property above described. Such levy shall have the same effect in all particulars as any tax levied against the property named:

In witness whereof ....., ha..... hereunto affixed ..... name.

(Signed)

State of ....., County of ..... ss.

Before me, a Notary Public, within and for said County and State on this ..... day of ....., 190....., personally appeared ....., to me known to be the identical person who executed the within and foregoing instrument and acknowledged to me that he executed the same as his free and voluntary act and deed for the use and purposes therein set forth. Witness my hand and official seal the day and year above set forth.

(Seal) .....

Notary Public.

My commission expires .....

From and after the filing of said pledge of contribution and its acceptance by the Board of County Commissioners the same shall become and be a lien upon said property, with all the effect of any tax that may be levied against the same, and shall be collected in yearly installments as specified.

Section 57. At the expiration of the time named the Board of County Commissioners shall meet and after deducting the bona fide contributions offered for the proposed road improvement, shall order that road to be built, or improved, and shall order the Engineer to prepare plats, surveys, plans, specifications, and all necessary data with itemized estimate of constructing the roadway to be built or improved, the original of which shall be filed with the County Clerk.

Section 58. All donations and funds received for the purpose of this Act, for and on behalf of any road improvement district shall be placed in the hands of the County Treasurer and by him disbursed upon the order of the Board of County Commissioners in accordance with the contract of construction.

Section 59. The Board of County Commissioners shall provide all roads improved under the provisions of this Act with suitable bridges of a permanent and substantial character and shall keep and maintain same in repairs.

Section 60. Within five days from the filing of the surveys, plans, specifications and estimates, the County Clerk shall advertise for bids for the building or improving of the highway in accordance therewith; said advertisements shall contain a brief statement of the location of the highway, the time and place of opening bids, where the specifications can be inspected, and that a bond or a guarantee shall be given that the roadway shall be improved in accordance with the plans and specifications.

Section 61. On the date advertised the Board of County Commissioners shall meet and in open session receive and open all bids; each bid shall be in the form prescribed by the Engineer and duly signed by the bidder; any system of hard road surface that meets the requirements of this Act may be specified by the bidder in his proposal. Every bid must be accompanied by a certified check for an amount equal to five per cent. of the proposed contract price and shall contain an agreement to furnish a good and sufficient bond for the faithful performance of said contract in a sum equal to one-fourth of the proposed contract price. The Board shall award the contract to the lowest responsible bidder, provided, however, that all bids may be rejected in the discretion of the County Commissioners if they are materially greater than the cost as estimated by the Engineer.

Section 62. After the contract is awarded the Board shall forthwith enter into a contract with the successful bidder in accordance with the provisions of this Act, and the said Board is authorized and empowered to execute such contracts and to pass and adopt all orders and resolutions necessary to carry out the provisions of this Act, and to secure the construction or improvement of said roads and highways, and may authorize the closing of any part of any road where necessary during construction.

Section 63. All acts and parts of acts in conflict herewith are hereby repealed.

Section 64. For the preservation of the public peace and safety, an emergency is hereby declared to exist by reason whereof this Act shall take effect and be in force from and after its passage and approval.

LOCATION OF ROADS.

In section I, all section lines are declared public highways and the width is established as not less than 33 nor more than 66 feet wide. Section 2 and 3 provides for the obtaining of right of way and opening of the section line roads. The advantages and disadvantages of section line roads have been discussed in another connection, but it may be repeated here that the attempt to follow section lines in the hillier portions of the State will result in poor roads on account of the steep grades and the difficulty of maintenance on these grades.

Provision is made, in Section 4, for the location of roads not on section lines. On petition of the voters of a township or of the township board, the county commissioners shall open any road for which there is public necessity. The county commissioners shall judge of the public necessity for such roads except when the petition is signed by a majority of the voters of the township. In this case the petition is taken as conclusive evidence of the public necessity for the road. In the location of such roads the distance between objective points, expense of construction and maintenance, and cost of right of way are to be considered. It is urged that the locations of such roads be left to competent engineers, as the factors which enter into the selec-

tion of the most practicable route are altogether too complex to be handled successfully by one not well trained in such work.

THE ROAD UNITS.

Under the law there are practically three road units: (1) the township, (2) the county, and (3) the road improvement district.

THE TOWNSHIP AS A ROAD UNIT.

The Township Board is made the Board of Highway Commissioners for their township and are given complete control of road affairs in that township. They appoint Supervisors for each of the road districts (not the same as the road improvement districts mentioned above) which shall not consist of less than four square miles. Each supervisor shall be a resident taxpayer of his district. The Township Board is given power to levy taxes for road purposes. They may also let contracts for building roads to the lowest responsible bidder or bidders. The Township Board may issue bonds not to exceed 3 per cent. of the taxable property in the township and to levy taxes to create a sinking fund to provide for the payment of these bonds and the interest upon them.

THE COUNTY AS A ROAD UNIT.

While not really a road unit, the county, through the County Commissioners, has power to open a road on the section line in any township, and on petition to locate roads not on section lines. The County Commissioners also have charge of building all bridges over 20 feet in length. They also have power to appoint a *Highway* Engineer for the county. This engineer must be a resident of the county in which he is appointed. It is specified that he shall have a practical knowledge of Civil Engineering. The pay of the Highway Engineer is to be fixed by the County Commissioners, but cannot exceed $5 per day for the time actually engaged in road work. It is provided that where competent the County Surveyor shall act as Highway Engineer. The County Commissioners shall also have power to work convicts upon public roads.

ROAD IMPROVEMENT DISTRICTS.

Where roads are desired in a certain portion of the county, this portion (not less than 18 square miles) upon petition of the majority of the legal voters, may be made a road improvement district by the County Commissioners. The roads are then laid out by the Highway Engineer and built under the direction of the County Commissioners. Three-fourths of the cost is paid by the district and one-fourth by the county.

OBJECTIONS TO THE ORGANIZATION.

From what has been said it may be seen that the township is practically the road unit of Oklahoma. The county has practically no power of initiative, but must act only upon petition of voters. The principal objection to the township unit is that it is too small. Important roads seldom lie wholly in one township and the improvement made on a principal highway in one township will often be rendered practically worthless by failure on the part of other townships to make improvements. The township is often powerless to purchase the machinery needed for road construction and maintenance on account of the lack of funds. The township cannot raise sufficient funds to employ a competent engineer.

The provision for road improvement districts may relieve this condition to some extent, but the same remarks hold true in large measure of the road improvement districts.

The provision for a Highway Engineer is good, but it seems to the writer that it is a mistake to require that he be a resident of the county in which he is appointed. The construction and maintenance of roads is of sufficient importance to require the services of the best engineer available no matter where he may live. The further provision that, where competent, the County Surveyor shall be Highway Engineer does not seem satisfactory. The question of his competency is left entirely to the County Commissioners and they may translate the term competent in any way they see fit. It is safe to say that few of the County Surveyors of Oklahoma, or of any other state, are really competent Highway Engineers, since years of training and experience in road location, construction and maintenance are required before one can be a competent Highway Engineer.

The states which have the best road systems are those which have abandoned the township as a road unit and made the county or preferably the state, itself, the unit. With the larger unit *road systems* may be planned, instead of isolated roads with little or no relation to each other. A truly competent engineer can be employed, who can give his whole time to road construction and maintenance. The larger units can control enough funds to buy the necessary machinery such as graders, stone crushers, etc., which are often out of reach of the township. The township unit in public roads is much the same thing as if the portions of a railroad system which happened to be in different counties or states should have totally separate managements, and be constructed by different engineers, who were not subject to any higher authority. Even with the county unit there should be a state highway engineer who should have power to co-ordinate the work in different sections and not merely to suggest what should or should not be done.

THE STATE HIGHWAY DEPARTMENT.

This office of State Highway Commissioner was established by the last legislature by House Bill No. 318, the text of which is as follows:

Enrolled.

HOUSE BILL NO. 318.

By Committee on Roads and Highways.

AN ACT

Establishing a State Department of Highways, Providing for the Appointment of a State Highway Commissioner and Prescribing His Duties and Compensation; Authorizing a State License Fee on Automobiles to Create a Fund for Establishing and Maintaining the Department of Highways.

Be It Enacted by the People of the State of Oklahoma:

Section 1. A state highway department is hereby created and established, and the governor of the state shall appoint a state highway commissioner, to be approved by the senate, who shall hold office for a term of four years. The commissioner so appointed shall be a person of recognized knowledge in the construction and maintenance of improved roads. Said state highway commissioner shall receive a salary of twenty-five hundred dollars ($2,500) per annum, and shall be allowed actual traveling expenses, not exceeding fifteen hundred dollars ($1,500) per annum. Said commissioner shall, before entering upon his duties, file with the secretary of state his oath of office, which shall be the same as is prescribed for other state officers, and shall furnish a bond in the sum of five thousand dollars ($5,000) for the faithful performance of his duties, said bond to be approved by the governor, and he shall give his whole time and attention to the duties of his position. A vacancy in said office shall be filled in the same manner as is prescribed for original appointment.

Section 2. The said state highway commissioner shall be provided with suitable office rooms at the state capitol, which shall be kept open at such times as the business of said department and the convenience or interests of the public shall require.

Such office shall be conveniently and properly furnished, and shall be the repository for all the records of said state highway department.

Section 3. It shall be the duty of the said state highway commissioner to consider all questions relating to the general policy of the state highway department, and the conduct of the work in general; to act for the state highway department in all matters relating to recommendation, estimates and appropriations; to prepare standard specifications for construction of roads; to employ an assistant engineer or

engineers and such clerical force as may be necessary to properly conduct his department, at an annual expense not to exceed $5,000, and to exercise authority in all matters relating to plans for the building and maintenance of improved public highways.

Section 4. The state highway commissioner shall keep a record of all proceedings and orders pertaining to the business of the office and of the department. He shall keep on file copies of all plans, specifications and estimates prepared by the office. He shall cause to be made and kept a general highway plan of the state, and shall collect such information as the department may require relative to mileage, character, construction and condition of the highways and bridges in the state, and shall investigate and determine the methods of road construction best adapted to various sections of the state ,and shall establish standards for the construction and maintenance of improved highways in various counties, giving due regard to the topography, natural conditions, character and availability of road-building material.

Section 5. The state highway commissioner may, with the approval of the state board of affairs, purchase for the state all necessary and office equipment or instruments that may be needed for the purposes of this act.

Section 6. County commissioners or county engineers of the several counties of this state, and the officers of all cities, towns and townships in the state, who now have, or may hereafter have by law, authority over the public highways and bridges, shall, upon the written request of the state highway department, furnish said department with any information relative to the mileage, cost of building and maintenance, condition and character of the highways under their jurisdiction, and with any other needful information relating to the said highways

Section 7. For the purpose of carrying out the provisions of this act, and to create a fund for the maintenance of this department, a state license fee of one dollar shall be charged annually the owner of each automobile owned by him. Said license fee shall be collected by the state highway commissioner, and shall be used for the payment of the salary of the highway commissioner, provided for in this act, and the expenses of said office. Any surplus from the above said amounts to be paid into the state treasury. The state highway commissioner shall issue to the owner of said automobile the license duly signed and sealed with the seal of his department, together with proper description for the proper identification of such automobile license, record of which, together with the number of the license, shall be made in the office of the state highway department. And no automobile so owned shall be operated within the state without having paid such annual state license, under penalty of the law in such cases made and provided. Non-residents operating automobiles within this state shall be

required to pay the same license as provided for in this section. Nothing in this act shall be construed to interfere with the right of cities and towns to license and regulate automobiles through the streets of such cities and towns.

Section 8. The state highway commissioner shall keep an accurate account of all the moneys received from licenses, as provided for in this act, and shall make a true and verified account of all receipts and expenditures of his office to the governor of the state, on or before October 1 of each year.

Section 9. Nothing herein shall be construed as limiting the power of the state to construct and build state highways and pay all costs of constructing and maintaining same under direction of the state highway commissioner.

Section 10. All acts and parts of acts in conflict herewith are hereby repealed.

This is a step in the right direction but it seems to the present writer that so far the principal result is to add a fourth road unit, the state, to the three already in existence and to still further complicate the road organization instead of simplifying it. The State Highway Department can draw up plans for highways and bridges in different counties of the State but the counties can use their own pleasure about following such plans. The State department can outline systems of roads but the building of such road systems may be prevented by the refusal of any township involved to enter into the plan. In short the Highway Department as it now exists seems to have very little executive power but seems to be entirely an advisory body. It can do a great amount of good in this way, however, and with this department already in existence it should be easier to secure the passage of laws completing the state organization on the basis of county or larger units under the control of the State Highway Department. This will end the condition of divided authority now existing and be the greatest advance which can be made in the Road administration of the State.

THE LABOR TAX.

Section 17 makes every male citizen between 21 and 50 years subject to road duty for four days each year. The supervisor of labor tax is inherited from England and is practised in almost all of the states. Although common there are many objections to this custom. Shaler[28] speaks of it in these terms:

"There is probably no other feature in our road system which has so far served to maintain the low state of our American road making as this 'corvee' or forced-labor system on the highway. It has bred, in a systematic manner, a shiftless method of work; it has led our

28. American Highways.

people to look upon road building as a nuisance. There is no situation in which the American workman makes so unsatisfactory appearance as when he is endeavoring to do the least possible amount of labor which is to count as a day's work on the highways of his district." This view may be correct in some regions, but is undoubtedly overdrawn for many localities. Many townships with the labor tax have roads superior to adjacent townships with cash tax. The objectionable feature of the labor tax arises from the fact that the majority of laborers are engaged in farming and are unable to spare the time when the roads are in best condition to be worked, if their crops demand their attention. However, it is difficult to see how the cash tax would help this matter as the farmers would still have to be employed to do the work. A few laborers might be employed the year around, but this is impracticable especially under the township organization.

The solution of the difficulty seems to lie in two directions: First, as the farmers come to realize the advantages of good roads to themselves, they will be willing to give a full measure of time and effort to road work instead of "endeavoring to do the least possible amount of labor which is to count as a day's work" as Shaler puts it. The price allowed ($1.25 per day) is not as much as they could make at private work, but on the other hand, the benefits to be obtained from the road improvement are worth much more than the difference in wages. In the second place, much of the success of the labor tax system depends upon the road supervisor. He should be one of the best men of the district; should insist upon a good day's work being done and should see that the work is done on the sections of road where it will do most good. The great trouble with the majority of the work done under the supervisor system is that it is wasted in doing a poor grade of temporary repair work in patches on the road. If only a small section of road is placed into permanently good condition each year, the final result is much better than if a few temporary improvements are scattered over the district.

STATE-AID ROADS.

Some of the states within the last few years have adopted the plan of giving state aid to road construction. These roads are built under the direction of the State Highway Commissioners, and upon petition of adjacent property owners. The proportion paid by state, county and township varies in the different states using this plan. In Massachusetts the state pays 75 per cent., and the county 25 per cent. of the expense; in New Jersey, the state pays thirty-three and one-third per cent., the county fifty-six and two-thirds per cent. and the township 10 per cent.; in New York the state pays fifty per cent. and the county thirty-five per cent. and the township fifteen per cent. New York is the only state giving state aid for the improvement of earth roads. The arguments in favor of state aid are that it secures centralized control

and establishes uniformity in construction and maintenance; that it makes the cities which profit by improved roads bear part of the expense; and that it compels state wide corporations to bear their share of the expense of improved roads. The plan of state aid is practicable only where there is a state Highway Commission or other similar department.

THROUGH-STATE ROADS.

There has been some agitation recently for the construction of permanently improved roads entirely across the state from north to south and from east to west, intersecting at Oklahoma City. Such roads would be advantageous for automobile tours or for advertising purposes, but their practical value would not be commensurate with their cost. They would have to pass through considerable areas which are sparsely settled and where the communities could not bear the expense of the construction. The same amount of money applied to roads radiating from the larger towns in different parts of the state would do vastly more good. It should be borne in mind that since the introduction of the railroad very little through traffic is carried on over the public highways and that while in times past through roads such as the National Road were very important, that they are so no longer. If such roads are built they should at least be paid for, wholly or in part, by the State.

SUMMARY.

1. Section lines are made public roads by the State law, but provision is made for roads not on section lines. Section lines should be followed where practicable, but should not be where the country is hilly, or where for any reason better roads can be had by leaving the section lines.

2. The width of the road may be 33 feet to 66 feet. The latter is much wider than is ordinarily necessary or advisable for county roads.

3. The road authority is divided, there being four units, the township, the Road Improvement District, the County and the State Highway Department. The County possesses no power of initiative except in bridge building and the functions of the State Highway Department is at present mostly advisory. This system is at fault in that the township is too small a unit to plan road systems, to purchase the proper machinery or to employ competent supervision. Better results are had where the county is the local unit and where there is active supervision by the State. There can be no great improvement in road conditions until there is better organization.

4. The roads are maintained by a labor tax, i. e. each able bodied male citizen must furnish four days' labor on the roads annually. This system is successful if the work is regarded in the proper spirit by the citizens and if it is well administered by the road supervisors.

CHAPTER VI.

ROAD MATERIALS OF OKLAHOMA

INTRODUCTION.

For the purpose of this report the State is divided into portions or districts as follows:

1. Eastern district.
2. Western district.
3. Cretaceous Area or Southern district.

In this chapter each of these districts is considered in reference to location and subdivisions, to available road material and to road conditions. Descriptions of practically all the quarries now operating are given together with reports of tests upon the stone which were made by the Office of Public Roads.

THE EASTERN DISTRICT.

THE LOCATION AND SUB-DIVISIONS.

The eastern district includes all or part of the following counties: Kay, Pawnee, Payne, Creek, Okfuskee, Seminole, Pontotoc and Coal and all lying east of them except the southern parts of Atoka, Pushmataha and McCurtain counties, which are in the Cretaceous area.

For clearer discussion the district is divided into the following areas, beginning at the north:

1. The Mississippian Area, or Ozark Uplift, the extreme northeastern part of the State.
2. The northern Pennsylvanian Area, the Pennsylvanian rocks north of Arkansas River.
3. The Southern Pennsylvanian Area, the Pennsylvanian rocks south of Arkansas River.
4. The Ouachita Mountain Region.

The location of these sub-divisions is shown on Plate III at the end of the book.

THE MISSISSIPPIAN AREA OR OZARK UPLIFT.

LOCATION OF AREA.

The Mississippian rocks outcrop as the southwestern extension of the Ozark Mountains, in the extreme northeastern part of the State. They occupy the following counties: all of Delaware, and the adjacent portions of Craig, Mayes, Cherokee and Adair.

STRATIGRAPHY.

The surface rock of most of this area is the Boone chert, a formation which consists of chert and limestone and which contains the lead and zinc deposits of the region. The deeper valleys have cut through the Boone chert into the underlying Devonian and, in some cases, through the Devonian into the Silurian and Ordovician. The exposures of the older rocks are relatively small and unimportant. The Boone chert is surrounded by a belt of the Pitkin and Morrow formations of Chester age.

Older Paleozoic rocks. These are exposed in the sides of the deeper valleys and gorges of the area. They consist principally of sandstones and shales with subordinate amounts of limestone. They contain little material suitable for road building and as the Boone chert always occurs in the same vicinity, it will be used in preference.

At Spavinaw, the Ordovician is cut by a red granite dike, 75 feet thick and 500 yards long. This material would probably be good both for building and road material, but at present is too far from transportation to be available.

The Boone chert. This formation consists of chert and limestone and has a thickness of about 300 feet. Some of the heavier limestone ledges have a thickness of 20 to 30 feet. All of this material should be good for macadam roads. For this purpose, the limestone and chert need not be separated, but can be crushed and used together. The mixture should be better than either stone used alone as the chert would give great resistance to wear while the limestone would furnish the bonding and cementing properties.

Almost any hillside in this area will give a good supply of material for local road building and furnish good sites for a portable crushing plant. Many of the streams contain considerable deposits of gravel which can be utilized for improved roads at very slight expense.

The Pitkin formation contains some limestones, that are thick enough to be available for road material and also some flaggy limestone which has been used for sidewalks and curbing. The quarry of the Muskogee Crushed Stone Company at Keough, 2 miles northeast of Fort Gibson, is probably in the Pitkin limestone, which is the top of the Mississippian in this section. The quarry is located on the St. Louis and San Francisco Railroad. A quarry floor of about one-half acre has been made with a face of 100 feet in height and 600 feet in length. The stone is screened by rotary screens to the desired size. The material has been used for concrete and also for macadam paving in Muskogee, and is reported to be giving satisfaction. No tests were made for this report.

ROAD CONDITIONS.

The surface of this area is rather rough due to the resistance of the Boone chert to weathering. The land is not very fertile and the country is thinly settled. The Boone chert and the limestones of the Pitkin and Morrow formations furnish a wealth of material for macadam roads and it is easily accessible to practically all the region. The natural roadways are easily the best in the State. The Boone chert outcrops along the roads and bowlders have rolled on to the roads and have been crushed by traffic, thus forming a natural macadam surface. The mixture of limestone and chert, as has already been noticed, makes an excellent road material.

So far practically nothing has been done toward permanent road improvement, the only improvements reported for the area at the close of the year 1909 being 4 miles of gravel macadam in Ottawa County. As the population increases and the counties begin to recover from excessive expenditures incident to their formation, there will undoubtedly be many miles of macadam roads constructed in this part of the State.

THE PENNSYLVANIAN AREA NORTH OF ARKANSAS RIVER.

LOCATION AND AREA.

This region (Plate I) lies west of the Mississippian area just described, east of the Redbeds and north of Arkansas River. It comprises all or part of the following counties: Kay, Osage, Washington, Tulsa, Rogers, Nowata, Craig, Mayes, Wagoner, Muskogee and Sequoyah.

STRATIGRAPHY.

In a recent paper[29], Gould, Ohern and Hutchinson have divided the Pennsylvanian system of Oklahoma into four groups.

1. The Muskogee Group outcrops over an area which is bounded on the west by a line extending southwest from Chetopa, Kansas, past Claremore, Okmulgee, Henryetta and Calvin to Ada; on the north and northeast by the Mississippian area and on the south by the Arbuckle Mountains, and the Choctaw fault.

2. The Tulsa group, whose outcrop lies between the western

29. Research Bull. No. 3, Okla. State University.

boundary of the Muskogee group and a line extending southwest from Lenapah past Nowata, Tulsa, Beggs and Okemah to near Holdenville.

3. The Sapulpa group, whose outcrop lies between the western boundary of the Tulsa group and an irregular line which extends west of south past Pawhuska, Cleveland and Cushing to Chandler.

4. The Ralston group lies between the western boundary of the Sapulpa group and the base of the Permian. In this report the lower Permian limestones of Kay County are taken up in connection with the Ralston group on account of their characteristics, although stratigraphically they belong to the western division of the State. The southern portion of the Ralston group and part of the Sapulpa group are Redbeds and are considered in that connection.

THE MUSKOGEE GROUP. 30.

This group consists principally of sandstone and shales with occasional lentils of limestone. None of these lentils have been worked out thoroughly enough to permit of complete discussion, but it is improbable that any of them will be developed unless for local use, for the limestones are not thick enough for development in a large way.

THE TULSA GROUP.

The only formation in the Tulsa group which is available for road material is the *Oologah formation,* named from the the town of Oologah, where it is well exposed along the west bank of Verdigris River. The formation occupies a narrow belt along the river in this vicinity, but widens out opposite Claremore and near Catoosa is six or seven miles wide. The belt narrows again near Broken Arrow and continues to Arkansas River, the limestone being largely replaced by sandstones and shales.

The Oologah is about 100 feet thick and consists of a succession of bluish cherty limestones separated by thin bands of black, fissile shale. The limestone becomes siliceous in the south part of the outcrop. Northeast from Talala the limestone splits, the two parts being separated by a black shale which thickens to the Kansas line.

A quarry is developed in this formation at Garnett, (fig. 27), a switch on the St. Louis and San Francisco Railroad a few miles west of Catoosa. No tests of the stone have been made, but it appears to be suitable for road material except on very heavy traffic roads.

THE SAPULPA GROUP.

This group consists of three formations as follows: The Lenapah limestone, the Curl formation, and the Wann formation, the latter

30. For the discussion of the stratigraphy of the groups of this region, I am indebted to Research Bull No. 4, Oklahoma State University, by D. W. Ohern.

subdivided into the Hogshooter limestone member, the Copan member with the Dewey and Avant limestone lentils, and the Stanton limestone member. These formations apply only to the northern portion of the area under consideration, the divisions of the southern portion being the Skiatook formation, and the Ramona formation with the Dewey, Ochelata and Avant members. Of these the Lenapah limestone, the Hogshooter limestone, the Dewey and the Avant limestones are considered in this connection.

The Lenapah limestone extends from the Kansas line south and southwest past Lenapah and Nowata to Tulsa. In the quarry 3 miles north of Lenapah it is over 30 feet thick, but the thickness decreases to 6 or 8 feet at Nowata and south of Nowata it is seldom over 30 inches thick. It is a dense, blue, partly crystalline limestone, containing an abundance of fossils. It has little chert. The only development of the limestone is at Lenapah where the Hickory Creek Lime and Stone Company has a small quarry and crusher.

The Hogshooter limestone member of the Wann formation is exposed along the west bank of Hogshooter Creek and occupies the slope to the eastward. It crosses Caney River 3 miles northeast of Ochelata and extends due south to Ramona, where it is exposed in the railroad cut south of town. The thickness of the Hogshooter is about 18 feet at the Kansas line, but thins to 6 or 8 feet along Hogshooter Creek and to 4 feet at Ramona. The limestone is massive near the Kansas line but becomes thin bedded and argillaceous toward the south. The Hogshooter is not worked and no tests have been made upon it.

The Dewey limestone lentil first appears near the center of Sec. 13, T. 28 N., R. 14 E., where it is about 3 feet thick. It thickens rapidly to the south and spreads over large areas in the vicinity of Dewey and Bartlesville. At the cement-plant quarry at Dewey it is 20 feet thick, southward from Caney River the outcrop narrows to near Ochelata and to Ramona and the thickness decreases to 15 feet. The Dewey is a bluish, semi-crystalline limestone, usually somewhat shaly, but often thick bedded. It has many seams of crystalline calcite and is very fossiliferous. No sample of this stone was secured for testing, but as it is so similar to the Avant the results would closely approximate those for that stone. A small crusher is installed between Bartlesville and Dewey, along the interurban line. The Dewey at this point consists of fairly hard crystalline beds 18 inches to 30 inches in thickness separated by shaly layers 6 to 10 inches in thickness. The shaly layers cause considerable waste and lessen the value of the stone for road material.

The Avant limestone lentil outcrops as a narrow band south from Bartlesville. It is exposed on top of the hills west and southwest of Ochelata and caps the hills southward from this point. It extends west along Bird Creek to Avant where it is typically developed. Near

Bartlesville it is only a few feet thick, but increases to 20 feet at Ochelata and to 40 feet at the Midland Valley quarry southeast of Avant. In character the Avant is very similar to the Dewey. It is blue in color, has pronounced seams of calcite and is very fossiliferous. In the vicinity of Avant it is massive and forms bold cliffs. The Midland Valley Railroad operates a quarry and small crushing plant 2 miles southeast of Avant. The rock is rather badly jointed and the joints are opened widely by solution and filled with clay. The report of the test on this material is as follows:

Sample No. 4383[31].

Location	Avant.	
Material	Limestone.	
Specific gravity	2.60	
Weight per cubic foot	162.	pounds.
Water absorbed per cubic foot	2.23	pounds.
Per cent. of wear	5.7	
French coefficient of wear	7.0	
Hardness	12.3	
Toughness	4.	
Cementing value	Good.	

Remarks: A soft rock with low resistance to wear, very low toughness and good cementing value. Not recommended except for very light traffic roads.

In the southward extension of the region discussed, the Lenapah, Dewey and Avant limestones continue to or beyond Arkansas River. All become thinner and the character of the rock changes considerably, the Avant becoming quite ferruginous, and the Dewey arenaceous.

Another limestone lens, appears in the Skiatook formation at Lost City on the south bank of Arkansas River 6 miles above Tulsa. Here it is 40 feet thick, but thins rapidly to the north, until 8 miles north of Tulsa it is only 8 feet thick. A quarry and crusher is operated at Lost City by the Lost City Stone Company of Tulsa. The workings are situated on a switch from the A. V. & W. Railroad. The stone is screened through rotary screens into bins or into cars on the side track. The principal use of the stone so far has been in concrete work.

The Stanton limestone member of the Wann formation is exposed on the slopes of the hills at and 2 miles west of Wann, and north of Copan and on Twin Mounds, 2 miles southeast of Copan. It is not exposed south of the latitude of Bartlesville. The Stanton in Oklahoma is 8 to 12 feet thick. It is a massive, bluish limestone, giving little chert on weathering.

31. The numbers given to the samples are those used by the laboratory of the Office of Public Roads of the Department of Agriculture. For the methods of making the tests, see Chapter III.

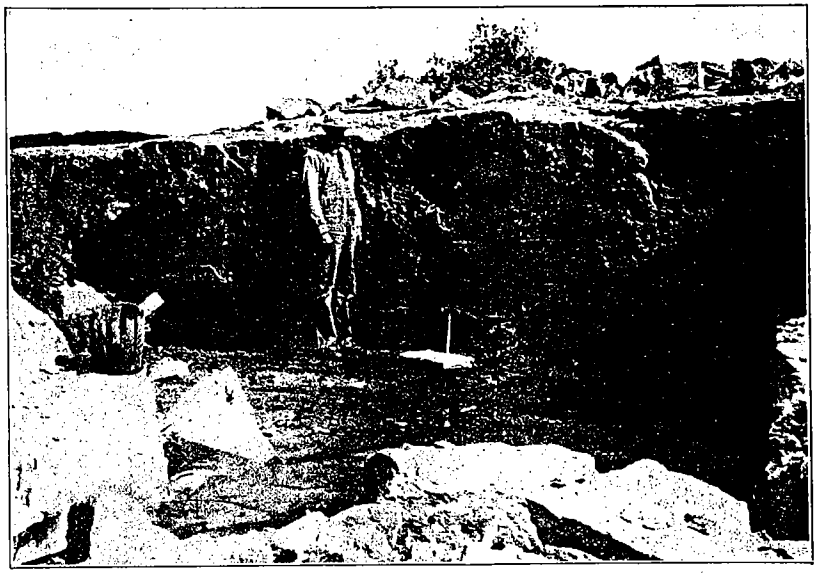

Fig. 27. Quarry at Garnett. (Oologah limestone)

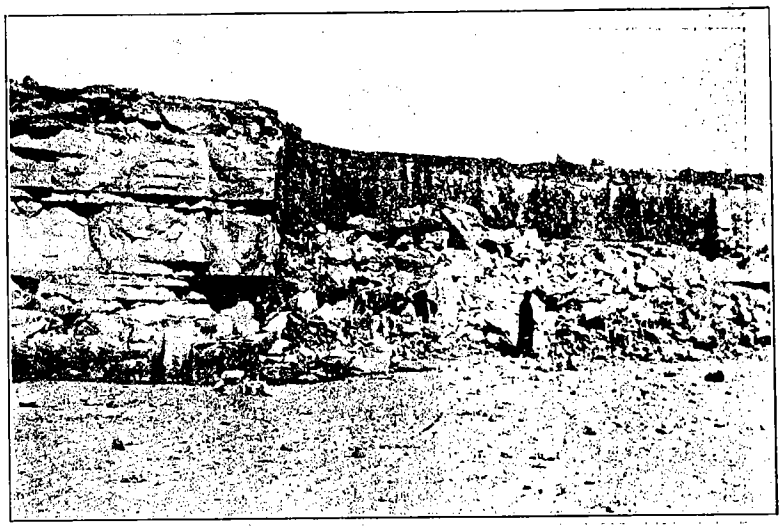

Fig. 28. Quarry at Uncas (Wreford limestone)

Fig. 29. Wapanucka limestone, at Wapanucka.

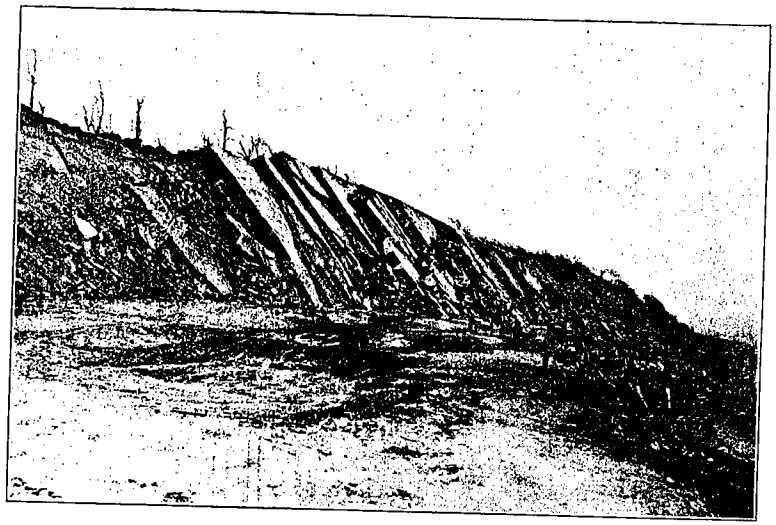

Fig. 30. Quarry at Chockie. (Wapanucka limestone)

THE RALSTON GROUP.

This group contains several ledges of limestone with shales and sandstones. The Pawhuska formation is taken as the base of the group. Just west of Pawhuska, this formation is exposed as two heavy ledges of limestone separated by a sandstone. The Midland Valley railroad cuts through the formation and gives good opportunity for development. The stone is hard and compact. A good crusher site is reported 1 or 2 miles west of Myers, where there is a ledge 15 to 20 feet thick of good firm stone. Limestone in abundance occurs along the railroad from Myers to Foraker. Near Foraker the limestone is 10 to 15 feet thick and contains considerable chert.

PERMIAN LIMESTONES OF KAY COUNTY.

THE WREFORD LIMESTONE.

The Wreford limestone enters the State from Kansas near Hardy, where it is about 15 feet thick. This limestone contains large quantities of chert in Kansas, but in Oklahoma it is almost a pure limestone. It can be developed at Hardy. At Ponca City it occurs in the slopes of the hills east of town where S. H. Lewis and Company of Emporia, Kansas, operate a quarry for building stone. This quarry is situated one and one-half miles northeast of Ponca City at the end of a spur track from the Atchison, Topeka and Sante Fe Railway. The stone occurs in two ledges, the top one 3½ feet thick and the bottom one 5 feet thick. The stone is cut by two sets of joints, approximately at right angles to each other and about 15 feet apart. These joints are badly affected by weathering and only a small portion of the upper ledge can be used. The stripping averages 5 to 6 feet. The quarry is equipped with 4 derricks and a gang saw.

The rock is a very soft limestone of a buff color. It is very porous and, in places, semi-crystalline. It has been used for buildings in Ponca City and other places, for ballast on the Santa Fe Railroad and for curbing in Oklahoma City. It is also used locally for fence posts, and the fine dust from the saw is used as fertilizer.

It is too soft to be considered available for a macadam road material. It might be used for the foundation course if a harder, tougher stone could be obtained for surfacing. Its use for curbing and sidewalks where there is much traffic is questionable owing to its extreme softness.

The results of the test of this stone follow :

Sample No. 4346.

Location	Ponca City, Quarry.
Material	Clay limestone.
Specific gravity	2.30

Weight per cubic foot	143. pounds.
Water absorbed per cubic foot	5.05 pounds.
Per cent. of wear	(Not enough for test)
French coefficient of wear	(Not enough for test)
Hardness	0.0
Toughness	3.
Cementing value	Fair.

Remarks: A very soft rock with very low toughness and fair cementing value. Not recommended for road building.

Another ledge of limestone crops out along the small creek at the foot of the hill below the quarry just described. The ledge shows a thickness of about 8 feet. The stone is a bluish-gray stone, more crystalline and less porous than the stone at the quarry. The stripping at the point observed would render working unprofitable, but detailed work should show other exposures with less stripping. The stone is much more pleasing in appearance than the buff stone, and is also somewhat harder and tougher but is still too soft for macadam material as is shown by the test.

Sample No. 4347.

Location	Ponca City.
Material	Limestone.
Specific gravity	2.45
Weight per cubic foot	153. pounds.
Water absorbed per cubic foot	3.77 pounds.
Per cent. of wear	5.7
French coefficient of wear	7.0
Hardness	8.3
Toughness	5.
Cementing value	Good.

Remarks: A soft rock with low toughness, low resistance to wear and good cementing value. Not recommended for road building.

Quarry at Newkirk. From Newkirk east one passes over a succession of limestones. The city of Newkirk is on the Herrington limestone, the hills to the east are of the Winfield limestone and the quarry near the foot of the hill is in the Fort Riley limestone. This quarry is located 4 miles east of Newkirk on the property of Charles Shaw. The limestone is in three layers, the top layer 3 to 4 feet, the middle layer 4 to 5 feet, and the bottom layer 2½ to 3 feet in thickness. Back in the hill the ledge appears solid, but still breaks into the three layers on quarrying. There is little difference in the different layers except that the top one is usually lighter colored than the others, due to surface leaching.

The stone is a rather soft, porous limestone, containing comminuted fossils. It is a buff to yellow color, the pores being filled with

dark yellow material. It has been used largely as a building stone in Newkirk and other towns of the vicinity, although its use is restricted on account of the haul by wagon from the quarry to Newkirk. The amount of this stone available in these hills is unlimited. The ledges higher up the hill are reported to be harder, but porous; these are also in the Fort Riley. The report of the tests on this material follows:-

Sample No. 4348.

Location	Shaw Quarry, east of Newkirk.
Material	Clay limestone.
Specific gravity	2.30 pounds.
Weight per cubic foot	6.79 pounds.
Per cent. of wear	9.9
French coefficient of wear	4.0
Hardness	0.0
Toughness	4.0
Cementing value	Good.

Remarks: A very soft rock with very low toughness, low resistance to wear and good cementing value. Not recommended for road building.

Uncas Quarry. The same stone is continuous to Uncas, 6 miles south and 1 mile east of the quarry described. For this distance the limestone comes almost to the surface and several outcrops of many acres in extent occur with little or no soil covering. The stone has been used with good results in building bridges and culverts in this section. At Uncas on the Eastern Oklahoma branch of the Atchison, Topeka and Santa Fe Railway, L. H. Lewis and Company of Emporia, Kansas, have installed a crushing plant and have a large quarry opening (fig 28). The stone here is harder, less porous and more crystalline than at the quarry east of Newkirk. There are 9 layers of stone ranging from 1½ foot or less to 7 feet in thickness. There are a few thin shale partings. The face of the quarry is about 25 feet in height. The stone is hauled from the quarry to the crusher in end-dump horse carts, where it is screened and run directly into the cars. A large Gates crusher with capacity of 500 tons per day is used. The amount of this stone available is unlimited for, as has been said, many acres are underlaid with this stone with practically no stripping.

A report of the test of this material follows:

Sample No. 4349.

Location	Uncas.
Material	Shell limestone.
Specific gravity	2.40
Weight per cubic foot	150. pounds.
Water absorbed per cubic foot	5.29 pounds.
Per cent. of wear	9.3

French coefficient of wear	4.3
Hardness	0.0
Toughness	3.
Cementing value	Good.

Remarks: A very soft rock with very low toughness, low resistance to wear and good cementing value.... Not recommended for road building.

THE WINFIELD LIMESTONE.

The Winfield limestone has been mentioned as occurring in the hills just east of Newkirk. At the quarry of Jesse Fagens 4½ miles northeast of town, it is a shaly limestone occurring in layers a few inches in thickness. It is quarried for flagstone and curbing. Many of the sidewalks, street crossings and curbings in Newkirk are of this stone. Where used as curbing it is usually set on edge and the water soaking into the bedding planes and freezing, causes it to crumble rapidly. The corners of the blocks used for street crossings grind off rapidly and the sidewalks show considerable tendency to shale off. In view of these facts it was not considered a suitable road material and no sample was secured for testing.

At Chilocco on the Indian school reservation, a small quarry is opened on the east side of the Atchison, Topeka and Santa Fe Railroad. There are 2 to 4 feet of hard crystalline limestone with a considerable number of geodes, underlaid by a soft, yellow, shaly limestone which grades downward into a black shaly limestone. The line between the yellow and black stone is irregular showing that the yellow color is due to the leaching out of the black rock. The top crystalline layer would make good macadam material, however, the quantity available is not sufficient for any but local use. Both the yellow and black stone is too soft for macadam material but the former stone has been used in the buildings at the Indian school with very satisfactory results. No samples of this stone were secured.

No limestones of economic importance occur west of Newkirk.

THE PENNSYLVANIA AREA SOUTH OF ARKANSAS RIVER.
STRATIGRAPHY.

All the limestones of this area mentioned in the discussion of the region north of Arkansas River disappear to the southward being replaced by shales and sandstones. A few persist beyond Arkansas River, but none of them are of importance for any distance south of Cimarron River.

In the neighborhood of Pawnee on the Eastern Oklahoma branch of the Atchison, Topeka and Santa Fe Railway, a thick ledge is shown which should be available for road material and several locations would be suitable for crusher sites.

Near Ripley on the same railroad a crusher is in operation. The quarry is located on a spur from the railroad 2 miles east of town. The stone is a very hard crystalline limestone occurring in layers about 1 foot thick with shale partings. The stripping is thick and this with the shale members makes it necessary to handle a large amount of waste material. A face of from 12 to 15 feet in height has been developed. The stone is run from the quarry to the crusher in gravity cars on tracks, and is crushed by a Gates crusher. The material has been used for macadamized streets in Guthrie. The screenings from the crusher have been used on the streets at Ripley and give a smooth firm surface. These limestones belong to the Ralston group, and the one at Ripley occurs near the eastern limit of the Pennsylvanian Redbeds.

The Sapulpa, Tulsa, and Muskogee groups south of Arkansas River consist of sandstones and shales. The Sapulpa group contains the easternmost extension of the Redbeds and a great thickness of shales and sandstones. The Tulsa group probably includes the Calvin sandstone, Wetumka shale, Wewoka formation and part of the Holdenville shales of the Coalgate quadrangle, a thickness of approximately 2000 feet. The Muskogee group thickens enormously and its outcrop consequently widens greatly south of Arkansas River. In the Muskogee quadrangle there are two formations, the Boggy and Winslow. In Coal and Hughes counties the following formations are shown:

Calvin sandstone	200 feet
Senora formation	500 "
Stuart shale	250 "
Thurman sandstone	200 "
Boggy shale	2000 "
Savanna sandstone	1200 "
McAlester shale	200 "
Hartshorne sandstone	200 "
Atoka formation	3000 "
Total	7750 feet

From this list of formations, it may be seen that the area contains little in the way of road material. There are occasional small limestone and chert lentils which will be of value for local use, but they are small and have not been mapped.

THE GRAVEL DEPOSITS.

A large bed of gravel occurs near Hotulke in the southwestern part of the Sapulpa group. It lies near the eastern limits of the Redbeds and seems to be an old river deposit. The deposit is located one-fourth mile from the Missouri, Kansas and Texas Railway at Harjo switch. There are about 80 acres known to be underlaid by this gravel

which varies from 2 to 15 feet in thickness. The gravel ranges in size from fine sand to pieces 2 inches in diameter. The larger pieces are principally water-worn chert and some limestone. The relative amounts of fine and coarse material vary considerably in different parts of the deposit. The gravel is very compact and must be shot loose, but when shot crumbles to pieces. The material is clean and free from loam except very near the surface. A small rotary screen is installed at the pit. The screened gravel is hauled to the switch at Harjo where it is loaded by means of a trap. It has been shipped to Shawnee and Oklahoma City principally for use in concrete, although it should make good macadam material.

A similar deposit is reported from Konawa, about 15 miles north of Ada on the same railroad. This may be an extension of the deposit at Hotulke or has been formed under similar conditions.

THE WAPANUCKA LIMESTONE.

This limestone is at the base of the Pennsylvanian rocks in southern and eastern Oklahoma. It appears from beneath the Trinity sands at Boggy depot and extends northwest to Wapanucka and to the northwest corner of the Atoka quadrangle. In the Coalgate quadrangle it appears in the extreme southeast corner. From this point it extends northeast past Limestone Gap and parallels the Ardmore branch of the Chicago, Rock Island and Pacific Railway to Hartshorne, here it turns east and extends almost to the Arkansas state line. The thickness in Limestone Ridge southwest from Hartshorne is about 200 feet, at Wapanucka about 125 feet while farther northwest it is only 30 feet. It finally grades into the Franks conglomerate. The western portion of the outcrop is shown on Plate II, and the eastern portion lies very close to the Choctaw fault. At Wapanucka the ledge is about 100 feet in height (fig. 29). Here it seems to consist of three layers, a layer of hard, crinoidal limestone at the base, and two heavy massive ledges of hard crystalline stone, the middle layer being blue, and the upper one buff in color. This would be an excellent site for a crusher as the Missouri, Oklahoma and Gulf and the Chicago, Rock Island and Pacific railways both pass near the ledge. A small lime kiln is installed at this place.

Quarry at Chockie. At Chockie, south of Limestone Gap, the Missouri, Kansas and Texas Railroad has had a crusher for several years, and has ballasted the right of way for many miles with this stone. The rock is a blue, cherty stone in layers of about 2 feet in thickness which is almost a chert at this place. The layers dip about thirty degrees to the southeast and are worked from the dip slope side (fig. 30). A heavy charge is used to break out the lower part of the layers, the ledge for the entire height of the quarry then slides down as fast as the lower part is broken out by small shots. The stone is hauled to the crusher in dump carts. The stone is crushed in a Gates crusher, screened

through rotary screens and run directly into cars. The report of the material follows:

Sample No. 4352.

Location	M., K. & T. Ry. at Chockie.
Material	Chert.
Specific gravity	2.60
Weight per cubic foot	162. pounds.
Water absorbed per cubic foot	0.65 pounds.
Per cent. of wear	2.7
French coefficient of wear	14.9
Hardness	19.2
Toughness	25.0
Cementing value	Fair.

Remarks: A hard and tough rock with high resistance to wear and fair cementing value. Should make a good road building material.

It is reported that the Cleveland-Trinidad Asphalt Company is planning to install a crusher where the railroad cuts through the limestone ridge one and one-half miles north of the Missouri, Kansas and Texas Railway crusher.

The quarry of the Choctaw Portland Cement Company is located about two and one-half miles south of Hartshorne in the Wapanucka limestone. The stone consists of two massive layers, an upper buff layer and a lower of blue stone. The amount of stone available is unlimited. The company is installing a Gates crusher of 600 to 800 cubic yards and smaller one of 200 to 300 cubic yards, daily capacity. Both the buff and the blue stone are dense, fine-grained, crystalline limestones. The buff seems to be somewhat tougher under the hammer. The lower portion of the blue stone contains some shale partings and near the base of the hill is a layer shale about 5 feet in thickness.

Reports of the tests on both stones follow:

Report of the test on the blue stone.

Sample No. 4351.

Location	Hartshorne, Okla.
Material	Blue limestone.
Specific gravity	2.65
Weight per cubic foot	165. pounds.
Water absorbed per cubic foot	1.14 pounds.
Per cent. of wear	4.4
French coefficient of wear	9.1
Hardness	16.6
Toughness	13.0
Cementing value	Excellent.

Remarks: A rock of medium hardness, medium toughness, medium resistance to wear and excellent cementing value. Should make a good road material.

Report of the test on the buff stone.

Sample No. 4370.

Location	Hartshorne.
Material	Buff limestone.
Specific gravity	2.70
Weight per cubic foot	168. pounds.
Water absorbed per cubic foot	0.31 pounds.
Per cent. of wear	Not enough for test.
French coefficient of wear	Not enough for test.
Hardness	16.8
Toughness	.8
Cementing value	Good.

Remarks: A rock of medium hardness, low toughness and good cementing value. Would probably make a satisfactory road material.

ROAD CONDITIONS IN THE PENNSYLVANIAN AREA.

Much of the surface of the northern portion of this area consists of a series of limestone ridges extending north and south with intervening valleys underlaid with shale. These shale valleys are rich farming land and the greater portion of the ridge land may be cultivated, although some of it is too rough for anything but pasture. In this section the limestone ridges furnish an abundance of material for macadam roads. Some of the limestone is very soft, but there is a large amount sufficiently hard for light or medium traffic roads. The value of the land for farming will make road building advisable and will provide sufficient funds to carry it on.

Farther south, the ridges die out as the limestones are replaced by shales and sandstones. For some distance the shales predominate and the country is more level, but the sandstones thicken to the south and produce a rougher topography. In Pittsburg, McIntosh, Hughes, Coal, Atoka, and Pontotoc counties, much of the surface is very rough and poorly adapted to farming.

In this region the road improvement will probably proceed more slowly than in the counties farther north, both on account of the scarcity of road material and on account of the sparsely settled condition of the land.

THE OUACHITA MOUNTAIN REGION.

This area comprises the following counties: northeastern Atoka, southwestern Pittsburg, south part of Latimer and LeFlore and the greater portions of Pushmataha and McCurtain.

The rocks of the area are principally sandstones and shales of great thickness. The section as given by Taff in the Atoka folio is as follows:

Jackfork sandstone:	Brown and drab sandstone, shaly sandstone, and thin shale beds	3800 feet.
Standley shale:	Bluish and greenish fissile shales, and massive and thin bedded friable drab sandstones	6100 feet.
Talihina chert:	Bluish, greenish, and white stratified flint and chert, cherty and clay shales. Black, brownish, and white stratified flint, chert and cherty shale with thin lentils of blue limestone	1150 feet.
Stringtown shale:	Black and blue shales with a bed of cherty shale	500 feet.

There has been very little published on the geology of this region so that it is impossible to discuss the distribution of the materials in detail. The Talihina chert is the only formation which contains much macadam road material. There are deposits of asphaltite at several localities in the region, principally near Antlers and Page. Most of this contains too much fixed carbon for it to be used as a paving material. The country is very rough on account of the mountains produced by the Jackfork sandstone and the principal roads follow the streams. Owing to these conditions, the country is very thinly settled and the need for improved roads is not so pressing as in other parts of the State. It will probably be many years before there is much done toward the extensive permanent improvement of roadways.

THE ARBUCKLE MOUNTAIN REGION.

LOCATION AND AREA.

This region includes all of Murray County except the extreme northern portion, the north half of Johnston County, the southern portion of Pontotoc County and the southwestern portion of Coal County. It is the smallest of the areas considered, but contains a wealth of road building material and will be the source of supply for much of the south central part of the State.

STRATIGRAPHY.

The Arbuckle Mountains consist of a great thickness of rocks, principally limestones, ranging in age from the Middle Cambrian to Middle Pennsylvanian. This great series is as a rule, conformable throughout, showing an immense lapse of time during which oceanic conditions existed. There were probably minor oscillations which brought the area of deposition to the surface for intervals, but there are no pronounced depositional unconformities within the series.

Unconformably below the sedimentary series, is the Pre-Cambrian granite and associated igneous rocks which now occupy the center of the area.

About the middle of the Pennsylvanian times, this region was uplifted, and folding and crumpling of the sedimentary series resulted, but the action was not great enough to produce metamorphism.

Since that time the region has remained above sea level and the vast amount of erosion, which has taken place, has removed the sedimentary rocks from above the granite in the center of the uplift leaving it exposed over a large area. This granite is encircled by the upturned sedimentary rocks beginning with the Cambrian sandstone next to the granite and extending to rocks of Middle Pennsylvanian age.

To the east and northeast the upturned strata lie unconformably beneath the later Pennsylvanian sediments which were deposited horizontally over them. The Redbeds of Permian age and the Cretaceous sands cover the older rocks on the west and south respectively.

Taff[32] gives the following succession of rocks beginning with the igneous rocks:

Pre-Cambrian granite and porphyry cut by dikes of other igneous rocks:

Formation.	*Age.*
Reagan sandstone	Lower and Middle Cambrian
Arbuckle limestone	Middle and upper Cambrian and Calciferous of the Ordovician
Simpson formation	Chazy and Stone's River
Viola limestone	Black River, Trenton, Richmond
Sylvan shale	Silurian about Medina
Hunton limestone	Niagara, Helderberg, Oriskany

32. U. S. Geol. Survey, Prof. Paper No. 31.

Woodford chert	Portage and Chemung
Sycamore limestone, Caney shale	Mississippian
Franks Conglomerate, Wapanucka limestone	Pennsylvanian

Of these, the Pre-Cambrian rocks, the Reagan sandstone, the Arbuckle limestone, the Viola limestone, the Hunton limestone, the Sycamore limestone, the Franks conglomerate and the Wapanucka limestone are suitable for road material and will be discussed at some length. The areas of the principal formation, and the location of quarries and asphalt pits and outcrops are shown on Plate II.

THE GRANITE AND ASSOCIATED IGNEOUS ROCKS.

Area. The principal granite area lies east of Washita River. It comprises approximately the southern half of T. 2 S., in R. 5, 6, and 7 E.; all of T. 3 S., R. 5 E.; the west ½ and N. E. ¼ of T. 3 S., R. 7, and 8 E. Over most of this area the granite is thinly covered with soil and residual clay containing disintegrated granite, but along the streams and in the cuts on the Ardmore branch of the Chicago, Rock Island and Pacific Railroad, the granite is well exposed.

Nature of the rock. The granite is rather coarse-grained, gray to pinkish rock. It is traversed by numerous joints in various directions, but the joints are not numerous enough to interfere with obtaining large blocks for building stone. A sample of this granite was obtained at the quarry site (fig. 31) near the Tishomingo reservoir and gave the following test:

Physical Tests.

Locality	Tishomingo.
Material	Biotite Granite.
Specific gravity	2.65
Weight per cubic foot	165. pounds.
Water absorbed per cubic foot	0.06 pounds.
Per cent. of wear	6.7
Hardness	19.2
Toughness	8.
Cementing value	Fair.

Remarks: A hard rock with low toughness, low resistance to wear and fair cementing value. Not recommended except for the foundation course.

Mineralogical analysis.

Character of material	Plutonic.
Name	Granite.

Essential Minerals.

Orthoclase	50.2
Quartz	13.4
Plagioclase	10.2
Biotite	8.2

Accessory Minerals.

Muscovite	1.2
Magnetite, Pyrite	1.2
Zircon	0.2

Secondary Minerals.

Kaolin	12.5
Epidote	2.5
Chlorite	0.4

Remarks: Specimen is a coarse-grained, light gray granite composed essentially of kaolinized orthoclase, quartz, plagioclase (oligoclase) and biotite.

Crusher sites. Several favorable locations for crushers were observed along the Chicago, Rock Island and Pacific Railway between Tishomingo and Wapanucka. The railroad cuts through several hills of granite. A switch could be easily run along the side of the hill so that a good quarry face could be secured and the handling of the stone done by gravity. The quantity of the stone available at any of these locations may be considered as unlimited. This material has not been used as a road material at the present time.

The dike rocks. Cutting the gray Tishomingo granite in all directions are numerous dikes of black rock, which is classed as diabase in Taff's report to which reference has been made. These dikes vary in thickness from a fraction of an inch to about forty feet.

The rock as a rule is very close-textured, and very hard and tough under the hammer. These qualities make it a better road material than the granite, but it will be more difficult to crush. It was not observed to occur in commercial quantities along either of the railroads which cross the region, but more detailed investigation will probably locate the occurrences. A dike six feet thick parallels Pennington Creek for some distance through the quarry site near Tishomingo which has been described. A sample secured from this location gave the following results on testing:

Sample No. 5354.

Physical Test.

Locality	Tishomingo.
Material	Diabase.
Specific gravity	3.05
Weight per cubic foot	19.0 pounds.
Water absorbed per cubic foot	0.14 pounds.
Per cent. of wear	4.1
French coefficient of wear	9.7
Hardness	18.9
Toughness	25.
Cementing value	Good.

Remarks: A hard tough rock with medium resistance to wear and good cementing value. Should make a satisfactory road material.

Mineralogical Analysis.

Character of Material	Igneous Rock.
Name	Diabase.

Essential Minerals.

Augite, Chlorite	50.1
Plagioclase	41.1

Accessory Minerals.

Magnetite	6.2
Biotite	2.6

Remarks: Specimen is a dark gray, medium grained rock composed essentially of chlorite, augite and plagioclase (labradorite).

Sand Creek cuts through a large dike of this material just north of the Tishomingo-Ravia road crossing in sec. 1, T. 4 S., R. 5 E. Many large bowlders of the rock lie in the stream and this location would supply enough material for local use in road building.

Granite at Ravia. A quarry is opened in the granite about two miles northwest of Ravia on a switch from the St. Louis and San Francisco Railroad. The material at this point is a dark red color and much finer grained than the granite at Tishomingo. It seems to be a large dike cutting the gray granite, but it was not followed far enough to disclose this absolutely. A black dike about four feet wide occurs at the north side of the ledge. The ledge is forty to fifty feet broad and the top is about twenty-five feet above the track (fig. 32). It can be worked back in both directions from the switch. The mass is cut

by joints and also by other planes of cleavage in all directions, so that when blasted it breaks up into small angular fragments. The majority of these fragments are 1½ to 3 inches in dimension and some difficulty was experienced in obtaining a six-inch cube which did not show cleavage planes. This property of the rock, while making crushing quite easy, necessitates much shovel and fork work and is the principal objection to the working of the quarry.

The quarry has been worked and a considerable quantity of ballast supplied to the railroad company, but at present the site is in litigation and is not being used. The switch is rapidly getting into bad condition.

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

Sample No. 4355.

Physical Tests.

Locality	Ravia.	
Material	Granite.	
Specific gravity	2.60	
Weight per cubic foot	162.	pounds.
Water absorbed per cubic foot	0.18	pounds.
Per cent. of wear	3.3	
French coefficient of wear	12.0	
Hardness	19.0	
Toughness	9.0	
Cementing value	Fair.	

Remarks: A hard rock with low toughness, medium resistance to wear and fair cementing value. Not recommended except for the foundation course.

Mineralogical Analysis.

Character of Material	Plutonic rock.
Name	Granite.

Essential Minerals.

Quartz	Percentages
Orthoclase	not
Microcline	reported.
Biotite	

Accessory Minerals.

Plagioclase	Percentages
Muscovite	not
Magnetite	reported.

Secondary Minerals.

Hematite	Percentages
Kaolin	not
Chlorite	reported.

Remarks: Specimen is a coarse-grained, pink granite composed essentially of quartz, orthoclase, microline and little impregnated with iron oxide.

Granite also outcrops along the Frisco Railroad from Ravia north to Mill Creek. It resembles the Tishomingo granite but is finer grained locally. Several localities would furnish favorable quarry and crusher sites.

Disintegrated granite. Over most of the granite area the slopes are steep enough to bring about the removal of the material as fast as it is broken down by weathering. Locally, however, the solid granite is covered by several feet of disintegrated granite and soil. The largest deposit of this sort visited is at Lester, a switch a few miles south of Mill Creek, in N. W. ¼ sec. 20, T. 29, R. 2 E. Here an opening covering ½ acre has been worked to the depth of 12-15 feet at the east end of the workings. There are large bowlders of solid granite and these make the working more difficult. Some of these were blasted to pieces and disposed of to the St. Louis and San Francisco Railroad for riprap. Switches were installed and a small switch engine was used for handling the cars. The material removed was used for ballast principally on the Frisco system. The pit has been idle for some time.

The Southern Ballast Co. of Lester is planning to open a similar pit southeast of the old one in the S. E. ¼ sec. 21, T. 2 S., R. 5 E. A switch is to be put in from the railroad and the material used principally for ballast. It will also be available for roads and should prove valuable for gravel roads and in concrete work.

Granite gravel. The streams which flow across the granite carry away the particles, which are broken loose by weathering, and build them up as gravel beds. Such streams as Blue River, Pennington Creek, Rock Creek and Mill Creek have almost inexhaustible deposits. Many of these are used locally. The streets of Tishomingo are covered with granite gravel from Pennington Creek southwest of town. It will not have the wearing properties of crushed stone macadam, but is a wonderful improvement over the clay and sand roads or streets. The gravel is very clean and free from dirt or soil and is sharp and angular. It is rather fine but a large percentage of the pieces have diameters of over one-half inch.

The Tishomingo Granite Gravel Company of Tishomingo has a switch from the Chicago, Rock Island and Pacific Railway to a very large bed on Pennington Creek. The gravel is shoveled onto gondola

cars by hand. Half the output is taken by the railroad for ballast and the other half is available for commercial use at prices approximating 50 cents per cubic yard free on board cars at Tishomingo. About 1500 carloads were shipped during the last year.

Granite porphyry. The igneous rocks of the portion of the Arbuckle Mountains west of Washita River, occur in the exposures known as East and West Timbered Hills. They are located in sec. 36, T. 1 S., R. 1 E., and E. ½ sec. 1, T. 2 S., R. 1 E. The material is a granite porphyry or a granite, the majority of whose crystals are microscopic in size with some larger feldspar crystals. The porphyry is cut by large dikes of aporhyolite which is usually glassy and vesicular in structure, but which is locally porphyritic. There are also numerous dikes of diabase similar to those described in the Tishomingo granites.

East and West Timbered Hills contain an immense amount of rock which, owing to its fineness of grain, would probably be superior to the Tishomingo granite as road material. However, at present, they are inaccessible and cannot be considered as a source of supply. If demand should ever exist for this stone it would be possible to install a switch from which the Gulf, Colorado and Santa Fe Railway which is about four miles from the hills but as the intervening land is rough and broken it would be a very expensive proposition, and, in view of the wealth of other material in the neighborhood, not likely to be undertaken.

THE REAGAN SANDSTONE.

The Reagan sandstone lies above the granite and is largely composed of the fragments of the granite which have been cemented together. In some localities it is absent by non-deposition and the lower part of the Arbuckle limestone rests directly on the granite. In other places the Reagan is faulted out. Its greatest area is a belt from one-fourth to one-half mile in width along the west side of the large granite area just described.

The Reagan sandstone, being composed of granite fragments, should make a fairly good surfacing for macadam roads, but since its outcrop is limited in area, and since it is not situated favorably as regards transportation, it will probably have only a limited local use and need not be considered further in this report.

THE ARBUCKLE LIMESTONE.

Area. The Arbuckle limestone is a ledge of from 4000 to 6000 feet in thickness, which overlies the Reagan sandstone where it is present or rests directly on the granite where the Reagan is absent through faulting or non-deposition.

It is exposed in three large areas in the Arbuckle Mountains: (1),

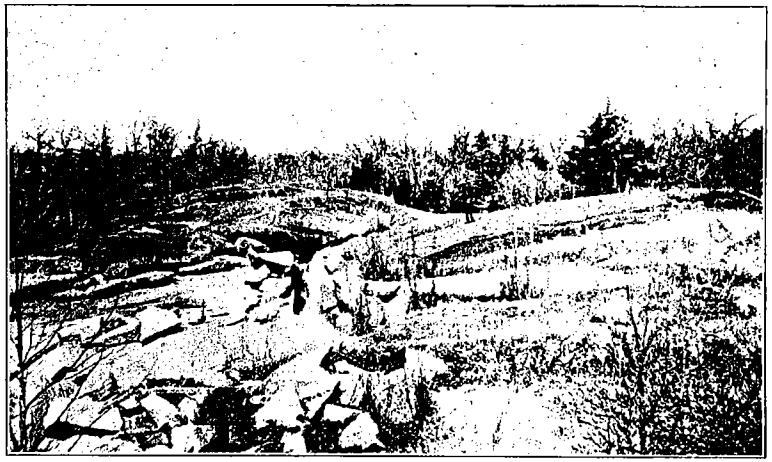

Fig. 31. Exposure of Granite near Quarry at Tishomingo.

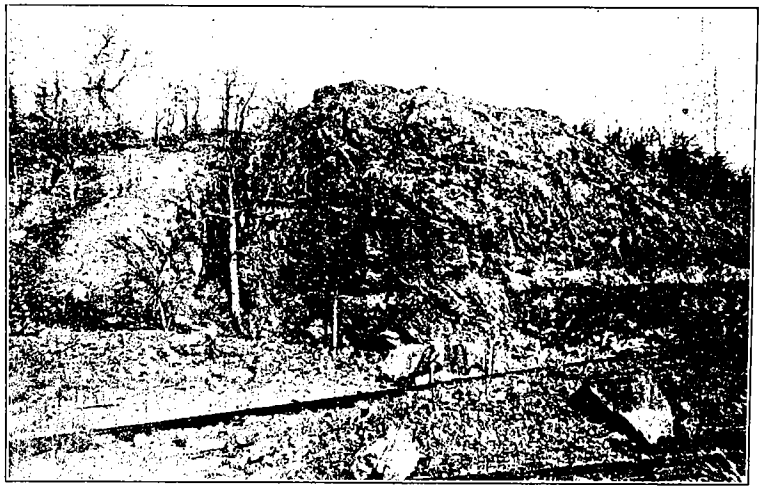

Fig. 32. Abandoned Quarry at Ravia.

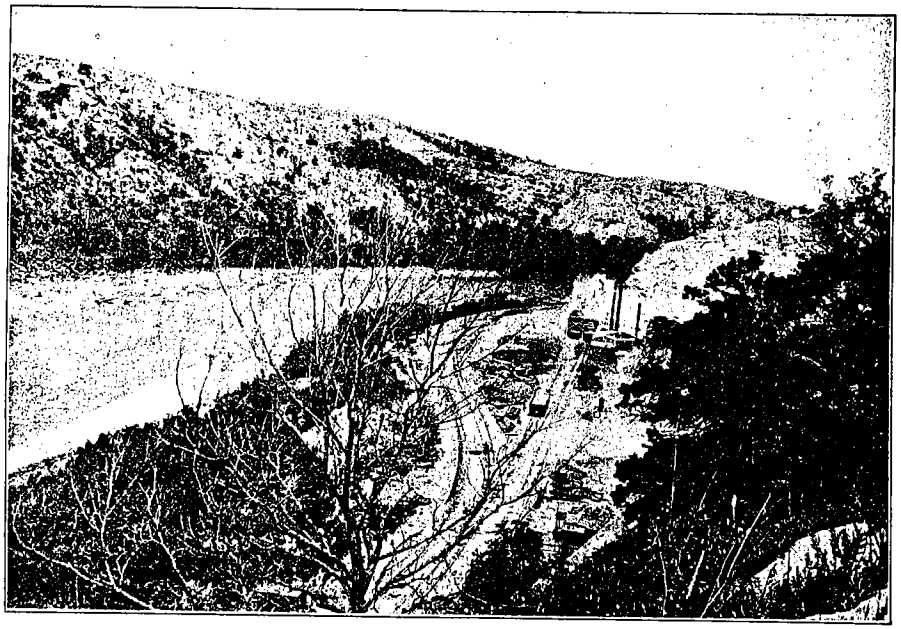

Fig. 33. Quarry at Crusher. (Arbuckle limestone)

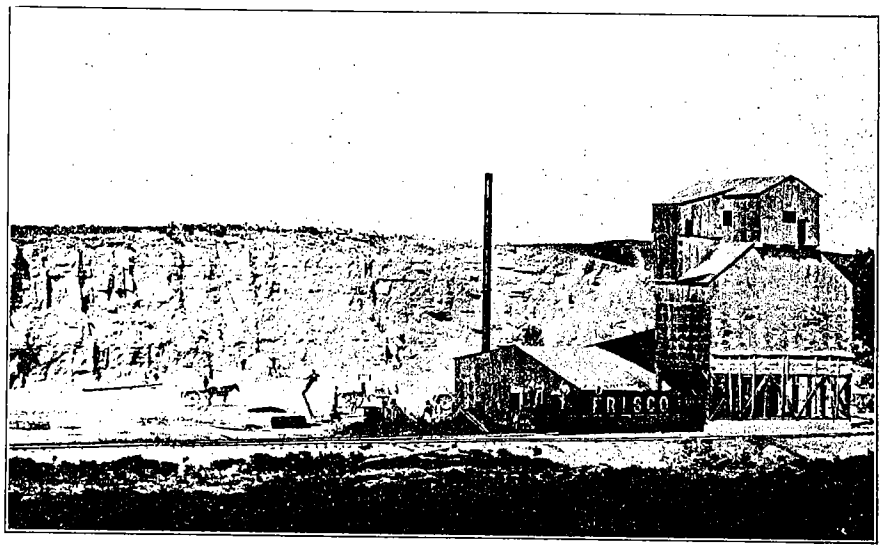

Fig. 34. Quarry at Fitzhugh. (Viola limestone)

the major portions of Townships 1 N., and 1 S., in Ranges 5 and 6 E., and smaller portions of the townships surrounding these; (2) an area of about one and one-half square miles in the southern part of Townships 2 and 3 S., R. 5 E.; and (3) west of Washita River, a roughly triangular area consisting of the south part of T. 1 S., in Ranges 1 E., and 1 W., and the northern parts of T. 2 S., in the same ranges and the central portion of T. 2 S., R. 2 E.

Nature of the rock. The base of the Arbuckle limestone is composed of thin bedded limestone, shaly in part and with intraformational conglomerates. From the base of the Upper Cambrian, upward, the rocks are largely dolomitic and massive up into the Ordovician. The upper 450 feet are thinner bedded and in places are associated with shaly strata.

The most accessible locations in the Arbuckle limestone in the Arbuckle Mountain region is at the gorge of Washita River, where it cuts across the Arbuckle limestone near the apex of the triangular area described above. The Gulf, Colorado and Santa Fe Railway parallels the river at this point and furnishes transportation facilities.

Quarries at Crusher: Two quarries are located at Crusher in the southwestern part of T. 2 S., R. 3 E. They are both in the middle part of the Arbuckle limestone and are working the massive beds.

The plant of Dolese Bros. of Chicago is located at the station of Crusher (fig. 33) which have a capacity of about 1000 cubic yards per day. The screen are 2½", 1½" and ½" perforations and a dust jacket is used. The stone is taken from the quarry face to the crusher in dump care by gravity.

Carter Bros. have a quarry and crushing plant about ½ mile north of the Dolese Bros. quarry. They use a No. 5 old style and a No. 5 improved Austin-Gates crusher with a combined capacity of from 300 to 500 cubic yards per day. The stone is screened to the same sizes as at the Dolese Bros. plant. The stone is also transported to the crusher by gravity.

The stone at both plants is very similar. It is a dark gray limestone, very hard but rather brittle. It breaks into angular fragments with sharp cut edges.

There are some local variations in the material, some of it being of a lighter color and somewhat softer than the majority of the stone. So far the principal use of the stone has been in concrete, but it will undoubtedly come into use as a macadam road and street material. The finer material has been disposed of principally to the railroad for ballast and platforms.

The stone is placed F. O. B. cars at Crusher at prices approximately 72 cents per cubic yard. The freight rate to Oklahoma City is about

80 cents. The following is the report of the test on the rock from Dolese Brothers' quarry. Owing to the similarity of the rock it was not deemed necessary to have tests made from both quarries.

Sample No. 4362.

Locality	Crusher.
Material	Limestone.
Specific gravity	2.70
Weight per cubic foot	168. pounds.
Water absorbed per cubic foot	0.24 pounds.
Per cent. of wear	4.4
French coefficient of wear	9.2
Hardness	15.1
Toughness	8.
Cementing value	Good.

Remarks: A rock of medium hardness and resistance to wear with low toughness and good cementing value. Should make a fairly satisfactory road material.

The Arbuckle limestone is also well exposed along the St. Louis and San Francisco Railroad from Mill Creek north to near Roff. Several localities would furnish favorable crusher sites, but none are being worked.

THE SIMPSON FORMATION.

This consists of a series of sandstones, shales and limestones, whose total thickness is from 1200 to 2000 feet. It lies just above the Arbuckle limestone and is exposed as a lowland belt around the plateau formed by the Arbuckle. Some of the limestones, especially in the upper part, are of sufficient thickness to furnish much road material. However, the beds are located so near the Arbuckle limestone and Viola limestone wherever they are exposed that where there is a demand for crushed stone one of these will be worked instead of the Simpson as they are thicker and more accessible. The Simpson contains some of the principal deposits of asphalt and will be noticed more fully in connection with these deposits.

THE VIOLA LIMESTONE.

Location and area. The Viola limestone lies above the Simpson formation and is exposed as a belt of rounded knobs separated from the Arbuckle plateau by a depression, the outcrop of the Simpson formation. It occurs entirely around the Arbuckle uplift except where the older rocks are buried by younger formations as at the northwest end of the uplift and along the south where the Cretaceous sands lie directly on the granite. The width of the outcrop varies from ¼ mile to 3 or 4 miles depending on the position or dip of the strata and

the topography. The largest areas are: (1) in the north and east portions of T. 1 S., R. 7 E., and contiguous portions of the adjoining townships on the north and east; (2) in the northeast part of T. 2 N., R. 5 E., (3) as a strip about 1½ miles wide extending from north to south through the middle of T. 2 S., R. 3 E. Of these large areas only No. (2) is situated near transportation.

Nature of the rock. The Viola limestone is about 300 to 500 feet in thickness. It is separated on the basis of slight differences in character into three beds. There is little difference between them; the lower one and upper one being somewhat argillaceous and cherty in places. On a fresh exposure the Viola appears to be massive, but on weathering it is shown to consist of thin layers, usually less than a foot in thickness. The great mass of the stone is a gray to light blue color, very hard, and rather brittle. At the places where it stands nearly on edge, it seems as if the force of the upheaval had caused the rock to become full of incipient cracks so that when blasted it breaks into small angular pieces.

Quarry at Wapanucka. About two miles south of Wapanucka the Chicago, Rock Island and Pacific Railway cuts through the Viola limestone. The rock stands about 30 feet high on both sides of the track. The railroad formerly had a crusher at this point. The rock is very brittle and badly checked. When shot it broke into very small pieces causing a great amount of shovel and fork work. This made the working expensive and the quarry was abandoned. No sample was obtained as no piece of the stone could be found large enough for the test (3″ by 3″ by 4″) which did not have cleavage planes through it.

Quarry at Fitzhugh. At Fitzhugh on the St. Louis and San Francisco Railroad south of Ada, the Webster Stone Company operates a crusher quarry in the Viola limestone (fig. 34). The quarry is located in the S. W. ¼ of sec. 35, T. 3 N., R. 5 E. A quarry face 500 feet long by 44 feet in height has been developed. The stone is hauled from the quarry face to the crusher in dump carts. No. 5 and No. 3 gyratory crushers are installed with a daily capacity of 400 cubic yards. The stone is screened through a 12 foot rotary screen and into storage bins of about 4 cars capacity. The average price of the stone F. O. B. cars at Fitzhugh is 75 cents per cubic yard. The amount of stone available at this locality is practically unlimited.

The report of the test on this stone is as follows:

Sample No. 4390.

Locality	Fitzhugh.
Material	Shell limestone.
Specific gravity	2.55
Weight per cubic foot	159. pounds.

Water absorbed per cubic foot	2.60 pounds.
Cementing value	Fair.
Not suitable for other tests.	

Remarks: This material would probably be suitable for very light traffic only.

Quarry of Oklahoma Portland Cement Co. at Ada. The Oklahoma Portland Cement Company at Ada obtain their limestone from a quarry at Lawrence in the N. ½ of sec. 36, T. 3 N., R. 5 E. A quarry face 400 feet long and 20 feet high has been developed. This stone has not been available for commercial use, but it is planned to install crushing machinery and screens and to place the crushed stone on the market. It is well suited for use in concrete and probably for foundation for macadam roads, but is too soft for the surface of macadam roads. It is very pure, crystalline limestone and does not seem to be filled with the incipient cracks as is the most of the Viola. The report of the test on this stone is as follows:

Sample No. 4364.

Locality	Ada.
Material	Fossiliferous Limestone.
Specific gravity	2.65
Weight per cubic foot	165. pounds.
Water absorbed per cubic foot	0.41 pounds.
Per cent. of wear	9.0
French coefficient of wear	4.4
Hardness	8.2
Toughness	3.
Cementing value	Good.

Remarks: A soft rock with very low toughness, low resistance to wear and good cementing value. Not recommended for road building.

Another very favorable location for a quarry and crusher site in the Viola limestone is at Rock Cut on the Gulf, Colorado and Santa Fe Railroad south of Davis, about the center of Sec. 21, T. 1 S., R. 2 E. (fig. 35). The top of the hill stands about 100 feet above the track and a little creek crosses the track at right angles just north of this hill. The bed of this creek would make an excellent location for a switch and also for the location of a crusher. The quarry could be operated by gravity and still have a face of 60 to 80 feet and a length of several rods.

THE HUNTON LIMESTONE.

This formation consists of three members, an upper and a lower limestone, and a middle shale, which is often calcareous, sometimes cherty. As it is usually steeply tilted, the differential weathering of these three members produces two narrow ridges and an intervening

trough. The Hunton trough is separated from the Viola trough by the Lower Hunton ridge which is wider than the Upper Hunton ridge. The Hunton limestones are hard, crystalline limestones, white to light blue in color. The base of the lower member is usually oolitic, and the upper member often contains concretions and bands of chert.

Either of the Hunton limestone members would be suitable for road material, but as neither has a thickness of over 40 feet, and as it always outcrops near the Viola limestone, the latter will almost certainly be used in preference to the Hunton.

THE WOODFORD CHERT.

The Woodford chert occurs above the Hunton. It is almost 650 feet in thickness and consists for the most part of alternating thin beds of shale and chert. The shale increases toward the top. The outcrop is usually a wooded valley lying between the upper Hunton ridge and a ridge due to the outcrop of the overlying Sycamore limestone. The chert members of the Woodford would make a good road material, but on account of the interstratified shales and the proximity of more easily accessible material, it is not a commercial proposition to try to utilize it.

THE SYCAMORE LIMESTONE.

This overlies the Woodford chert and is exposed principally as a narrow ridge along the south side of the Arbuckle Uplift. It is about 130 feet thick in the Tishomingo region and thickens westward. The limestone is thin bedded, the layers averaging about one foot in thickness. It is blue in color and very hard and tough. It breaks into small fragments due to jointing oblique to the bedding planes. While undoubtedly the Sycamore is a good road material, no favorable locations for development are known to the writer and no samples were obtained for test.

THE CANEY SHALE AND GLENN FORMATION.

These two formations outcrop in rather large separated areas in the outer parts of the Arbuckle Mountains but neither formation contains anything suitable for road material except the asphalt deposits of the latter, which will be discussed later.

THE FRANKS CONGLOMERATE.

The Franks conglomerate was formed by the erosion of the pre-carboniferous deposits in early Pennsylvanian times. It is an inshore deposit and consequently is variable in thickness and nature. Usually it consists of pebbles of limestone cemented by calcareous cement. Sometimes a portion of the pebbles are of granite. The conglomerate is very hard although it weathers down somewhat rapidly. It is exposed in

most places around the western portion of the Arbuckle Uplift and decreases in thickness from west to east. It is well exposed along the Atchison, Topeka and Santa Fe Railroad between Davis and Sulphur and in the vicinity of the latter place.

The nature of conglomerate as road material has already been noticed, but it may be repeated here that the irregular composition of the rock with the varying hardness of the pebbles and the cementing material make a conglomerate very difficult to work. The Franks will be of some value for local use on the roads of the regions where it occurs but will not be of general use.

THE WAPANUCKA LIMESTONE.

This limestone occurs in the eastern part of the Arbuckle Mountains but is much more prominent farther east and has been taken up in connection with the eastern part of the State.

THE ASPHALT OF THE ARBUCKLE MOUNTAINS.

As the general nature of the asphalt deposits have already been discussed in Bulletin No. 2 of this Survey, only the deposits which have been used as paving material will be noticed here. The asphalts of the Arbuckle region usually occur as impregnations of sandstone, limestone and shale of the Simpson formation. Of these the shale asphalt is of no value in paving. The principal producing area is known as the Brunswick district and is located east of Dougherty and south of Sulphur.

"Brunswick Rock." This is an asphaltic limestone which occurs in section 31, T. 1 S., R. 3 E., about 4 miles northeast of Dougherty. The exposure is in the banks of a dry run about one-fourth mile from Rock Creek. A large quarry has been developed with a face 25 to 35 feet high. It is located in the side of a considerable hill that seems to consist entirely of the bituminous limestone. The 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 unevenly saturated with heavy maltha. Some of the crystalline portions are free from bitumen. The bitumen content varies from 5 to 8 per cent. The rock has a tendency to split into irregular fragments because of the asphalt having infiltrated into the joints or seams of the rock. The material is probably as of much value in paving on account of its mineral matter and structure as on account of its bitumen.

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

Sample No. 4359.

Locality	Murray County.
Material	Bituminous limestone.
Specific gravity	2.50
Weight per cubic feet	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.

No. 2 sand. This is also located on Rock Creek about 1 mile east of the limestone just described, and ¼ miles up Rock Creek from its confluence with Buckhorn Creek. The development consists of a large circular pit on the banks of the creek. The pit reaches a depth of 35 feet in the asphaltic sand. 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 to 10 feet of conglomerate and varying thickness of soil. The amount available is limited by the thickness of the overburden which makes an excessive amount of stripping necessary.

The product consists of subangular grains of sand cemented by a 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 follow:

Sample No. 4360.

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	%
" "	80 "	"		9.8	%
" "	100 "	"		14.3	%
" "	200 "	"		45.1	%
Passing	200 "	"		30.6	%
				100.0	%

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

Number 3 sand. This 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:

Sample No. 4358.

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	%
" "	50 "	"		1.3	%
" "	80 "	"		40.0	%
" "	100 "	"		39.5	%
" "	200 "	"		18.6	%
Passing	200 "	"		.6	%
				100.0	%

Asphalt at Ravia. The asphalt at Ravia is on segregated land about 1 mile from a switch from the Frisco Railroad. It is an evenly impregnated lime asphalt. The layer is 5 to 6 feet thick and lies

practically horizontal. The stripping is only 2 to 3 feet thick where it is worked but increases rapidly back into the hill. The material was quarried and shipped for paving but is not now being used. There is a large amount of quarried material on hand at the quarry. The area of the deposit is unknown.

Richardson[34] gives several analyses for this material which show considerable variation.

Bitumen soluble in CS_2	3.4 to 10.8%
Mineral matter soluble in HCl	63.7 to 77.9%
Mineral matter insoluble in HCl	11.3 to 30.8%
Difference	0.8 to 5.5%

A sample was selected which gave nearly as possible the average material from this deposit for analysis for this report.

The results follow:

Sample No. 4356.

Locality	Ravia.
Material	Bituminous Limestone.
Special gravity	2.15
Weight per cubic foot	134. pounds.
Water absorbed per cubic foot	2.69 pounds.
Per cent. of wear	4.0
French coefficient of wear	10.0
Hardness	3.2
Toughness	6.0
Cementing value	Excellent.

Remarks: A very soft rock with low toughness, medium resistance to wear and excellent cementing value. Would make a very good binder in connection with some better wearing material.

The examination for bitumen showed only 2.19% with a residue of coarse calcareous sand.

Asphalt at Ada (fig. 36). One and one-half miles west of Ada, on the land of D. A. Herring, is an immense deposit of lime asphalt. The deposit consists of a long hill, the area of the top being at least 100 acres. Prospect holes have been dug over the hill which show that the deposit underlies the whole hill. A depth of 80 feet was shown by some of the drill holes. At present the product is hauled by wagon to Ada. The material has been used for the surface of streets of Lawton and is contracted for at Ft. Worth, Texas, and at Oklahoma City. At Lawton the material is used alone as the surface and the weathered stripping is used as a foundation.

34. Op. Cit., Page 238.

The results of the examination are as follows:

Sample No. 4363.

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 %
" " 50 " "	6.3 %
" " 80 " "	36.0 %
" " 100 " "	18.3 %
" " 200 " "	25.7 %
Passing 200 " "	13.7 %
	100.0 %

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

ASPHALTS OF THE ARDMORE BASIN.

The Ardmore Basin is located southwest of the Arbuckle Mountain region. The surface rocks are shales and sandstones of Carboniferous age. They contain little road material besides the asphalts. It has not been decided whether these asphalts have been formed in place in the Carboniferous rocks or have worked upward from the Simpson formation which is supposed to be buried beneath the younger rocks.

"Consolidated Sand." This sand asphalt is found near Overbrook, 7 miles south and 1 mile west of Ardmore. The ledge is 25 feet thick and dips at an angle of 20 degrees. The outcrop is ½ 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 variation 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 examination of this material gave the following results:

Sample No. 4357.

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 %
" " 80 " "	4.4 %
" " 100 " "	14.0 %
" " 200 " "	57.5 %
Passing 200 " "	24.1 %
	100.0 %

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

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. There are the remains of an old extraction plant at this place and the present owners operate a pulverizing mill here. 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 and Santa Fe Railroad about two miles distant.

There is a ledge of bitumen limestone on the same property which is only partially developed.

"Aleck" mine. This is located 12 miles northwest of Ardmore, in section 18, T. 3 S., R. 1 E. 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 per cent. of bitumen which is a heavy maltha not so soft and oily as that of sand No. 3 from the Brunswick

district. The extent of the deposit is not known, but the material in sight may be said to be inexhaustible. A pit 60 feet by 60 feet has been opened without reaching the limit of the bed. The product is hauled by wagon to Ardmore. It is used as the flux in the paving mixtures.

Richardson[33] gives the following analysis of this material:

Bitumen soluble in CS_2	11.1%
Passing 200-mesh sieve	8.9%
" 100 " "	75.0%
" 80 " "	22.0%
" 50 " "	2.0%
" 40 " "	1.0%
" 30 " "	.0.0%
" 20 " "	0.0%
" 10 " "	0.0%

Extracted bitumen:

Loss at 212° F., 1 hour	0.1%

Residue after heating to 212°F—Too soft for penetration.

Dry Substance.

Loss, 325°F., 7 hours	3.5%

Residue after heating to 325°F:

Penetration 110.	
Bitumen soluble in CS_2 air temperature	68.7%
Difference	1.5%
Inorganic or mineral matter	29.8%
Maethenes	100.0%
Bitumen soluble in 88° naphtha, air temperature	57.3%
This is per cent. of total bitumen	83.4%
Bitumen soluble in 66° naphtha, air temperature	62.6%
This is per cent. of total bitumen	91.1%

Character of extracted bitumen—Soft at 78°F.

THE WESTERN DISTRICT.

GENERAL DESCRIPTION.

This area comprises practically the western half of the State. Over most of this area the surface rocks are of Pennsylvanian-Permian age and are predominantly red in color. "The eastern line of the Redbeds is a line crossing the Kansas-Oklahoma line at Caldwell, then trending

33. The Modern Asphalt Pavement, p. 235.

southeast near Hardin, Tonkawa, and Red Rock, cutting diagonally across the strike of the Pennsylvanian limestones and shales through the eastern parts of Payne and Lincoln counties to the western end of the Creek and Seminole nations, (now Creek, Okfuskee, and Seminole counties.) Here the line swings to the southwest and continues through the Chickasaw Nation (Pottawatomie County) passes around the western end of the Arbuckle Mountains, crossing Red River 35 miles west of Gainesville, Texas."[35]

The major portion of the Redbeds is of Permian age but the eastern portion is of Upper Pennsylvanian. The boundary between the red Pennsylvanian and the red Permian has never been worked out exactly but is approximately a line starting west of Pawnee and extending south-southwest past Stillwater, passing about midway between Guthrie and Fallis, past Moore and Norman and further south swinging to the east near the Arbuckle Mountains. This line is shown in Plate III.

STRATIGRAPHY.

THE RED BEDS.

Gould[36] gives the following classification of the Permian:

Quartermaster formation		300 feet
Greer formation	Mangum dolomite Collingsworth gypsum Cedar Top gypsum Haystack gypsum Kiser gypsum Chaney gypsum	295 feet
Woodward formation	Day Creek dolomite Whitehorse sandstone Dog Creek shales	425 feet.
Blaine formation	Shimer gypsum Medicine Lodge gypsum Ferguson gypsum	100 feet.
Enid formation		1500 feet.

The Enid formation consists entirely of red shales with thin soft sandstones. The clays are often gypsiferous and contain gypsum concretions and thin layers of a selenite in the upper portion. The Blaine formation consists of three gypsum members separated by thin red shales. Dolomite occurs locally near the top of the formation. The

35. Gould. Charles Newton, U. S. G. S. Water-Supply and Irrigation Paper No. 148, p. 37.

36. Op. Cit. page 40.

Woodward formation consists of a shale member, a sandstone member and a dolomite member. The Greer formation consists of five gypsum members separated by thin red shales and a dolomite member at the top. The Quartermaster formation consists of sandstone and arenaceous shales.

CRETACEOUS ROCKS.

Rocks of Comanche Cretaceous age occur in isolated areas in several places in western Oklahoma. They usually consist of limestones and shales, the limestone being known locally as "shell rock" on account of the number of fossil oyster shells it contains. The Cretaceous rocks lie upon the eroded surface of the Redbeds and usually occur on the hill tops. They are probably the remnants of a large area of Cretaceous deposits, the major portion of which has been removed by erosion. Outcrops of the Comanche Cretaceous occur in Woodward, Dewey, Custer, Harper, Washita, Roger Mills, Woods and Beaver counties.

The Dakota sandstone of Upper Cretaceous age, occurs in the extreme northwestern corner of Cimarron County.

TERTIARY ROCKS.

The Tertiary rocks occur on the high plains of the extreme northwestern part of the State and along the higher divides farther to the east. The Tertiary, like the Cretaceous, probably covered all of this region at one time but has been largely removed by erosion. The largest areas of the Tertiary are in the Panhandle where it occupies almost all of Cimarron, Texas and Beaver counties (except the valleys of the streams) and the level prairies between Cimarron and South Canadian rivers in Ellis and Woodward counties.

The rocks of Tertiary age consist of clay, sand and gravel very irregularly stratified giving rise to a peculiar structure known as "mortar beds." The gravel is sometimes cemented to form a conglomerate. The slopes of the hills are often covered with pebbles which have been washed from the mortar beds and considerable deposits of gravel from the same source occur in some of the streams.

ROAD MATERIALS.

GENERAL STATEMENT.

From the preceding brief review of the stratigraphy, it may be seen that this section of the State, with the exception of the Wichita Mountains, is almost without material for the construction of improved roads, unless the sand-clay road be considered. The only materials suitable for macadamized roads are the dolomites of the upper Redbeds, the limestones of the Comanche series and the gravels of the Tertiary.

DOLOMITES.

The dolomites occur at three horizons, (1) locally near the top of the Blaine formation which extends in a narrow belt northwest from El Reno to the Kansas line, (2) at the top of the Woodward formation, the Day Creek dolomite and (3) at the top of the Greer formation, the Mangum dolomite.

The dolomites of the Blaine formation are usually thin and lenticular in occurrence, and arenaceous or argillaceous in composition. They often occur as the cap rock of the hills. Owing to the nature of their occurrence, they will be of little importance except for local use.

The Day Creek dolomite overlies the Whitehorse member of the Woodward formation. In Kansas it is about 5 feet in thickness but in Oklahoma is seldom over 3 to 4 feet thick. It outcrops on several hills in Woodward County, caps the red hills between Geary and Watonga and extends as far southwest as the headwaters of Cobb Creek. Dolomites at Mountain View and at Harrison were provisionally referred to the horizon of the Day Creek by Gould[37].

A road has been constructed near Watonga, Blaine County, of this material. The foundation was made of anhydrous gypsum and only the surface is composed of the dolomite.

The reports of the tests of the gypsum and the dolomite are as follows:

Report on anhydrous gypsum.

Location	12 miles north of Watonga, Oklahoma.
Material	Gypsum.
Specific gravity	2.30
Weight per cubic foot	143. pounds.
Water absorbed per cubic foot	3.34 pounds.
Per cent. of wear	38.2
French coefficient of wear	1.0
Hardness	4.8
Toughness	4.0
Cementing value	Excellent (500)

Remarks: This material runs very low in hardness, toughness and resistance to wear, but has an excellent cementing value. It is best adapted for use as a binder in connection with some form of siliceous rock.

Report on dolomite.

Location	Watonga, Oklahoma.
Material	Dolomite.
Specific gravity	2.70

37. Op. cit. p. 58.

Weight per cubic foot	158.	pounds.
Water absorbed per cubic foot	1.16	pounds.
Per cent. of wear	5.5	
French coefficient of wear	7.3	
Hardness	16.3	
Toughness	13.0	
Cementing value	Good.	

Remarks: A rock of medium hardness and toughness, with rather low resistance to wear and good cementing value, should make a fairly satisfactory macadam road.

Mineral analysis of dolomite.

Essential Minerals.

Dolomite—Carbonate of lime and magnesia	99.0%

Accessory Minerals.

Quartz—silica	0.5%
Hematite—iron oxide	0.5%

Remarks: Specimen is fine grained, pinkish white dolomite containing but a trace of iron oxide and quartz as impurities.

A chemical analysis of the dolomite from the hills between Geary and Watonga give the following results:

Calcium carbonate	42.47%
Magnesium carbonate	52.86%
Total dolomite	95.33%
Water	1.82%
Oxides of iron and aluminum	1.35%
Silica or insoluble residue	1.82%
	99.88%

At Cement, in the southeastern part of Caddo County, there is a much thicker ledge, of what appears to be a siliceous limestone. This caps the hills to the east of the town and also the butte in the north end of the town. It is a blue-gray stone very hard and tough under the hammer. G. A. Heman of Chickasha operates a quarry in the large hill east of town. The area controlled is about 40 acres, on which there is 5 to 10 feet of soil. The upper layer of limestone is badly weathered and makes considerable waste. The main body of the stone is the blue siliceous stone mentioned. This is being worked to the depth of 12-15 feet. The thickness of the ledge is not accurately known but a well at the crusher plant is reported to have passed through 54 feet of the same stone.

An Austin-Gates crusher of 150 cubic yards daily capacity is installed. The material is hauled to the crusher in side-dump track cars, and from the farther part of the quarry by end-dump horse cars. The crushed stone is elevated to a rotary screen and screened into storage bins. The stone is hauled to the railroad in end-dump carts and dumped into the cars from a trap. The haul is about four squares and is all down a slight grade. It is proposed to install an aerial tramway as there is 74 feet of fall from the crusher to the loading point. The stone has been used in concrete work, principally in Chickasha.

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

Sample No. 4365.

Location	Cement.	
Material	Siliceous limestone.	
Specific gravity	2.65	
Weight per cubic foot	165.	pounds.
Water absorbed per cubic foot	0.66	pounds.
Per cent. of wear	4.1	
French coefficient of wear	9.9	
Hardness	16.2	
Toughness	7.	
Cementing value	Very good.	

Remarks: A rock of medium hardness and resistance to wear with low toughness and very good cementing value. Should make a fairly satisfactory road material.

The large hill west of town is of the same stone. It is reported that another plant is to be installed at this hill and that a No. 6 and two No. 5 crushers have been ordered. Surveys have been made for a spur from the Frisco railroad to the hill. It is claimed that an area of 32 acres, with no stripping, is available.

The stratigraphic position of this ledge of rock is not known. From Gould's[38] map it should be at the top of the Woodward formation and it may be the same horizon of the Day Creek dolomite. However, it is much thicker and greatly different in character from the Day Creek so its position is doubtful.

The Mangum dolomite is a dolomite 3 to 5 feet thick at the top of the Greer formation. It is exposed near Mangum, the county seat of Greer County, and on most of the divides between the streams of that county. Owing to the thickness of the bed it can be of only local importance, but many miles of roads in the vicinity of its outcrop can be improved by its use.

38. Op. cit. Plate 1, opp. p. 12.

CRETACEOUS LIMESTONE.

These occur in relatively small isolated areas and the limestone members are thin. The amount of material at one place will seldom be great enough to justify installing a crusher but the material could be hammered up and used on the worse portions of the local roads with good effect.

GRAVEL.

Where the Tertiary gravel occurs in sufficient quantity it should be good macadam material, as it is composed principally of quartz which would furnish good wearing qualities and it also has sufficient other material to make it cement.

THE ROAD CONDITIONS OF THE WESTERN DISTRICT.

Topography. The greater portion of the Redbeds region is fairly level. The gypsum hills and the hills capped by Tertiary rocks are the principal exceptions. As a general statement it may be said that the roads may be built along section lines throughout this section without having excessive grades.

Climate. The climate of most of the region is rather dry. Sufficient rain falls in all except the most western part to permit of the raising of all the principal crops, but the rain falls principally during the growing seasons when there is the least need for heavy hauling on the roads. The fall and winter seasons are usually dry. The cold of the winters is seldom great enough to freeze the roads to any appreciable depth, especially in the dry condition which is common, so that the roads are free from the long period of "thawing out" which renders earth roads impassible for several weeks in the spring in the more northern states. The wind in this section is very strong and often blows for days at a time.

The effect of the climatic conditions enumerated is to make the earth road, properly constructed, a much better road in this part of the State than it is in almost any other section of the country. An earth road when smooth and solid is as satisfactory as any form of improved road. Proper grading and surfacing will produce roads in most of this section which will be in good condition for ten months out of a year, and the two months when they are likely to be bad come at the season of the year when little hauling is necessary.

On the other hand, such climatic conditions are very unfavorable for macadam roads unless they are oiled with heavy oils. The high winds will keep the unoiled roads continually free from a dust covering so that all the wear of the traffic will come directly on the stone and cause it to wear down rapidly. The long dry seasons will dry the stone out thoroughly, and will cause "raveling" or separation of the pieces

of stone in the road surface. Raveling when once started proceeds very rapidly in dry weather, and especially where there is no protective dust covering. Oiling the macadam will render these conditions less harmful but will not entirely overcome the difficulties.

Nature of the soil. In the greater portion of the district, the subsoil is a clay containing considerable percentages of sand. The earth roads therefore approach the composition of sand-clay roads and may be called natural sand-clay roads. In localities where there are heavy ledges of sandstone in the Redbeds, the natural earth will be too sandy for a good sand-clay road and will work up loose under traffic in dry weather. On the other hand, where the Redbeds are of soft shale the roads are clay and become sticky in wet weather. In either case it is almost always possible to find beds of sand or clay—whichever is needed—within reasonable distance so that the road may be made a good sand-clay road with little expense.

It should be borne in mind that, after all, the grading and drainage are the fundamental things in road construction and that no amount of surface improvement will make a good road if the foundation is not well made and well drained. For miles of road in western Oklahoma all that is necessary is to make a good crown with a scraping grader and to keep this crown in shape by the use of the same grader or the split-log drag. The natural earth road made in this way will be almost as satisfactory, in many cases more so, than the macadam roads constructed at great expense. In the eastern portion of the Redbeds area where the rainfall is heavier it will be necessary to build tile drains to keep the earth roads in good condition, but in the western portion it is believed that good side ditches will give all the drainage required.

The sand areas. In a belt along each of the rivers crossing this section, and in large areas in Roger Mills, Ellis, Dewey, Beckham and Tillman counties, the surface is of sand and the regions are known as the sand hills. The road problem is a very serious one in these localities as the natural sand roads are extremely bad in dry weather. Where clay is close at hand it may be used in making sand-clay roads. This may be done in a good deal of the sandhill area especially near the "breaks" of the river valleys. In other places clay may be so far removed that the construction of sand-clay roads will be almost as expensive as macadam. In localities where clay or other material for surfacing cannot be obtained, any means of keeping the road as moist as possible should be employed. Planting trees, encouraging the growth of grass on the roadway, covering with leaves, straw or weeds all have a beneficial effect on a sand road. The road bed should be left level instead of being graded into a crown.

Sand roads as well as the clay may be improved by oiling with asphaltic oil. In any case, oil should not be used where the soil shows

any alkali as the alkali decomposes the oil causing it to lose its bonding power.

THE WICHITA MOUNTAIN REGION.

NATURE OF THE MOUNTAINS.

The Wichita Mountains lie to the northwest of the Arbuckles. Their long axis is in the same direction as that of the latter mountains and they are undoubtedly part of the same general uplift. The seas in which the Redbeds were deposited rose much higher around the Wichitas than around the Arbuckles so that the former were almost buried in the Redbed sediments. Consequently, while the Arbuckles consist of a plateau consisting of a core of igneous rocks surrounded by great thicknesses of sedimentary rocks which are steeply inclined, the Wichitas consist of isolated areas and peaks of igneous rocks surrounded and separated from each other by the flat, level-lying Redbeds. The great series of older sedimentary rocks which are so prominent in the Arbuckles are certainly present in the Wichita uplift, but, with the exception of the Reagan sandstone and Arbuckle limestone, exposures northeast of the main range of the mountains and three knobs of Viola limestone near Rainy Mountain Mission, they are deeply buried beneath the Redbeds. The mountains are rough, weathered peaks of granite and other igneous rocks sticking out abruptly from the Redbeds plain (fig. 37)

LOCATION AND AREA.

The Wichita Mountain group consists of several separated ranges and isolated peaks. The group extends from Fort Sill northwest to Granite City, a distance of 65 miles. The mountains are about 30 miles wide at the middle but narrow rapidly towards the ends.

DIVISIONS OF THE GROUP.

The principal range is the *Wichita Mountains,* which lie in T. 4 N., and the north half of T. 3 N., in ranges 13, 14, and 15 W. The range is composed of granite peaks separated by deep gorges. The highest peaks are Mount Baker and Mount Scott at the east and west ends respectively. They rise to a height of about 1500 feet above the level of the surrounding plain.

The *Quana group* lies along the south side of the Wichitas in the south half of T. 3 N., R. 13, 14 and 15 W. They resemble the Wichita group but the peaks are not so high. The *Carlton Mountains* lie between the east ends of the Wichita and Quana groups. They are composed of porphyries and rhyolites which weather into small fragments instead of into large bowlders as the granite does. Consequently the Carlton Mountains have a more rounded topography than the Wichita or Quana groups. Medicine Bluff is the most striking feature of this group. It

is formed by Medicine Bluff Creek flowing against the north side of a porphyry hill 1 mile west of Fort Sill and is a bluff 100 to 400 feet high and one-half mile long.

The Raggedy Mountains consist of a broad group of isolated mountains and hills extending nearly north and south and lying west of the Wichita-Quana groups, and separated from them by a broad, flat plain of Redbeds. The Redbeds also separate the individual mountains. In these Redbeds the igneous rock often comes near the surface, showing that the whole Wichita Mountain group is really a continuous mass of igneous rock of which all but the highest peaks are buried in the Redbeds. As the sediments for the Redbeds were derived from the mountains themselves, they are often said to be buried in their own ruins.

The central mass of the Raggedy Mountains is composed of gabbro and black granite. The only elevated area of this rock occurs in the vicinity of Roosevelt and Cold Springs. This rock weathers into bowlders but they are not so angular as the granite bowlders and the topography is rounded and is more like that of the Carlton Mountains than of the Wichita-Quana group. The northern and southern portions of the Raggedy Mountains are composed of small isolated granite peaks.

The Devil's Canyon group consists of several granite peaks near Lugert. The principal peaks are Devil's Canyon Mountain, Tepee Mountain, Dome Mountain, Quartz Mountain and Soldier Mountain. The group lies northwest of the Raggedy Mountains and is separated from them by a Redbeds plain. Headquarters Mountain is a mass of granite about three square miles in area which is near the town of Granite City. This mountain and the accompanying small peaks are the extreme northwestern end of the system.

THE IGNEOUS ROCKS OF THE WICHITA MOUNTAINS.

The igneous rocks of the Wichita Mountain system are divided into four divisions on the basis of age.

The gabbro and black granite seem to be the oldest of these rocks. They occur in four principal erposures, (1) along the north side of the main or Wichita range; (2) along the west side of the same range and in the plain separating the Wichita-Quana from the Raggedy Mountains; (3) in the plain between the Wichita and Quana groups, and (4) in the central part of the Raggedy Mountains. Of these, the last named is the only exposure that has sufficient relief or is favorably enough situated in regard to transportation to render it of commercial importance.

In this exposure, the rock is a close-textured, gray to black rock. It is very tough under the hammer and has a somewhat irregular fracture. The samples which were collected by Taff are described as follows[39]: "the prevailing physical aspect of the gabbro is that of a dark

39. Taff, J. A. Op. Cit. page 60.

gray to black, rather coarsely crystalline rock. The gabbro proper consists of labradorite, augite, and magnetite with a little biotite and accessory titanite. It is a typical gabbro, fairly fresh, or with the augite altered to uralitic hornblende." The black granite which is younger than the gabbro often grades into diorite.

The black granite has been quarried for building and ornamental stone at Cold Springs on the St. Louis and San Francisco Roalroad, and it is planned to put in a crushing plant at the quarry to utilize the waste stone. The quarry is located along the railroad in the side of a large hill. The quantity in sight is inexhaustible. The analysis and result of the tests of a sample of the stone from this quarry are as follows:

Sample No. 4367.

Physical Tests.

Location	Cold Springs, Oklahoma.
Material	Diorite.
Specific gravity	2.85
Weight per cubic foot	178. pounds.
Water absorbed per cubic foot	.24 pounds.
Per cent. of wear	2.8
French coefficient of wear	14.3
Hardness	18.4
Toughness	22.0
Cementing value	Fair.

Remarks: A hard and tough rock with high resistance to wear and fair cementing value. Should make a satisfactory road material.

Mineralogical Analysis.

Plutonic rock	Diorite.

Essential Minerals.

Plagioclase	41.1
Hornblende	28.0
Quartz	10.7

Accessory Minerals.

Biotite	5.7
Magnetite	3.1
Apatite	1.0

Secondary Minerals.

Chlorite, Augite	7.3
Kaolin	3.1

Remarks: Specimen is a dark gray, coarse grained rock composed essentially of plagioclase (andesine) hornblende and quartz.

In close association with the gabbro is a bluish white rock resembling the gabbro in structure but which on close study proves to be anorthosite. This rock is composed almost entirely of labradorite feldspar with a trace of magnetite. It is exposed along the railroad between Cold Springs and Roosevelt. It is favorably located for quarrying and should be a valuable stone for either building or road purposes. It has been quarried to some extent just north of Cold Springs by the same company which operates the granite quarry.

The red or pink granite makes up the greater part of the mass and area of the Wichitas. It comprises almost all of the Wichita-Quana groups, the northern and southern portion of the Raggedy Mountains and all of Devil's Canyon and Headquarters groups. Portions of all of these exposures are favorably located to railroads. The easternmost peak of the Wichita range comprises an area of over one square mile and is about one-half mile distant from the Chicago, Rock Island and Pacific Railroad, four miles north of Fort Sill. The Quana Mountains can be reached from the St. Louis and San Francisco Railroad in the neighborhood of Cache by from 1 to 3 miles of switch. Several of the peaks of the southeastern Raggedy Mountains are easily accessible to either branch of the St. Louis and San Francisco Railroad at Snyder, and another area of four square miles is near the north and south line midway between Mountain Park and Cold Springs. The Kansas City, Mexico and Orient cuts the Devil's Canyon Mountain at Lugert, and the Chickasha-Mangum branch of the Chicago, Rock Island and Pacific passes very near Headquarters Mountain at Granite City.

The granite is usually a moderately coarse-grained, red-colored rock. It consists largely of quartz and feldspar in about equal amounts with subordinate amounts of hornblende. The feldspar is a red orthoclase which gives the characteristic color to the rock. Local variations in color and structure are common, especially near the contact with the gabbro. The rock is somewhat porphyritic, the large crystals of feldspar being surrounded by micropegmatitic growths of quartz and feldspar. The granite is usually firm and massive in structure, but near lines of faulting it is often shattered so that it is easily broken into small angular fragments. The gabbro and black granite previously described are often cut by dikes of this granite which vary in thickness from a fraction of an inch to 30 or 40 feet. In the exposure of gabbro on the west end of the Wichita range the granite lies above the gabbro. This relation and the dikes of granite in the gabbro prove conclusively that the granite is younger than and has been intruded into the gabbro.

The only one of the locations mentioned above that is being worked for crushed stone is the one at Granite City (fig. 38). The Ruggles Granite Company has had a quarry and mill in operation about 1 mile northwest of town on the south side of Headquarters Mountain for some years and have recently installed a crusher. The granite is the typical

red granite of the region. It is moderately coarse-grained, and when shot by heavy charges for the crusher, shatters rather badly, producing a large percentage of fine material. Both the building stone quarry and crusher quarry are located on a spur from the Chicago, Rock Island and Pacific Railroad. The machinery at the crushing plant consists of a No. 5 Austin-Gates crusher, with rotary screens and storage bins of a few tons capacity. The rock is hauled from the quarry face to the crusher, by side-dump gravity cars. A sample gave the following analysis and tests:

Sample No. 4369.

Physical Tests.

Locality	Granite City.	
Material	Hornblende granite.	
Specific gravity	2.69	
Weight per cubic foot	165.	pounds.
Water absorbed per cubic foot	0.20	pounds.
Per cent. of wear	6.3	
French coefficient of wear	6.3	
Hardness	18.7	
Toughness	8.0	
Cementing value	Fair.	

Remarks: A hard rock with low toughness, low resistance to wear and fair cementing value. Not recommended except for the foundation course.

Specimen is a coarse-grained pinkish, brown, granite, composed essentially of quartz, green hornblende and orthoclase impregnated with iron oxide.

A few rods west of the quarry of the Ruggles Granite Company is a high bluff where the rock is extremely fine grained, porphyritic, is somewhat brittle and breaks with a clean fracture. This material is reached by a spur from the Chicago, Rock Island and Pacific Railroad, and considerable of the material has been used as rip-rap by that company. Time was not taken to determine whether this was a dike through the coarse-grained granite or merely a porphyritic phase of the granite[40]. In either case the amount of material available would be reckoned in millions of cubic yards. A sample taken from this point gave the following analysis and tests:

Sample No. 4368.

Physical Tests.

Location	Granite City.
Material	Granite porphyry.

40. According to C. H. Taylor who has examined the region in detail since the above was written the fine-grained rock occurs as large bowlders in the coarse-grained granite.

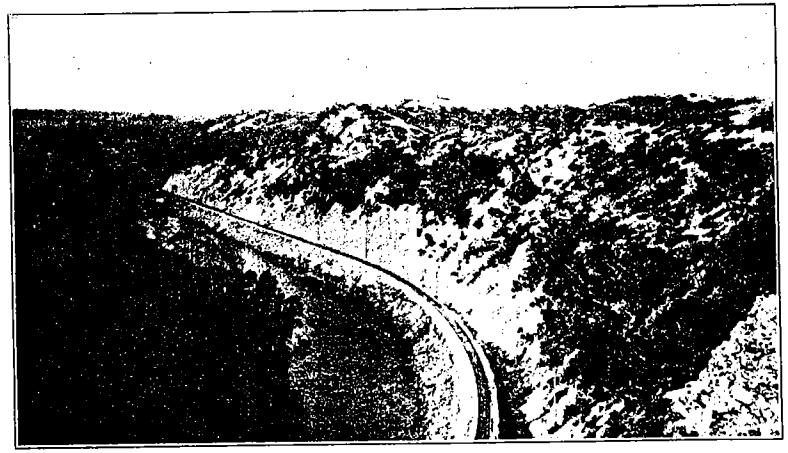

Fig. 35. Viola limestone at Rock Cut, South of Davis.

Fig. 36. Portion of Asphalt pit at Ada.

Fig. 37. Wichita Mountains from Cache.

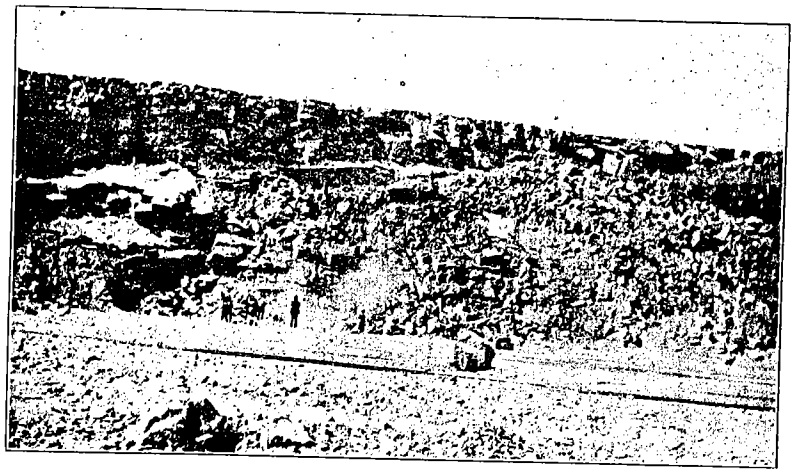

Fig. 39. Quarry at Richards. (Arbuckle limestone)

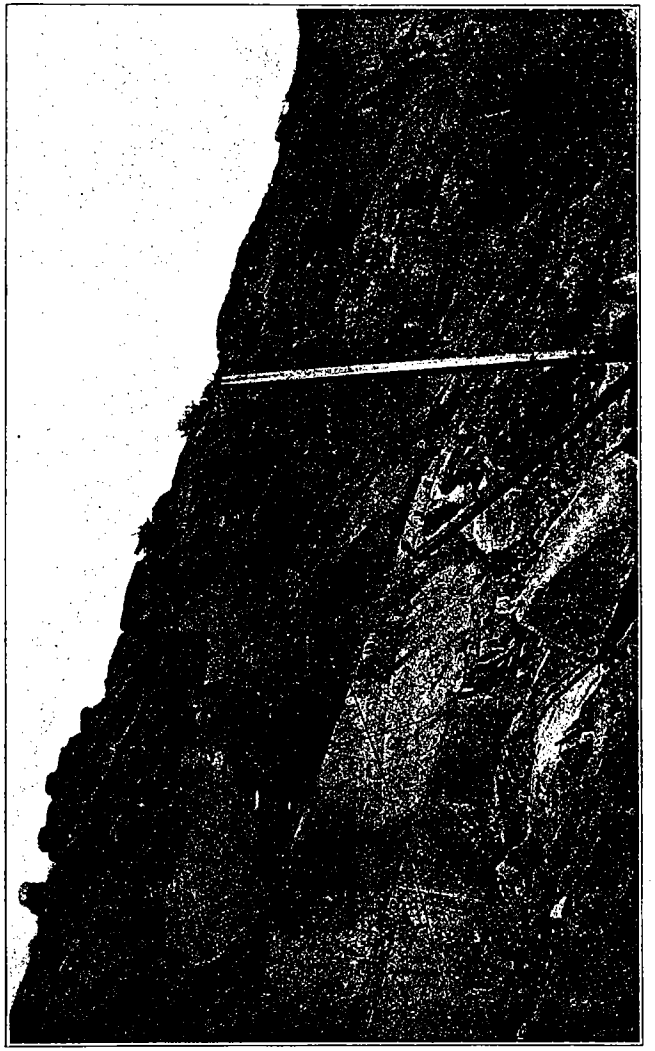

Fig. 38. Quarry at Granite.

Fig. 40. Outcrop of Goodland Limestone near Garvin.

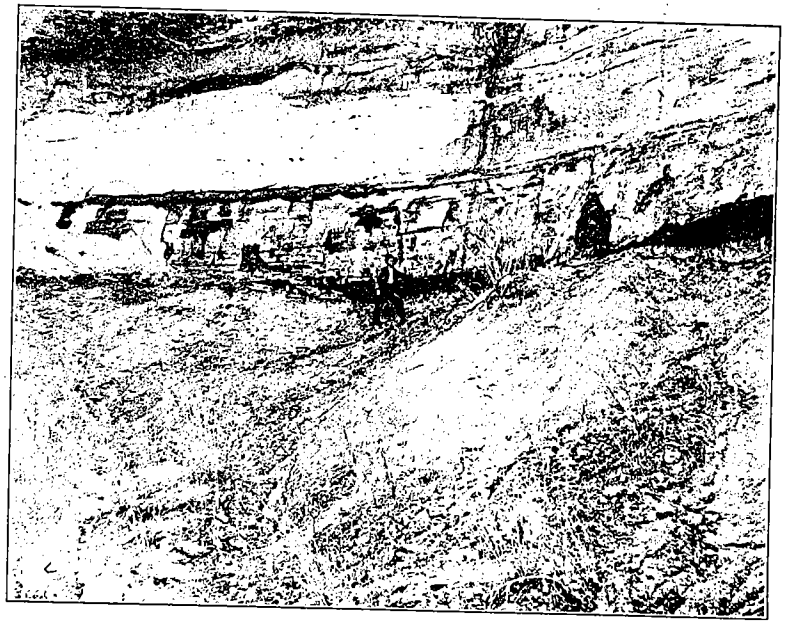

Fig. 41. Asphalt in Trinity sand near Russett.

Fig. 42. Natural Roadway over Limestone near Hardy.

Fig. 43. Sandstone Bridge over Clear Creek near Pawhuska.

Specific gravity	2.65	
Weight per cubic foot	165.	pounds.
Water absorbed per cubic foot	0.12	pounds.
Per cent. of wear	2.5	
French coefficient of wear	15.7	
Hardness	19.3	
Toughness	21.0	
Cementing value	Fair.	

Remarks: A hard and tough rock with high resistance to wear and fair cementing value. A binder of higher cementing value should be used if possible.

Mineralogical analysis.

Character of material	Intrusive rock.
Name	Granite porphyry.

Essential Minerals.

Orthoclase	50.1
Quartz	24.2
Plagioclase	9.5
Biotite	5.4

Accessory Minerals.

Hornblende	0.6
Apatite	0.2
Hematite	
Magnetite	5.8

Secondary Minerals.

Kaolin	4.2

Remarks: Specimen is a pinkish-gray, porphyritic rock composed essentially of large crystals of orthoclase, quartz, plagioclase (oligoclase) and biotite embedded in a granophyric intergrowth of quartz and orthoclase.

The Oklahoma State Reformatory is located one mile southeast of Granite beside a granite hill of several acres in area and over 100 feet in height. The granite in this hill varies considerably from that of Headquarters Mountain. It is of a lighter color, being a pink, somewhat resembling the Texas granite. It is not so coarse grained as the red granite and seems to be of a firmer texture. Hornblende seems more abundant than in the red granite.

As soon as arrangements can be made, it is planned to install quarrying and crushing machinery at this location, the labor to be furnished by the convicts. A spur from the Chicago, Rock Island and Pacific Railway may be easily installed. The product will be available for the construction of public buildings and public roads.

There are slightly varying kinds of granite, the principal variation being in color. The sample was taken from the predominating type and as the variations are so slight it may be taken as representative of the whole hill.

The analysis and tests follow:

Sample No. 4370.

Physical Test.

Location	Granite, Oklahoma.	
Material	Hornblende granite.	
Specific gravity	2.65	
Weight per cubic foot	165.	pounds.
Water absorbed per cubic foot	0.20	pounds.
Per cent. of wear	3.8	
French coefficient of wear	10.5	
Hardness	19.0	
Toughness	9.0	
Cementing value	Fair.	

Remarks: A hard rock with low toughness, medium resistance to wear and fair cementing value. Not recommended except for the foundation course.

Mineralogical Analysis.

Character of material	Plutonic rock.
Name	Granite.

Essential Minerals.

Orthoclase } Kaolin }	43.5
Quartz	31.9
Plagioclase	13.0
Hornblende	8.8

Accessory Minerals.

Zircon	0.2

Remarks: Specimen is a medium grained, pinkish gray granite composed essentially of kaolinized orthoclase, quartz, green hornblende and plagioclase (oligoclase).

The Granite-porphyry. This rock is younger than the gabbro and the granite as it rests upon the granite and dikes of it cut both the gabbro and the granite. It is exposed in the Carlton mountains west of Fort Sill, in the limestone hills in T. 4 N., R. 12 and 13 W., and in a few hills in T. 6 N., R. 14 W., east of the Rainy Mountain Mission. The only exposure accessible to railroad is the east end of the Carlton Mountains which can be reached by about 1 mile of spur track from

the Chicago, Rock Island and Pacific Railroad one mile north of Fort Sill. The rock in this section is described as follows by Taff[41]:

"It is a dull-pink rock, with phenocrysts of feldspar and quartz, in a dense or finely granular ground mass. The feldspar phenocrysts are all orthoclase, frequently twinned according to the Carlsbad law, and from 3 to 4 millimeters in length. The ground mass is largely feldspathic, and in part possibly micropegmatitic, is now very much decomposed, and looks not unlike the divitrified base of a surface glassy flow. With the exception of a little doubtful hornblende there are no dark silicates to be made out. The feldspars are all charged with a fine reddish dust, probably hematite."

No observation of this location was made nor any samples collected by the writer.

The Dike rocks. The gabbro, granite and porphyry are cut in all directions by diabase dikes similar to those in the Arbuckle Mountains. The rocks are not known to occur in sufficient quantities to be used as a road material so will not be considered further here.

Granite gravel. Granite gravel occurs in the streams which flow across the granite areas of the Wichitas. It occurs in large quantities in Cache Creek near the town of Cache. A spur has been built from the St. Louis and San Francisco Railroad along the creek and considerable gravel and sand have been shipped to Chickasha and Lawton. The sand and gravel is angular and very free from clay or loam. Pettey and Thompson of Cache are the principal operators. The price of the material is about 65 cents per cubic yard F. O. B. cars at Cache. This material on the clay of the level plains makes a fine road surface and should be used extensively on the roads in the vicinity of the mountains.

LIMESTONES OF THE WICHITA MOUNTAINS.

Of all the immense series of sedimentary rocks exposed in Arbuckle Mountains only the Reagan sandstone, Arbuckle limestone and Viola limestone are exposed in the Wichitas.

The Arbuckle limestone is exposed in two parallel ranges of hills north of the main range of the mountains. They extend from southeast to northwest and at the southeastern end the two ranges are separated by the exposure of the porphyritic granite. The southeastern extremity of the northern ridge is about one mile south of the station at Apache. Dolese Brothers have a quarry and crusher plant at this point which is known as Richard's Spur. It is reached by a spur from the railroad and is well provided with switching and storage facilities. The Company controls about 40 acres and have a quarry face 50 feet high by about 500 feet long (fig. 39). The stone is hauled from the quarry face to the

41. U. S. G. S., Prof. Paper No. 31.

crusher by side-dump push cars on tracks. The screens are of the usual size. Three crushers are installed, Nos. 8, 5, and 4 Gates style, with an average daily output of 500 cubic yards. The product is distributed to the neighboring towns, principally for concrete work. Oklahoma City, Enid, El Reno, Chickasha and Lawton take the most of it.

The stone is very similar to the Arbuckle limestone quarried by the same company at Crusher in the Arbuckle Mountains. The report of test of the Richards material follows:

Sample No. 4366.

Location	Richards Spur.
Material	Limestone.
Specific gravity	2.70
Weight per cubic foot	168. pounds.
Water absorbed per cubic foot	0.20 pounds.
Per cent. of wear	4.0
French coefficient of wear	10.0
Hardness	16.6
Toughness	6.0
Cementing value	Good.

Remarks: A rock of medium hardness and resistance to wear and good cementing value. Should make a fairly satisfactory road material.

ROAD CONDITIONS IN THE WICHITA MOUNTAINS.

In the mountains themselves the population is very thin and much of the area is comprised in the United States Forest Reserve. Consequently there is little need of improved roads over the mountains. On the level plains at the foot of the hills the conditions are those of the remainder of Western Oklahoma and are considered in that connection. It may be said, however, that where the granite sand occurs mixed naturally with the Redbeds clay at the base of the mountains, a very firm, satisfactory roadway results. All that is necessary to produce good roads where the clay contains the granite sand is proper grading and drainage.

The sand can be used advantageously on all the roads which are in hauling distance of the streams which flow across the mountains and many miles of good road should result from its use.

THE CRETACEOUS AREA.

LOCATION AND AREA.

The Cretaceous area comprises the extreme southern portion of Oklahoma. It lies south of a line which crosses Red River a short distance west of Marietta, and extends northeast to near Ardmore, east and northeast past Tishomingo to Atoka, then swings southeast past Antlers and cuts the Oklahoma-Arkansas line not far from Red River. The area includes all of Marshall, Bryan, and Choctaw counties, the southern portions of McCurtain, Pushmataha, Atoka and Johnston counties, with the southeast corner of Carter County and the east half of Love County.

STRATIGRAPHY.

The Cretaceous rocks dip gently to the southeast. To the north they lie upon the upturned edges of the Paleozoic rocks of the Arbuckle Uplift, the Pre-Cambrian granite or the Carboniferous rocks of the Ouachita Uplift.

The following generalized section of the Cretaceous rocks is given by Taff[42]:

Silo sandstone	Brown friable sandstone, locally indurated by ferruginous cement, shale and shaly limestone.
Bennington formation	10-15 feet. Blue shell limestone.
Bokchito formation	140 feet. Red and blue shale with thin ferruginous limestone and lentils of friable sandstone.
Caddo limestone	60 feet, yellow and white limestone interstratified with thin marly beds.
Kiamichi formation	150 feet. Blue friable shale with thin shell limestone beds in lower portion.
Goodland limestone	25 feet. Massive white limestone.
Trinity sand	200-400 feet. Fine yellow sand with conglomerate beds locally at the base.

ROAD MATERIALS OF THE CRETACEOUS AREA.

Of these formations, the Goodland limestone, the Caddo limestone and the Bennington limestone are suitable for material for macadamized roads. Some of the limestone lentils in the Kiamichi and Bokchito formations may be available for local use but as the Goodland, Caddo and Bennington are never separated by any great distance, it will be better to develop the thicker ledges.

The Goodland limestone is a massive white limestone about 20 feet thick. It outcrops as a north facing bluff standing above the soft, easily eroded Trinity sands (fig. 40). The outcrop is sinuous owing to the small streams from this bluff cutting back into it. Almost any place along its outcrop will be a suitable location for small crushers for local road building purposes and good locations for larger plants were observed at Madill and Goodland. At Goodland the St. Louis and San Francisco Railroad cuts through the limestone. At Madill, the

42. U. S. Geological Survey, Atoka Folio.

limestone forms a pronounced bluff along a small creek near the intersection of the Red River division and Arkansas and Choctaw division of the St. Louis and San Francisco Railroad. The Goodland is also well exposed near Garvin and Idabel in McCurtain County.

The Caddo limestone consists of clay, marls and limestones, the last increasing in proportion toward the top. The limestone beds even at the top are separated by thin marly layers. This limestone is well exposed along the Missouri, Kansas and Texas Railroad near Caddo, from which town the formation is named.

The Bennington limestone is a massive, dull blue limestone about 10 feet in thickness. It caps the hills near Caddo and is well exposed at Bennington. The limestone is in large part composed of the shells of a small species of oyster.

The asphalts of this region occur for the most part in the Trinity sands, usually as lens-shaped bodies, of variable thickness and extent (fig. 41). All the asphalts observed in the Cretaceous by the writer are soft malthas and not suitable except as fluxes for the harder pitches and for oiling earth or sand roads as previously discussed. Deposits are known in many places in the region, the principal ones having been described by Hutchison in Bulletin No. 2 of this survey.

ROAD CONDITIONS IN THE CRETACEOUS AREA.

Topography. The Trinity sands form a broad plain 10 to 18 miles in width with low rounded knobs. Rising above this is the escarpment of the Goodland limestone. South from this is a succession of steps caused by the alternation of hard and soft strata of the Kiamichi, Caddo, Bokchito and Bennington formations. The streams in cutting through these give rise to many hills none of which, however, are of great height or are very rugged. There are broad belts of level land on top of the limestone ledges due to the weathering back of the softer shaly formations. The Silo sands weather into rather steep hills separated by V-shaped valleys.

Climate. The rainfall in this section is rather heavy and as many of the roads are on the black soil of the limestone belt they become very muddy. The roads practically never freeze in winter.

The Trinity sands weather rapidly and form sandy soils or sand with very little loam in it. The roads through the sand belt resemble those of the other sand areas and the methods of improvement should be the same. The use of the asphalt which occurs in the same sands in improving the natural roadways has already been discussed and need not be repeated here.

Over most of the Cretaceous region, macadam is the logical improved roadway. The presence of the different limestones and the climate are both favorable to the construction of such roads. The land, too, for the most part, is very fertile and the development of the agricultural resources will require permanently improved highways and at the same time the land will be valuable enough to support taxation sufficient to build such roads.

The only improved roads reported from this area in 1909 were 30 miles of sand-clay roads in Bryan County.

CHAPTER VII.

ROAD MATERIALS AND CONDITIONS BY COUNTIES

INTRODUCTION.

In this chapter an attempt is made to review very briefly the present situation of the road affairs in each county. The location of the county is given, the principal road materials named, and the topography and drainage noted. Since the different formations have been discussed in the proceeding chapter the observations on the formations and the character of the material are not repeated here. Reference can easily be made by Chapter VI for more detailed information concerning any formation. The data for the second paragraph were obtained as the result of information from the county surveyors, county commissioners and county clerks of the several counties. No reports were received from eight counties but in some of these cases the conditions were known to some member of the Survey staff so that they could be filled in.

While the consideration of each county separately makes necessary a great deal of repetition, it is believed that the advantage of having the data for each county in compact and easily accessible form more than compensates for this repetition.

COUNTIES.

Adair County lies in the east-central part of the State and has the state of Arkansas as its eastern boundary. The surface rocks are almost entirely of Mississippian age (Boone chert); the exceptions being Pennsylvanian rocks on some of the hills and in the southeast portion. The drainage is principally to the south and southwest through Barren Fork of Illinois River and through Caney, Sallisaw and Lees creeks. The topography is rough and broken. Road material in the form of chert, gravel or limestone is abundant in all parts of the county and the macadam road is the logical improved road for the county. Many of the natural roadways are covered with fragments of chert and with some grading and drainage can be made into satisfactory roads.

Since statehood many of the roads have been re-located on section lines but much of the county is so hilly that such location is not practicable. About one-half of the roads are worked to some extent each year. Several culverts have been built of wood and two 40-foot wooden bridges have been constructed. No steel bridges have been built. No bonds have been voted for road improvement. The townships are provided with plows and scrapers but none have graders nor stone crushers.

Alfalfa County borders on the Kansas line west of the middle of the State. The surface rocks are the Permian Redbeds and consist of red shales and soft sandstones. The surface rocks are soft sandstones and shales, except a broad belt of sand hills along the north side of Salt Fork of Arkansas River. The roads are all laid out on section lines and with the exception of those in the sand hills are easily kept in passably good condition. About 25 per cent. of the roads are worked each year. There is no material for macadam roads in the county and none of importance within reasonable distance. Permanently improved roads will probably be of sand-clay or oiled earth. About thirty steel bridges and many culverts have been built. No permanently improved roads have been built and no bonds for road purposes have been voted. The townships are equipped with drag scoops and with graders.

Atoka County is situated in the southeastern portion of the State. The surface rocks of the northeastern portion are those of the Ouachita Uplift, viz., the Stringtown shale, Talihina chert, Standley shale and Jackfork sandstone; the Hartshorne, McAlester, Savanna and Boggy formations outcrop in the north-central part; the Wapanucka limestone and rocks of the Arbuckle Uplift occur in the western portion and the Trinity sand and Goodland limestone of Cretaceous age form belts extending across the southern third of the county. The drainage is to the southeast through Clear Boggy, Muddy Boggy and McGee creeks. The greater portion of the surface is rough and hilly but there is much level land in the creek valleys and on the Trinity sand outcrop in the south portion. Practically all of the county is in reach of either the Wapanucka, or Goodland limestone outcrops so that material is at hand for macadam roads. The soft asphalt which occurs in the Trinity sand may be used to advantage as a dressing for the roads crossing the outcrop of this formation. There are also several deposits of asphalt reported from other parts of the county but they have not been studied in detail. There are at present no permanently improved roads in the county but the abundance of material and demand for such roads in the more level portions will undoubtedly cause a rapid improvement in road conditions in the near future.

Beaver County occupies the eastern third of old Beaver County or No Mans land. The surface rocks are principally of Tertiary age with a belt of Redbeds along the south side of Beaver Creek and a belt of sand hills along the north side of the same stream. The county lies entirely in the High Plains region and the surface is a plain into which Beaver Creek and its tributaries have cut deep channels. There is little

material for improved roads but the natural earth roads are not bad and if properly graded and cared for would be satisfactory. The roads through the sand hills should be treated with clay. The county is thinly populated and it is improbable that extensive road improvements can be undertaken for some time.

At present not over one-tenth of the roads are worked each year. The townships are supplied with plows and drag scoops; some have graders. Three pile bridges have been built across Beaver Creek, one at Beaver, one 15 miles west of Beaver and one at Cline in the eastern portion of the county.

Beckham County is located in the extreme western portion of the State and is bounded by Texas. The Permian Redbeds occupy the entire county except for a belt of sand hills from 5 to 10 miles in width on the south side of North Fork of Red River, which drains the county to the southeast. In the southern part of the county the Redbeds belong to the Greer formation and contain several ledges of gypsum. The gypsiferous clay from this formation will be very valuable for the construction of sand-clay roads through the sand hills. There is little or no material for macadam roads but sand-clay roads will probably prove more valuable than macadam in this section of the State on account of climatic conditions. The surface is level to rolling.

Practically all the roads are laid out on section lines and about half of them are worked each year. About 10 miles of sand-clay roads have been built and twenty steel and twenty wooden bridges have been constructed over the smaller streams. Corrugated steel is used for culverts. The townships are provided with drag scoops and with road graders. No road or bridge bonds have been issued.

Blaine County lies to the northwest of the center of the State. It is entirely within the Redbeds area and the surface rocks are of the Permian series except for belts of sand hills along the north sides of North Canadian and Canadian rivers which drain the county to the southeast. The Blaine formation extends from southeast to northwest across the county and gives rise to a pronounced escarpment, the main line of gypsum hills. Dolomite caps some of these hills and furnishes the only macadam road material for the county.

At present all the roads are on section lines but only a small portion of them are worked each year. Three-fourths mile of macadam road was built near Watonga in 1909. Anhydrous gypsum was used for the foundation and dolomite for the surface. Since 1907 eight bridges with spans of from 50 to 75 feet, one bridge of two 70-foot spans with 16-foot steel approaches and one bridge of three 70-foot spans have been built. All are of steel on reinforced concrete foundations. Forty-three concrete box culverts have been built in the same time. No bonds for road purposes have been issued and no road improvement districts

have been organized. The townships have scoops and graders and the city of Watonga has a stone crusher.

Bryan County is bounded on the south by Texas and lies to the east of the middle of the State. It is entirely in the Cretaceous area and the surface rocks are limestones and soft shales with sandstone in the southern part. There is a belt of alluvium along Red River. The drainage is into Red River, principally through Washita and Blue rivers. The soil, especially on the limestone and shale, is rich and well adapted to farming. It is a black clay loam which when wet makes almost impassable roads. Under these conditions the demand for improved roads will soon be imperative. The different limestone ledges which cross the county, the Goodland, Caddo and Bennington will furnish an abundance of material for macadam roads. These limestones are rather soft for such usage but roads constructed of them will wear for many years if properly maintained. There are some deposits of asphalt near Durant which will furnish material for the improvement of roads in the sandy regions of the country.

Only a part of the roads have been re-located on section lines. No improved roads have been built and no road bonds have been issued. Several steel bridges and culverts of wood and of corrugated steel have been installed. A small portion of the roads are worked with plows and drag scoops each year.

Caddo County lies southwest of the center of the State. It is included in the western district of the State and the rocks belong to the Permian Redbeds except for an area of Arbuckle limestone in the southwest corner. A ledge of siliceous limestone in the Redbeds at Cement in the southeast corner of the county also affords excellent macadam road material. Except for a few thin ledges of dolomite there is no macadam material in the northern part of the county and sand-clay construction will probably have to be used here. Many of the natural roadways contain very nearly the proper proportions of sand and clay and are already tolerably good through the greater part of the year.

No permanently improved roads have been built at present and no road bonds have been issued. The roads are on section lines except in a few instances where such location is not practicable. Only a small portion of the roads are worked with road graders each year. Three large steel bridges have been built; one across Little Washita River at Cyril; one across Cache Creek south of Apache; and one across Washita River near Carnegie. Several smaller bridges and many wooden and concrete culverts have been constructed, and more concrete culverts are planned. The people of the county are deeply interested in the road question and several plans for improvement are under consideration.

Canadian County lies just west of the center of the State. North Canadian River flows southeast across the central part of the county

and the South Canadian across the southwest corner. The rocks of the county are all Permian Redbeds (except a narrow strip of sand hills along North Canadian River) and consist of soft red sandstones and shales. The surface is level to rolling. Many of the natural roadways are mixtures of sand and clay, and sand or clay can be secured to improve those roads which are lacking in either constituent. In view of the lack of macadam material and the climatic conditions it is doubtful if macadam roads would be advisable, since sand-clay roads can be constructed so much more cheaply and will give as good satisfaction.

Practically all the roads are on section lines and all are worked and graded to some extent. No road improvement bonds have been issued. Over one hundred steel bridges have been built in the county. Concrete is used for culverts. All the townships have plows, scoops and graders.

Carter County is situated in the south-central part of the State. The northeastern portion is in the Arbuckle region; the eastern portion is underlaid by the Glenn formation and the western portion by the Permian Redbeds. There is an area of older Paleozoic rocks known as the Criner Hills in the southern part of the county and the extreme south-central and southeastern portions are in the Cretaceous area. The surface is hilly in the Arbuckle Mountains, rolling to hilly in the other portions. The drainage is to the southeast through Caddo Creek and Washita River. The limestones of the Arbuckle Mountains and Criner Hills will supply macadam material and some of the largest deposits of asphalt in the State occur in the Glenn formation, in this county.

Many of the roads have not been re-located on section lines on account of the difficulty of securing the right of way through Indian lands, but the work of re-location is proceeding rapidly. Many bridges have been built and new ones are being built at the rate of four to six per month. All over 20 feet in length are of steel and the larger ones over Washita River, Caddo Creek and Walnut Bayou are of high truss construction. One 40-foot bridge of reinforced concrete built as an experiment has so far been satisfactory. Corrugated steel is used for culverts. The county has issued $100,000 bridge bonds and the townships have issued $60,000 for opening roads, buying machinery, building culverts, etc. All of this improvement has been made since statehood so that Carter County bids fair to take the front rank in the matter of road improvement in the future.

Cherokee County is situated in the east-central portion of the State. The greater part of the county is in the Mississippian area but the southwestern part is underlaid by Pennsylvanian limestones, shales and sandstones. The northern part is very rough and hilly, the southwestern part is rolling to hilly. The drainage is into Arkansas River through Grand and Illinois rivers. The Boone chert and the Pitkin limestone furnish inexhaustible supplies of macadam material. The hills are often covered

to a depth of several feet with disintegrated chert and there are large quantities of chert gravel or "chats" in the stream beds.

About 50 per cent. of the roads have been re-located on section lines. Much of the county is too hilly for section-line roads to be feasible. Some work is done upon all the roads and a small part of them are graded each year. Most of the townships have plows and scoops but only one has a scraping grader. Three small steel bridges with concrete piers and wing-walls have been built. Concrete and corrugated steel have been used for culverts.

Choctaw County lies in the southeast part of the state, Texas forming its southern boundary. The whole county is in the Cretaceous area. The surface is level to rolling. The drainage is into Red River principally through Boggy Creek and Kiamichi River. The Goodland, Caddo and Bennington limestones extend the length of the county and furnish abundant macadam material. The soil is mostly a black loam, which makes very fine farming land but very bad roads.

The majority of the section lines have been opened as highways since statehood, and some work is done on all the roads each year. Twenty-four small bridges have been built by the county. The majority of the culverts are of wood but corrugated steel and concrete are coming into use. Bonds for $120,000 have been voted to build steel bridges. All townships have plows and scoops and some have graders. Graders are difficult to use on account of the limestone exposures on the prairie land and the stumps on the newly opened roads through the timber. Wilson Township has a rock crusher.

Cimarron County is the extreme northwestern county of the State and occupies the western third of No Mans Land or the "Pan Handle." Tertiary rocks outcrop over about three-fourths of the surface. The northwestern portion is underlaid by Dakota sandstone, and there is a small area of lava rock known as Black Mesa in the extreme northwestern corner. The surface is in general a plain into which Cimarron River and Beaver Creek have cut channels. The Tertiary deposits consist principally of soft sand and clay, and except for the lava rock there is little material for macadam roads. The county is thinly settled and the climate is dry so that there will probably be little demand for macadam roads. The natural roads if properly graded, or sand-clay roads will serve all purposes.

The roads are all on section lines. Very few are worked, and no bridges or culverts have been built. One township is provided with drag scoops.

Cleveland County lies just south of the center of the State. It is entirely in the Redbeds area. The rocks of the eastern portion belong to the Pennsylvanian Redbeds and the surface is rather hilly, while the rocks of the western portion are of Permian age and the surface is

level. Canadian River forms the southern boundary and Little River flows east across the northern portion. The Redbeds rocks are all sandstones and shales and there is no macadam road material of any sort. Some of the natural roadways closely approximate a sand-clay mixture but many, especially in the eastern part of the county and near Canadian River, are too sandy.

The roads are all on section lines and are kept in fair condition. The townships have scoops and graders. Several steel bridges have been built across Little River and across Chouteau Creek in the southeastern part of the county.

Coal County is located southeast of the center of the State. The surface rocks, except in the extreme southwest corner belong to the Pennsylvanian system and consist almost entirely of sandstone and shale. There is a small area in the southwest corner of the county in which the limestones of the Arbuckle Mountains and the Wapanucka limestone are exposed. The surface as a whole is hilly although there are large areas which are fairly level. The drainage is to the southeast through Muddy Boggy and Clear Boggy creeks.

Since statehood the majority of the roads have been relocated on section lines and some work has been done on part of them. No improved roads have been constructed and no road improvement districts have been organized. Twenty-eight steel bridges and a large number of stone and corrugated steel culverts have been built. A bond issue of $35,000.00 has been made for bridges. The townships have plows, scoops and road graders and one has a rock crushing outfit.

Comanche County is situated in the southwestern part of State. The Wichita Mountains occupy the northwestern portion and the Permian Redbeds the eastern and southern parts. Except for the Wichita Mountains the surface is level to rolling. Drainage is into Red River principally through Cache Creek. The granite, porphyry and limestone of the Wichitas offer an inexhaustible supply of macadam road material. A large commercial crushing plant is operated in the Arbuckle limestone at Richard's Spur. The streams flowing from the mountains carry large quantities of granite gravel which can be used with splendid effect on the roads. There are some deposits of asphalt near Lawton.

Practically all the roads are on section lines. Only a small portion are worked each year and no permanently improved roads have been built. All the streams are bridged at the more important crossings. Bridges of over 20-foot span are of steel. Wood and corrugated steel are used for culverts. Some of the townships have road graders.

Craig County borders on Kansas and is separated from Missouri by Ottawa County. The surface rocks belong to the lower part of the Pennsylvanian system (Cherokee shales or Vinita formation) except for an area of Mississippian limestone in the southeast part. Besides

this limestone there is little macadam material in the county. The surface is generally level. The drainage is to the south, principally through Big Cabin Creek.

The majority of the highways have been re-located on section lines; about one-fourth of the roads are worked each year. No permanently improved roads have been built and no bond issues have been made. Six large bridges with spans of from 70 to 145 feet have been built of steel with concrete floors. There are several smaller bridges and culverts. The townships have plows, scrapers and road machines.

Creek County lies northeast of the center of the State. The surface rocks are a succession of shales and sandstones of Pennsylvanian age. A few ledges of limestone occur in the northeastern part. The sandstone ledges are resistant to weathering and form pronounced ridges and hills. The drainage is to the east through Polecat Creek, Deep Fork of Canadian River and Cimarron River. There is very little macadam material in the county and material for permanently improved roads except for sand-clay roads will have to be imported.

Few of the roads are located on section lines and no permanent roads have been built. Not over 10 per cent. of the roads are worked annually. Sixty-nine steel bridges have been built, two of them being 600-foot spans over Cimarron River at Mannford and 12 miles west of the same town. Corrugated steel is the principal material used for culverts. The county has voted bridge bonds for $100,000 and Creek Township has voted $5,000 for road improvement.

Custer County lies in west-central Oklahoma. It is entirely in the western district and is underlaid by Permian Redbeds except for several small areas of Lower Cretaceous limestone or shell rock which caps the hills in the western half of the county. This limestone and some local occurrences of dolomite are the only macadam material in the county and they occur in too small quantities to be available except for local use. There are vast quantities of gypsum in the county and the gypsiferous clay can be used to advantage on sandy roads. The surface is somewhat broken by ledges of gypsum and the hills capped by the limestone. The drainage is to the southeast principally through Washita River.

All the roads are on section lines and about one-fourth are worked annually. No improved roads have been built and no bonds issued. Nine steel bridges and fifty frame bridges have been built and forty old bridges have been rebuilt since 1907. Wood and concrete are used for culverts. The townships are well equipped with plows, scoops and graders which are little used on account of poor organization of road system.

Delaware County is situated in northeastern Oklahoma. The surface rock is practically all the Boone formation which gives a rough, hilly topography. The drainage is to the southwest through Grand River and Spavinaw Creek. The chert and limestone of the Boone formation

provide an abundance of good macadam material which is available in all parts of the county. Where the hills are not too steep, the natural roads are fairly good on account of the disintegrated chert which the soil contains.

Owing to the rough topography, the county is thinly settled and practically nothing has been done toward road improvement. Few roads are on section lines and very little road work is done. No bridges nor culverts have been biult.

Dewey County lies in the northwestern part of the State. The surface rocks are Permian Redbeds except a belt of sand hills on the north side of Canadian River and small areas of Cretaceous limestone capping the hills in the western portion of the county. This limestone and some thin ledges of dolomite in the northeastern portion are the only macadam material. The gypsiferous clay of the Redbeds can be used to good advantage in building sand-clay roads through the sand hills.

Less attention is paid to the road situation in Dewey County than in most of the neighboring counties. No improved roads and no large bridges have been built. Only sufficient work is done on the roads to render them passable. Some of the townships have graders but little use is made of them.

Ellis County lies immediately northwest of Dewey County and is bounded on the west by the Pan Handle of Texas. The surface rocks of most of the county are Tertiary deposits consisting of clay and sand. There is a small area of Redbeds in the extreme southeastern portion. About half of the county is in the sand-hills region. There are belts five to six miles in width on each side of Wolf Creek in the north part of the county and a belt eight to twelve miles wide along Canadian River in the south portion. There is no macadam material in the county.

The roads are principally on section lines and about one-fourth of them are worked each year. Eight miles of sand-clay roads have been built. Thirteen steel bridges, two of which are 180 feet long, and six wooden bridges have been built. Corrugated steel is used principally for culverts. One road improvement district was organized but the bond issue was voted down. The townships in the "hard land" have plows, scoops and graders. Those in the sand hills have purchased large mowers and rakes to use in "haying" the roads.

Garfield County is situated in north-central Oklahoma. It lies entirely in the Redbeds area and the surface rocks are of soft sandstone and shale. There is no macadam material of any kind. An area of sand-hills lies in the southwest portion of the county. The surface is level to rolling.

The roads are all on section lines and the majority are worked to some extent each year. All the principal stream crossings are bridged

with steel bridges. No improved roads have been built and no road bonds have been voted. The townships are equipped with plows, scoops and graders.

Garvin County lies south of the center of the State. The greater portion of the county is in the Redbeds area. The eastern part is underlaid by Pennsylvanian rocks below the Redbeds and there is a small area of the limestone of the Arbuckle Uplift in the southeast corner. The streams contain considerable quantities of gravel. The surface is level to rolling. The drainage is to the south through Washita River which has a broad valley through the northwest and central parts of the county.

No great advance has been made in road conditions since statehood. The majority of the roads have been located on section lines but they are not worked extensively. No large bridges have been built. Wood and corrugated steel are used for culverts. No improved roads have been built and no road bonds voted. Some of the townships have plows, scoops and graders. The County Commissioners plan to work the county convicts on the roads.

Grady County lies just southwest of the center of the State. It is entirely in the Redbeds area and has no hard rock except one ledge of quartzitic sandstone which outcrops near Ninnekah. The availability of this stone for macadam roads is doubtful as it seems very low in cementing value. The surface is level to rolling. Drainage is to the southeast through Washita River and its small tributaries.

Less than half of the roads are on section lines and no regular system of working the roads has been established. Some good work is being done locally with convict labor. Several steel bridges have been built in various parts of the county but no culverts have been installed. The county has voted $65,000 bridge bonds. All the townships have small tools and scoops and a few have graders. Interest in improved roads is rapidly increasing but it has not yet crystallized into a definite plan for road improvement.

Grant County borders on Kansas west of the middle line of Oklahoma. The county lies entirely in the Redbeds region and has no macadam material of any sort. A belt of sand-hills averaging 10 miles in width lies along the north side of Salt Fork of Arkansas River which drains the county to the east. The surface is level to rolling. Sand-clay roads will be the principal improved roads of this as of other counties in the Redbeds area.

Practically all the roads are on section lines and the majority of them are worked to some extent each year. Twenty miles of sand-clay roads have been built. Concrete is being largely used for bridges and culverts. The townships are equipped with small tools and graders.

Greer County is situated in southwestern Oklahoma. The surface

rocks are the gypsums, soft sandstones and shales of the Redbeds, with some granite hills of the Wichita Mountains in the eastern portion, and an area of sand-hills in the north-central portion. The granite hills will furnish inexhaustible supplies of macadam material. The surface, except for the granite hills, is level. The drainage is to the southeast through North Fork of Red River and its tributaries.

The roads are on section lines and a good share of them are worked each year. Ten miles of sand-clay roads have been built. Many of the natural roadways are of a natural sand-clay mixture which only needs grading to form a good surface practically throughout the year. Two 400-foot bridges have been built across Elm Fork of Red River. Stone and corrugated steel are used for culverts. No road bonds have been voted. The townships are well equipped with graders and smaller tools.

Harmon County is the extreme southwestern county of the State. It lies entirely in the Redbeds region and the only hard rock is a ledge of dolomite from 1 to 5 feet thick. The surface is a plain into which the streams have cut rather deep valleys. In the northern part there are several gypsum hills and in the southern part, a belt of sand-hills lies between Sandy Creek and Red River.

No report on the present conditions in this county has been received but as it is a part of old Greer County the conditions are probably very similar to those of that county.

Harper County is located in the northwestern part of the State. It lies in the Redbeds area and the surface rocks are all soft, red sandstones and shales, except for some small areas of Tertiary and Cretaceous rocks on the uplands. The Cretaceous limestone and a ledge of dolomite in the northeast part are the only macadam material. A belt of sand hills about 10 miles in width extends across the county along the north side of Beaver Creek. The surface is generally level.

Practically all the roads are on section lines. There is no organized system of working the roads, and they are worked at only enough to keep them passable. The county is not thickly populated and there is a great road mileage, much of it sand roads, so that great improvement is not to be expected in the near future. No improved roads have been built and no bonds have been issued. Four bridges of 40-foot span of wood and steel and one wooden bridge of 200-foot span across Beaver Creek at May have been built. The townships have graders, and small tools.

Haskell County is situated in east-central Oklahoma. Canadian River forms the northwestern boundary and Arkansas River the northeastern boundary. The surface rocks are sandstones and shales of Pennsylvanian age. There is no material suitable for macadam roads. The ledges of sandstone are very resistant to weathering and produce a very rough surface.

The roads have been re-located on section lines where practicable. About one-fourth of the mileage is worked to some extent each year. No improved roads have been built and no road or bridge bonds have been issued. Three steel bridges have been built across Sans Bois Creek. Most of the townships have graders, scoops and plows.

Hughes County lies southeast of the center of the State. The surface rocks are sandstones and shales of Pennsylvanian age and afford no macadam material. The surface is hilly. Canadian River flows across the middle of the county.

The majority of the roads are on section lines. There is little work done on the roads beyond sufficient grading and drainage to keep them passable. No road or bridge bonds have been issued although attempts have been made to have an election called. A large amount of the land is not taxable and this would make the burden of road improvement very heavy and inequitable. Thirty-four bridges have been built by the county and several small ones by the townships. Various materials, wood, steel, stone, are used for culverts. All of the townships have plows and scoops, some have graders.

Jackson County lies in the extreme southwestern part of Oklahoma between the North and South forks of Red River. The county is entirely within the Redbeds area and the rocks consist of red sandstones and shales with gypsum and at least one ledge of dolomite of importance. There are a few granite hills near Navajoe and Headrick in the northeast part of the county. This granite and the dolomite which in the vicinity of Creta and Eldorado attains a thickness of ten to fifteen feet, furnish a supply of commercial macadam material. The surface of the county is generally level although the gypsum and dolomite ledges give rise to some hills of considerable prominence. The drainage is south into Red River, principally through North and Salt Forks.

The roads are all on section lines and the most of them are worked over and a good portion of them are graded each year. The natural roads are fairly good, a great part of them being natural sand-clay. Grading is all that is required to make them satisfactory through practically the whole year. No permanently improved roads have been built and no bond issues have been made for road purposes. Several bridges have been built, one of 1000 feet in length and others smaller. Steel is used for the larger bridges and wood for the smaller ones. Corrugated steel is used for culverts. All the townships have plows, drag scoops and graders.

Jefferson County lies in extreme southern Oklahoma along Red River. The surface rocks are all Redbeds and consist of soft sandstones and shales. There is no hard rock for macadam material in the county. The surface is level to rolling. Drainage is into Red River through Beaver and Mud creeks.

The roads are upon section lines and the majority of them are worked over each season. No permanently improved roads have been built but the natural roads are fairly satisfactory when graded.

Johnston County lies in the southern part of the State. The greater portion of the county lies in the Arbuckle Mountains and has a rough surface. The southern part is underlaid by Cretaceous rocks, the Trinity sand and Goodland limestone. The county has an inexhaustible supply of macadam road material consisting of granite and related rocks, granite gravel and the Arbuckle, Viola, Hunton Sycamore, Wapanucka and Goodland limestones. No part of the county is out of reach of an abundant supply of good macadam material. There are also considerable deposits of asphalt near Ravia and Russett (see fig. 41).

The majority of the roads are on section lines and all are worked more or less. About 50 miles have been graded. No road improvement districts have been organized. Bonds for $100,000.00 have been issued for bridges. Steel bridges with spans of from 300 to 340 feet have been built across Washita River at Mannsville, Russett and Tishomingo; and with spans of from 190 to 220 feet across Blue River at Egypt, Milburn, Connerville and Belton. About thirty smaller steel bridges and ten wooden bridges have been built. Native oak and concrete are the principal materials used for culverts. The townships are equipped with plows and drag and wheeled scrapers.

Kay County is situated in the extreme north-central part of the State. There are several massive ledges of limestone in the eastern part of the county, most of which are very soft and not suited for macadam surface. The rocks west of the main line of the Atchison, Topeka and Santa Fe Railway are shales with a little sandstone. The surface of the eastern part is hilly; that of the western part is level to rolling. Drainage is to the southeast through Arkansas River and Salt Fork.

The roads are on section lines and are worked enough to keep them passable. Five miles of sand-clay roads have been built. Large bridges have been built over Arkansas River east of Newkirk and Ponca City and south of Kaw City. A concrete bridge crosses Chickasha River in the northwest part of the county. Limestone is used for culverts and small bridges. Miller Township has voted bonds for $18,000.00 for road improvement. Several townships use the split-log or King drags.

Kingfisher County lies just northwest of the center of the State. It lies entirely in the Redbeds area and there is no hard rock for macadam material in the county. There is a belt of sand-hills from five to ten miles or more in width along the north side of the Cimarron River in the northeastern part of the county. The extreme southwestern corner is in the Gypsum Hills region. The surface is generally level. The drainage is into the Cimarron which crosses the county from northwest to southeast.

The roads are all upon section lines and are kept in fairly good repair. Ten miles of sand-clay roads have been built in the sand-hills region. One road improvement district was organized but the bond proposition failed to carry. Several bridges have been built since statehood, among them two pile and two steel bridges across the Cimarron, concrete bridges across Trail and Kingfisher creeks, a 90-foot span has been added to an old bridge across Cimarron River, and thirty-one smaller bridges mostly of steel, ranging from 30 to 90 feet in span.

The townships have plows and scoops and there are also five road graders and one elevating grader with a traction engine in the county.

Kiowa County is situated in southwestern Oklahoma. The surface rocks, except some outliers of the Wichita Mountains in the southern half of the county, are Redbeds. These outliers consist of granite and limestone. The surface of the county with the exception of the granite and limestone hills is level. The drainage of the major portion of the county is south through North Fork of Red River and Elk Creek; that of the northeast corner is east through Washita River.

The roads are upon section lines and the majority are kept up in fairly good shape. No permanently improved roads have been built and no bond issues have yet been made although an issue of $40,000.00 is being considered. Attempts are being made to organize a road improvement district. Practically all of the road crossings over streams are bridged with steel bridges. Corrugated steel is used for culverts. Most of the townships are provided with plows, drag scoops and road graders.

Latimer County lies in southeastern Oklahoma. The greater portion of the county lies in the Ouachita Mountain region; the northern part is in the Pennsylvanian area. The rocks are principally sandstone and shale with an area of chert along the south line. Besides this chert there is practically no macadam material in the county. The surface is very hilly. Owing to the rough surface and sparsely settled condition there will be probably few improved roads built in the near future.

The roads have been located upon section lines where this is practicable but the greater portion of the country is too hilly for the roads to be so located. All of the roads are worked sufficiently each year to keep them in passable condition. No road improvement districts have been organized and no road or bridge bonds have been issued. The smaller streams have almost all been bridged with wooden bridges and a steel bridge has been built over Fourche Maline Creek at Latie. Corrugated steel is being used for culverts. The townships are equipped with plows and drag scoops.

LeFlore County is situated in extreme eastern Oklahoma. The state of Arkansas forms the eastern and Arkansas River the northern boundary. The southern half of the county is in the Ouachita Moun-

tain region and the northern half in the Pennsylvanian area south of Arkansas River. The rocks are all sandstones and shales which produce a very rough surface except in the valleys of the larger streams. There is no macadam material in the county. On account of these conditions it will probably be some time before there is a great amount of permanent improvements in the road system. The principal drainage is north through Poteau River into the Arkansas.

About one-half of the roads have been located on the section lines, the mountainous nature of the country rendering such location of the remaining roads impracticable; no permanently improved roads have been built, the only work done so far being toward opening up the right of way and sufficient work to render the roads passable. No road improvement districts have been organized and no bonds have been issued. Two steel bridges, one of 100-foot span and another of the 50-foot have been built and one old bridge of 150-foot span has been purchased by the county. A contract has been let for the building of three steel bridges, one 250-feet, one 200 feet and one 75 feet in length. Eight of the townships have purchased plows, drag scoops and road graders.

Lincoln County is situated in the central part of the State. The greater portion of the county is underlaid by rocks of Pennsylvanian age which consist of sandstones and shales. In the western part of the county these rocks merge into the Redbeds. The only macadam material in the county is a thin ledge of limestone which outcrops near Agra. The surface is rolling to hilly. Drainage is to the east through Deep Fork of the Canadian.

The roads are upon section lines and are worked over by the labor-tax system each year. Two miles of macadam road, one mile of sand-clay and one-fourth mile of oiled-earth road have been built. No road improvement districts have been organized and no bonds have been issued for road purposes. Three large steel and three concrete bridges have been built recently. The townships are provided with the ordinary road working machinery including road graders.

Logan County is situated just north of the center of Oklahoma. The surface rocks are entirely of the Redbeds and consist of soft sandstones and shales. There is no macadam material in the county. The surface of the eastern half of the county is rather hilly, while that of the western part is more level. There is an area of sand hills in the west-central portion. Drainage is principally into Cimarron River which forms part of the northern boundary.

The roads are mostly upon section lines and are worked over to some extent each year under the labor tax. One-tenth mile of macadam road has been built and a total of five miles of sand-clay road has been built in the sand areas. A petition for one road improvement district was made, but was withdrawn before election was held as it was felt that

the expense of road construction was not equitably distributed. No bonds have been issued for road improvement purposes. About $10,000.00 is expended annually for bridges. Several steel bridges ranging from 30 to 240 feet in length have been built across Cimarron River, Skeleton and Cottonwood Creek and Deep Fork. About half of the townships have the large eight horse graders and several of them have a smaller one for four horses. There are a few of the King split-log drags in use.

Love County lies in the extreme southern part of the State. Red River form the southern boundary. Almost all of the county is underlaid by rocks of Cretaceous age, only the extreme western part being in the Redbeds area. The Goodland limestone outcrops from southwest to northeast across the county and will furnish an abundance of macadam material which is available from the great part of the area. The Trinity sand outcrops in broad belts to the northwest of the Goodland limestone and in this portion of the county the roads are very sandy. There are deposits of asphalt in the county but nothing is known as to their suitability for road material. The surface of the county is level to rolling. The drainage is south into Red River.

The roads have practically all been relocated on section lines; all of them worked to some extent and about one-tenth are graded each year. No permanently improved roads have been built. A $20,000 bond issue for road purposes was voted but failed on account of a technical defect in the election. Thirty steel bridges of from 25 to 80 feet in length have been built. A large number of culverts have been installed, about equally of wood and corrugated steel. Washington Township has a road grader but the others are provided only with plows and drag scoops.

McClain County lies south of the center of Oklahoma. The surface rocks belong entirely to the Redbeds. Those of the eastern part of the State are Pennsylvanian in age, while those of the western part are Permian. The rocks are all sandstones and shales and there is no macadam material in the county. The surface is rolling to hilly in the eastern part and generally level in the western. The drainage is to the southeast through Canadian River which forms the northeastern boundary of the county.

The roads are all practically on section lines. Very little work is performed on the roads each year, only enough being done to keep them passable. About four miles of sand-clay roads have been built. Three steel bridges and several smaller bridges of wood have been built. No bond issues have been made for road improvement purposes and only a moderate interest seems to be taken in the question of road improvement. Most of the townships have drag scoops, graders and plows and the county has a complete road outfit consisting of graders, plows and scoops that are used in working the county convicts on the roads.

McCurtain County is the extreme southeastern county of the state. The greater portion of the county is in the Ouachita Mountain region and the topography is extremely rough and the country is very sparsely settled. The southern portion is in the Cretaceous area and is more level. The drainage is to the south and is principally through Little River and its tributaries, Glover Creek, Lukfata Creek and Mountain Fork River.

The northern portion of the county, the Ouachita Mountain area, is entirely too hilly for the roads to be laid out upon section lines and in this same region the population is so sparse that practically no work is done on the roads. The roads are in reality only winding lanes over the hills and through the thick timber. In the southern portion, or the Cretaceous area, the roads have been located largely upon section lines and the most of them are worked to some extent annually. There are no bridges or culverts in the northern portion and only small wood culverts and bridges in the southern. No large bridges have been built. The townships are not yet equipped with road building machinery. Valliant Township being the only one having a road grader.

McIntosh County is situated in the east-central part of the State. It is underlaid by sandstones and shales of Pennsylvanian age. The surface is generally level in the eastern part but becomes more hilly towards the west. There is no macadam road material in the county. Much of the soil is a sandy clay which forms fairly satisfactory roadways when properly graded. The county is drained to the east through Canadian River.

The majority of the roads are on section lines and about one-half are worked to some extent each year. There have been no permanently improved roads built. Nine large steel bridges have been built since statehood. Tile is the principal material used for culverts. All of the townships are provided with necessary tools for road work, including plows, drag scoops, graders, etc. A few of the townships have rollers and traction engines.

Major County lies northwest of the center of the State. It is entirely in the Redbeds area and the surface rocks consist of red sandstones and shales. There are belts of sandhills along the northern branches of Cimarron River which crosses the central portion of the country from the northwest to the southeast and along North Fork of the Canadian River which crosses the southwest portion of the county in the same direction. The sandhills area northeast on the Cimarron River is from five to fifteen miles in width. There is no macadam material in the county and the sand-clay road will probably be the prevailing type of permanently improved road. The surface of the county is level to rolling.

The roads are practically all on section lines and the majority of them are worked to some extent each year. There have been no permanently improved roads built. Several steel bridges have been built by the county. One road district was organized and voted bonds but the bonds were not sold, so no improvement has been made. The townships are equipped with plows, drag scoops and graders.

Marshall County lies in the extreme south-central part of the State. Red River forms the southern boundary and Washita River the eastern boundary. The surface rocks of the county are those of the Cretaceous area. Trinity sand occurs in the northern portion. The Goodland limestone extends from southwest to northeast past Madill and the other Cretaceous formations occur in succession, the Silo sandstone forming considerable hills in the south portion of the county. The Goodland, Caddo, and Bennington limestones are all suitable material for macadam roads for light traffic and any portion of the county can be reached from one of these ledges by a reasonable haul. The soil on the limestone is a rich and fertile black loam which, however, forms extremely bad roads, so that road improvement is almost imperative over the greater portion of the county. There are some deposits of asphalt in the Trinity sands in the vicinity of Madill, but they have not been exploited sufficiently to show the available amount or their adaptability for roads. The surface of the county is rolling to hilly.

At present the roads have mostly been re-located upon section lines and considerable work has been done in the way of grading them and rendering them passable. No improved roads have been built and no important bridges have been constructed.

Mayes County is situated in northeastern part of Oklahoma. The greater portion of the county is in the Mississippian area and the surface rock is Boone chert or Pitkin limestone. The western portion lies in the Pennsylvanian area and is underlaid by shale and sandstone of the Vinita formation. The part of the county east of the main line of the Missouri, Kansas and Texas Railway is hilly, while that west of that railway is level. The Boone chert and Pitkin limestone furnish abundance of macadam material and since the county lies in a portion of the State that has a heavy rainfall, macadam roads should in time be built for all of the principal highways of the county. The drainage is south through Grand River.

Many of the roads in the western portion of the county are on section lines but in the eastern part such location is not feasible on account of the hills. Very little progress has been made in road improvement since statehood. There are probably not over 60 miles of graded or worked road in the county. No permanently improved roads have been built. The county has expended about $10,000.00 for steel bridges and about $2,500.00 for culverts. Corrugated steel is being used for the latter. No bond issues have been made but an issue for bridges is being

agitated. Three-fourths of the townships are equipped with road graders.

Murray County lies in the south-central part of Oklahoma. The greater portion of the county is included in the Arbuckle Mountains and the limestones of this mountain system form the majority of the surface rocks. The Arbuckle, Viola, Hunton and Sycamore limestones are all well exposed over considerable areas. Granite porphyry occurs in East and West Timbered Hills in the western portion of the county. Large stone crushers are operated in the village of Crusher, in a gorge of the Washita River.

About two-thirds of the roads are on section lines, these being all that can be so located on account of the hills. Nearly all of the roads have been worked to some extent and a considerable portion have been graded. No improved roads have been built and no road districts have been organized, or road bonds issued. Four steel bridges of 80-foot spans with approaches have been built and about six smaller bridges have been built. The townships are equipped with plows and drag scoops. Morgan Township and the city of Sulphur have graders.

Muskogee County is located in the northeastern part of Oklahoma. The surface rocks are lower Pennsylvanian in age and consist of sandstones and shales. The surface is rolling to hilly. There is no macadam material in the county except some limestone of the Pitkin and Boone formations in the extreme eastern part of the county north of Arkansas River.

The majority of the roads are upon section lines and about one-third are worked over each year. No permanently improved roads have been built. Thirty-five steel and concrete bridges are now being built which will make a total of fifty-three bridges of over 20-foot span which have been built since statehood. Two large toll bridges, one over the Arkansas River have been purchased by the county. Many smaller bridges and culverts have been installed by the different townships. A bond issue of $100,000.00 has been made for bridges. Most of the townships are provided with drag scoops and plows and road machines. The County Commissioners furnish a team and foreman for the road machines to the townships where the latter furnish other labor and so grade the principal highways. The county convicts follow the grader and work the rough places where the grader cannot be used. In this way Muskogee County is rapidly obtaining one of the best road systems in the new portion of the State.

Noble County lies in north-central Oklahoma. It is entirely in the Redbeds area and the rocks are principally red sandstones and shales although in the extreme northern portion there are several limestone ledges, the southern continuation of ledges which are much more prominent in Kay County and farther north in Kansas. These limestones

are generally too soft for macadam material unless on very light traffic roads. The surface is hilly in the eastern portion, but becomes more level to the west. The drainage is to the east through Black Bear and Red Rock creeks.

Practically all of the roads are upon section lines and probably 90 per cent. of them are worked each year of which a considerable portion are graded. No permanently improved or hard surfaced roads have been built. About thirty bridges ranging from 30 to 140 feet in length have been built. Seventy-five arch culverts have been constructed of stone and concrete. No bond issues for road purposes have been made and no road improvement districts have been organized. The townships are well equipped with drag scoops, wheeled scoops and graders.

Nowata County is situated in the northeastern part of the State and borders upon Kansas. The surface rocks are limestone, shales and sandstones of Pennsylvanian age. The Lenapah and Oolagah limestones furnish abundance of macadam material and no part of the county is out of reach of limestone. The surface of the county is level to rolling. The drainage is to the south through Verdigris River.

The majority of the roads are located upon section lines and are worked sufficiently to keep them in passable conditions. No permanently improved roads have been built. Twenty-five small bridges have been built and three large bridges are in process of construction; one large toll bridge has been purchased. A $100,000.00 bond issue has been made for bridge purposes. The townships have plows, drag scoops and graders.

Okfuskee County lies east of the center of Oklahoma. The surface rocks are sandstones and shales of Pennsylvanian age. The surface in most parts of the county is rough on account of the ridges and hills formed by the resistant ledges of sandstone. Little or no macadam material is to be found in the county. The county is drained to the southeast by North Canadian River which forms part of the southern boundary.

The roads have been re-located upon section lines wherever the nature of the country is such as to render this feasible. Over a considerable portion of the county the surface is too hilly to permit the location of roads on section lines without great difficulty. About half of the roads are worked over each year but very few of them are graded. A $100,000.00 bond issue has been made for bridge purposes and several steel bridges have been constructed, five of the larger ones across North Canadian River and two across Deep Fork River. Several smaller bridges have been built. The culverts are of concrete or galvanized iron. Most of the townships have the ordinary road working machinery.

Oklahoma County is situated in the central part of the State. The county lies entirely in the Redbeds area and the rocks are all soft red sandstones and shales. There is no macadam material in the county.

The surface is rolling to hilly. There are small areas of sand-hills along the north side of North Fork of Canadian River and the roads over the sandstone hills in the east part of the county are also quite sandy. Drainage is east through North Fork of Canadian River. The roads are all on section lines and probably ten per cent. are worked over each year. No permanently improved roads have been built and no bond issues have been made. Oklahoma County has voted to pay 25 per cent. of the expense of road improvement whenever the road improvement districts should be formed. One such district has been proposed, but as this district contains Oklahoma City, it will be compelled to pay about 90 per cent. of the expense of road construction and the proposition has not yet carried. Several steel bridges have been built. Practically all the crossings over the streams have steel bridges. A large concrete bridge is now being built in Oklahoma City. All the townships are provided with ordinary road machinery including plows, drag scoops and graders.

Okmulgee County is situated northeast of the center of the State. It lies entirely in the Pennsylvanian area south of Arkansas River and the rocks consist of sandstones and shales. There is no macadam material in the county. The eastern half of the county is level to rolling while the western half is more hilly and rugged. Drainage is principally to the east through Deep Fork.

The roads have been re-located upon section lines except in the hillier portion of the county. They are worked over sufficiently to keep them passable. No permanently improved roads have been built and no road improvement districts have been organized. No bond issues have been made for road purposes. Three steel bridges, two of 110 feet and one of 120 feet in length have been built over Deep Fork River. Nineteen smaller steel bridges and a few wooden bridges over the smaller streams have been built. Corrugated steel is the principal material used for culverts. Most of the townships have graders, plows and drag scoops.

Osage County lies in the extreme northern part of the State. The greater portion of the county lies in the Pennsylvanian region north of Arkansas River; the western portion is in the non-red Permian area. There are some limestones in the extreme eastern part especially in the vicinity of Avant. From Avant west to Pawhuska the rocks are all sandstones and shales. West of Pawhuska there are several ledges of limestone and all of this part of the county is in reach of limestone for road building purposes. The surface of the entire county is rather rough and hilly (fig. 42). The drainage is southwest into the Arkansas River and its tributaries.

Only a small percentage of the roads have been located on section lines and are only worked sufficiently to keep them in passable condition. No permanently improved roads have been built. All road improvement in this county has been hindered greatly owing to the fact that

all the land with the exception of four or five townsites, is the property of the Osage Indians and has not been taxable. This makes it necessary to raise all the necessary funds for county government and for roads and bridges by taxes on the personal property of the white citizens. Eleven steel bridges of 100 feet in length and upwards have been built since statehood, four of which are county line bridges built in connection with Pawnee, Kay and Washington counties. Four of these are over Arkansas River, two over Hominy Creek and one each over Salt, Bird, and Candy creeks and Caney River and Sand Creek. A stone-arch masonry bridge across Clear Creek at Pawhuska (fig. 43) and one across Quapaw Creek four miles west of Skiatook have been built. The two latter bridges are excellent examples of what can be done with Oklahoma sandstone as bridge material. The stone bridges have been built at an average cost of $29.00 per lineal foot while the steel bridges cost $25.00 per lineal foot. When the long life and freedom from repairs of the stone bridge is considered, it is evident that the stone bridge is much cheaper than the steel and in view of the fact that all eastern Oklahoma has inexhaustible supplies of sandstone, it is to be hoped that many such bridges will be built in this part of the State. Three of the townships have road graders, one has a stone crusher and all have plows, drag scoops and smaller tools.

Ottawa County is in the extreme northeastern portion of the State. Missouri forms the eastern and Kansas the northern boundary. The county lies principally in the Mississippian area and the surface rock is Boone chert. The northwestern portion lies in the Pennsylvanian area and the surface rocks are principally shale. No portion of the county is so far from the chert areas as to render use of chert for macadam roads impossible. The surface of the county is hilly in the Mississippian area and level in the Pennsylvanian or northwest portion. Drainage is to the south through Grand River which is formed by the junction of Spring and Neosho rivers near the center of the county.

Most of the roads have been re-located on section lines except in the hilly portion of the county. All the roads are worked over to some extent each year. No permanently improved roads have been built; no road improvement districts have been organized and no bonds have been issued. About five small bridges and culverts have been built. Wood, steel and concrete have all been used for bridges and culverts. All the townships have one or more graders and plows and drag scoops. Some of them have wheeled scrapers but there are as yet no stone crushers used.

Pawnee County lies northeast of the center of the State. The greater portion of the county lies in the Pennsylvanian area south of Arkansas River. The extreme western portion is in the Redbeds area. In the eastern part there are several ledges of limestone which furnish abundance of macadam material. The surface is hilly, there being many ridges

which are capped by limestone and sandstone. Drainage is to the southeast through Arkansas and Cimarron rivers which unite at the southeast corner of the county.

Practically all the roads are upon section lines. They are worked by the labor tax but the amount of labor secured in this way is sufficient only to keep the roads passable and not to put them in good shape. Since the surface of the county is rough it will require a large amount of work to put the roads in anything like good condition. Practically the only thing in the line of permanent improvement that has been done is covering the rocky hills near Terrelton with clay to a depth of 11 inches in some places. Three steel bridges across Arkansas River have been built by Pawnee and Osage counties jointly. Four steel spans with concrete and stone piers and one bridge of steel throughout, have been built in the interior of the county. The smaller bridges and culverts are practically all stone arches. Most of the townships are provided with the ordinary road-working tools.

Payne County lies just north of the center of the State. The surface rocks are Pennsylvanian in age, those of the western half of the county belonging to the lower part of the Redbeds. There are several ledges of limestone in the east part of the county; all the rocks in southeastern part are soft sandstones and shales. The surface is level to rolling, with some large hills in the eastern portion. The limestones of the eastern part will furnish an abundance of macadam material. Most of these limestones, for instance the one quarried at Ripley, are harder than those farther northwest and are consequently better road material. The drainage of the county is east through Cimarron River.

Practically all the roads are upon section lines. Only a small per cent. of them are worked over each year. Two and a half miles of macadam roads have been built. Suspension bridges have been built across Cimarron River at Ripley and Cushing and a truss bridge 700 feet in length across the same river at Yale. A concrete bridge has been built across Stillwater Creek. Concrete is being used extensively for culverts. No road improvement districts have been organized and no road bonds have been issued. The townships are provided with drag scoops and graders.

Pittsburg County lies in the southeastern part of the State. The greater portion of the county is in the Pennsylvanian area south of Arkansas River. The southwestern portion is in the Ouachita Mountain area. The Wapanucka limestone crosses the county nearly from east to west through the southern part. This is the only macadam material in the county, the rest of the rocks being sandstones and shales. The surface of the county is generally rough and hilly, being extremely so in the southeastern portion. The north portion of the county drains into South Canadian River and the southern portion into Red River through the branches of Boggy Creek.

The roads have been re-located upon section lines except in the rough parts of the county. Only a small portion of the roads are worked over each year as there is a large road mileage and a good deal of the county is thinly settled. No permanently improved roads have been built except some in the immediate vicinity of coal mines which have been covered with clinker from the culm heaps. Thirty-seven steel bridges with spans of from 24 to 100 feet have been built by the county and eighty steel bridges with spans up to 20 feet have been built by the townships. Corrugated steel and stone have been used for culverts. No road improvement districts have been organized and no bond issues have been made for road purposes. All the townships have plows and drag scoops and a few of them have graders.

Pontotoc County lies southeast of the center of the State. The southern portion of the county is in the Arbuckle Mountain Uplift and contains vast quantities of limestone which will furnish an adequate supply of macadam material. The northern part of the county is underlaid by the Pennsylvanian system of sandstones and shales. There are some large asphalt deposits in the vicinity of Ada, (see fig. 36) Fitzhugh and Roff. The surface of the county is generally hilly. The north part of the county is drained by Canadian River and the southern portion by Boggy Creek and Blue River.

The majority of the roads are located upon section lines except in those parts of the county where the surface is too hilly to render section-line roads advisable. The roads on the section lines are worked over sufficiently to keep them in passable condition; none are worked thoroughly. Two large steel bridges have been built over Clear Boggy Creek in the south part of the county. Wooden bridges have been built over the principal crossings of the other large streams. Corrugated steel is the principal material being used for culverts although several have been built of concrete and of wood. No improved roads have been built and no bond issues have been made for road purposes. All the townships have plows and drag scoops and two or three have graders which are little used on account of the stumps still remaining in the newly located roadways.

Pottawatomie County lies in south-central Oklahoma. The surface rocks are Pennsylvanian in age and merge into the Redbeds in the western part of the county. The rocks are all sandstones and shales with one bed of conglomerate. This conglomerate is well exposed at Hotulke southeast of Shawnee where it is quarried for concrete gravel. It would probably make an excellent macadam material. The surface of the county is rolling to hilly. The drainage is east through South Canadian and Little rivers.

The majority of the roads have been located on section lines and are worked sufficiently each year to render them passable. Several bridges have been built over the principal stream crossings. No permanently

improved roads have been built and no bonds issued for road purposes. The townships are provided with plows and drag scoops.

Pushmataha County lies in the southeastern part of the State. All of the county except the extreme southern portion is in the Ouachita Mountain region and is extremely rough and hilly. The county is thinly settled and it will probably be some time before great improvement can be expected in the road conditions. There is very little macadam material in the county. Some of the hills in the north-central portion are composed of chert that may be used to some extent. Drainage is south, principally through Kiamichi and Little rivers.

About one-half of the roads have been re-located on section lines but the greater part of the county is too hilly to make section line roads convenient. All the roads have been cleared and worked sufficiently to keep them in passable condition. No permanently improved roads have been built and no bonds have been issued. The county has built nine wooden bridges above 20 feet in length and one steel bridge across Big Cedar Creek. The townships have built many small bridges and culverts of wood. It is planned to build several bridges across Kiamichi River as soon as funds will permit. The townships are provided with plows and drag scoops and the smaller tools such as shovels, picks etc. It is impossible to use road graders under present conditions.

Roger Mills County lies in western Oklahoma, and is bounded on the west by the Pan Handle of Texas. The surface rocks are Redbeds and consist of soft sandstones and shales and there is no macadam material in the county. There are large areas of sand-hills in the western part of the county. The surface is generally level. Canadian River forms the northern boundary of the county and Washita River flows east across the middle portion.

All the roads are upon section lines. Most of them are worked over each year, but few are worked thoroughly. Between one and two miles of macadam roads and about one-half mile of sand-clay road have been built. Several miles of road in the sand-hills region are covered with hay and straw each season. Several bridges have been built, the larger ones of steel and the smaller ones of wood. Corrugated steel is principally used for culverts. The townships are provided with graders and drag scoops.

Rogers County lies in northeastern Oklahoma. The surface rocks belong to the Pennsylvanian system and consist of limestones, shales and sandstones. Several ledges of limestone which outcrop across the county from north to south will furnish abundance of macadam material and are accessible from all parts of the county. The surface is rolling to moderately hilly. Drainage is south through Verdigris River.

Most of the roads have been located on section lines and all are worked over to some extent each year. No permanently improved roads

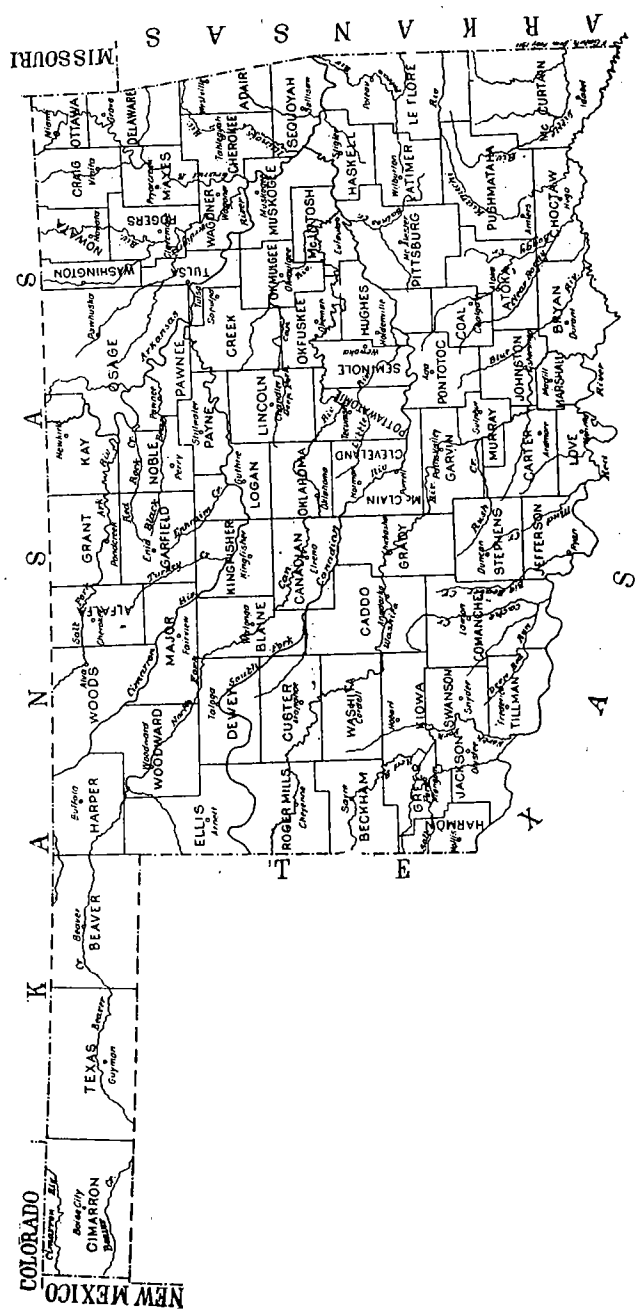

Fig. 44. Location of Counties in Oklahoma.

have been built. Several bridges have been constructed, but no report has been received at this office as to the exact number.

Seminole County lies east of the center of Oklahoma. The surface rocks are Pennsylvanian in age and consist of sandstones and shales with one thin ledge of limestone which outcrops near Wewoka and Sasakwa. This limestone and a bed of gravel at Konawa will furnish some macadam material for the roads of the county. The surface of the county is generally hilly. Drainage is east through North Canadian and South Canadian rivers which respectively form the northern an ' southern boundaries.

No report has been received concerning the present state of the road conditions.

Sequoyah County lies in the extreme east-central part of Oklahoma and is bounded upon the east by the state of Arkansas and on the south by Arkansas River. The surface rocks of most of the county are Pennsylvanian in age and consist of sandstones and shales. The northern part of the county lies in the Mississippian area and contains inexhaustible supplies of macadam material from the Pitkin formation. The surface is hilly. The drainage is south into Arkansas River.

Wherever practicable the roads have been re-located on section lines and are worked over sufficiently to keep them in passable condition. No permanently improved roads have been built. Four steel bridges with spans of from 50 to 120 feet and several short wooden bridges have been built. Corrugated steel has been used for culverts. Most of the townships have plows and drag scoops and a few of them have road graders and stump pullers.

Stephens County lies in southern Oklahoma. It is entirely in the Redbeds area and the exposed rocks are all soft red sandstones and shales. There is no material for macadam roads in the county. Several deposits of asphalt have been reported from the eastern part of the county, but there has not been enough work done to determine their extent and availability for road material. The surface is generally level. Drainage is east through Wild Horse Creek and Washita River and south through Mud and Beaver creeks into Red River.

Most of the roads are upon section lines and about half of them are worked annually. Two miles of sand-clay roads have been built. A great deal of the soil approximates a sand-clay mixture and the natural roads are satisfactory when graded. The principal stream crossings are bridged, the larger bridges being of steel. Wood and corrugated steel is used for culverts. No road improvement districts have been organized and no road or bridge bonds have been issued. All the townships have plows and drag scoops and part of them have graders. One township has a gasoline engine to draw the grader.

Swanson County is situated in southwestern Oklahoma. The greater portion of the surface is in the Redbeds area and the rocks consist of soft red sandstones and shales. The Wichita Mountains extend into the northwest corner of the county and there are several peaks of granite and related rocks occurring over most of the area of the county. A black granite or diorite has been quarried near Cold Springs and Roosevelt. The igneous rock will furnish an abundance of macadam material for the entire county and very little of the area is far removed from an outcrop of this rock. The surface of the county except the hills of granite, is generally level. Drainage is into North Fork of Red River through several small tributaries.

No report upon the road conditions of this county has been received but as the county has been recently separated from Kiowa and Comanche counties, the conditions are practically the same as those given for the counties mentioned.

Texas County occupies the central part of the "Pan Handle" of Oklahoma. The surface rocks are almost entirely of Tertiary age and consist of clays and sand with some gravel. There is a small area of Redbeds in the central part of the county and another in the extreme southeastern portion. Sand hills occur along the north side of Beaver Creek in the east-central part of the county. The surface is a level plain into which Beaver Creek has cut a valley averaging 75 feet deep and two miles wide.

Practically all the roads are located upon section lines, but only a very small percentage of them are worked to any extent. There is a very large road mileage and as the county is thinly populated a great improvement in the present road conditions cannot be expected in the near future. The rainfall is not heavy and the natural roads are sufficient to serve the needs of the traffic. Three steel bridges have been built. There is little demand for culverts or small bridges. Most of the townships are equipped with road graders.

Tillman County lies along Red River in southwestern Oklahoma. The surface rocks consist of red clay shales and a little sandstone of the Permian series. There is a large area of sandhills in the western part of the county. There is no macadam material in the county and sand-clay roads will probably be the important type of improved road. The natural roads in the eastern part of the county are fairly satisfactory when graded.

All the roads are upon section lines and about half of them are worked each year. No improved roads have been built, but it is planned to begin covering some of the worst of the sand roads with clay. Ten steel bridges have been built across Deep Red Run and Suttles Creek. Several wooden bridges have been built across the smaller streams. Wood is also used for culverts. All the townships are equipped with road graders.

Tulsa County lies in northeastern Oklahoma in the area of Pennsylvanian rocks. These consist of sandstones, shales and limestones. The limestones outcrop across the county from north to south. They will furnish an abundance of macadam material when permanent improvement of the roads is begun. Practically all the county can be reached from one of the ledges of limestone. The surface of the county is generally level to rolling, but is broken by hills along the Arkansas River and in the southwestern part of the county.

No report on the road conditions of the county has been received. From personal observation, however, the conditions seem to be very similar to the other counties in this portion of the State. The principal stream crossings have been bridged, roads have been mostly re-located on section lines and are worked sufficiently to keep them passable. No permanently improved roads have been built to the writer's knowledge.

Wagoner County is located in eastern Oklahoma. The northeast part is in the Mississippian area or Ozark Uplift and the rocks are principally limestones of the Boone and Pitkin formations. The greater portion of the county lies in the Pennsylvanian area and the rocks consist of shales and sandstones with a ledge of limestone near Coweta and Broken Arrow in the western part of the county. The surface of the greater part of the county is level to rolling but there are some high hills in the northeastern and western parts. Verdigris River flows south across the county and the Arkansas forms part of the southern boundary. About three-fourths of the roads have been re-located on section lines and about one-fourth of the total mileage has been graded. The roads are worked sufficiently to keep them in passable condition. No permanently improved roads have been built and no bonds have been voted for road improvement or for building bridges. Four steel bridges of 60-foot span have been built over Verdigris River. A great number of wooden bridges from 24 to 40 feet in length have been built in the county. Concrete and corrugated steel have been largely used for culverts. The county commissioners have a camp of the county convicts at work on the roads the greater part of the year. The townships are all supplied with the ordinary road working tools including graders.

Washington County lies in northeastern Oklahoma and has Kansas as the northern boundary. The surface rocks are of Pennsylvanian age and consist of shales and limestones and some sandstones. The Hogshooter, Dewey and Avant limestones outcrop over a considerable part of the county and will furnish an abundant supply of macadam when road improvement is begun. The surface of the county is level to rolling with some hills along the eastern line. Drainage is south through Caney River.

Practically all the roads have been re-located upon section lines and all of them are worked as much as is possible with the labor-tax system. No permanently improved roads have been built. The principal stream crossings have been bridged. The townships have the ordinary road working tools.

Washita County lies in west-central Oklahoma. The surface rocks all belong to the Permian series or Redbeds and are soft sandstones and shales with some gypsum. There are local occurrences of dolomite and some of the hills in the western part of the county are capped with Cretaceous limestone. The dolomite and limestone will furnish some macadam material but the majority of the roads as the other counties in the western part of the state will probably be a sand-clay mixture. The surface of the county is a plain into which streams have cut rather deep channels. The principal drainage is into Washita River which flows southeast across the county.

Practically all the roads are upon section lines and the majority of them are satisfactory when properly graded. Only a small percentage of them, however, are kept in proper condition. No permanently improved roads have been built. The State convicts were at work in the county during the winter of 1910-11 and placed the principal road running east and west in fairly good condition. Several bridges have been built since statehood, the larger ones being of steel over Washita River. Concrete has been used for culverts. Most of the townships have road graders and other ordinary road working tools.

Woods County lies in northwestern Oklahoma and is bounded on the north by Kansas. The county lies entirely in the Redbeds area and the rocks consist of soft sandstones and shales. Some of the hills in the northwest part of the county are capped by Cretaceous limestone. An area of sand-hills from 5 to 10 miles in width occurs along the north side of Cimarron River which forms the southwestern boundary of the county and along South Fork of Arkansas River which flows through the northeastern portion. The surface of the county is generally level to rolling.

All the roads are upon section lines and approximately one-fourth of them are worked over annually. Twenty-five miles of sand-clay roads have been built. There are no hard surfaced roads. The principal stream crossings have been bridged with steel bridges, one across Salt Fork at Alva being 175 feet in span with a concrete floor and steel tubes filled with concrete for a substructure. Corrugated steel has been principally used for culverts but is reported to give poor satisfaction. All the townships have drag and wheeled scrapers and some of them have Fresno scrapers. There are two elevating graders and seven or eight ordinary road graders in the county.

Woodward County lies just to the southwest of Woods County which has just been noticed. The county lies in the Permian or Redbeds area but over half the surface is of sand-hills in two belts extending from

northeast to southwest across the county. There is a small area of Tertiary rocks in the southwest corner and Cretaceous limestone caps some of the hills in the central part. Dolomite occurs in some of the hills in the northeastern portion. The Cretaceous limestone and dolomite will furnish macadam material but so much of the county is sandy it seems probable that sand-clay will be the principal improved road. The surface of the county is rough in the northeastern portion and level to rolling in the southern parts. Drainage is southeast through Cimarron River which forms the northeastern boundary and through North Fork of Canadian River which flows southeast across the county.

Practically all the roads are upon section lines and the most of them are worked to some extent. The large area of sand-hills in the county makes the road problem a very difficult one. About 10 miles of sand road has been covered with clay which is reported to have been "cut up" very badly during the dry summer of 1910. It seems probable that this is due to a poor mixing of the sand and clay as the dry season gave very little opportunity for the mixing and puddling which are necessary for the construction of this type of road. The city of Woodward is reported to have donated $2,000.00 for improvement of sand roads northeast of the city. Several steel bridges from 30 to 200 feet in length have been built since 1907. Corrugated steel has been the principal material used for culverts but concrete is beginning to be used and is giving satisfaction. The townships are equipped with plows and drag scoops and some of them have graders.

PUBLICATIONS OF THE OKLAHOMA GEOLOGICAL SURVEY.

The following reports have been issued by the Oklahoma Geological Survey and will be sent on receipt of postage:

BULLETINS.

Bulletin No. 1. Preliminary Report on the Mineral Resources of Oklahoma, by Chas. N. Gould, L. L. Hutchison and Gaylord Nelson, 1908, pp. 84. Postage 3 cents.

Bulletin No. 2. Preliminary Report on the Rock Asphalt, Asphaltite, Petroleum and Natural Gas in Oklahoma, by L. L. Hutchison, 1911, pp. xvi-256. Postage 10 cents.

Bulletin No. 3. Report on the Geological and Mineralogical Resources of the Arbuckle Mountains, Oklahoma, by Chester Albert Reeds, 1910, pp. 69. Postage 5 cents.

Bulletin No. 4. Coal of Oklahoma, by Chas. N. Gould. In preparation.

Bulletin No. 5. Structural Materials of Oklahoma, by Chas. N. Gould and others, 1911, pp. xvi-182. Postage 6 cents.

Bulletin No. 6. Part I. Director's Biennial Report to the Governor of Oklahoma. Part II. Brief Chapters on Oklahoma's Mineral Resources, by Chas. N. Gould, pp. xvi-96. Postage 3 cents.

Bulletin No. 7. Preliminary Report on the Clay and Clay Industries of Oklahoma, by L. C. Snider, 1911, pp. xvi-270. Postage 10 cents.

CIRCULARS.

Circular No. 1. Origin, scope and purpose of the Oklahoma Geological Survey. (Edition Exhausted.)

Circular No. 2. Brief statement of the Geological History of Oklahoma. Postage 1 cent.

Circular No. 3. Oklahoma among the Southern States. Postage 1 cent.

Address

Director Oklahoma Geological Survey,
Norman, Oklahoma.