GRAVEL DEPOSITS OF THE CADDO GAP AND DE QUEEN QUADRANGLES, ARKANSAS.

By Hugh D. Miser and A. H. Purdue.

INTRODUCTION.

Several thick deposits of gravel are widely distributed along the north edge of the Gulf Coastal Plain, of which a narrow belt is embraced in the southern parts of the Caddo Gap and De Queen

FIGURE 5.—Map showing location of the belt containing gravel deposits along the south side of the Caddo Gap and De Queen quadrangles, Arkansas and Oklahoma.

quadrangles, Ark. This belt is shown on Plate I, and its location is shown on figure 5, a key map of this region. It comprises parts of Pike, Howard, and Sevier counties and a narrow strip of Hempstead County, in southwestern Arkansas, and a strip along the east edge of McCurtain County, in southeastern Oklahoma. The gravels are of Lower Cretaceous, Upper Cretaceous, and Quaternary age, and are composed mainly of pebbles of novaculite (a variety of chert) derived from the Arkansas novaculite exposed in the Ouachita Mountain region, which is north of the Gulf Coastal Plain. They are used in making concrete, in ballasting railroads, and in the construction of wagon roads. Very small quantities of pebbles are also used in the washing plant of the Kimberlite Diamond Mining & Washing Co., at Murfreesboro, to assist in the disintegration of the altered peridotite which carries the diamonds.

Interest in possible American sources of flint pebbles or substitutes therefor to be used in tube mills, in which minerals, ores, cement materials, and clinker are extensively ground in this country, has been aroused since the beginning of the present world war. This interest is due to the partial interruption of imports of flint pebbles from Denmark and France, which have supplied most of the pebbles used in this country. The main reasons for the preparation of this report are to present a description of the gravels under discussion and to indicate the possibility of their use in tube mills.

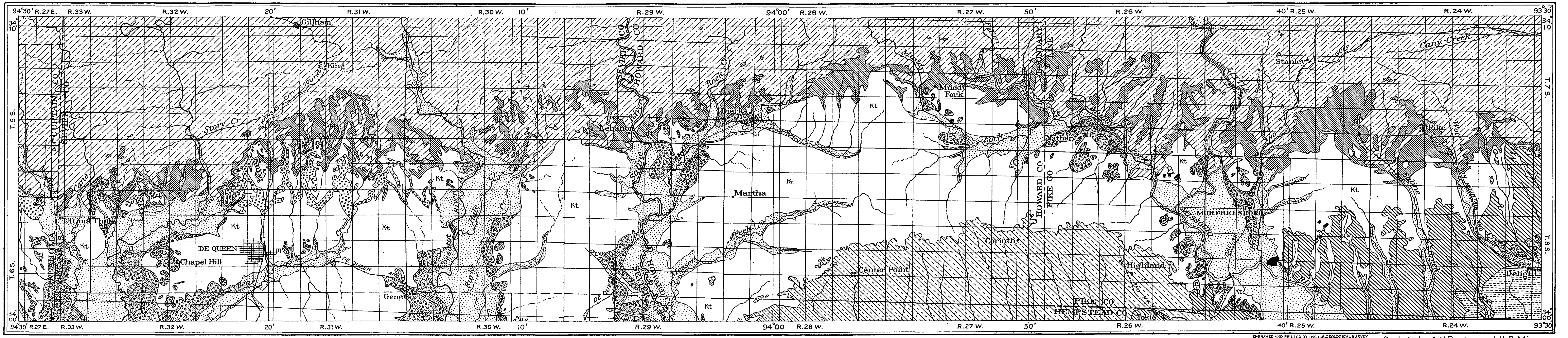
The information for this report is the result of detailed field studies in the Caddo Gap and De Queen quadrangles by the authors in 1908 and 1911 and by the senior author in 1912 and 1916. Mr. R. D. Mesler rendered valuable assistance in 1912. Much of the information is abstracted from the De Queen-Caddo Gap folio, which is nearing completion.

GEOGRAPHY.

The area under discussion comprises part of the north edge of the Gulf Coastal Plain and part of the south edge of the Ouachita Mountain region. The Ouachita region, 50 to 60 miles wide, extends from Little Rock, Ark., to Atoka, Okla., a distance of 200 miles. It contains numerous nearly eastward-trending ridges, several intermontane basins, and a dissected piedmont plateau 15 miles wide, which lies along its southern border in Arkansas and adjoins the Coastal Plain. This plateau is lowest on the south, ranging from about 750 to 1,100 feet above sea level, and the valleys of the larger streams trenching it are about 350 feet deep.

The part of the Coastal Plain embraced in the area under discussion is an east-west belt 5 to 10 miles wide. It has a gently undulating surface, consisting of shallow valleys of rather wide alluvial bottoms and remnants of terraces along the larger streams, and of irregular hilly interstream areas, but a southward-sloping plateau-like area, on which Center Point, Corinth, and Highland are situated, is on the south border of the area shown on the map. Most of the surface is between 400 and 600 feet above sea level.

The drainage of the area is to the south. The principal streams are Little Missouri, Saline, and Cossatot rivers and Rolling Fork; the Little Missouri is the largest.



Base from Caddo Gap and De Queen topographic maps of the U.S. Geological Survey

GEOLOGIC MAP OF THE SOUTHERN PARTS OF THE CADDO GAP AND DE QUEEN QUADRANGLES, ARKANSAS AND OKLAHOMA

ENGRAVED AND PRINTED BY THE U.S.GEOLOGICAL SURVEY

Geology by A.H.Purdue and H.D.Miser, assisted by R.D.Mesler

1 ½ 0 1 2 3 4 5 6 7 8 9 10 MILES

1918

6	5	4	3	2	1
7	8	9	10	11	12
18	17	16	15	14	13
19	20	21	22	23	24
30	29	28	27	26	25
31	32	33	34	35	36

DIAGRAM OF TOWNSHIP

LEGEND

QUATERNARY

- Alluvium
- Terrace deposits

CRETACEOUS

UPPER CRETACEOUS

- Brownstown marl
- Bingen formation
  a, Tokio sand member
- Peridotite

LOWER CRETACEOUS

- Kt — Trinity formation
  a, Ultima Thule gravel lentil
  b, Pike gravel member

CARBONIFEROUS

- Atoka formation, Jackfork sandstone, and Stanley shale

The area is not densely populated; though all parts of it are inhabited. The rural population is sparse except in the level or gently rolling upland and valley areas where tillable land occurs in greatest amounts. The largest town is De Queen, the county seat of Sevier County. Among the other important towns are Murfreesboro, the county seat of Pike County; Dierks, Center Point, Highland, and Delight. All these towns except Center Point are on railroads.

The main line of the Kansas City Southern Railway runs northward through De Queen. The De Queen & Eastern Railroad extends eastward from De Queen as far as Dierks, though a few miles of its track lies south of the area shown on Plate I. The Prescott & Northwestern Railroad enters the area at Tokio and extends as far as Highland. The Memphis, Dallas & Gulf Railroad also enters the area at Tokio and passes northeastward through Murfreesboro to the east border. A branch of the St. Louis, Iron Mountain & Southern Railway enters the area and extends to the northwest as far as Pike.

Public and secondary roads reach all parts of the area, but only a few are maintained in good condition. On account of the character of the topography not many of the roads follow section lines.

GEOLOGY.

GENERAL FEATURES.

The rocks of the area shown on the map (Pl. I) and of adjoining parts of the Gulf Coastal Plain and the Ouachita Mountain region are all of sedimentary origin except four bodies of diamond-bearing peridotite near Murfreesboro. Those in the Ouachita region are of Paleozoic and Quaternary age. The Paleozoic rocks, which range from Cambrian to Carboniferous, consist mainly of shale, sandstone, novaculite, and chert and have an aggregate thickness of 26,000 feet in west-central Arkansas. They have been subjected to intense folding, so that the beds stand at high angles. Most of the folds have an eastward trend. The rocks along the northern border of the area here described are shales and sandstones of Carboniferous age. In that part of the area stream gravels and silts of Quaternary age occur only as narrow strips or small patches along some of the streams.

The sedimentary rocks of the Coastal Plain portion of the area are of Lower Cretaceous, Upper Cretaceous, and Quaternary age. The Lower Cretaceous series is represented by the Trinity formation, the Upper Cretaceous series by the Bingen and Brownstown formations, and the Quaternary system by extensive terrace and alluvial deposits. The Trinity and Bingen formations and the terrace and alluvial deposits contain the gravels here described.

The gravels and their residual materials consist mainly of novaculite pebbles and are very similar in lithologic character. Their abundance and resistance to weathering make them the predominating surficial deposits in the area. Because of disturbance by creep, landslides, and redeposition and because of the great number of beds, it is difficult at many places to follow them across the country and to determine whether or not they are in their original place of deposition. As they have yielded no fossils, their age has been determined by their stratigraphic relations to adjacent beds.

TRINITY FORMATION.

The Trinity formation is exposed in a belt extending from east to west across the area shown in Plate I. This belt has irregular north and south borders, is narrowest to the east, and is continuous except where the formation is covered by surficial deposits of alluvium and terrace remnants along the southward-flowing streams and their tributaries.

The character of the formation is graphically represented in figure 6. It consists of clay, sand, gravel, limestone, gypsum, and celestite, named in the descending order of abundance. The limestone occurs in two beds. The older one is here named the Dierks limestone lentil, and the younger the De Queen limestone member, from the towns at and near which they are exposed. The gravel also occurs as two beds, one at the base of the formation, here named the Pike gravel member, from the village of Pike, and one younger than the Dierks limestone, here named the Ultima Thule gravel lentil, from the village of Ultima Thule.

The Trinity and overlying Cretaceous strata have a low southward dip, as explained in the next paragraph, but they rest upon the peneplaned edges of highly tilted Carboniferous strata. A pronounced unconformity, therefore, occurs at the base of the Trinity. A notable though less striking unconformity exists between the Trinity and the Bingen formation, of Upper Cretaceous age. This unconformity is shown by the eastward truncation of the beds of the Trinity and the resulting overlap of the Bingen.

The formation ranges in thickness from about 70 feet north of Delight to over 600 feet, indicated by a well 2 miles north of Center Point, which reached a depth of 500 feet without striking bedrock. The southward dip of the strata and also of the Cretaceous floor, as determined from the different elevations of the Pike gravel member along its outcrop, averages about 80 feet to the mile, being in few places less than 60 feet or more than 100 feet to the mile. But according to the well just mentioned the dip increases toward the south and is over 100 feet to the mile near Center Point. A similar southward dip exceeding 100 feet to the mile near De Queen is indi-

System.	Series.	Formation and member.	Thickness in feet.	Character of rocks.
Cretaceous.	Upper Cretaceous.	Brownstown marl.	100±	Fossiliferous blue or gray calcareous clay.
		Bingen formation. Tokio sand member.	(100–150)	Gravels; gray cross-bedded quartz sand; lignitic material; light-colored and dark clays, some of which contain fossil plants.
		Bingen formation.	100–500	Gravels; greenish arkosic sand; red clay; and dark plant-bearing clay.
		Unconformity		
	Lower Cretaceous.	Trinity formation.		Gray cross-bedded sand in heavy beds; some clay.
		De Queen limestone member.	(60–72)	Fossiliferous limestone and an equal or greater amount of green clay. Gypsum and celestite near base.
		Trinity formation.	70–600±	Variegated clays.
		Ultima Thule gravel lentil.	(0–40)	Pebbles less than an inch in diameter.
				Variegated clays.
		Dierks limestone lentil.	(0–40)	Fossiliferous limestone and a smaller amount of green clay.
				Gray cross-bedded sand in heavy beds; some clay.
		Pike gravel member.	100)	Irregularly bedded pebbles and cobbles as much as 10 inches in diameter.
		Unconformity		
Carboniferous.		Atoka formation, Jackfork sandstone, and Stanley shale.		Shale and sandstone.

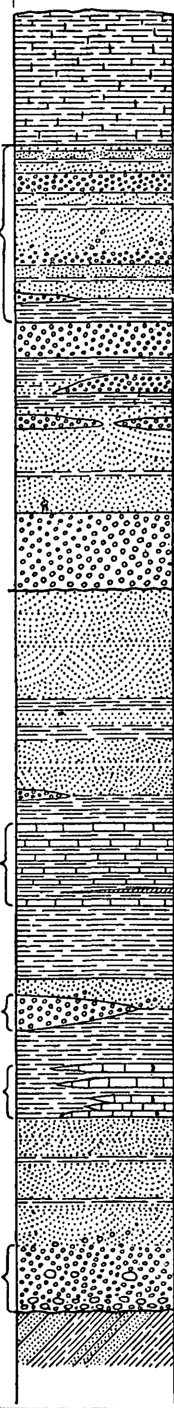
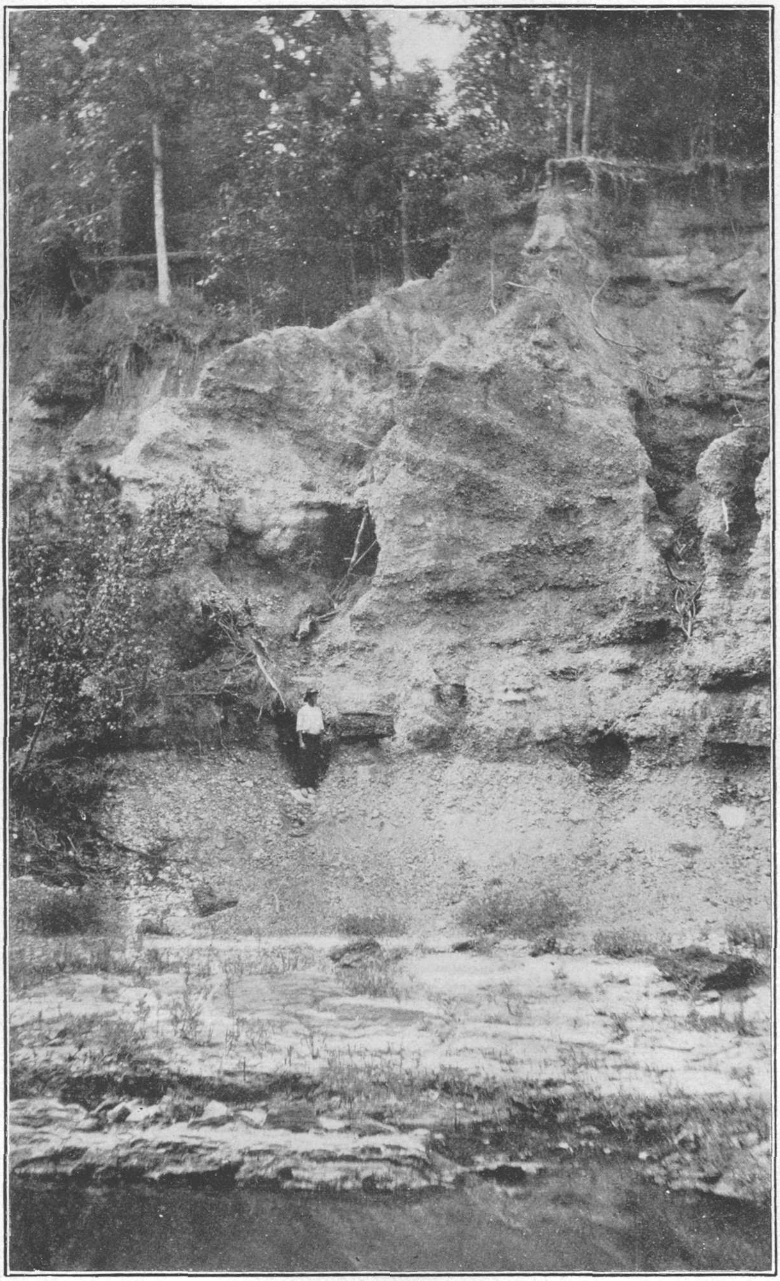


FIGURE 6.—Generalized section of Cretaceous rocks exposed in the Caddo Gap and De Queen quadrangles, Arkansas and Oklahoma.

cated by the ice-factory well at that place, which was put down to a depth of 249 feet without reaching Carboniferous rocks. As a result of this southward dip the beds are exposed in east-west belts in which the younger rocks lie to the south and the older ones to the north.

The Pike gravel member is the thickest and most persistent gravel bed in the area, and has a larger surface distribution than any other. In much of its belt of outcrop it forms an even though dissected southward-dipping upland. This form is due to the resistant nature of the gravel and the ease with which the overlying unconsolidated clay and sand have been eroded. Some of the larger areas of outcrop are at or near Pike, Nathan, Muddy Fork, Dierks, Lebanon, and King. The thickness is rather uniform, being in most places between 20 and 50 feet, but it apparently attains 100 feet near Pike. The gravel thins out at a few places, as near Murfreesboro and Lebanon, where rocky headlands and islands of Carboniferous sandstone along the old Cretaceous shore were not completely buried by the gravel, though they were by higher beds. The sand and clay separating the Ultima Thule and Pike gravels thin to the west and are absent just west of the State line, in consequence of which the Ultima Thule gravel rests either upon the Pike gravel or upon Carboniferous rocks. If the Pike gravel is present there it can not be distinguished from the overlying gravel.

This gravel consists of pebbles usually less than half an inch in diameter, but it contains many larger ones and also many cobbles as much as 10 inches in diameter. These larger pebbles and cobbles are at most places especially abundant in a thickness of several feet at the base. The pebbles and cobbles are partly to thoroughly rounded. Most of them are dense white, gray, brown, black, or red novaculite, unquestionably derived from the Arkansas novaculite, which is exposed in the Ouachita Mountains north of the area here described. A small number, however, are quartz, quartzite, and sandstone. Those of quartzite and sandstone are most abundant in the cobble bed, but they constitute a minor portion of it. The proportion of quartz pebbles in the Pike gravel and the Ultima Thule gravel increases westward from the longitude of De Queen. They are derived from quartz veins in McCurtain County, Okla., which are largest and most numerous in the Ordovician shales in the central part of the county. The proportion of pebbles derived from the novaculite in that county likewise increases westward from the longitude of De Queen. Some of the gravel is conspicuously cross-bedded. Most of it is loose and contains some sand or clay as lenses in the upper part and as a filling in the interstices between the pebbles. Nearly horizontal beds of gravel are in places cemented by brown



PIKE GRAVEL MEMBER AT BLUFF FORD ON MUDDY FORK, 1 MILE WEST OF NATHAN, ARK.

The feet of the man in the picture are level with the contact of the gravel with steeply dipping Carboniferous sandstone which is well exposed in the bed of Muddy Fork in the foreground. Note the cross-bedding.

iron oxide and are thus converted into hard conglomerate. Much of the gravel in the vicinity of Nathan is firmly cemented with a small percentage of silica. Three exposures of gravel thus cemented were observed along the wagon road leading south of east from Nathan to Murfreesboro; the one farthest east is at the ford across Bacon Creek, 2½ miles from Nathan. The best exposed section of the Pike gravel in the area here described is at Bluff Ford, 1 mile west of Nathan. (See Pl. II.)

The Ultima Thule gravel lentil is exposed in a discontinuous crooked belt extending from a point near Ultima Thule eastward as far as Cossatot River, beyond which it is represented here and there by lenses a few feet thick. The lentil itself is also only a few feet thick just west of the Cossatot and is a short distance above the Dierks limestone and about 100 feet above the Pike gravel. It thickens toward the west and reaches a maximum of 40 feet near the State line. Just west of the State line it rests upon the Pike gravel or upon Carboniferous rocks. It resembles the Pike gravel, except that its pebbles are usually smaller, only a few exceeding 1 inch in diameter.

Lenses of gravel as much as 25 feet thick occur above the De Queen limestone northwest of Provo. They resemble the two gravels just described.

In addition to the bedded deposits much gravel occurs scattered over the surface as residual material, from the erosion of beds that now crop out and of others that have entirely disappeared.

The Dierks limestone lentil is exposed in an irregular belt extending from the vicinity of Delight westward to Cossatot River. It is cut out on the east, owing to an overlap of the Bingen formation upon lower beds of the Trinity; on the west it thins out and seems to give way horizontally to clay, which occupies a part of the interval between the Pike and Ultima Thule gravels. The limestone occurs about 50 feet above the base of the Trinity formation along the western part of its outcrop and probably 200 feet above the base north of Delight. Northeast of Murfreesboro it laps up against rocky headlands of Carboniferous sandstone, which jutted out into the old Cretaceous sea. The lentil usually approximates 40 feet in thickness, but at some places it is only 10 feet thick. It is composed of alternating beds of limestone and green clay, with the limestone predominating. Much of the limestone is compact, gray, and hard and occurs in even-bedded layers 1 foot thick, but a considerable portion is earthy and shaly. It is made up of small oyster (*Ostrea franklini*) and other shells, most of which are more or less comminuted. It usually produces a black soil, which gives the belt of country underlain by this limestone the popular name "black-land belt."

The De Queen limestone is exposed in a narrow, somewhat sinuous band extending north of west and west from Plaster Bluff, 3 miles south-southwest of Murfreesboro, passing north of Corinth and Center Point, and thence through De Queen and into Oklahoma. The member is about 60 feet thick at most places but is a little over 70 feet thick along Messer Creek and 72 feet thick at De Queen. It consists of limestone with an equal or greater amount of tough green clay and with some gypsum and celestite. The limestone is usually gray, hard, and compact and is in layers 10 inches or less thick, but much of it is earthy, platy, and yellowish gray and contains small lenses of clay. Fossils, consisting mainly of oysters and other pelecypods, are numerous in many layers. The gypsum occurs in the lower part of the member. The thickest exposure is in Plaster Bluff, where the gypsum is found in a single bed ranging from 10 to 14 feet in thickness. There are a few outcrops and reported occurrences of gypsum as far west as Messer Creek, but they are not over 3 feet thick. Coarsely granular white to pink celestite occurs in clay in the lower part of the member, in some places as short lenses and in others as a single layer 1 to 6 inches thick. Only a few exposures of this mineral have been observed, the westernmost one near Provo and the easternmost one at Plaster Bluff. The most extensive exposures are near Martha post office.

The clay occurs throughout the formation but constitutes a greater proportion of the middle than of the lower and upper parts. It is interbedded with sand, gravel, and limestone and in places contains sand, iron pyrites, novaculite pebbles, lenses of impure limestone, pieces of carbonized fossil wood, and pot-shaped concretions of iron oxide. The fresh clay is white, blue, green, purple, or red, and all these colors may be represented in different layers in a single exposure.

Most of the sand in the Trinity formation occurs in two beds. The lower lies between the Pike gravel and the Dierks limestone. It is thickest to the east and thinnest to the west, and it is impregnated with asphalt at a few localities near Pike, Delight, Murfreesboro, and Lebanon. The higher sand is at the top of the formation and is not exposed east of the longitude of Center Point, beyond which it is overlapped by the Bingen formation. The sand is cross-bedded and fine grained, is interbedded with some clay, and is usually compact, but a small quantity is firmly cemented by iron oxide. It is gray where unweathered but is red or yellow in most exposures and produces a gray soil.

BINGEN FORMATION.

The Bingen formation receives its name from the village of Bingen, 3 miles southwest of Tokio. It succeeds the Trinity formation unconformably, resting in different places upon different parts of that formation. The Brownstown marl in turn succeeds the Bingen, the two grading into each other.[1] The Bingen is composed of near-shore deposits of sand, clay, and gravel and contains at its top the beds here named the Tokio sand member, from the village of Tokio.

The formation is exposed in north-south interstream areas east of Little Missouri River and over the whole of the southward-sloping plateau on which Center Point, Corinth, and Highland are situated. It has a low, southward dip. Only its lower part, which has an estimated thickness of 350 feet along the edge of the area mapped (Pl. I), south of Corinth and Center Point, is exposed north and west of Tokio; but the Tokio sand member, which appears to range in thickness from about 100 to about 150 feet, overlaps this part and is exposed at Tokio and farther east. This member is in fact the only part of the formation exposed east of Little Missouri River and is the only part that contains beds of quartz sand.

The gravel in the Bingen occurs in several beds. The thickest and also the most widely distributed bed is at the base. This basal gravel was deposited on a transgressing beach and thus varies in exact age from place to place, being youngest at the east. East of Little Missouri River it underlies the Tokio member and ranges in thickness from a foot to 25 feet; west of that stream it underlies the lower part of the formation and has a usual thickness of 30 to 50 feet. Its maximum thickness of a little over 60 feet is attained 3 miles southwest of Center Point. Other widely distributed beds of gravel as much as 25 feet thick occur in the lower part of the formation, and probably three beds at least, one or more of which is 50 feet thick, occur above the basal gravel of the Tokio sand. Besides these, much gravel is found through the sandy and clayey parts of the formation.

These different gravel deposits resemble one another as well as those of the Trinity formation. They are cross-bedded and are composed of partly rounded to well-rounded pebbles, most of which are less than 1 inch in diameter, but many of which reach a diameter of 6 inches. Some beds, 12 to 15 feet thick, as well as thinner ones, have in places been converted into hard conglomerate by the infiltration of iron oxide, which has cemented the pebbles together. Most of the pebbles are novaculite; the rest are quartz, quartzite, and sandstone. The novaculite pebbles are usually white, but different shades of red, blue, gray, green, brown, and yellow are common. It is obvious from the character of these pebbles that they were derived from the rocks of the Ouachita Mountain region, but many doubtless came directly from partly eroded gravel beds in the Trinity.

[1] Veatch, A. C., Geology and underground water resources of northern Louisiana and southern Arkansas: U. S. Geol. Survey Prof. Paper 46, p. 25, 1906.

In addition to the kinds of pebbles just mentioned, various types of igneous pebbles, which are similar to or identical with some of the crystalline rocks of Arkansas, are found in the basal part of the formation from the vicinity of Murfreesboro westward. Their best-known exposure is on Mine Creek at the edge of the area mapped (Pl. I), south of Corinth. This exposure shows gravel lenses 4 feet in maximum thickness in an arkosic sand. Some of the pebbles are quartzite, novaculite, and millstone grit, but the bulk of each lens consists of well-rounded, fresh igneous pebbles, some of which have a diameter of 6 inches. The igneous rocks, as indicated by the study of thin sections, are tinguaite, fourchite, and syenite, named in the descending order of abundance. A few igneous pebbles completely altered to clay were observed in a gully in the basal gravel of the Bingen in the northern part of Center Point; a pebble of tinguaite and other indeterminable pebbles were found in the same gravel 3 miles southwest of this place; and pebbles of altered peridotite were observed in a pit and a well in the W. ½ SW. ¼ sec. 22, T. 8 S., R. 25 W., southeast of Murfreesboro.

A greenish cross-bedded arkosic sand composed of kaolinized feldspar and a less amount of mica, quartz, chlorite, magnetite, red iron oxide, and other particles, all of which are cemented together with calcite, is widely distributed west of Tokio and Highland. It weathers to a red plastic clay at and near the surface and shows its comparatively fresh character only in wells and a few outcrops.

Besides the sand just described the lower part of the formation contains red clay and dark plant-bearing clay.

The Tokio sand member contains sand and clay, in addition to a basal gravel and the three higher gravel beds that have already been described. The sand is an incoherent, though firmly packed gray quartz sand in beds some of which are over 30 feet thick. It is conspicuously cross-bedded, contains disseminated particles of kaolin and a few scattered pebbles, becomes red on weathering, and produces a gray sandy soil. Light-colored and dark-colored clays are interbedded with the sand. Some of them contain fossil plants and small quantities of iron pyrites and lignitiferous matter. The light-colored clays are in beds reaching a thickness of 5 to 6 feet and consist of plastic ball clays and nonplastic kaolins. A 5-foot bed of kaolin in the NE. ¼ SE. ¼ sec. 24, T. 8 S., R. 25 W., is reported to be fuller's earth.

BROWNSTOWN MARL.

The lower part, probably 100 feet or more, of the Brownstown formation occupies about 5 square miles in the southeast corner of the area under discussion. Veatch,[1] who has studied the formation

[1] Veatch, A. C., Geology and underground water resources of northern Louisiana and southern Arkansas: U. S. Geol. Survey Prof. Paper 46, p. 25, 1906.

over a much larger area than the present authors, describes it as follows:

The Brownstown formation, into which the Bingen sand gradually grades, is well developed in the southern part of Sevier County, Ark., about Brownstown, from which place it takes its name. It is a blue or gray calcareous clay containing many fossil oysters and is characterized by the presence of the large oyster *Exogyra ponderosa*, whence it has sometimes been called the *Exogyra ponderosa* marl. The soil derived from this formation, when not mixed with surficial deposits, is black and waxy, but the subsoil is yellow, and in most of its outcrops the bed is a yellow clay marl. It is limited above by the Annona chalk and has a total thickness of 150 feet in the eastern part of the area [southwestern Arkansas] and 600 feet in the western.

TERRACE DEPOSITS.

The terrace deposits are in general unassorted mixtures of small and large gravels and sand and are in most places overlain by a loam, producing a good soil. The gravels are local in origin, having been derived directly from the rocks of the Ouachita Mountains and indirectly from the same source through the gravel beds of Cretaceous age in the area here described. They are mostly novaculite pebbles, which are partly to well rounded, and they range in size from minute pebbles to cobbles a foot in diameter. A few pebbles are sandstone and quartz.

The terrace gravels so closely resemble those of Cretaceous age that in places it is difficult or apparently impossible to distinguish them. In such places the altitude of the gravel deposit, the character of the surface, and the assortment and size of the pebbles have to be considered in determining their age. These gravels range from a thin mantle to deposits 50 feet or more thick, but they are usually 15 to 20 feet thick. As a rule the largest patches contain gravels and cobbles at the base and sand or loam at the top, and the smallest patches contain only gravels and cobbles.

These deposits are found chiefly along Little Missouri, Saline, and Cossatot rivers and Rolling and Muddy forks. They occupy benches at heights from 35 to 150 feet above these streams. Some deposits are in places strewn along the slopes between the different benches.

ALLUVIUM.

The larger and most of the smaller streams flow in flat-bottomed valleys and are bordered by flood plains that are, as a rule, widest in the Coastal Plain, where the rocks are largely unconsolidated and soft, and narrowest in the Ouachita Mountain region, where the rocks are hard. Although gravels and cobbles make up a large part of this filling, the surface is usually covered with rich loam and sand, and most of it makes good farm land. These gravels and cobbles have been derived from the erosion of the outcropping edges of the other gravel deposits of the region, though some of them have been carried by the streams from the Ouachita Mountain region. Accordingly they do not differ, except in their distribution and lack of assortment, from the other gravels already described. Little is known of the thickness of the alluvium, but it is probably less than 25 feet at most places.

ECONOMIC USES OF THE GRAVELS.

TUBE-MILL PEBBLES.

The novaculite pebbles in the deposits herein described have never been used in tube mills. They are, however, of such a character that the authors believe well-selected pebbles may be suitable for this purpose. The only way to determine their adaptability to this use is by actually using some of them in tube mills. If the pebbles are found to be suitable, the farmers living in the region could be employed at idle times to collect, grade, and size them. The industry would thus not require the investment of a great amount of capital.

The pebbles range from a small fraction of an inch to 10 inches in diameter, but the smallest ones predominate. The tube-mill pebbles in greatest demand are from 2 to 4 inches in diameter, though some as small as 1 inch and some as large as 7 inches are used. The 2 to 4 inch pebbles are most abundant in the basal part of the Pike gravel from Ultima Thule eastward, in the gravels of the Bingen formation, and in the terrace deposits and gravel bars along Muddy Fork, Little Missouri River, and other streams farther east. The gravel bars are largest along the two streams just named, some of them occupying several acres, and the gravels in them are in places roughly assorted according to their size.

Some of the pebbles larger than 1½ inches in diameter were collected in 1916 by the senior author from the surface of an area 10 feet square by the roadside in the NW. ¼ SE. ¼ sec. 24, T. 8 S., R. 25 W., about 4½ miles south of east from Murfreesboro. The pebbles at this locality occur in the basal gravel of the Tokio sand member, the only part of the Bingen formation that is present east of Little Missouri River. The collection was made here not because the locality is the best for pebbles of tube-mill size—for such pebbles are exposed as well or probably better at numerous other localities—but because the spot was free of vegetation and was one of the most convenient the day the collection was made. The pebbles 1½ inches or over in diameter constitute 10 to 20 per cent of the bulk of the gravel on the slope, and about 100 of such pebbles lying loose on the surface or partly embedded among the finer pebbles were placed in a pile. From these were selected 36 of the best-shaped pebbles and

PEBBLES FROM THE BINGEN FORMATION.

These pebbles, which are $1\frac{1}{2}$ to $5\frac{1}{4}$ inches in diameter, show the usual shape of selected novaculite pebbles to be expected at most localities in the Caddo Gap and De Queen quadrangles.

those freest of flaws. (See Pl. III.) They probably represent the usual shape of pebbles that would be selected in this way from most localities in the region where pebbles of such size occur. The largest pebble shown on Plate III is 5¼ inches in its longest dimension.

Most of the novaculite pebbles are of dense gritty fine-grained homogeneous novaculite that is translucent on thin edges. They break very much like flint or chert, with an uneven to conchoidal fracture, and usually have a waxy luster like chalcedony. Most of the pebbles are white with a bluish tint, but many of them show different shades of red, gray, green, yellow, and brown, and some are black. In some parts of the area all the pebbles are bleached white, but upon being fractured they show their original color.

In shape the pebbles vary from slightly rounded to well rounded. None of them are spherical, and very few are nearly so. Although the slightly rounded pebbles predominate, their edges are well rounded. Part of the rounding took place in the streams that carried the pebbles from the Ouachita Mountains, but most of it probably took place on the beaches of the Cretaceous sea. A few pebbles have smooth faces that are parts of joint planes of the beds from which they came. Most pebbles have such planes and other cracks within them, but many are free of these flaws. The pebbles, as a rule, have smooth surfaces; but some have pits, owing to the presence of cavities in the parent rock, and some have rough surfaces from impact with one another. A few are highly polished. A small proportion of the pebbles consist of porous novaculite that would wear down faster than the denser rock. Some of the pebbles have parallel laminae, and such pebbles usually have planes of weakness. The novaculite pebbles are almost pure silica, as is shown by the accompanying average of several analyses of the Arkansas novaculite,[1] and they are so resistant to weathering that they are usually as fresh as the unweathered novaculite found along its outcrops in the Ouachita Mountains.

Average analysis of Arkansas novaculite.

Silica (SiO_2)	99.50
Alumina (Al_2O_3)	.20
Ferric oxide (Fe_2O_3)	.10
Magnesia (MgO)	.05
Lime (CaO)	.10
Soda (Na_2O)	.15
Potash (K_2O)	.10
Loss on ignition (water)	.10
	100.30

[1] Griswold, L. S., Whetstones and the novaculites of Arkansas: Arkansas Geol. Survey Ann. Rept. for 1890, vol. 3, p. 90, 1892.

The specific gravity of dense chalcedonic novaculite from Caddo Gap, Ark., has been determined by the Bureau of Standards to be 2.614. A determination, by C. E. Wait, of the specific gravity of what is called in the trade the "Arkansas stone," a variety of novaculite used for abrasives, gave 2.649.[1] A determination of the specific gravity of the same kind of stone at the standard temperature, made by the Arkansas Geological Survey, gave 2.648.[1] The specific gravity is less than that of quartz in crystals, which varies from 2.653 to 2.660, but it falls within the limits for pure cryptocrystalline forms such as flint or chert, which may have a specific gravity as low as 2.60.

The percentage of absorption by weight of the dense novaculite from Caddo Gap was determined by the Bureau of Standards to be 0.127. Similar tests of the Arkansas stone from two quarries near Hot Springs were made by the Arkansas Geological Survey; the percentages of absorption found were 0.06 and 0.07.[2]

The hardness of the novaculite is the same as that of quartz, but as shown by the slight protrusion of quartz veins, due to differential abrasion, on surfaces of many of the pebbles containing such veins the novaculite is somewhat less resistant to abrasion than vein quartz. Novaculite is comparatively brittle, being easily broken by a hammer. Its brittleness may, in fact, bar its economic use in tube mills.

The crushing strength, as determined by taking the average of three compression tests made by the Bureau of Standards on novaculite from Caddo Gap, is 44,137 pounds to the square inch.

The gravels in the Tokio sand member are usually mixed with less red clay than those in the Trinity formation and in the lower part of the Bingen formation. The stream gravels are also in most places free of clay.

ROAD MATERIAL.

The many beds and lenses of gravels in the Trinity and Bingen formations are widely distributed. They consist of novaculite and other hard pebbles intermixed or interbedded with clay and sand, and, although they range in thickness from a few inches to 100 feet, some beds present thicknesses of 25 to 50 feet over large areas. Enough sand and clay are usually mixed with them to make a firm, compact road. These gravels thus constitute an accessible and inexhaustible supply of good road material. They form a natural pavement in those parts of the area where they occur on the surface.

Gravels of much the same character as those just mentioned constitute a large proportion of the deposits along the large and small

[1] Griswold, L. S., op. cit., p. 93. [2] Idem, pp. 93–94.

streams. The larger areas of such gravels are indicated on the map (Pl. I) as "alluvium" and "terrace deposits." Most of these areas are covered by deposits of sand and loam a few feet thick. In areas where the gravels are thus covered the best places for obtaining road material are along slopes where the gravels crop out and from the gravel bars usually found along the streams. These bars are largest along Muddy Fork and Little Missouri River. The gravels in this area are used but little in the construction of roads.

The cobbles and large pebbles commonly found in greater quantities at the base of the Pike gravel than elsewhere are suitable for riprap and curbing, and great quantities of them occur in places along the streams.

OTHER USES.

The abundance and wide distribution of the gravels make them an important source of material for concrete and railroad ballasting. Stream gravels from the bed of Wolf Creek at Delight are used for this purpose. A pit has been opened in the Pike gravel on the Memphis, Dallas & Gulf Railroad 1½ miles north of Murfreesboro. Gravels have been extensively quarried along the Kansas City Southern Railway 3 miles north of De Queen. They were presumably used for ballasting.

Gravels in the Tokio sand and in the Pike and Ultima Thule gravels are in places fine enough and free enough of clay to be suitable for roofs made of felt, tar, and gravel. Screening would probably be necessary at all places to free the pebbles of sand and to obtain pebbles of uniform size.

Small quantities of novaculite and other pebbles found on the surface at the Mauney and Ozark diamond mines, near Murfreesboro, are used in the concentrating pan in the plant of the Kimberlite Diamond Mining & Washing Co. to assist in the disintegration of the altered peridotite from these mines.

Some of the gravel conglomerate in the area is used in rough masonry. No quarries have been opened; only loose pieces on the surface are used. The cobbles found in the deposits indicated as terrace and alluvial deposits on the map and in the base of the Pike gravel are suitable for rubble work, and some of them have been so used at Murfreesboro.

A few of the purest novaculite pebbles could be crushed and used as "flint" in the manufacture of pottery, but such a use would not be advisable, for much whiter and purer novaculite is available at the whetstone quarries at and near Hot Springs, where large quantities are thrown away on the dumps as waste.