THE ROAD AND CONCRETE MATERIALS OF SOUTHERN IOWA

by

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INTRODUCTION

Foreword

The building of roads has become one of Iowa's greatest industries. The rapid increase in use of motor vehicles, which has been one of the conspicuous features of the last two decades, has created a demand for a state-wide system of highways that can be traveled with safety and comfort at all seasons of the year. In response to this demand, highway improvement has, since 1920 or earlier, constituted a large portion of state, county, and township activities.

An idea of the magnitude of these road improvement operations may be obtained from the Annual Report of the Iowa State Highway Commission for 1932, which shows that during that year approximately $17,400,000 was spent on construction and maintenance of the Primary Road System of 7,844.7 miles, and approximately $18,500,000 was spent on construction and maintenance of the Secondary Road System of 94,628.05 miles. Expenditures for 1930 and 1931 were even higher, being some $46,000,000 on the Primary Road System and some $22,000,000 on the Secondary Road System in 1930.

Purpose and Scope of the Report

Under the laws of the State of Iowa, the State Highway Commission has complete charge of the improvements on the Primary Road System and exercises general supervision over the improvement of the Secondary Road System as well. In order to plan this work for the greatest benefit with the least cost, it is necessary that the Highway Commission have complete knowledge of the location of possible sources of road material and of the kind and quality of material which may be obtained from them. Such knowledge serves a twofold purpose: First, it enables the Commission to form an accurate judgment of material possibilities in any locality, which judgment has important effect on improvement plans in that locality. Second, it is available to road material producers and to those who desire to produce road material, and often results in the development of valuable deposits, with more active competition and consequent lower prices.

In order to obtain such information on road material supplies, the State Highway Commission has conducted a material resource survey since the organization of a Materials and Tests Department in 1920. This survey covers all parts of the state and all classes of material that are believed to be of interest. The writer has been connected with this survey since 1921 and has been in charge of it since 1925.

Early in the progress of this material resource survey it became evident that not all parts of the state were equally promising as sources of supply. It was found that the gravel that is so plentiful in north-central and northern Iowa is almost entirely lacking in the southern part of the state. Furthermore, ledge rock was found to be almost entirely absent from the southwestern part, and though it is more abundant in the south-central and southeastern parts, even there it is in some places of poor quality or is available only in limited quantity. Consequently the southern part of the state has received special attention; in many counties every known material deposit, no matter how small or how far from any primary road, was carefully tested out. Thus much more detailed information has been collected for southern Iowa than has been the case in northern Iowa. A large part of this detailed information has never before been published, and it is believed that it should be made available to the people of the state.

It has been found in the past few years that the second purpose served by material resource information has been of increasing importance. Many inquiries as to conditions in southern Iowa have been received at the office of the Materials Department. These inquiries have come from producers within the state, from persons in Iowa and in other states who wish information on road material developments in Iowa, and from scientists and other interested persons. This report is written for publication in the hope that those who are interested in the road material situation may find herein some assistance in answering the questions that have occurred to them.

Road construction practice in Iowa favors portland cement concrete for paving, and gravel or crushed stone of some kind for loose-top surfacing. The past few years have seen the application of oil or asphalt treatments to surfaced roads, and it may be that a wide extension in the use of various asphaltic mixtures, such as sheet asphalt or asphaltic concrete, will take place in the near future. Consequently this report gives most emphasis to sources of concrete aggregate, asphaltic aggregate, and road surfacing materials. Such other materials as cement, paving brick, drain tile, etc., which may be used extensively in road building, and which may be manufactured in Iowa, are not given consideration because they are the result of complicated manufacturing processes requiring much capital, and the interest in their production is much less widespread than the interest in the development of sand, gravel, or stone deposits. The Highway Commission has given only superficial attention to those material deposits that are of special value in the manufacture of such products, and such deposits will be treated in this report only in so far as they may be of interest as sources of concrete aggregate or surfacing material.

Acknowledgments

The Iowa State Highway Commission has furnished the funds by means of which this material resource survey has been carried on. Special mention should be made of Mr. R. W. Crum, now Director of the Highway Research Board, Washington, D. C., who organized the Materials Department of the Highway Commission, and who inaugurated and at all times encouraged the survey. Other members of the State Highway Commission organization, too numerous to mention by name, have given encouragement and advice. Mr. Bert Myers, Engineer of Materials and Tests, has been of special assistance with the chapter on "Road and Concrete Materials" and with those chapters having to do with the development of materials deposits.

The publications of the Iowa Geological Survey have been an invaluable aid in working out the geology of the road materials of southern Iowa and have been a dependable source of information on locations of material deposits. Of special value have been Volume XXIV, containing the report of Dr. S. W. Beyer and H. F. Wright on "Road and Concrete Materials of Iowa," and Volume XXX, containing the report of Dr. F. M. Van Tuyl on "The Stratigraphy of the Mississippian Formations of Iowa."

Many geologists throughout the state have assisted with encouragement and advice. Among these may be mentioned Dr. G. F. Kay, Director, and Dr. James H. Lees, Assistant Director, of the Iowa Geological Survey; Dr. A. C. Tester, and the late Dr. A. O. Thomas of the Geology Department of the State University at Iowa City; Dr. C. S. Gwynne of the Geology Department of Iowa State College at Ames; the late Dr. Geo. L. Smith of Shenandoah; and others, too numerous for individual mention.

CHAPTER I

ROAD AND CONCRETE MATERIALS

As was mentioned previously, road building in the state of Iowa has in recent years favored two types of construction, as follows: In the paving field, portland cement concrete; and for loose-top surfacing, gravel or crushed stone. This chapter is concerned with the qualifications of materials which may be used in these types of construction without expensive manufacturing processes and with the tests and specifications that are employed in determining their fitness. This discussion of properties and tests of road materials is made so that the reader may the better understand the reasons for the suitability or lack of suitability of the products of the various deposits which are to be considered.

GENERAL DEFINITIONS

Portland cement concrete is essentially an artificial stone similar to the conglomerate found in nature. This artificial stone is composed of particles of inert material, included under the term "aggregate," which are joined together by a paste of portland cement and water. In an asphaltic concrete the aggregate has the same function, with tar or asphalt taking the place of the portland cement and water paste. Strength and durability of a concrete depend upon the properties of the aggregate composing it and upon the degree of cementation between the aggregate particles. Since aggregate constitutes 60 to 80 percent of a concrete mixture, its qualities have an important bearing on the quality of the finished product.

The aggregate particles in a concrete are bonded together to the greatest possible degree only when the cementing medium completely coats them and completely fills the void spaces between them. Particles of an aggregate of good quality possess greater structural strength than do equivalent volumes of the cementing medium; also aggregate is usually much cheaper than is the cementing medium; therefore, a well-graded aggregate, one containing a minimum of void space, ordinarily gives the best quality of concrete at the lowest cost. In cases where local supplies of poorly graded aggregate are much cheaper to obtain than shipped-in supplies of better graded material, it may be more economical to use the local material, with enough additional cementing medium to fill the increased void space. A condition of minimum voids is obtained when spaces between particles of any certain size up to the maximum allowable are filled as completely as possible by particles of smaller size.

To secure uniformity of proportioning, aggregates are usually divided into two parts, fine and coarse. For portland cement concrete some engineers divide the fine from the coarse aggregate on the $\frac{1}{4}$-inch size, while others prefer to make that division at a smaller size, for example $\frac{1}{8}$-inch or $\frac{1}{10}$-inch. In asphaltic concrete the division may be made in a still smaller size, or three sizes may be used, the smallest being known as filler. Fine aggregate in Iowa is nearly always sand, though some hard rock screenings may be usable. Coarse aggregate in Iowa is screened gravel or crushed stone, as no other suitable materials occur within the state.

FINE AGGREGATE FOR PORTLAND CEMENT CONCRETE

Grading

The grading of an aggregate is usually expressed in terms of percentages of particles passing openings of various sizes. These percentages are determined by means of sieves; Table I indicates the sizes of sieve openings most commonly used.

TABLE I

Sieve Numbers and Openings [1]

Sieve	Sizes		
No.	Meshes per Lineal Inch	Diameter of Wire Inches	Width of Opening Inches
4	4	.065	.165
10	10	.035	.065
20	20	.0328	.0172
30	30	.0167	.0166
50	50	.01	.01
80	80	.0063	.0062
100	100	.005	.005
4	4	.065	.185
8	8	.032	.093
14	14	.025	.046
28	28	.0125	.0232
48	48	.0092	.0116
100	100	.005	.005

Table showing sizes of sieve openings used in screening rock.

1 Courtesy W. S. Tyler Co., Cleveland, Ohio.

The last six screens listed are sometimes used together in the so-called "logarithmic set," each screen having an opening twice as large as the one following.

As previously stated, the most desirable grading for aggregate is achieved when particles of all sizes from coarse to fine are present. It is often advisable to exclude from fine aggregate an excess of the finer grains, which, per unit of volume, require a much greater quantity of cement to coat them and bond them properly to each other than do coarser particles. The current specifications of the Iowa State Highway Commission allow up to 40 percent passing the No. 30 sieve, with the qualifying provision that finer sands may be used if experimentation shows that mortar of satisfactory strength can be made economically from them.

Impurities in Fine Aggregate

Mineralogically, the sands found in Iowa consist almost entirely of grains of quartz or flint, which may be either well rounded or angular. If rock screenings are used they must be from a hard and sound rock that will possess durability and strength comparable with that of quartz. The grains of a fine aggregate, whatever their composition, must be clean and uncoated by clay, limonite, or similar substances, and must be free of foreign matter that may be injurious to the concrete. The 1933 specifications of the Iowa Highway Commission, which may be considered as typical for paving concrete, allow not over 1.5 percent by weight of shale and coal particles larger than 0.046 inch, not over 1.5 percent of clay and silt, and 0.0 percent of chemically active organic impurities. Highway pavements are subjected to heavy loads and severe exposure conditions, and the concrete of which they are made must possess a high order of strength and durability. For concrete that does not carry extremely heavy loads or is not subjected to severe conditions of exposure, a fine aggregate containing higher percentages of the above-mentioned impurities may be used with satisfaction.

Shale and Coal. — Shale particles have but little structural strength, and they also possess the property of taking up water slowly, causing swelling of the particles after the concrete has set, which may in turn lead to the disruption of the concrete. Coal likewise has little structural strength, and in addition, being an organic substance, it is undesirable in the concrete mixture, as will be explained later.

It has been found that the smaller shale particles, such as those occurring in some sands, are not capable of exerting a force in swelling which is sufficient to cause disruption of any appreciable part of the concrete in which they are placed. The objection to these smaller particles lies, then, only in their lack of structural strength, and it is therefore customary to permit a higher proportion of shale in fine aggregate than in coarse aggregate. Thus, the Iowa State Highway Commission specifications for 1933 permit 1.5 percent of shale and coal in fine aggregate, but only 0.8 percent in coarse aggregate. Other specifications now in use or under consideration permit greater amounts, up to 3.0 percent, in sand. In unimportant structures where use of local materials is desirable, this percentage may be increased to 5.0 without serious impairment of the quality of the concrete.

Shale and coal have a much lower specific gravity than the quartz and other minerals that constitute the bulk of the Iowa sands, and their presence in test samples is usually determined by floating them off in some liquid of high specific gravity, such as a concentrated solution of zinc chloride.

Silt and Clay. — So far as their association with fine aggregate is concerned, silt and clay are defined as being composed of particles of such fineness that they will remain suspended in water for fifteen seconds. They consist for the most part of minerals that are chemically inert and that in small quantity are harmless in the concrete. In larger quantity they may coat the grains of aggregate and prevent the cement from satisfactorily bonding them. The amount present in a sample is determined by repeated washings of a weighed quantity of aggregate, allowing the wash water to stand for fifteen seconds each time before pouring it off.

Organic Impurities. — Organic substances, such as peat or animal or plant refuse, have an injurious chemical effect on concrete, causing a marked reduction in its strength when they are present in any but minute amounts. The approximate amount in a sand is usually determined by reaction of sodium hydroxide with the tannic acids present; the sodium tannate that is formed from the reaction gives the solution a yellow to dark brown color, varying according to the amount of organic material present.

COARSE AGGREGATE FOR PORTLAND CEMENT CONCRETE

As with fine aggregate, the value of a coarse aggregate depends upon its grading and upon the amounts of various impurities which may be present. Furthermore, while most of the gravel in Iowa is composed principally of fragments of igneous and metamorphic rocks, which generally show a high degree of strength and durability, much of the crushed rock available here for use as aggregate is lacking in that strength and durability, and thus, to determine its value, certain additional tests are required. The following discussion takes up these various matters in the order above given.

Grading

The matter of grading, or the proportion of the various pebble sizes in a deposit of coarse aggregate, is of less importance than with fine aggregate, for the reason that coarse aggregate particles are much more easily screened out, and any undesirable grading is thus corrected without difficulty. The maximum size depends upon the thickness to which the concrete is to be built and upon the amount of reinforcing steel to be used. Though grading of a coarse aggregate may safely range within rather wide limits, the aggregate that is most desirable includes pebbles or fragments of all sizes, from the coarsest admissible down to the point of division from fine aggregate. Many of the Iowa gravels contain an excess of material from one-fourth inch to one-half inch in size ("pea gravel"). This is screened out and finds a use in thin-section reinforced concrete in building work. The Iowa State Highway Commission specifications (Series of 1933) for paving concrete permit from 70 to 100 percent of a coarse aggregate to pass a $1\frac{1}{2}$-inch screen, 20 to 90 percent to pass a $\frac{3}{4}$-inch screen, and 5 to 50 percent to pass a $\frac{3}{8}$-inch screen. Experimentation by various engineers has shown that even these wide limits may be exceeded safely by using a higher proportion of cement.

Injurious Impurities

The 1933 specifications of the Iowa State Highway Commission permit not over 1.5 percent of silt and clay, 0.8 percent of shale, 0.5 percent of coal, 0.1 percent of sticks, 0.0 percent of organic matter other than coal and sticks, and 0.5 percent of clay in lumps. An additional clause provides that the total of shale (including some iron-bearing varieties which might be classified as argillaceous iron oxides), unsound chert, and other kinds of materials whose disintegration (as a result of weathering processes) is accompanied by an increase in volume that may cause the spalling of concrete or mortar in which they are contained, shall be not over 2.0 percent.[2] Another clause provides that the total of objectionable particles above listed, plus any unsound particles whose weathering is not accompanied by an increase in volume, plus coated particles, shall be not more than 5.0 percent.

The specifications given in the preceding paragraph are somewhat cumbersome, but are so written for the purpose of drawing a distinction between two broad classes of injurious impurities in coarse aggregate, as well as limiting the amount of each individual impurity. The first class, including clay, coal, sticks, soft stones, and some unsound stones, may be characterized by their property of disintegrating and sloughing away under atmospheric weathering, without, however, causing any appreciable damage to the concrete surrounding them. The second class includes the unsound varieties of iron oxides, shale, shaly limestone, chert, etc., whose disintegration as a result of weathering is accompanied by an increase in volume supported by sufficient force to break off such concrete as is necessary to accommodate their expansion. The relative importance of these two classes of impurities is indicated roughly by the amounts of them allowed in the specifications just given. These limits are proper for concrete which is to be subjected to severe loading and exposure conditions. For work of lesser importance, the allowance on the first class might be increased to 10.0 percent, while, in order not to sacrifice durability, the second class should probably not exceed 3.0 or 4.0 percent.

The Highway Commission specification just given also requires an abrasion test, similar to that described in the following section on "Additional Tests for Crushed Stone Aggregate," for the purpose of establishing the amount of soft stone present. Other specifications accomplish the same result by designating soft stone as that which can readily be broken in the fingers. Such designation has the merit of simplicity, and though less exact than the abrasion test, is probably accurate enough for determinations on the southern Iowa gravels.

Additional Tests for Crushed Stone Aggregate

If the gravels of southern Iowa consisted in large measure of fragments of limestone or other rock that shows a wide range of strength and durability, as is true in some parts of the United States, the tests

2 This clause is quoted from the Highway Commission specifications, except that the interpolations in parenthesis are added by the writer.

described in this connection should be applied to all of the Iowa coarse aggregates. The reason for not running them on southern Iowa gravel is not that these tests measure physical properties which in this gravel are unimportant; rather, the gravels contain such a small proportion of fragments of these questionable rocks that the tests are not necessary to establish their suitability.

Abrasion Test. — In the abrasion test, the stone is broken into 50 small blocks as nearly cubical in shape as possible and of such size that their total weight is 5,000 grams; this will make them about $1\frac{1}{4}$ inches on a side. These pieces are placed in a cast iron cylinder and turned through 10,000 revolutions at a speed of 30 to 35 revolutions per minute, on an axis which is at an angle of 30 degrees with the axis of the cylinder. The effect of this turning is to roll the pieces of rock from one end of the cylinder to the other twice for each revolution and to wear off the corners of the rock against the walls of the cylinder and against each other. Upon the completion of the required number of revolutions, the material is screened over a No. 20 screen and that which passes through is computed as a percentage on the original 5,000 grams; this is known as the "percentage of wear."

The French Coefficient (so-called from the name of the engineer who developed the abrasion test) is an arbitrary coefficient obtained by dividing 40 by the percentage of wear. It is in very common use as a means of indicating the suitability for use in concrete aggregate of the crushed product of all the softer varieties of rock. The current specifications of the Iowa State Highway Commission for crushed stone intended for concrete aggregate in paving or bridge work require a percentage of wear of 8 or less (French Coefficient 5 or more). Other states, more favorably situated with respect to supplies of hard stone, require a percentage of wear as low as 5, 6, or 7. On the other hand, experimentation has shown that concrete with strength adequate for ordinary purposes may be made from crushed stone having a percentage of wear as high as 15 or 20.

Soundness Test. — The question of soundness of the fragments of crushed rock has received considerable attention from engineers in recent years; it even seems probable that a soundness test will in the future be much more generally applied to gravel than is the practice at present. This quality in a fragment of rock is usually determined by subjecting it to a condition intended to approximate that of greatly accelerated atmosphere weathering. For this purpose, alternate freezings and thawings in water, repeated from 10 to 50 times, are often used. An approximately equivalent test consists of prolonged immersions in a saturated solution of sodium sulphate, with complete drying following each immersion. Such a solution has the property of penetrating fine openings within the stone and the further property of rapid crystal growth upon evaporation, the force exerted by the growing crystals being sufficient to disrupt the stone in much the same manner as does the expansive force of freezing water. The current specifications of the Iowa State Highway Commission for soundness of crushed stone for paving or bridge concrete require that it shall withstand five such immersions in a sodium sulphate solution without more than a superficial cracking or failure of any kind. An unsound or questionably sound coarse aggregate cannot be recommended for any structure that is subjected to outside exposure conditions, such as frequent wetting and drying or repeated freezing and thawing. The soundness test, as was previously mentioned, is but comparatively new, and the next few years may bring outstanding improvements in it.

Absorption Test. — A test for absorption (of water upon prolonged immersion) is often made upon crushed limestone to guard further against porous or weak stones. Absorption under such conditions should not exceed 3 or 4 percent.

Asphaltic Aggregates

In asphaltic mixtures the aggregate consists of gravel or crushed stone for the coarser part and sand or stone screenings for the finer part. The requirements for such materials are substantially the same as those for the same materials when used in portland cement concrete, except that in the asphaltic mixes a larger proportion of the very finely divided material ("filler") is used. This filler may be any substance that is not affected chemically by the bituminous binder, such as fine sand, stone screenings, clay, or even portland cement. In addition to the filler, the asphaltic mixtures usually employ an aggregate of finer grain than that used in portland cement concrete. Thus, certain sands that are too fine for use in portland cement concrete may be of suitable grading for the finer portion of an asphaltic aggregate, either with or without the addition of a filler.

Surfacing Materials

Materials and Manner of Use. — The materials commonly used for surfacing are gravel or crushed stone of various kinds. In order to give a better understanding of the importance of the physical properties determined in evaluating materials of this class, the consideration of those properties is preceded by a brief discussion of the manner in which the material is used.

The type of surfacing in greatest favor in Iowa is a modification of the long-established water-bound macadam type, the chief difference being that in Iowa the material receives no special rolling while it is being placed but is left to be compacted by traffic. It is spread evenly over the road to a thickness of one or two inches, and, as it becomes compacted, more is added from time to time until a firm crust is formed to a thickness of six inches or more.

As this material is laid on a foundation of earth, which may become very soft during prolonged wet weather or during the thawing period of spring, the crust sometimes breaks through under heavy traffic. When this occurs, the usual remedy is to fill the hole with additional surfacing material.

General Qualifications. — A good surfacing material should consist of strong, hard particles of such size as to be stable under traffic, but not so large as to give rise to roughness in the road, and with some kind of cementing material so that they will be bound together firmly under traffic. Iowa materials that meet these requirements are ordinary pit-run gravel, crushed limestone or dolomite, or crushed coal-mine refuse. Iowa gravel, which consists for the most part of pebbles of various igneous and metamorphic rock or of fragments from the more durable sedimentary rocks, is acceptable for this purpose when it is coarse enough to be stable under traffic. Most of the limestones or dolomites found in southern Iowa also are satisfactory. Most Iowa sandstones are not sufficiently indurated to serve for this purpose, but locally they are acceptable. Shales are too soft and break up too readily under weathering and traffic, unless burned, as in coal-mine dumps, by the method that will be described later.

Grading. — As was previously stated, the pieces of surfacing material should be large enough to be stable when compacted under traffic, but not so large that individual fragments which may project above the general roadway level will give rise to roughness of the road surface. The water-bound macadams used extensively in the eastern states are built in courses, the larger sizes of material being placed beneath for stability and the smaller sizes on the surface for smoothness. The surface type common in Iowa uses only one grade of material, which is adjusted in size to meet both of these requirements so far as possible.

Experience has shown that the maximum practical size of fragment or pebble is 1 inch or 1½ inches and that the material should grade down uniformly from this size to the smallest palpable particles. Some engineers allow only three-fourths inch maximum size. The purpose of the smaller sizes is to fill in the spaces between the larger fragments and in some cases to serve as a cementing material. The 1933 specifications of the Iowa State Highway Commission for Class A road surfacing material require that not more than 35 percent of the gravel used shall pass the No. 8 screen, and that not more than 20 percent of the crushed limestone shall pass that screen. Material with this grading, while not giving as dense and firm a surface as is found on the water-bound macadams of the eastern states, has the advantage of requiring lower construction and maintenance costs and is therefore widely used in Iowa and surrounding states. On roads that carry a light traffic, where the necessity for low-cost improvement has dictated the use of local materials, a gravel containing up to 80 percent passing the No. 8 screen, or limestone containing up to 30 percent passing this screen, has been used with good results.

Impurities. — The presence of shale, silt, clay, sticks, soft or unsound stone, or various other impurities, is a much less serious defect in surfacing materials than in aggregates. Consequently, the sum of these substances is ordinarily allowed to be as high as 15 or 20 percent or even more, if local material containing them is available at low cost. It must be remembered, however, that these impurities have little or no value as surfacing material, and the cost of transporting them from material deposit to highway in quantity greater than 20 percent of the total is often not justifiable.

Additional Tests for Crushed Stone. — As was mentioned in the case of coarse aggregate for portland cement concrete, the tests considered under this heading are for the determination of properties which are important in gravel also, but whose determination in the Iowa gravels has not been found necessary in order to establish their value.

When crushed stone is used for road surfacing, it is customarily subjected to the abrasion test to determine the French Coefficient, for the purpose of eliminating the weaker and less durable types. However, a softer stone can be permitted for this purpose than for concrete aggregate. In Iowa, crushed stone with a percentage of wear as high as 20 has been used satisfactorily, the principal objection to this softer stone being that it wears out rapidly to a disagreeable yellow or white dust. In other states, with a more plentiful supply of the harder rocks, the maximum allowable percentage of wear may be as low as 8 or 10.

Soundness is of importance in a surfacing stone though not so much so as in a concrete or asphaltic aggregate. Fragments of unsound stone break down rapidly to smaller particles, making the road surface deficient in stability and hastening the time when extensive repair work or reconstruction is necessary.

Mine Shale. — Coal-mine refuse is an important source of surfacing material in certain areas in southern Iowa. This consists principally of burned shale and clay or occasionally impure limestone which comes from beds associated with the coal seams. Such material, together with a small proportion of inferior or wasted coal, is removed from the mine and accumulates in large refuse heaps at the mine mouth. The small percentage of sulphur, both free and in various compounds, present in Iowa coal is in many instances sufficient to cause spontaneous combustion of the coal in these waste heaps, and they burn slowly over a long period of time, the interior of the heap usually attaining a high temperature. This temperature is sufficient to fire the clay and shale in much the same way as similar materials are fired in the ordinary clay works kiln. This burned clay or shale may then be crushed and used as surfacing material. Where the waste heap has contained an important percentage of coal, with a correspondingly high temperature of combustion, the resulting material is of excellent quality for this purpose; but when the percentage of coal has been low, the burning is incomplete and the resulting material is too soft and friable.

The mine shale used for road surfacing should conform in grading to the requirements previously set forth for that class of work, except that there is no objection to a larger maximum size of fragment. The larger pieces of burned mine shale are usually so brittle as to break down readily under traffic, and thus they offer no obstacle to the maintenance of the road in good condition.

The abrasion test, with some modification, may be run on mine shale. It is not usually done in Iowa, for the reason that the suitability of the material has been found to depend largely upon the degree of burning, which can usually be estimated satisfactorily from its color and texture. Mine shales with abrasion losses of 30 to 35 percent (corresponding to a percentage of wear from 7 to 10 in the abrasion test on block limestone) have been found to give satisfaction as surfacing materials.

Cementing Materials. — Road surfacing material must contain some cementing substance that will bind it together firmly under traffic. A percentage of clay up to about 15 is satisfactory for this purpose. However, on most Iowa roads, with a clay soil foundation, it is obviously cheaper to work this clay into the surfacing material from beneath than to haul it in from some outside source. Limestone dust, when wet, has a cementing power equal to or greater than that of clay; and crushed limestone, with the smaller particles and dust left in, is a satisfactory surfacing material without the addition of any outside substance. When coal-mine refuse is used, there is nearly always present a sufficient quantity of unburned or of partly burned clay to give an adequate cementing effect. On a road with a sandy rather than a clayey subsoil, crushed limestone or crushed coal-mine refuse is preferable to gravel, unless the gravel contains a rather large percentage of clay which will serve as the cementing medium.

Concluding Statement

From the foregoing discussion it will be seen that materials that are used in road building must have certain peculiar characteristics. By no means all of the materials found in southern Iowa possess these characteristics; hence the need for the material resource investigations and surveys whose results are embodied in the remaining portion of this paper.

Test Results on Typical Southern Iowa Road and Concrete Materials. — In the following tables (Table II and Table III) are given the results of tests that have been made on samples of road or concrete materials from the part of Iowa included in this study. All of these tests have been made in the Iowa State Highway Commission Laboratory. No attempt has been made to tabulate all of the tests which have been made; rather, the aim has been to select certain tests, each one typical of some certain type of deposit and in their aggregate illustrating the general nature and normal differences in southern Iowa materials.

The various headings in Tables II and III are, in general, self-explanatory. However, it may be well to add the following notes, in order to clarify further the test results given in Table II.

On those samples for which a complete sieve analysis is shown, the method of running and reporting sieve analysis is as follows: The sample is first split on the No. 4 screen to separate sand from gravel, the

TABLE II

Tests on Sand and Gravel

COUNTY	LOCATION	SOURCE	Gravel or Gravel Portion of Pit-Run: Percent Passing 1½"	¾"	⅜"	#4	Specific Gravity	Percentages of: Shale	Clay lumps	Iron oxide	Soft Stone	Percent Passing #4 Screen	Sand or Sand Portion of Pit-Run: Percent Passing #4	#8	#14	#28	#48	#100	Specific Gravity	Colorimetric Test	Percent of: Silt & Clay	Shale	REMARKS
Appanoose	SE.¼ SE.¼ Sec. 32 Vermillion Twp.	Upland (Pleistocene)											96	90	77	49	12	5		#1	6.7	0.6	
Cass	NE.¼ NE.¼ Sec. 29 Union Twp.	Upland (Pleistocene)	100	86	53	0		0.2	1.2	Tr.	2.8	71	100	80	55	37	18	9	2.60	#2	11.4	0.2	
Clarke	N. of center Sec. 23 Fremont Twp.	Upland (Pleistocene)	100	90	76	0		Tr.	1.0	0.2	3.0	77	100	87	66	36	6	1	2.62	#1	5.8	Tr.	
Des Moines	NW. ¼ Sec. 36 Union Twp.	Mississippi River Terrace	100	87	47	0		0	0	Tr.	0.6	80	100	89	73	29	3	1	2.65	#1	0.8	Tr.	
Des Moines	Burlington Sand and Gravel Co., Burlington	Mississippi River Channel											99	72	42	19	4	2	2.65	#1	1.2	Tr.	Washed sand
Harrison	S.½ SW.¼ Sec. 23 Boyer Twp.	Boyer River Bottomland	100	76	41	0		0			1.22	76	100	85	61	30	7	1		#1	1.1	0	
Henry	NE.¼ SE.¼ Sec. 28 Marion Twp.	Big Creek Bar	68	37	17	0	2.30	0.4	1.7		11.5	35	100	69	37	14	4	2	2.53	#1	10.4	0.7	Material above No. 4 screen contains 40% chert
Henry	SE.¼ NE.¼ Sec. 4 Tippecanoe Twp.	Skunk River Bar	100	91	73	0		Tr.	6.9		Tr.	93	100	96	87	63	12	1	2.62	#1	1.5	Tr.	
Lee	SW.¼ SW.¼ Sec. 11 Jefferson Twp.	Mississippi River Terrace											96	93	86	49	5	1		#1	0.4	Tr.	
Lee	SE.¼ Sec. 2-66-7 Des Moines Twp.	Des Moines River Bar	100	64	34	0		0			0.7	58	100	84	72	42	6	1		#1	1.2	0	
Lee	SE.¼ Sec. 3-65-6 Jackson Twp.	Des Moines River Bar	82	66	44	0		0	0.5		1.3	73	100	83	63	35	9	1	2.66	#2	1.0	Tr.	
Lee	Keokuk Sand Co.	Mouth of Des Moines River											96	86	65	32	8	1	2.65	#1+	0.2	0	Washed sand
Louisa	NE.¼ Sec. 36-74-3 Jefferson Twp.	Iowa River Bottomland	76	59	36	0		0			2.0	82	100	86	64	37	5	1		#1	0.64	0	
Louisa	SE.¼ SE.¼ Sec 22-73-2	Mississippi River Terrace	100	87	48	0		Tr.	Tr.	1.4	1.6	75	100	89	73	43	11	2	2.66	#1	1.9	0	
Madison	SE.¼ SW.¼ Sec. 30 Jefferson Twp.	Upland (Pleistocene)	100									83									11.9		
Mahaska	SW.¼ SW.¼ Sec. 35 Madison Twp. (76-16)	Upland (Pleistocene)	75	53	26	0					8.25	59	100	80							6.2		
Mahaska	SE.¼ NW.¼ Sec. 19 Scott Twp.	Des Moines River Bar	93	75	47	0		0			0.6	82	100	86	62	29	3	1	2.66	#1	0.2	Tr.	
Mahaska	S. of center Sec. 23 East Des Moines Twp.	Des Moines River Bottomland	96	55	25	2	2.64	Tr.		0.5	2.8												Screened gravel from Concrete Materials Corp.
Mahaska	S. of center Sec. 23 East Des Moines Twp.	Des Moines River Bottomland											100	90	68	33	6	1	2.66	#1½	0.2	Tr.	Washed sand from Concrete Materials Corp.
Marion	NW.¼ SE.¼ Sec. 33 Clay Twp. (76-18)	Des Moines River Bar	100	79	47	0		0			0.9	68	100	78	50	24	3	1		#1	0.5	0	

Marion	SE.¼ SE.¼ Sec. 3 Lake Prairie Twp. (75-18)	Des Moines River Bottomland	99	80	45	4	2.64	Tr.			2.3												Screened gravel from Harvey Sand & Gravel Co.
Marion	NW.¼ SW.¼ Sec. 20 Lake Prairie Twp. (76-18)	Des Moines River Bottomland	100	72	38	0		0			1.5	80	100	91	74	44	4	1	2.67	#1	0.4	Tr.	
Mills	NW.¼ SW.¼ Sec. 22 Glenwood Twp.	Missouri River Bottomland	100	90	60	0		Tr.			0.7	88	100	90	68	37	16	3		#3	0.4	Tr.	At 60′-80′ depth
Mills	W.½ NW.¼ Sec. 25 Plattville Twp.	Missouri River Bottomland										97	100	92	77	44	18	3		#1	1.0	0	At 15′-65′ depth
Montgomery	SE.¼ SE¼ Sec. 33 Washington Twp.	Upland (Pleistocene)	100									76									9.6		
Montgomery	N.½ SW.¼ Sec. 17 Grant Twp.	Cretaceous Gravel (Conglomerate)	82	74	63	0		0	Tr.	—	0.3	59	100	66	38	16	5	1		#1	10.8	0	38% firmly cemented conglomerate lumps
Page	E.½ SW.¼ Sec. 17 Grant Twp.	Nishnabotna River Bottomland											93	86	71	38	7	1		#1	1.4	0	
Shelby	NW.¼ SW.¼ Sec. 10 Fairview Twp.	Nishnabotna River Bottomland	100	98	75	0		Tr.		Tr.	1.0	78	100	71	36	11	4	2	2.64	#1	0.4	Tr.	
Union	NE.¼ SW.¼ Sec. 19 Jones Twp.	Upland (Pleistocene)	100									74									7.1		
Union	SW.¼ SW.¼ Sec. 17 Jones Twp.	Grand River Bottomland	100	78	46	0		0			1.8	71	100	89	71	37	7	1		#1	4.0	0	9.9% of mud balls
Van Buren	N. of center Sec. 31 Van Buren Twp. (69-9)	Des Moines River Bar	67	51	28	0		0 0			0.7	61	100	77	56	39	4	0		#3	0.3	0	Tr. of coal
Van Buren	SW¼ SW¼ Sec. 5 Bonaparte Twp.	Coates Creek Bar	67									45									6.6		Oversize nearly all limestone
Van Buren	NW¼ SW¼ Sec. 1 Farmington Twp.	Des Moines River Terrace	100	58	30	0		0				91	100	95	82	51	13	2		#1	2.64	0	
Van Buren	NW.¼ Sec. 12 Farmington Twp.	Des Moines River Terrace	89	57	34	0		0	0.8	0.1	4.6	62	100	87	67	27	5	2	2.65	#1½	2.9	0	
Wapello	SE.¼ NE¼ Sec. 25 Center Twp. (72-14)	Des Moines River Bottomland											93	87	71	41	5	1	2.66	#3	0.2	Tr.	0.1% coal
Wapello	SW.¼ NW¼ Sec. 25 Center Twp. (72-14)	Des Moines River Bottomland											96	87	71	42	8	0		#1	0.2	0	Washed sand from Ottumwa Sand Co.
Wapello	NW.¼ SW¼ Sec. 27 Washington Twp.	Des Moines River Bar	100	91	65	0	2.63	Tr.			1.5	81	100	87	66	35	5	1	2.66	#1½	0.4	Tr.	

TABLE III

Tests on Stone (Limestone Except as Noted)

County	Location	Source	Specific Gravity	Percent Absorption	Percent of Wear	Soundness in Sodium Sulphate 10-Piece Sample	Remarks
Adair	SE.¼ NE.¼ Sec. 12 Grove Twp.	Henrietta Stage Des Moines Series	2.62	1.2	4.93	10 pieces OK	
Adams	SE.¼ SW.¼ Sec. 3 Jasper Twp.	Shawnee Stage Missouri Series	2.50	3.5		9 pieces sound 1 piece partially distintegrated	
Appanoose	NE.¼ Sec. 25 Johns Twp.	Cherokee Stage Des Moines Series	2.07		29.8	10 pieces sound	Mine shale (burned)
Appanoose	SW.¼ SW.¼ Sec. 24 Vermillion Twp.	Cherokee Stage Des Moines Series	2.68	0.35	4.52	10 pieces sound	
Clarke	SE.¼ Sec. 2 Ward Twp.	Bethany Falls Ls. Missouri Series	2.63	0.85	6.14	10 pieces sound	Sample was accidently run 44000 revolutions in the abrasion test
Decatur	SE.¼ SW.¼ Sec. 3 New Buda Twp.	Bethany Falls Ls. Missouri Series	2.61	0.69	4.90	10 pieces sound	
Des Moines	Center NW.¼ Sec. 25 Flint River Twp.	Upper Burlington Limestone	2.53	0.9	8.9	10 pieces sound	
Des Moines	NW.¼ NW.¼ Sec. 21 Concordia Twp.	Kinderhook Limestone	2.53	3.6	8.4	8 pieces sound, 1 piece checked 1 piece cracked	This bed shows peculiar banding or mottling, due to uneven dolomitization
Des Moines	NW.¼ NW.¼ Sec. 21 Concordia Twp.	Lower Burlington Limestone	2.49	3.4	10.2	10 pieces sound	
Des Moines	NW.¼ NW.¼ Sec. 21 Concordia Twp.	Upper Burlington Limestone	2.52	1.9	14.1	10 pieces sound	
Fremont	S. of Center Sec. 14 Scott Twp.	Deer Creek Ls. Missouri Series	2.38	2.9	5.7	10 pieces sound	
Henry	W.½ NE.¼ Sec. 18 Center Twp.	Upper St. Louis Limestone	2.66	0.21	4.3	10 pieces sound	
Henry	W.½ NE¼ Sec. 18 Center Twp.	Upper St. Louis Limestone	2.58	0.75	3.6	6 pieces sound 4 pieces cracked	
Keokuk	SE.¼ NW.¼ Sec. 10 Jackson Twp.	Keokuk Limestone	2.50	4.0	7.6	10 pieces sound	
Keokuk	SW.¼ Sec. 13 Van Buren Twp.	Ste. Genevieve Limestone	2.58	1.7	4.8	10 pieces sound	
Lee	NW.¼ Sec. 10 Franklin Twp.	Upper St. Louis Limestone	2.61	1.1	5.04	10 pieces sound	
Lee	NW.¼ NE.¼ Sec. 29 Van Buren Twp.	Lower St. Louis Limestone	2.44	4.1	7.6	10 pieces sound	
Lee	NW.¼ NE.¼ Sec. 29 Van Buren Twp.	Upper St. Louis Limestone	2.65	0.4	5.94	10 pieces sound	
Lee	NW.¼ NE.¼ Sec. 29 Van Buren Twp.	Upper St. Louis Limestone	2.58	1.6	4.56	10 pieces sound	
Lee	NW.¼ NE.¼ Sec. 29 Van Buren Twp.	Ste. Genevieve Limestone	2.66	0.6	4.70	10 pieces sound	

Table showing results of tests on stone.

TABLE III (Continued)

Tests on Stone (Limestone Except as Noted)

County	Location	Source	Specific Gravity	Percent Absorption	Percent of Wear	Soundness in Sodium Sulphate 10-Piece Sample	Remarks
Lee	SW.¼ Sec. 12 Montrose Twp.	Keokuk Limestone	2.64	1.2	5.4	10 pieces sound	
Lee	NE.¼ Sec. 36 Montrose Twp.	Keokuk Limestone	2.50	4.0	6.64	10 pieces sound	
Lee	NE.¼ Sec. 36 Montrose Twp.	Keokuk Limestone	2.48	5.9	6.64	6 pieces sound, 3 pieces cracked 1 piece partly disintegrated	
Lee	NW.¼ Sec. 36 Jackson Twp.	Keokuk Limestone	2.44	3.86	6.92	4 pieces sound, 5 pieces cracked 1 piece disintegrated	
Lee	NW.¼ Sec. 36 Jackson Twp.	Keokuk Limestone	2.58	1.42	6.39	10 pieces sound	
Louisa	NE.¼ NW.¼ Sec. 3-74-5	Burlington Limestone	2.64	0.9	10.6	10 pieces sound	
Louisa	NW.¼ NW.¼ Sec. 23-73-3	Lower Burlington Limestone	2.25	5.3	7.48	10 pieces sound	
Louisa	SW.¼ SW.¼ Sec. 29-73-2	Upper Burlington Limestone	2.64	0.6	6.4	10 pieces sound	
Louisa	SW.¼ SW.¼ Sec. 29-73-2	Lower Burlington Limestone	2.63	2.1	12.3	10 pieces sound	
Lucas	SE.¼ Sec. 22 Pleasant Twp.	Pleasanton Stage Des Moines Series	2.49	0.8	6.22	10 pieces sound	Sandstone
Madison	NW¼ Sec. 20 Union Twp.	Bethany Falls, Ls. Missouri Series	2.52	2.8	4.4	10 pieces sound	
Madison	NW¼ Sec. 20 Union Twp.	Bethany Falls, Ls. Missouri Series	2.48	3.3	8.2	9 pieces sound 1 piece cracked	
Madison	NW¼ Sec. 20 Union Twp.	Bethany Falls, Ls. Missouri Series	2.63	1.0	5.5	10 pieces sound	
Madison	NW.¼ NW.¼ Sec. 6 Scott Twp.	Winterset Ls. Missouri Series	2.56	2.0	5.7	10 pieces sound	
Madison	NW.¼ NW.¼ Sec. 6 Scott Twp.	Winterset Ls. Missouri Series	2.63	1.1	5.0	10 pieces sound	
Madison	SW.¼ SE.¼ Sec. 5 Webster Twp.	DeKalb Ls. Missouri Series	2.58	1.7	5.9	9 pieces sound 1 piece cracked	
Madison	SW.¼ SE.¼ Sec. 5 Webster Twp.	DeKalb Ls. Missouri Series	2.49	1.2	7.66	10 pieces sound	
Mahaska	SE.¼ SE.¼ Sec. 34 White Oak Twp.	Upper St. Louis Limestone	2.62	1.28	4.80	9 pieces sound 1 piece chipped	
Mahaska	NE.¼ SE.¼ Sec. 14 East Des Moines Twp.	Ste. Genevieve Limestone	2.56	2.3	5.04	10 pieces sound	
Marion	NW.¼ Sec. 14 Dallas Twp.	Cherokee Stage Des Moines Series	2.27	2.1	4.54	8 pieces sound, 2 pieces cracked	Black carbonaceous limestone

Table showing results of tests on stone.

TABLE III (Continued)

Tests on Stone (Limestone Except as Noted)

County	Location	Source	Specific Gravity	Percent Absorption	Percent of Wear	Soundness in Sodium Sulphate 10-Piece Sample	Remarks
Marion	NE.¼ NW.¼ Sec. 2 Knoxville Twp. (75-20)	Pleasanton Stage Des Moines Series	2.57	1.75	8.76	10 pieces sound	Calcareous conglomerate
Marion	NW. Corner Sec. 28 Dallas Twp.	Pleasanton Stage Des Moines Series	2.51	2.1	9.2	10 pieces sound	Calcareous conglomerate
Marion	SW.¼ SE.¼ Sec. 35 Knoxville Twp. (76-20)	Pleasanton Stage Des Moines Series	2.45	2.6	9.8	8 pieces sound, 1 piece cracked 1 piece chipped	Sandstone
Marion	NW.¼ SE.¼ Sec. 35 Clay Twp. (75-18)	Ste. Genevieve Limestone	2.41	3.2	5.64	9 pieces sound 1 piece cracked	
Mills	SE. Corner Sec. 22 Glenwood Twp.	Oread Limestone Missouri Series	2.50	1.9	4.46	10 pieces sound	
Monroe	NE.¼ NW.¼ Sec. 31 Pleasant Twp.	Cherokee Stage Des Moines Series			33.7		Mine shale (burned)
Montgomery	N.½ NW.¼ Sec. 3 Red Oak Twp.	Deer Creek Limestone Missouri Series	2.44	4.9	4.76	10 pieces sound	
Montgomery	N.½ NW.¼ Sec. 3 Red Oak Twp.	Deer Creek Limestone Missouri Series	2.59	1.6	5.18	5 pieces sound 5 pieces partially disintegrated	
Montgomery	W.½ SW.¼ Sec. 17 Red Oak Twp.	Deer Creek Limestone Missouri Series	2.49	2.9	4.66	10 pieces sound	
Pottawattamie	NW.¼ NW.¼ Sec. 23 Macedonia Twp.	Deer Creek Limestone Missouri Series	2.55	2.5	6.7	10 pieces sound	
Pottawattamie	SW. Corner Sec. 14 Macedonia Twp.	Deer Creek Limestone Missouri Series	2.47	3.6	6.4	7 pieces sound,1 piece chipped 2 pieces slightly disintegrated	
Van Buren	NE.¼ SW.¼ Sec. 25 Village Twp.	Upper St. Louis Limestone	2.67	0.6	4.0	10 pieces sound	
Van Buren	NE.¼ SW.¼ Sec. 25 Village Twp.	Lower St. Louis Limestone	2.54	2.4	6.58	9 pieces sound 1 piece chipped	
Van Buren	Center NE.¼ Sec. 5 Farmington Twp.	Ste. Genevieve Limestone	2.68	0.3	3.6	10 pieces sound	
Wapello	SE.¼ Sec. 27 Columbia Twp.	Ste. Genevieve Limestone	2.67	0.6	5.74	9 pieces sound 1 piece slightly checked	
Wapello	South Line of Sec. 31 Washington Twp.	Cherokee Stage Des Moines Series	2.41	3.34	2.98	10 pieces sound	Black carbonaceous limestone
Warren	Center NW.¼ Sec. 11 White Oak Twp.	Pleasanton(?) Stage Des Moines Series	2.26	9.65	16.84	10 pieces disintegrated	Sandy shale
Washington	SW.¼ SW.¼ Sec. 20 Cedar Twp. (76-8)	Burlington Limestone	2.59	2.2	8.9	10 pieces sound	
Washington	SE¼ NE¼ Sec. 30 Brighton Twp.	St. Louis Limestone	2.62	1.0	4.06	10 pieces sound	
Washington	SE.¼ NE.¼ Sec. 30 Brighton Twp.	Ste. Genevieve Formation	2.58	1.0	4.56	10 pieces sound	White sandstone
Wayne	SW¼ NE¼ Sec. 24 Walnut Twp.	Cherokee Stage Des Moines Series	2.14		29.8	10 pieces sound	Mine shale (burned)

Table showing results of tests on stone.

result of that split being shown as "Percentage Passing No. 4 Screen." A sieve analysis is run on the gravel portion alone; then, a separate sieve analysis is run on the sand portion alone.

Results of the color test are reported by numbers, these numbers referring to figures in a color chart accompanying the description of the standard method for running the test.[3] It has been found that Color Nos. 1 or 2 denote "sands suitable for use in high-grade concrete," [4] Nos. 2 or 3, "sands which may be used in unimportant concrete work," [4] Nos. 3 or 4, "sands which should never be used in concrete," [4] and Nos. 4 or 5, "an unusually bad sand, soil, or loam." [4] High colors are not uncommon in river sands but are seldom found in bank sands. Washing usually removes the organic impurities, so that washed sands nearly always show satisfactory colors.

The abbreviation "Tr." is for "Trace," indicating less than 0.1 percent of the substance in question.

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3 United States Department of Agriculture, Bulletin No. 1216, Tentative Methods of Sampling and Testing Highway Materials, p. 28, 1928.

4 Idem, Plate II, following p. 28.

CHAPTER II

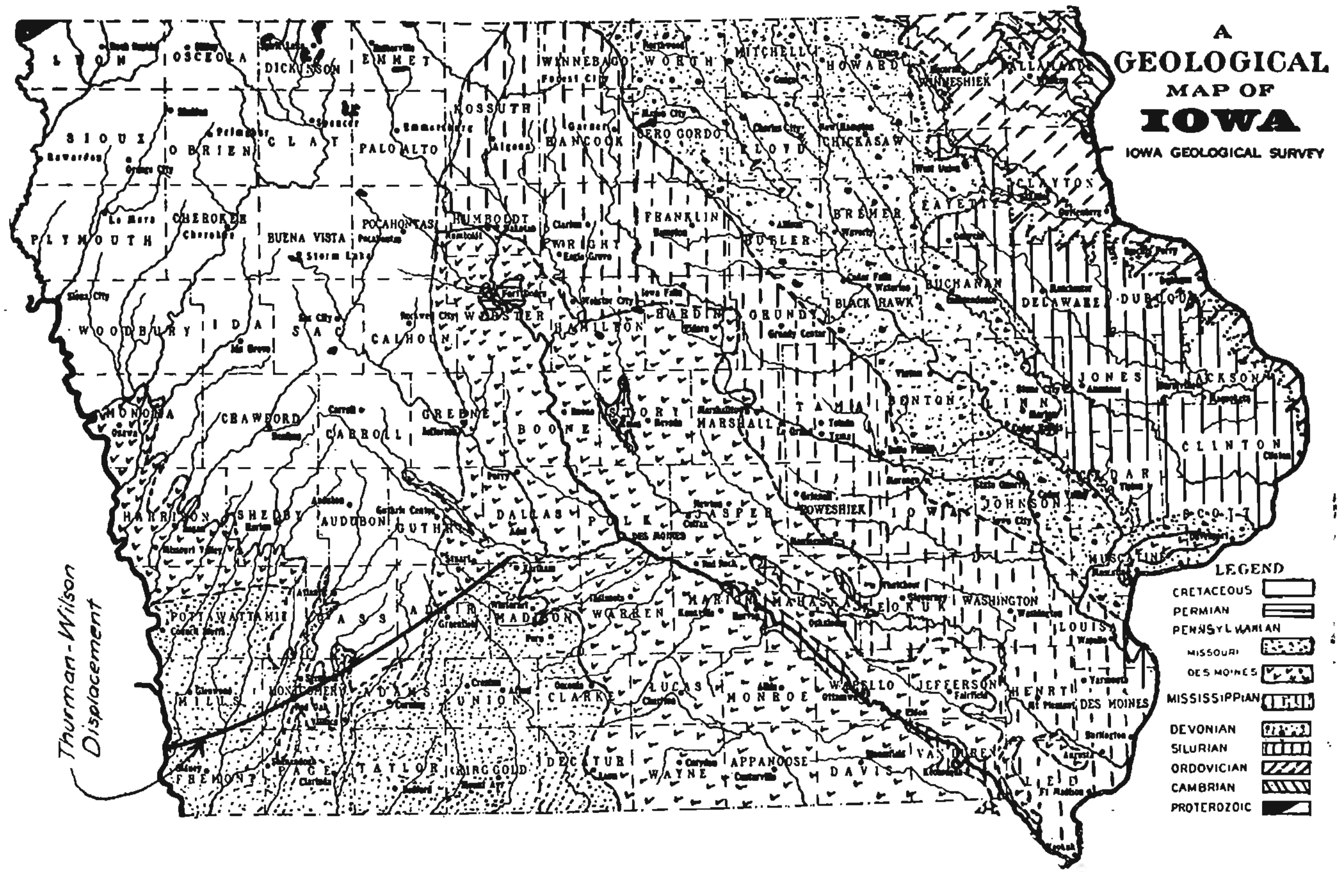
GEOLOGY OF THE ROAD AND CONCRETE MATERIALS OF SOUTHERN IOWA

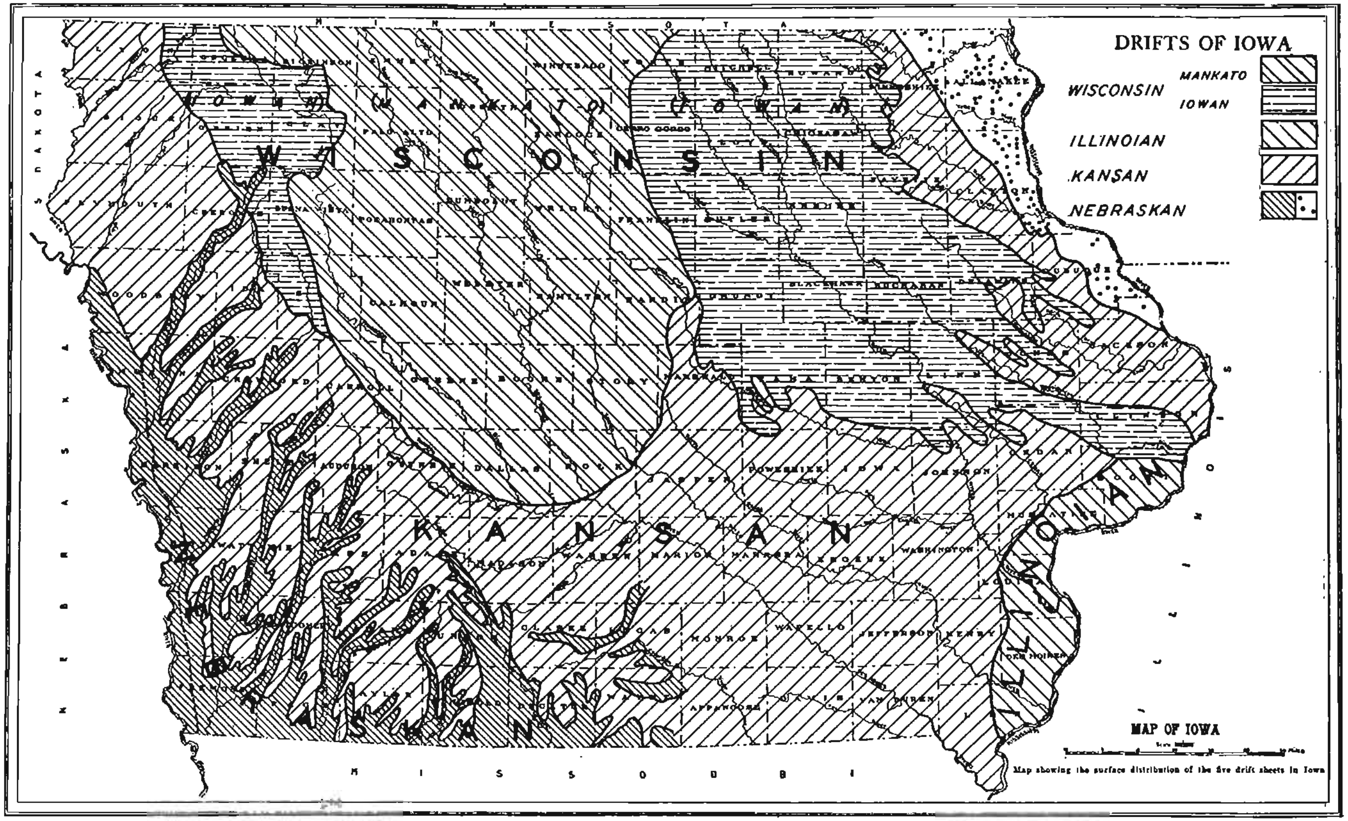
Geologic Features of the State of Iowa

The State of Iowa is included in the glaciated portion of Blackwelder's "Interior Lowlands Orographic Element" [1] of the United States. This element extends from New York to Texas and from Montana to Tennessee. It is characterized geologically by a succession of sedimentary rocks, principally of Paleozoic age and for the most part undisturbed or but slightly disturbed. Topographically, this part of the country is a level or slightly rolling plain, dissected locally by Pleistocene or post-Pleistocene erosion, with a relief usually not more than a few hundred feet. The Paleozoic sedimentaries were deposited in a number of broad basins, and the State of Iowa lies on the northeastern slope of such a basin. The northern and northeastern rim of the basin extends from central Minnesota through central and southern Wisconsin, and its deepest part is not far from the southeast corner of Nebraska. In the western part of the state are sediments of the Dakota stage of the Upper Cretaceous system, and throughout the whole state are found the deposits of one or more of the great Pleistocene ice sheets. Of igneous intrusion or folding on large scale there is no record, although certain beds are conglomeratic in nature or distinctly brecciated.

A general section for the rocks of Iowa is given in the Table between pages 316 and 317. Plate I shows the areas of outcrops of the various rock systems, with the exception of the Pleistocene.[2] It will be noted from this plate that the oldest Paleozoic rocks appear in the extreme northeast corner of the state, and that successively younger formations appear in roughly parallel belts to the southwestward, this being an expression of the general southwestward dip of the Paleozoic formations. Plate II indicates the surface distribution of the various members of the Pleistocene system in Iowa.[3]

1 Blackwelder, Eliot, Regional Geology of the United States of America: pp. 103-121, G. E. Stechert and Co., New York.
2 After Iowa Geological Survey, Vol. XXXIII, 1927.
3 The Kansan and Nebraskan Glacial Tills are very difficult of differentiation except where exposed in contact and are therefore as a rule not mapped separately. After Iowa Geological Survey, Vol. XXXIV.

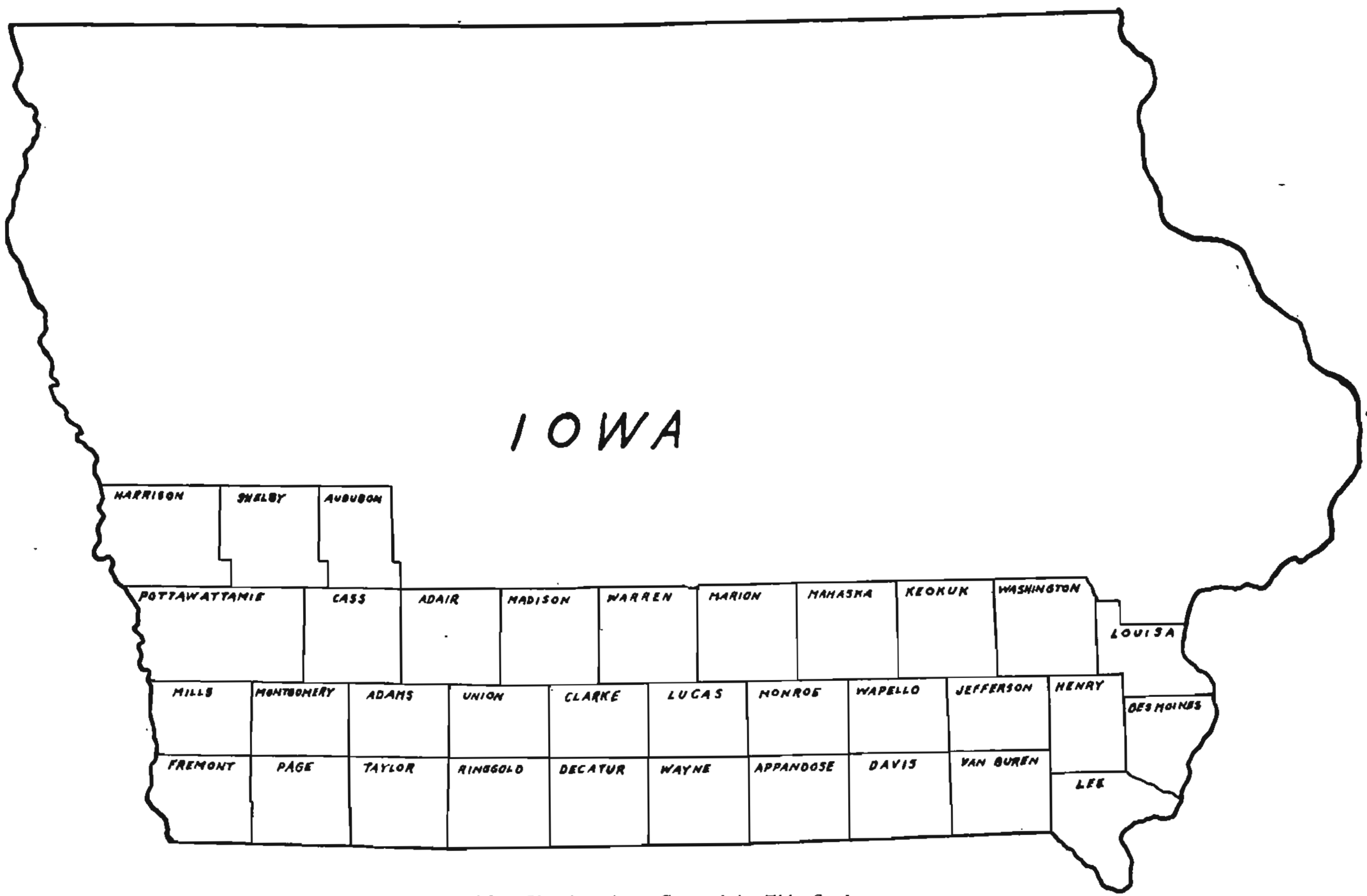

A GEOLOGICAL MAP OF IOWA
IOWA GEOLOGICAL SURVEY
LEGEND
CRETACEOUS
PERMIAN
PENNSYLVANIAN
MISSOURI
DES MOINES
MISSISSIPPIAN
DEVONIAN
SILURIAN
ORDOVICIAN
CAMBRIAN
PROTEROZOIC
Thurman-Wilson Displacement



Map showing the Surface Distribution of the Five Drift Sheets in Iowa

PLATE III

MAP OF AREA COVERED



Map Showing Area Covered in This Study

Geological Distribution of Road Materials

General Statement. — The gravels of Iowa are of glacial, fluvioglacial, and interglacial origin. Of the four glaciers which invaded Iowa, not all carried the same proportions of sand and gravel. In southern Iowa the Nebraskan, Kansan, and Illinoian ice sheets deposited relatively small amounts, while abundant deposits were left by both the Iowa and Mankato lobes of the Wisconsin glacier. Consequently the sand and gravel supplies of Iowa are largely within the northern half of the state, which tends to set off southern Iowa as the comparatively barren area for road material.

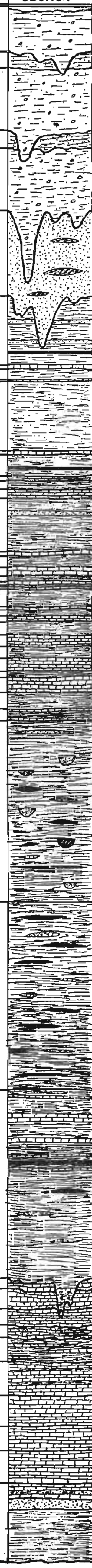
A second factor is that most of the southern part of the state shows country rock of the Pennsylvanian system, one which in Iowa contains a smaller proportion of desirable road materials than do the older systems. It is this comparatively barren area of Pennsylvanian bedrock and of Kansan and Nebraskan glacial till that is the scene of the more intensive material resource survey mentioned at the beginning of this paper.

Limits of Area Studied. — It will be noted that the northern boundary of the area to be covered in this discussion (Plate III) follows approximately the southern boundary of the Iowan and Wisconsin drift sheets. Woodbury, Monona, Crawford, Poweshiek, and Iowa Counties, which fall outside the area of these drift sheets, are omitted because they are well situated with respect to facilities for rail shipment from neighboring counties, or because large streams that head in the Wisconsin or Iowan Drift Areas flow through them and carry sand and gravel within their boundaries. Certain other counties along Mississippi River in southern Iowa show rather extensive supplies of road material but are nevertheless included because, as compared with counties farther north, they are much less fortunately situated in that respect.

Geological Section for Southern Iowa

Plate IV gives in columnar form the chronological order of the formations of southern Iowa, indicating their stratigraphic relationships and in a general way their character and thickness. This columnar section is compiled from various sources, chiefly the publications of the Iowa Geological Survey, with such modifications as this study has shown to be desirable. The formational names given in this section are those adopted by the Iowa Geological Survey and require no explana-

SYSTEM	SERIES	STAGE	SUBSTAGE	COLUMNAR SECTION	THICKNESS FEET	CHARACTER
Pleistocene		Illinoian			30±	Till, with a few pockets of sand or gravel
		Yarmouth			25±	Peat, silt, sand, or gravel
		Kansan			50±	Till, with a few pockets of sand or gravel
		Aftonian			25±	Peat, silt, sand, or gravel
		Nebraskan			100±	Till, with pockets of sand or gravel
Cretaceous		Dakota			100±	Sandstone, chiefly. With lenses of clay and beds of conglomerate
Pennsylvanian	Missouri	Wabaunsee	Mc-Kissick's Grove		91	Shale (Includes Nyman Coal and two sandstones)
			Tarkio		4	Limestone
			Unnamed		12	Shale
			Preston			Limestone
		Shawnee	Scranton		90±	Shale
			Howard		4	Limestone
			Severy		25	Shale (incl. Nodaway Coal)
			Topeka		6	Limestone
			Calhoun		11	Shale
			Deer Creek		8-16	Limestone
			Tecumseh		65	Shale
			Lecompton		7	Limestone
			Kanwaka		16	Shale
			Oread		10	Limestone
		Douglas	Lawrence		7	Shale
			[illegible]		[illegible]	Limestone
			[illegible]		[illegible]	Shale
		Lansing	Vilas		21	Shale
			Plattsburg		6	Limestone
			Lane		7	Shale
		Kansas City	Iola		3	Limestone
			Chanute		17	Shale
			De Kalb		14	Limestone
			Cherryvale		16	Shale
			Winterset		14	Limestone
			Galesburg		12	Shale
			Bethany Falls		20	Limestone
			Ladore		21	Shale
			Hertha		17	Limestone and Shale
	Des Moines	Pleasanton				Shale, chiefly. Several channel sandstones and conglomerates. Limestones few and thin. Coals less frequent than in the Henrietta.
		Henrietta			700±	Shale chiefly. Very little sandstone. A few thin discontinuous limestones. Numerous coal seams.
		Cherokee				Shale, chiefly. In the upper half are thin persistent limestones, and one coal. In the lower half are thin lenses of sandstone, limestone, or coal.
Mississippian	Meramec	Ste. Genevieve			0-25	Limestone, chiefly
		St. Louis	Upper		15-40	Limestone, white, fine-grained
			Lower		15-25	Limestone, brown, magnesian
		Spergen			0-35	Limestone, variable
		Warsaw			0-75	Shale, calcareous, and shaly limestone
	Osage	Keokuk	Upper		40	Limestone, thin-bedded, with shale seams
			Montrose		40	Limestone, gray, very cherty
		Burlington	Upper		15-30	Limestone, white, crinoidal
			Lower		25-50	Limestone, brown, magnesian
	Kinderhook	Kinderhook			15-35	Limestone, variable
					10-20	Sandstone
					60+	Shale, calcareous



Columnar Section for Southern Iowa.

tion here. As a rule they are based upon geographic localities where the various formations are well exposed, and it will be noted that many of them have their origin in Iowa.

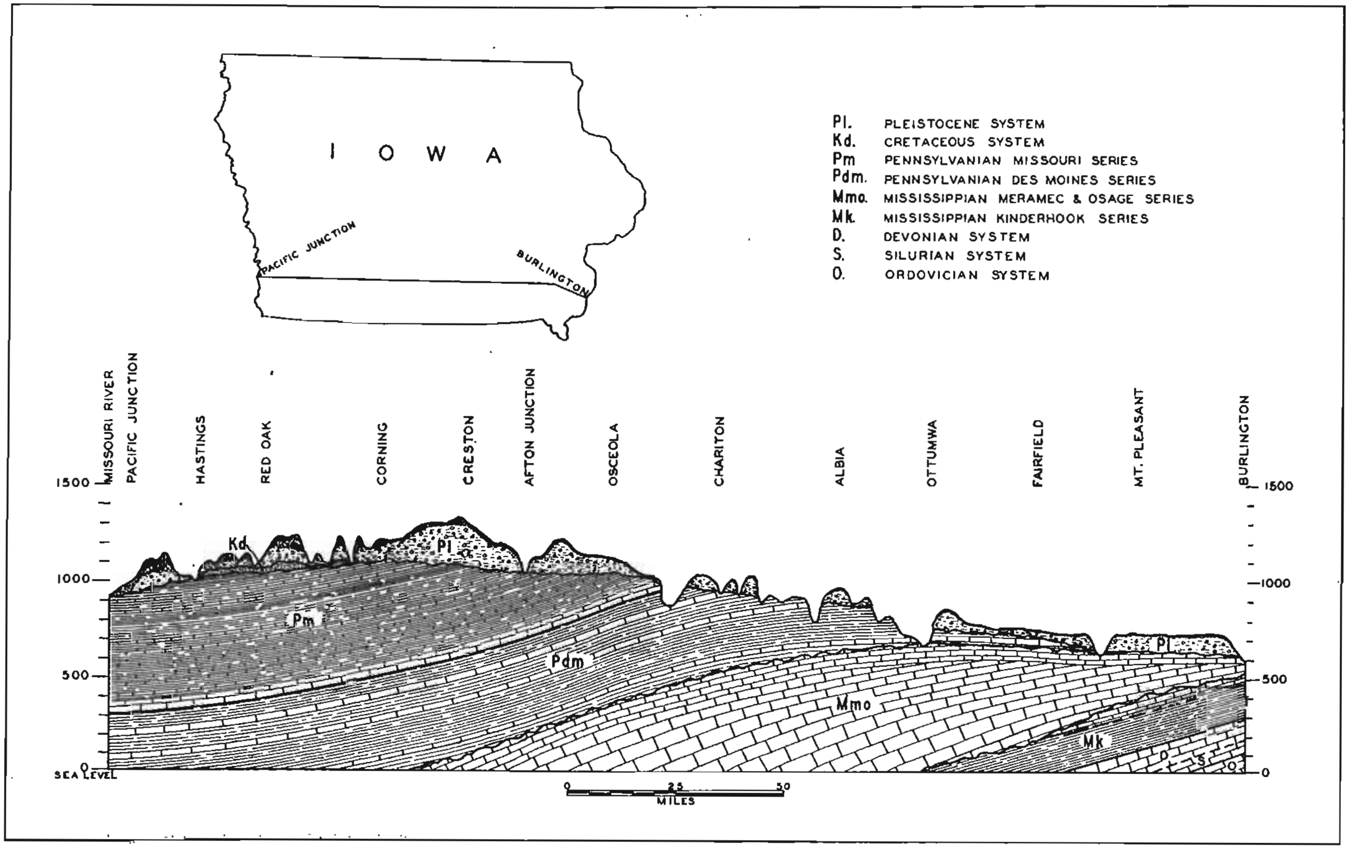
Structure of Southern Iowa

Attitude of the Strata. — The strata of southern Iowa are essentially flat-lying. The indurated sedimentary rocks were all laid down in seas of wide extent and upon the smooth and gently sloping floors which usually characterized those bodies of water. The seas for the most part encroached from the southwest upon the ancient land mass, whose remains still appear in central Wisconsin. The sediments have remained comparatively undisturbed, and consequently their prevailing dip is to the west or southwest.

The accompanying generalized structure section (Plate V), from Pacific Junction to Burlington, indicates the magnitude of this dip. Such a slope is of course so small as to be usually indistinguishable by eye. Locally it may be greater or smaller or even be reversed. The essential flatness of the rock structure is reflected in the topography of southern Iowa. When viewed in detail, that area is seen to be intricately dissected by a well-developed system of drainage ways, so that it shows a relief of 100 to 400 feet. When viewed in a more general way, however, the area is seen to be the remnant portion of a flat or gently sloping plain, whose elevation is still preserved on the divides between the streams. The hills are of erosional origin and for the most part postdate the Kansan drift. The whole area is unbroken by major escarpments or by the great upthrust rock masses so characteristic of mountain regions.

Faults. — Of the rock formations found in southern Iowa, only the St. Louis shows widespread evidence of faulting. The disturbances here are on a small scale, with only very few displacements of more than one foot. They are in most cases confined to the St. Louis limestone itself, and their origin is believed to be nearly contemporaneous with the deposition of the strata.

Contrasting with the disturbances in the St. Louis is a displacement of rather large magnitude, which has been located in Fremont County, and which apparently extends northeast as far as Earlham, Madison County. Its location is indicated on the geological map, Plate I of this paper. The displacement is known as the Thurman-Wilson fault, from



Profile and structure section from Pacific Junction to Burlington the names given to the two exposures in Fremont County at which its presence was first recognized. The fault plane itself is nowhere exposed, and it is indeed quite possible that the structure is at some places a steep monocline. The vertical displacement is about 300 feet, the south side being downthrown. The age of the displacement is post-Pennsylvanian and pre-Cretaceous. The depth of strata affected is not certainly known, but it seems probable that the displacement extends at least as deep as the Ordovician. Its occurrence is of interest to this subject in its effect upon the surface distribution of the various members of the Missouri series; thus the areas of exposure of these strata are offset to the east where they cross the fault line from north to south.

Unconformities. — In southern Iowa, unconformity is found between the Mississippian and the Pennsylvanian, the Pennsylvanian and the Cretaceous, the indurated rock (be it Mississippian, Pennsylvanian, or Cretaceous) and the Pleistocene, and between the various members of the Pleistocene system.

Of these breaks of sedimentation, the only one of importance in connection with this paper is that at the top of the Mississippian system. The upper series (Chester) of the standard section of the Mississippian was never deposited in Iowa, and the long time interval during which it was laid down elsewhere found the earlier Mississippian rocks subjected to erosion there. The surface, perhaps originally somewhat irregular, was dissected by a well developed drainage system to a topography perhaps quite similar to that seen in southern Iowa today.[4] The fact of this unconformity is of much importance in evaluating deposits of the upper Mississippian limestone in southeast Iowa, as will be mentioned later.

Descriptions of the Formations of Southern Iowa

Kinderhook Group. — The Kinderhook is one of the less important formations of southern Iowa; it has a restricted range of outcrop, it shows but a small proportion of material usable to the road builder, and in general it is unavailable in quantity by stripping. It appears principally in the Mississippi River bluffs near Burlington and northward into the southeast part of Louisa County and thence westward in the hills south of Iowa River to the vicinity of Morning Sun. Scattered

4 A. L. Lugn has found in Lucas County a relief as great as 200 feet developed on the surface of the Mississippian. Geology of Lucas County: Iowa Geological Survey, Vol. XXXII.

outcroppings in northern Washington County also are referred to this formation.

In southeastern Iowa the Kinderhook may be subdivided as follows:

3. Limestone, magnesian for the most part; usually of brownish color, differing in hardness; includes some oölitic limestone.
2. Sandstone, fine-grained, shaly; or sandy shale.
1. Shale, plastic, drab in color, with thin calcareous zones.

The upper limestone member is about 25 feet thick at Burlington and includes a 3-foot bed of finely oölitic limestone and several feet of very soft sandy unsound limestone. The lower eight feet is curiously mottled brown and white, apparently on account of uneven dolomitization. This upper limestone thins to about 15 feet in southern Louisa County and there also includes an oölitic member, a soft sandy member, and at the bottom an unevenly dolomitized member, mottled in various shades of brown. The upper limestone again has a maximum thickness of 35 feet in northern Washington County but is there nearly all a soft buff earthy dolomite with a small proportion of white chert. In northern Des Moines and southern Louisa Counties the upper 5 to 10 feet of the upper limestone is subcrystalline, brownish, magnesian, hard and sound, and much of it suitable for concrete aggregate.

The sandstone member of the Kinderhook is fine-grained, shaly, and soft, in Des Moines and Louisa Counties, and differs in thickness from 22 feet at Burlington to 10 feet near Elrick Junction in Louisa County. In northern Washington County it is less argillaceous, though still poorly indurated, and ranges from 15 to 20 feet in thickness.

The shale member is nowhere exposed in its full thickness, but it is found from well records to be about 300 feet thick at Burlington and 198 feet thick at Sigourney. In the natural exposures the greatest thickness observed is about 50 feet.

Burlington Limestone. — The Burlington is somewhat more important than the Kinderhook as a source of road or concrete materials, not only on account of the more commonly calcareous nature of the sediments, but also on account of its wider distribution. It appears above the Kinderhook and forms the main part of the Mississippi River bluffs south and north of Burlington and of the bluffs south of Iowa River from Oakville to Morning Sun. It also forms the middle and lower parts of the bluffs along both sides of Skunk River from Augusta to Wever, and it appears commonly along some of the smaller streams near Denmark and Augusta. Near Flint River and several smaller tributaries of the Mississippi in Des Moines County it is well developed. Scattered exposures near Long Creek in western Louisa County and near Crooked Creek west of Washington are referred to it, as are also a few limited outcrops in the east part of Washington County. At the crest of the Bentonsport dome it appears at the surface in the bed and banks of Des Moines River in a very small area east of the town of Bentonsport.

On the basis of well-defined lithologic distinctions the Burlington limestone is divided into two parts, commonly known as the Lower Burlington and Upper Burlington.

The Lower Burlington limestone consists for the most part of brown medium- to fine-grained magnesian limestone, usually sound, but differing in hardness. Associated with these beds are soft brown shaly or earthy limestones and beds of moderately hard brown crinoidal limestone, the latter usually constituting the lower 5 to 10 feet of the formation. Chert is present in various quantities (making possibly 10 percent of the formation as a whole) but is very irregularly distributed. The formation ranges in thickness from about 25 feet in southern Louisa County to 50 feet near Burlington. In Washington, Van Buren, and most of Lee Counties it does not appear at all.

The top of the Lower Burlington is marked in many places by a few feet of very cherty irregularly bedded limestone; this is found on the floor of many of the quarries opened in the Upper Burlington and it may serve to set off the upper division from the lower. The strata at the bottom of the Lower Burlington are indistinguishable at most of the exposures, on lithologic grounds, from those at the top of the underlying Kinderhook, the division usually being made on the basis of fossil content.

The Upper Burlington limestone consists principally of heavy beds of moderately hard, sound, richly crinoidal limestone, usually white to gray in color, but locally showing a distinct brownish tinge. In places one or two beds of softer brownish magnesian limestone or brown shaly limestone are present in the middle part. Chert is usually present in very small quantity except at the extreme top, where it marks the transition to the overlying Montrose chert member of the Keokuk formation. The thickness of the Upper Burlington is nearly 35 feet near Augusta, 15 to 20 feet in southern Louisa County, and 19 feet in the old Eckles quarry west of Washington (SW¼ sec. 2, T. 75 N., R. 8 W.).

Keokuk Formation. — The Keokuk formation lies in conformable succession above the Burlington, both stages of sedimentation being usually considered by geologists under the term "Osage group." The Keokuk appears high in the bluffs near and south of Augusta, and the lower part of it is exposed at intervals in connection with the underlying Burlington near and north of Burlington to Oakville and thence west to Morning Sun. The Keokuk appears in many places in the lower part of the hills near Keokuk and from Keokuk to Montrose, its top being about 50 feet above low water level below the Keokuk dam (or 10 feet above water level above the dam) and about 25 feet above water at Montrose. North and northwest of Montrose and west of Keokuk for several miles no outcrops of bedrock appear, this area being the site of an Illinoian Mississippi River channel now filled with glacial drift materials. Beyond this channel the Keokuk reappears in numerous outcrops in the lower bluffs near Bentonsport and in a few scattered exposures near Mount Pleasant and southeast of Sigourney.

It is convenient to divide the Keokuk formation into two parts of approximately equal thickness. The lower is commonly known as the Montrose chert and has in earlier writings often been treated as a separate lithologic unit or as a part of the Burlington limestone. It is true that there is no definite line of demarcation between the Burlington and the Montrose, but the tendency among the later geologists is to class the Montrose with the Keokuk on the basis of the paleontological affinities between them. The upper part is the Keokuk limestone proper of the earlier geologists. The total thickness of the Keokuk, including the Montrose chert member, is about 75 feet at the type section but somewhat less to the north and west, as is the case with the Burlington limestone.

The Montrose chert consists of gray or bluish limestone, which is hard and generally sound, locally crinoidal, interbedded with 10 to 50 percent of gray or white, usually unsound chert. Little or no shale is found in this member, but thin seams of soft and unsound argillaceous limestone are not uncommon. The chert is in the form of nodules or thin continuous beds and is present throughout the whole formation, no beds being free from it. Wherever the Montrose is exposed it shows this same character, although as a distinct formation it has been definitely recognized in Iowa only in Lee, Van Buren, and Des Moines Counties.

The Keokuk limestone proper is an assemblage of strata markedly uniform as to general character but differing greatly in detail. The greater part of this member consists of gray or bluish-gray limestone in regular beds from one half foot to four feet in thickness, some beds being pure, sound, and free from chert, while others are shaly and unsound or contain chert in amounts ranging up to 25 percent. Associated with the limestones are beds, usually thin, of dark-colored calcareous shale. Study of ten detailed sections of this upper member near Keokuk and Montrose shows that about 10 percent is shale or very shaly limestone, 35 percent is limestone which is fairly hard but of questionable soundness, and the remainder is strong and durable limestone of good quality. No more detailed description can be made that will be generally applicable to the formation as a whole, though it is often noted that the shale beds are thicker or more numerous near the top. Certain of the limestones are of purity rivalling that of the white crinoidal stone of the Burlington; such beds have been noted wherever the Keokuk is exposed, and they are usually near the top. The whole assemblage of strata is strongly fossiliferous, various brachiopod types being usually most conspicuous.

Warsaw Formation. — The Warsaw formation has a range of outcrop somewhat to the west of that of the Keokuk limestone. It is well exposed above the Keokuk in the bluffs from Keokuk to Montrose but appears only infrequently in northern Lee, Des Moines, and Louisa Counties. It forms the lowermost part of the hills bordering the deeper valleys in the western part of Lee County and the central and eastern parts of Van Buren County. It is widely exposed along the major valleys of southern Henry County and in a few localities in Keokuk and Washington Counties.

In southeastern Iowa the Warsaw consists of plastic clay shales or shaly impure limestones, commonly massive. Associated with these are thin beds of compact nonargillaceous limestone.

Certain zones in the Warsaw are characterized by the presence of numerous geodes, which range in size from one-half inch to one foot in diameter. These geodes are of roughly globular or nodular shape and consist usually of a siliceous shell which is lined or filled with crystals of calcite, quartz or chalcedony, or less commonly, many other minerals or even petroleum or water. The geodes are of little or no commercial value, except possibly as curios, but they are important geologically as affording a ready means of identification of this formation wherever it is found in southeastern Iowa.

The thickness of the Warsaw ranges from 75 feet at the type section near Keokuk to only 20 feet in southeastern Henry County; still farther west it pinches out entirely. The Warsaw sea, though apparently approximately equivalent in extent to the preceding Keokuk and Burlington seas, covered a much smaller area in Iowa than the St. Louis and Ste. Genevieve seas, which followed not long after it.

Spergen Formation. — The Spergen (equivalent of the Salem of Illinois and Missouri geologists) is recognized as a separate formation in Iowa only since 1912 and is even yet not well understood. It is found locally between the Warsaw and the St. Louis, but it is inconstant in character as well as in its thickness, which is almost everywhere small. Its area of outcrop is roughly coextensive with that of the Warsaw, but at many points where the upper part of the Warsaw is well exposed the Spergen does not appear at all. This inconstancy of outcrop above the Warsaw is believed to be due principally to post-Spergen, pre-St. Louis erosion, which appears to have been active and long-continued.

Spergen strata are typically deposited and well exposed below the St. Louis limestone in the western part of Lee County, in southwestern Des Moines County, southern Van Buren County, southeastern Henry County, and northeastern Jefferson County.

Where found in these localities the Spergen is nearly everywhere overlain by the lower part of the St. Louis limestone, from which it is in most places difficult of distinction. Its typical facies is a soft brownish granular magnesian limestone, but locally this is replaced within a short distance by unaltered crinoidal limestone, soft dolomitic sandstone, or sandy shale. The maximum observed thickness is 35 feet, and at many exposures it is but a few feet thick.

Because it is so thin and has such a range in character and thickness, and thus is very difficult to trace and identify as a separate unit, the Spergen has been considered by the State Highway Commission in connection with the Lower St. Louis limestone, to which it commonly bears much lithologic resemblance. It will be thus considered in this report.

St. Louis Limestone. — With an area of outcrop including eleven of the counties covered in this report, the St. Louis is one of the more important of the formations with which this study is concerned. Its distribution in southern Iowa is approximately as indicated in the following table:

TABLE IV

Outcrop of the St. Louis Limestone

County	Points of Outcrop
Lee	Upper part of the bluff from Keokuk to Montrose. East and southeast of Farmington as far as West Point and Belfast.
Van Buren	All along Des Moines River and the lower courses of its tributaries.
Henry	Near Skunk River and the lower courses of its tributaries.
Jefferson	Near Skunk River in the northeast part of the county. Along Cedar Creek in the east half of the county.
Wapello	Scattered outcrops near Des Moines River.
Washington	Along Skunk River and the lower courses of its tributaries. Along Crooked Creek and the lower courses of a few of its tributaries.
Keokuk	Near both branches of Skunk River and along many of their tributaries.
Mahaska	A few exposures along both branches of Skunk River but at many points along the lower courses of some of their tributaries. Near Des Moines River and a few of its tributaries.
Marion	Near Skunk River in the northeast part of the county.

Besides these counties, in which it is well and widely exposed, the St. Louis also appears near Des Moines River in the northeast corner of Davis County, in a few scattered outcrops near Augusta in Des Moines County, and near Des Moines River in the northeast corner of Monroe County.

To the geologist, the most distinctive features of the St. Louis limestone are those that bear witness to the inconstant and frequently disturbed conditions of its deposition. Of these features, the following may be mentioned: first, brecciation, of various degrees of intensity; second, the abundant presence of conglomeratic limestone, formed in swift currents with accompanying contemporaneous erosion; and third, at some levels, a notable range in the character of the sediments within short horizontal distances, indicating rapidly changing conditions of deposition.

The St. Louis limestone may be separated on lithologic grounds into two divisions, commonly designated as the Lower and Upper. The Upper St. Louis may be further divided in Lee, Van Buren, and Henry Counties into a brecciated division below and a compact and granular division above. This recognition of a certain zone as a brecciated divison, however, must not be taken to mean that brecciation is confined to that zone; it may be seen at any level in the St. Louis, from top to bottom, or even continuously from top to bottom.

The Lower St. Louis limestone is distinguished first of all by the dominance of magnesian stone. The bedding is usually massive and nearly undisturbed, and the character of the stone is much more persistent than that in the Upper St. Louis. The most common type is a buff to brownish, granular to subcrystalline, moderately hard magnesian limestone, sparingly fossiliferous. A variation from this common type is seen in the conglomeratic buff magnesian limestone well exposed at Keokuk. Thin beds of shale or sandstone are present, but nowhere abundantly. Where the Lower St. Louis is a lithologically distinct unit, its thickness is normally about 25 feet.

The brecciated division of the Upper St. Louis limestone is composed for the most part of limestone breccia. The fragments included in this breccia range in size from the most minute up to blocks a foot or more in length or breadth. Most of them are nearly unworn and consist commonly of light gray hard fine-grained nonmagnesian limestone. The matrix differs more in composition; though gray fine-grained hard nonmagnesian limestone predominates, it gives way locally to soft sandy or shaly material, much of which has a greenish color. As might be expected from the conditions of deposition, fossil plant or animal remains are very uncommon. The thickness of this division is normally 5 to 15 feet, but in places brecciated stone extends throughout the whole of the Upper St. Louis, or even into the Lower, with a thickness as great as 35 feet. The brecciated division is not lithologically distinct except in western Lee, Van Buren, and part of Henry Counties.

The compact and granular division of the Upper St. Louis limestone consists for the most part of gray hard nonmagnesian limestone of fine or medium grain, in regular and fairly heavy beds, and very sparingly fossiliferous. Associated with the limestone are beds, mostly thin, of hard calcareous sandstone or of greenish calcareous shale. Where this member is lithologically distinct from the brecciated division its thickness is normally not more than 10 feet; and on account of numerous displacements of the usual type of stone by mounds and ridges of brecciated limestone and of soft sandstone, the thickness is locally much less.

In Marion, Mahaska, Keokuk, Washington, and Jefferson Counties, the Upper St. Louis shows a high proportion of sandstone. There is usually a capping of limestone 5 to 15 feet thick, underlain by soft yellowish calcareous sandstone or shaly sandstone which at some outcrops is as much as 30 feet thick. The limestone is commonly light gray in color, fine of grain, and hard and durable. At many points it is divided into two approximately equal parts by a bed of shale. The total thickness of the Upper St. Louis in this region is 20 to 40 feet.

At this point it may be well to mention again the distinct erosional unconformity at the top of the Mississippian system in Iowa, separating it from the overlying Pennsylvanian. Though this unconformity affects the Ste. Genevieve to greater extent than the St. Louis, at many points in southeastern Iowa the Ste. Genevieve is missing entirely and the old Mississippian erosion surface lies well down in the St. Louis. In developing any deposit in this latter formation, it is therefore necessary that careful prospecting be done, to make sure that buried channels, filled with Pennsylvanian shales, do not cut out a part or all of the desirable stone in parts of the area to be exploited.

Ste. Genevieve Limestone. — Previous to 1915, the Ste. Genevieve was known to geologists as the Pella (from the city of that name in Marion County) and was considered by them as a part of the St. Louis limestone. In that year, however, Van Tuyl demonstrated [5] the presence of disconformity at the base of the Pella; and on this basis, supported by paleontological evidence, the Pella beds were separated from the St. Louis and were correlated with the Ste. Genevieve of the Missouri geologists.

The range of outcrop of the Ste. Genevieve is much the same as that of the underlying St. Louis but is somewhat more restricted. It usually appears with the St. Louis where the latter outcrops in Lee (except near Keokuk and Montrose), Van Buren, Henry, Jefferson, and Wapello Counties. In addition, the Ste. Genevieve is well exposed near Brighton in Washington County; near What Cheer and Sigourney in Keokuk County, at various scattered points in Mahaska County, and abundantly near Pella and Tracy in Marion County.

The Ste. Genevieve is prevailingly calcareous. The typical limestones found in it are fine-grained, hard and sound, nonmagnesian, light gray in color, and mostly rather thinly bedded. With these limestones are associated calcareous shales, sandy shales, yellowish calcareous sandstones, or light-colored fossiliferous marls.

In Lee and Van Buren Counties the upper portion exhibits an uninterrupted sequence of beds of hard fine-grained limestone originally about 15 feet in thickness but reduced by post-Mississippian erosion

5 Van Tuyl, F. M., The Stratigraphy of the Mississippian Formations of Iowa: Annual Reports, Iowa Geological Survey, Vol. XXX, p. 287, 1921-22.

usually to 10 feet or less. The lower portion is predominantly arenaceous with some beds of fossiliferous calcareous shale and is 5 to 20 feet thick.

Limestone is less prominent to the northwest and appears in various positions with respect to the sandy and shaly strata. Thus, in southeastern Jefferson County there is found a succession of alternating thin beds of limestone and marl, about 17 feet in thickness. At Ottumwa and Dudley, shales and thin limestone overlie a heavier bed of limestone which is followed in turn by a sandy member. At Brighton the limestone lies above an arenaceous shale. Near Tracy a layer of limestone about 12 feet thick lies between shale above and sandstone below. In general, 10 to 12 feet is the maximum thickness of the limestone member of the Ste. Genevieve in the counties northwest of Lee and Van Buren.

Owing to post-Mississippian erosion, the upper surface of the Ste. Genevieve is irregular, even more so than is the case with the St. Louis. At many points, therefore, where the desirable stone is at the top of the formation, it is very necessary that careful prospecting precede any development project, to make sure that the expected thickness of material is present over the area to be worked.

Des Moines Series. — Partly because of obscurity of outcrops, but to greater extent because of the inconstant and lenslike character of the beds, the stratigraphy of the Des Moines series for southern Iowa is not yet worked out in detail. However, three stages are now generally recognized — the Cherokee, Henrietta, and Pleasanton. Many of the exposures of Des Moines series strata are not susceptible to ready or positive reference to any one of these stages; consequently the lines of demarcation between areas of occurrence of the three are not sharply drawn. On the other hand, the Des Moines series as a whole is lithologically well marked off from the calcareous strata of the Mississippian system beneath and the basal limestones of the Missouri series above, and its boundaries in Iowa are thus well established.

The Des Moines forms the country rock over nearly all of Warren, Lucas, Wayne, Marion, Monroe, Appanoose, Wapello, Davis, Jefferson, and Van Buren Counties. In some of these counties the Upper Mississippian is well exposed, but only along the deeper valleys and in relatively small areas, with the Coal Measures forming the country rock in nearly all the uplands. The Des Moines series also lies next beneath the unconsolidated materials in parts of Madison, Clarke, Decatur, Mahaska, Keokuk, and Lee Counties. Small outliers, of no importance to the road builder, occur in Washington, Louisa, Henry, and Des Moines Counties. Certain limestones with associated shales appearing near Logan, Harrison County, in the northeast part of Adair County, and near Stuart, Guthrie County, are considered by many geologists to represent the Des Moines, though this correlation is rather uncertain and in the writer's opinion is not supported by satisfactory evidence.

The total thickness of the Des Moines series differs locally and is difficult to estimate; however, the upper and lower limits of that thickness may be placed at 800 feet and 200 feet respectively. The three stages, Cherokee, Henrietta, and Pleasanton, divide it into three approximately equal parts.

The lower part of the Cherokee stage is not well known, as exposures definitely referable to it are not numerous and the beds lack persistence and uniformity. In general, it may be said that this lower part consists principally of shale with lenses of sandstone and discontinuous thin coals and limestones. The sandstone is, as far as known, not well enough indurated to be of value for crushing and is too fine of grain to be broken down and used as fine aggregate. The limestones are too thin to be of value to the road builder and the shales are likewise useless in their original condition. While a number of coal mines are worked in this horizon, they are all very small and hence burned shale from mine dumps is not found.

During the time of deposition of the upper part of the Cherokee stage, conditions must have been uniform over wide areas, for at this horizon, in contrast with the remainder of the Des Moines series, beds of limestone, coal, or clay, even though thin, are remarkably persistent and may be traced over hundreds of square miles of area. Thus, in Appanoose and eastern Wayne Counties, a well-defined succession of beds has been worked out by Bain.[6] The following is condensed from his general section for Appanoose County:

	Feet
11. Limestone, gray, subcrystalline; the "Floating Rock"	2-4
10. Shale, argillaceous, of different colors	12-30
9. Limestone, in heavy ledges, the "Fifty-foot Limestone"	4-10
8. Shale, blue and red above, and blue or gray below, sandy in the middle part	32
7. Limestone, the "Seventeen-foot Limestone" or "Little Rock"	1-3
6. Shale, gray or dark	7
5. Limestone, gray or dark gray, at some places shaly, the "Cap Rock"	2-4

6 Bain, H. F., Geology of Appanoose County: Iowa Geological Survey, Vol. V, 1896.

4.	Shale, of different kinds	1-3
3.	Coal, in three beds, with clay partings, the "Mystic Coal"	2½-3
2.	Fire clay	1-6
1.	Limestone, the "Bottom Rock"	3½

In explanation of the above section it may be well to state that the terms "Fifty-foot Limestone" and "Seventeen-foot Limestone" refer to the distances above the Mystic coal at which these members are often found.

A regular succession of the strata in Lucas County has been worked out by Lugn.[7] This differs from Bain's section as to detail and shows fewer and thinner limestones, but these are persistent and continuous.

Sandstone is almost entirely absent from the Upper Cherokee of Appanoose, Wayne, and Lucas Counties.

In the Henrietta stage the lenticular deposits so typical of the Des Moines series are noticeable, especially so in the case of the coal beds, of which there is a considerable number. Shale constitutes the bulk of the formation, with sandstone appearing at a few horizons, but much less commonly than in the overlying Pleasanton stage. A few beds of limestone have been noted, some fairly persistent, but in only one case known to be more than about four feet thick. This case is in section 12 of Grove Township (T. 76 N., R. 31 W.), Adair County. Here a bed of limestone about 15 feet thick includes shale seams totaling about two feet in thickness. The formation is referred to the Henrietta.

Exposures of Des Moines series strata in eastern Madison, Clarke, and Decatur Counties may be confidently referred to the Pleasanton stage because of their proximity to the easily identified basal limestones of the Missouri series. Other exposures farther to the east are referred to the Pleasanton less positively. Like the Henrietta, this stage is characterized by basin-like deposits and by a predominance of shale. Limestones are thin and nonpersistent and require no further mention here. Coal is present usually in very thin or discontinuous beds. The distinguishing characteristic of this stage is the presence in it of channel deposits of sandstone, which is locally a conglomerate and is well enough indurated to be of value as a source of road or concrete materials.

The sandstones and conglomerates were evidently laid down by strong and persistent currents of water moving in well-defined channels. Geologists disagree as to whether these were surface channels, cut out while the newly formed beds were temporarily elevated above

7 Lugn, A. L., Geology of Lucas County: Iowa Geological Survey, Vol. XXXII, 1926.

water, or whether they are the result of contemporaneous erosion acting upon the yet unindurated strata on the sea bottom. Evidence now at hand indicates that the former is more probably the true explanation. Whatever the case, it seems that shales or muds were eroded from these channels and the depressions were later filled with sand or, in a few cases, with gravel.

The larger pebbles, constituting the conglomerate parts of these channel deposits, are nearly all of fine-grained gray hard fossiliferous limestone, probably of pre-Pleasanton Pennsylvanian age. The small grains consist of chert or quartz, and the sand is almost entirely of quartz. In some of the conglomerates the matrix is ferruginous, and in others siliceous and calcareous, while in the sandstones this matrix is siliceous. A coarse conglomerate from 1 foot to 10 feet thick nearly everywhere makes up the lower part of the channel deposit, with finer-grained materials above. Strong and erratic dips are the general rule for the conglomerates and the coarse-grained sandstones, these dips being observed in places to parallel the slope of the shale surface on which the channel deposit was laid down.

In the area under consideration, channel deposits of origin as described above are well exposed near Red Rock, Knoxville, Columbia, and Melcher, of Marion County; in Pleasant Township of northeastern Lucas County; near Moravia and south of Centerville in Appanoose County; and west of Fairfield in Jefferson County. Besides these, other channel sandstones are known, as at Cliffland in Wapello County, but the stone is there so poorly indurated as to be of no value to the road builder.

Kansas City Stage of the Missouri Series. — In view of the fact that the major portion of the valuable road material in the Missouri series occurs in this, the lowermost stage, it seems advisable to consider it separately.

The area of outcrop of the Kansas City stage occupies a sinuous belt about 15 to 20 miles in width, including most of Madison County except the northeast quarter and the western two-thirds of Clarke and Decatur Counties. Within this area, its various limestone and shale members appear in narrow and roughly parallel belts trending from north to south. The oldest of these belts is to the east, this being an expression of the prevailing westward dip in the region. Exposures are rather abundant throughout the whole area, as it is deeply trenched by the valleys of North, Middle, South, and Grand Rivers and their tributaries. Along many of these streams a complete section of Kansas City strata may be made out with little difficulty. Further, in Madison County glacial materials are thinner than in the surrounding counties, and the indurated rock is thus found along many of the smaller streams.

The following section indicates the prominent stratigraphic characteristics of the various members of the Kansas City stage:

Formations of the Kansas City Stage of the Missouri Series

		Feet
Iola limestone	Two limestones, separated by a bed of shale	3
Chanute shale	The upper two thirds is gray and red argillaceous shale and the lower one third a nodular shaly limestone	17
DeKalb limestone	Alternating limestones and shales, the former predominant, especially in the top and bottom parts. This member shows a somewhat different facies in Decatur County from that in Madison County	48-56
Cherryvale shale	Contains three limestone layers, none of them more than 1 foot thick. The lower part is strongly fossiliferous	16
Winterset limestone	Five feet of gray fragmental limestone at the top, underlain by thick ledges of hard and sound gray fossiliferous nonmagnesian limestone. With a small proportion of dark-colored nodular flint at or above the middle. Includes several shaly partings, none more than a few inches thick. The upper part is missing in many places on account of erosion	10-16
Galesburg shale	Argillaceous shale, with a black fissile shale at or near the top	9-11
Bethany Falls limestone	Limestone ledges, separated by thin shale seams. Shale constitutes about 10 percent of the member, while shaly zones of limestone adjacent to the shale seams total about 10 percent more	15-23
Ladore shale	Gray for the most part, with a few thin but very persistent limestone beds. The section from the top down unvaryingly shows 1½ to 2 feet of drab plastic shale, 1½ to 2 feet of black fissile shale, and 6 inches of dark gray hard limestone. The lower portion is in many places very sandy	17-22
Hertha limestone	One bed of fairly hard but somewhat fragmental or shaly limestone	5

Except as noted, these formations are remarkably uniform in character throughout their whole range of outcrop. Their thickness also is uniform within the limits given, except where affected by post-Pennsylvanian or recent erosion. Thus it is a comparatively simple task to describe them and to recognize them wherever they are found in the field.

The limestones of the Kansas City stage extend westward from their area of outcrop beneath the newer formations and are found by well records at such points as Bedford, Clarinda, and Glenwood to be somewhat thicker than where exposed.

Stages of the Missouri Series Above the Kansas City. — Strata of this age occupy a large but rather ill-defined area, including the counties west of the strip of outcrops of the Kansas City stage and as far north as the middle part of Adair, Cass, and Pottawattamie Counties. Through this area exposures are rather scattered, usually of limited extent, and confined to the lower parts of the deeper valleys. The nature of the major part of the strata accounts in a measure for the paucity of outcrops; shale, where exposed to the weather, tends to break down quickly and form a slope that is soon covered with sod. Other reasons for scarcity of outcrop are the heavy covering of unconsolidated materials on the rock and the mature character of the topography, with erosion thus only moderately active.

As in the Kansas City stage, these higher beds show a fair degree of uniformity and persistence over wide areas. Correlation would thus become easy and positive in spite of the scarcity of outcrops, were it not for the puzzling repetition of limestone and shale shown throughout the whole succession. The following table of formations, adapted from Tilton's [8] Iowa Section of the Missouri series, indicates the order and nature of the strata from the top of the Missouri series as found in Iowa down to the top of the Kansas City stage and well illustrates this repetitive characteristic.

Stage	Areas of Outcrop	Subdivisions	Feet	Character
Wabaunsee	In Fremont, Page, southern Montgomery and southern Mills Counties, along only the larger streams	McKissicks Grove shale	91	Argillaceous shale, with several limestones up to 3 feet in thickness, the Nyman coal 1 foot thick, and several zones of soft incoherent sandstone
		Tarkio limestone	4	In two beds, with a shale seam between
		Unnamed shale	12	Argillaceous shale
		Preston limestone	1	One bed of limestone
Shawnee	In western Union, western Ringgold, Adams, Taylor, and parts of Adair, Pottawattamie, Montgomery, Mills, Fremont, and Page Counties, scattered exposures, principally along Missouri and Nishnabotna Rivers	Scranton shale	194	Almost entirely argillaceous shale, variously colored
		Howard limestone	4	One or two beds of yellowish limestone
		Severy shale	25	Includes the Nodaway coal, 1½ feet in thickness, mined near Clarinda and New Market and northwest of Corning
		Topeka limestone	6	Includes a 3-foot bed of hard and durable limestone, with thin limestones and shale

8 Tilton, J. L., The Missouri Series of the Pennsylvanian System of Southwestern Iowa: Iowa Geological Survey, Vol. XXIX, 1920.

Stage	Areas of Outcrop	Subdivisions	Feet	Character
		Calhoun shale	11	Includes a few very thin limestones
		Deer Creek limestone [9]	12-15	Limestone, fossiliferous, gray, hard, pure and sound above, but shaly and unsound below. The limestone beds are separated by thin shales which total one tenth to one eighth of the member. In some localities certain beds are crowded with Fusulinids
		Tecumseh shale	65	Shale, with a few very thin limestones and one sandstone, 5 to 10 feet thick
		Lecompton limestone	7	Limestone, with interbedded shale
		Kanwaka shale	16	Argillaceous shale
Douglas	In eastern Adair, southwestern Madison, eastern Union, central Ringgold and parts of Mills, Pottawattamie, Cass, Montgomery, Counties	Oread limestone	10	Limestone, with fusulinids, locally shaly or interbedded with shale
		Lawrence shale	7	Gray argillaceous shale
		Iatan limestone	4	Two beds, with shale intervening
		Weston shale	4	Shale, black in the middle part
Lansing	In a belt about 5 miles wide, through western Madison, eastern Union, and eastern Ringgold Counties. Also near Council Bluffs	Stanton limestone	4	Two beds, with shale intervening
		Vilas shale	21	Green or gray argillaceous shale with a few iron concretions in the upper part
		Plattsburg limestone	6	The upper half is thin bedded and shaly. The lower half is dense, hard, and sound
		Lane shale	7	Includes two thin limestone ledges. The lower 1 foot is arenaceous

In explanation of the foregoing section it may be said that some of the formations are known only from one or two exposures, and it is quite probable that observations as to thickness or character in such cases are inaccurate. Others, for example the Deer Creek limestone, have been observed at a number of points, and their nature is well understood.

The members of the Lansing and Douglas stages extend westward from the area of their outcrop beneath the newer formations, and the limestones (particularly the Oread) are shown by well records at such points as Bedford, Red Oak, and Clarinda to be much thicker than where exposed.

[9] The thickness of this member is given by Tilton as 8 feet at Stennett, Montgomery County. The writer's observations there and elsewhere lead to the belief that 8 feet is considerably too low.

Cretaceous System

Only the Dakota stage of this system is represented in southern Iowa. Of the area covered in this study, beds of Dakota age form the country rock in all of Audubon, a major part of Shelby and Cass, and small parts of Harrison, Pottawattamie, Montgomery, Adams, Page, and Adair Counties. Outcrops are confined for the most part to Cass and Montgomery Counties near East Nishnabotna River but are also present in various localities in Adams, Page, and Pottawattamie Counties. In a large part of the area of its occurrence beneath the unconsolidated materials, the Dakota is known only from well records.

The Dakota stage consists predominantly of quartz sandstone. This sandstone is rather fine of grain and white to buff in color. The degree of cementation differs, but most of the rock is poorly cemented; at some deposits the material can be excavated by pick and shovel. Nowhere is the sandstone firmly enough cemented to be of value for crushing. With the sandstone are associated small lenses or beds of light-colored plastic clay, well exposed near Red Oak. In southwestern Montgomery County, the sandstone grades into a conglomerate that is worthy of consideration in more detail.

The component pebbles of the conglomerate are almost entirely of flint or quartz, well rounded, well sorted, and in few cases more than one inch in diameter. The matrix, if such it can be called, is of sandy nature, with 2.0 to 15.0 percent of clay and appreciable amounts of iron oxide. Most of this matrix is quite incoherent, the deposit having much the appearance of the ordinary glacial gravel deposit. Elsewhere, the proportion of iron oxide is greater, and the rock is well indurated. These more indurated portions are usually in thin streaks of veinlike form and appear in many cases to have been deposited from solutions that circulated in the more permeable zones of the formation. The conglomerate deposits are locally lenticular or basin-like, grading off both vertically and laterally into the typical soft sandstone. In places the conglomerate occurs as thin lenses or streaks in the sandstone.

Pleistocene System

Drift deposits of Pleistocene age in Iowa are of glacial or fluvioglacial origin. They are considered to be the result of four distinct ice invasions, in chronological order, the Nebraskan, Kansan, Illinoian, and Wisconsin. In the area covered by this report, the Wisconsin is not found and the Illinoian appears only in Des Moines and eastern Louisa, Henry, and Lee Counties. The Nebraskan appears to underlie practically the whole area and the Kansan all of the area except small patches along the deeper valleys where it has been removed by erosion.

Drift deposits in southern Iowa consist of till with associated pockets and lenses of stratified silt, sand, or gravel. The till is typically a pebbly or bouldery clay, dark gray when unoxidized but weathering to yellow or buff. The pebble and boulder content rarely exceeds five percent. Interglacial deposits of Pleistocene age in southern Iowa consist of gumbotil (weathered till) with subordinate amounts of peat, sand, or gravel. The sand or gravel pockets or lenses associated with the till or gumbotil are scattered and mostly of small size, but some are important enough to be worthy of consideration in this study.

As to the thickness of the three tills, only the most general statement can be made. It appears that the Illinoian may average in the neighborhood of 30 feet, the Kansan about 50 feet, and the Nebraskan about 100 feet.

Where not exposed in contact, the Kansan and Nebraskan tills are lithologically indistinguishable. However, recent studies[10] by Kay have demonstrated a number of points, as follows: 1. During the Aftonian interglacial interval following the Nebraskan, and again during the Yarmouth interglacial interval following the Kansan, sufficient time elapsed for the formation on uneroded surfaces of these two till sheets of several feet of gumbotil, or till which has been weathered to such an extent that the pebbles have been largely removed by solution. 2. Exposures in southern Iowa, beyond the margin of the Illinoian till, that show a gumbotil with fresh till overlying, serve at those points to determine the level of the uneroded parts of the old Aftonian plain, now almost entirely buried. 3. The level of this Aftonian plain is easily traceable by the gumbotil exposures throughout southern Iowa, though the plain is undoubtedly dissected to a certain extent by the drainage ways which developed during that time. 4. Consequently, where fresh till or pockets of sand or gravel are found above that level, it may be safely inferred that they are of Kansan age, while if found below that level they are of Nebraskan age, or possibly of Kansan age filling some Aftonian valley. These facts serve to establish fairly satisfactory criteria for differentiating the Nebraskan and Kansan tills.

10 Kay, G. F., and Apfel, Earl T., the Pre-Illinoian Pleistocene Geology of Iowa: Iowa Geological Survey, Vol. XXXIV, 1928.

The Illinoian till may often be identified by the somewhat less mature character of its topography as compared with that of the older drift sheets. Furthermore, it appears only in the extreme eastern part of this area, and, as glacial gravels which originate from it are scarce, its positive identification becomes a matter of minor importance in this study. Its west boundary in Henry and Lee Counties is marked by an ill-defined ridge of modified morainic hills.

Loess remains to be mentioned under the head of Pleistocene deposits. It is a rather fine-grained eolian silt, gray to yellowish in color, of very porous texture. The particles which compose it are of nearly uniform size, and at only a very few places does it contain sand or pebbles. It forms a blanket of differing thickness over all the glacial deposits of southern Iowa, except where removed by recent erosion. This blanket is as much as 100 feet thick in western Harrison and Pottawattamie Counties, but over most of this area the thickness is not more than 10 feet. Loess is of no value to the road builder as a source of surfacing or paving material. Its presence has a bearing upon highway construction, however, since its porous texture permits ready underdrainage of water, and it thus makes a well-drained subgrade for surfacing or paving, firm at all seasons of the year and therefore much more desirable for the purpose than the impervious till or gumbotil.

The Alluvium

Under the head of alluvium are included three types of gravel or sand deposits: namely, terrace deposits, bottomland deposits, and bar deposits within the limits of the present stream channel. These three types are all of similar origin. For example, there may be seen in the channel of a stream a point where that channel is floored with sand or gravel, which is from a few inches to several feet in thickness. Part of this deposit may be built up to, or above low water level. In such a case, it appears as a bar, and indeed it has been found that the typical bar deposits extend on out to or across the adjacent submerged part of the channel floor. In the course of time, perhaps only a few years, the stream may, by meandering, change its course; the deposit under consideration then becomes one of the bottomland type, partly above and partly below water level, but not in the channel. With the further passage of time, usually many years, except in case of streams of high gradient, conditions may be such as to allow the stream to cut its valley to greater depth. The old flood plain then is left well-above the new stream level and appears as a terrace, underlain by the usual alluvial materials, silt, sand, or gravel.

Thus, terrace, bottomland, and bar deposits have a similar origin, and certain characteristics, common to all three, are mentioned in the following paragraphs.

Where the water current is swift, it will deposit only the coarser materials, such as gravel or coarse sand, while at points of lower velocity, only fine sand or silt are dropped. It is well known that the swiftest current in a stream is normally near its center, with more quiet water near the edge. Thus, alluvial deposits formed across the whole width of the stream have the coarser material near the center, while those formed as bars along one bank are coarser near the "outside edge," i.e., the edge nearest the center of the stream. The observer, applying this rule in the field to bottomland and especially to terrace deposits, must, however, remember that the course of the stream at the time of deposition may have been quite different from its present course.

Another condition found in more than half of the cases observed by the writer is that coarser materials are at the upstream end of the deposit; this may be expected from consideration of the fact that a decreasing stream velocity is a necessary condition for any deposition, and thus, when alluvium is laid down, the coarser portion may be expected to be dropped first.

Nearly all the materials in alluvial deposits are well worn, clean, and distinctly stratified. The assortment as to size is usually good and is a factor favorable to the development of such deposits; on the other hand, in many cases cross-bedding is well developed, and the strata may change character or pinch out entirely within short distances.

Alluvial deposits in southern Iowa consist for the most part of reworked glacial materials, and all kinds of rocks and minerals are present. In the smaller sizes, only the more durable substances, such as quartz, will survive the abrasion incident to water transportation, while in the larger sizes many other minerals and rocks, even including sandstone and limestone, may survive.

As any stream is followed down its course, alluvial materials usually become progressively finer; thus, coarse gravel and sand may be found in the upper reaches, but only sand or fine sand farther downstream. This reflects the fact that with most streams the gradient, and consequently the velocity, is greater in the upper part of its course.

The exact age of the alluvial deposits of Iowa is often difficult of determination, as fossils occur in them only sparingly. Though a few may be pre-Pleistocene, many were laid down at some time during the Pleistocene, many were formed since the retreat of the last ice sheet, and some are being deposited even now.

In the area under consideration in this study, alluvial deposits are most valuable along the Mississippi, Iowa, Des Moines, and Boyer Rivers, all of which streams rise in the Wisconsin or Iowan drift areas and thus tap the immense storehouse of sand and gravel in northern Iowa. To these would be added the Skunk were it not for the fact that in its valley just north of the point where it enters this area is an embayment past which the stream has not had sufficient energy to transport the materials obtained by it in its upper course. Missouri River is of some interest as a source of sand, though it must be said that such sand is largely of Platte River origin, even though found in the valley of the Missouri. Other streams in southern Iowa carry minor amounts of sand or gravel.

CHAPTER III

DESCRIPTIONS OF MATERIALS BY COUNTIES

ADAIR COUNTY

Road material supplies in Adair County are very limited in extent and mostly inferior in quality. A large number of gravel prospects have been reported and investigated in recent years, and from time to time others will probably be discovered. None so far has been found to have more than a very limited local value. The limestone bedrock is exposed only along Middle River and the immediate lower courses of its tributaries, and many of the beds are thin and under heavy stripping.

The indurated rocks exposed in this county are referred to the Pennsylvanian system. Some may confidently be assigned to the Missouri series on the basis of their connection with unquestioned Missouri series outcrops on Middle River in Madison County. Others may represent the Henrietta stage of the Des Moines series, though evidence supporting this correlation is not conclusive.

Upon the indurated rocks is a mantle formed by two phases of glacial deposition, the Nebraskan and the Kansan. The former appears only along a few of the deeper valleys in the south part of the county, while the latter is well exposed in every township. A layer of post-Kansan loess, of different thicknesses up to about 10 feet, overlies the Kansan drift in all except the most dissected areas.

Limestone

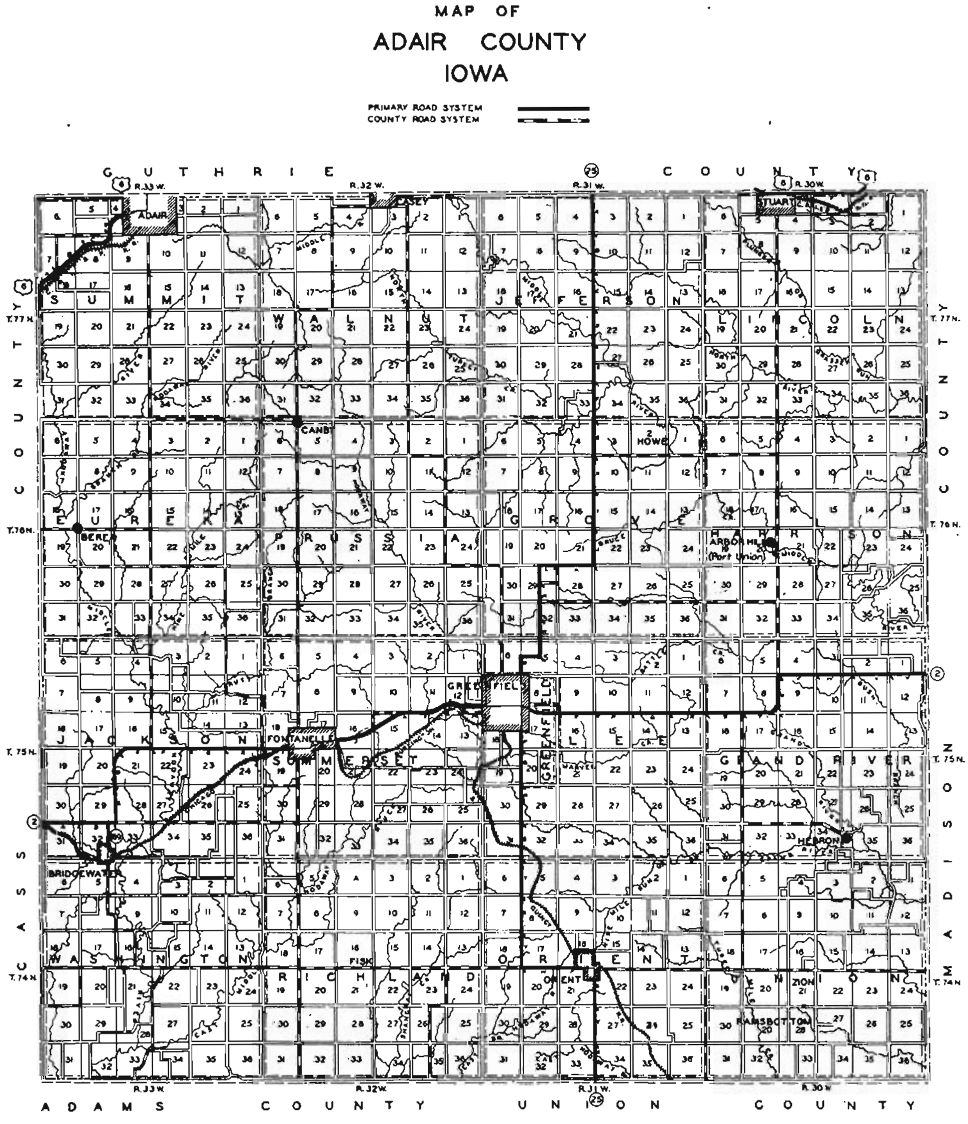
Limestone exposures are limited to the immediate vicinity of Middle River from section 21, Jefferson Township, to the east county line, and to Bush Branch in sections 12 and 13, Grand River Township. The only localities where any quantity of stone suitable for road or concrete work is available are in the NW¼, section 12, Grove Township, and in sections 26 and 27, Harrison Township. The uppermost of the thick limestones of the Kansas City stage (DeKalb limestone) passes beneath the bed of Middle River in Madison County within a mile of the east boundary of Adair County and is thus unavailable.

Gow [1] and Beyer [2] have published sections at the Perry quarry in the

[1] Gow, James E., and Tilton, John L., Geology of Adair County: Iowa Geological Survey, Vol. XXVII, p. 288, 1916.

[2] Beyer, S. W., and Wright, H. F., Road and Concrete Materials in Iowa: Iowa Geological Survey, Vol. XXIV, p. 56, 1913.

IOWA GEOLOGICAL SURVEY. PLATE VI



NW¼ NW¼ section 12, Grove Township, and they have mentioned the occurrence of the same strata at other points along Middle River in the NW¼ and near the center of section 12. A few years ago a quarry was opened in the SE¼ NW¼ section 12, and about 17,000 cubic yards of rock was removed for surfacing the road between Greenfield and Menlo. The following is the section at and just north of this quarry:

	Feet	Inches
11. Overburden, loess and drift clay, locally with 1 foot to 2 feet of drab calcareous shale at the bottom	8–15	
10. Limestone, one bed, gray, hard, crystalline, medium-grained, filled with small fossil fragments, among which segments of crinoid stems are conspicuous, with a layer of chert nodules near the middle	4	2
9. Shale, calcareous, gray, weathers drab		8
8. Limestone, gray, hard, rather fine-grained, sparingly fossiliferous except for the upper 4 inches, which is similar to No. 10. Locally in one bed, but usually divided by very thin wavy shale seams into two or three beds	2	9
7. Irregular thin nodular or lenticular masses of gray hard medium-grained limestone separated by seams of gray to drab calcareous shale. About two thirds of this member is limestone	1	
6. Limestone, medium-grained, gray, hard, crystalline, filled with fossil fragments among which brachiopod shells can be recognized. In two beds, separated by a thin shaly parting	1	3
5. Shale, calcareous, locally becoming a shaly limestone. Yellow in the middle and gray above and below	1	
4. Limestone, gray, medium fine-grained, hard, massive and may be one bed when unweathered. The upper 4 inches is shaly and unsound. With about 2 percent of dark chert in scattered nodules. Filled with very small fossil fragments of species not recognized	3	6
3. Limestone, shaly, unsound		1
2. Limestone, similar to No. 4	1	1
1. Limestone, drab, shaly, rather soft. Bottom of exposure	4	

This series of beds corresponds to the limestones in the sections previously mentioned by Gow and Beyer. Tilton [8] refers these strata to the Henrietta stage of the Des Moines series, but it is believed that this correlation is not yet supported by sufficient evidence to be considered as positive. The whole succession of beds can be used for road surfacing work, and many of the individual members are usable for concrete aggregate. An acre or two of stone is still available at this location under not more than 15 feet of overburden, and under heavier overburden even more might be obtained. Near the old Perry quarry, in the NW¼ NW¼, usable quantities are still available, though probably not as much as in the SE¼ NW¼.

The upper part of the section just given reappears at intervals on Middle River in the central and southeastern parts of section 21, Jefferson Township, and on Middle River and Turkey Creek in section 34,

[8] Tilton, J. L., Missouri Series of the Pennsylvanian System in Southwestern Iowa: Iowa Geological Survey, Vol. XXIX, p. 296, 1919.

Jefferson Township, but it shows no rock available under moderate stripping.

In sections 26, 27, and 35 of Harrison Township a fragmental, somewhat shaly limestone appears in a number of places. It is usually from four to seven feet thick and it is correlated as the Oread limestone. It does not appear to be suitable for concrete aggregate but might be used for surfacing stone. It is available at several points by stripping, in quantities up to a few thousand cubic yards. On account of the proximity of deposits of better material in the western part of Madison County, this formation does not appear to have more than a very limited local value.

Beyer's[4] section and description of the exposures at Port Union (sec. 20, Harrison Twp.) indicate thin limestones, with almost nothing available under moderate stripping. Numerous other exposures at various points in Harrison Township and in the northeast part of Grand River Township show similar conditions.

Sand and Gravel

About thirty gravel prospects in various parts of the county have been investigated, but none was found to have more than local value for small surfacing projects. The best ones found are in the SW¼ SW¼ section 2, Orient Township, where 1,500 cubic yards is available, and in the NW¼ SE¼ section 17, Harrison Township, where 1,200 cubic yards is available. A few small gravel pits have been worked in the past, but none is known to be open now.

Alluvial deposits, as far as known, consist only of silt and fine sand. Those streams in the east part of the county that cut into the limestones of the Missouri series have in their channels a few bars of sand and gravel mixed with much broken rock, but these are all of small extent and of little value as a source of road or concrete materials. It is doubted that any of them contains more than 100 cubic yards of sand, gravel, or broken rock. Other streams may accumulate small quantities of sand or gravel from the drift, but no such deposits of usable size are known.

ADAMS COUNTY

With regard to presence and availability of road or concrete materials, Adams is one of the most barren of the counties in the area cov-

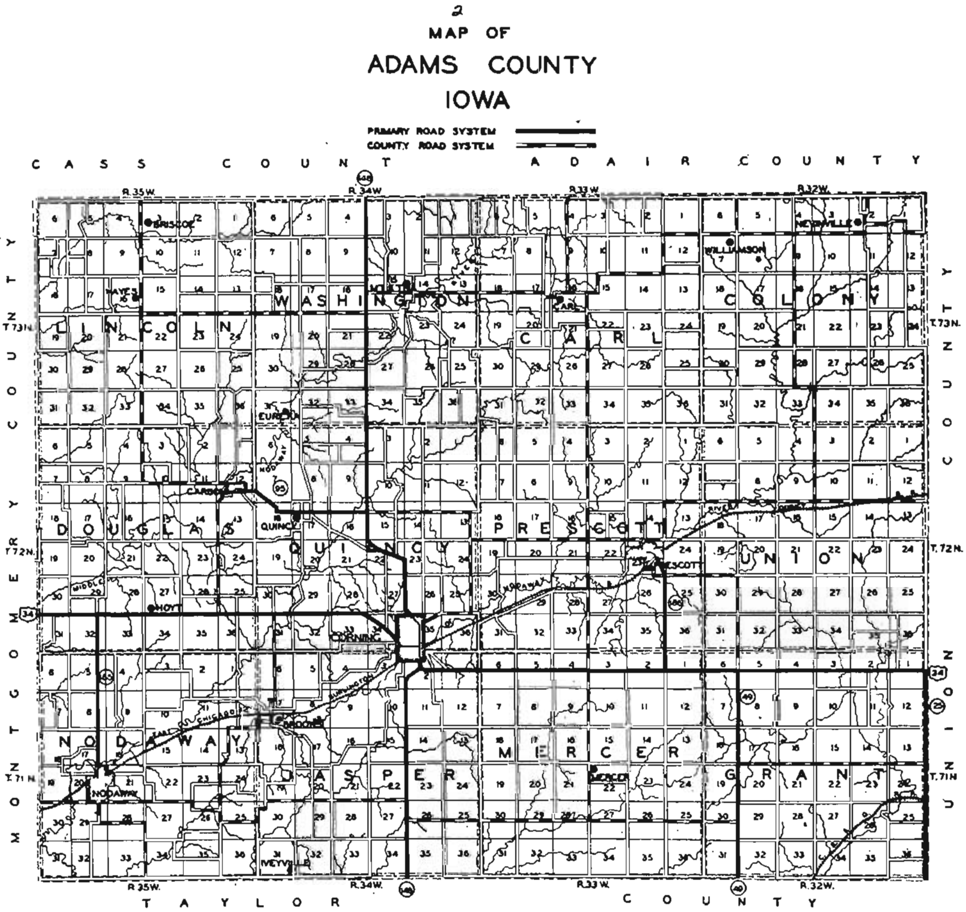
4 Beyer, S. W., and Wright, H. F., Road and Concrete Materials in Iowa: Iowa Geological Survey, Vol. XXIV, p. 57, 1913.

ered by this study. Scattered exposures of the limestones and shales of the upper portion of the Missouri series of the Pennsylvanian system are found near Corning and Brooks. Cretaceous sandstones appear at a few points in the west part of the county but are not known to be coarse-grained there or to be associated with beds of conglomerate as is the case in Montgomery County. The eroded slopes of Nebraskan and Kansan drift show the usual outcroppings of gravelly material, and a number of prospects have been investigated; these have shown, however, little or no available material.

Limestone

Beds of limestone appear at a number of points along the deeper

IOWA GEOLOGICAL SURVEY. PLATE VII



valleys in the west half of the county, but nearly all that have been found are thin and show no available quantity of road or concrete materials. The following section in the NW¼ SW¼ section 31, Douglas Township, is typical:

	Feet	Inches
6. Limestone, blue-gray when freshly broken, weathers yellow. Granular texture. No fossils noted	2	9
5. Shale, gray and drab	10	
4. Shale, black, bituminous	1	6
3. Shale, yellow		4
2. Limestone, hard, blue-gray		8
1. Shale, gray and drab. To creek bottom	21	

These beds probably represent a part of the Shawnee stage of the Missouri series, but no exact correlation has been made. No rock is available under moderate stripping. Other outcrops near Corning and Brooks show a similar succession of strata, and these also are referred to the Shawnee stage.

The Deer Creek limestone of the Missouri series appears at a few points southwest of Corning, its top being a few feet above low water level in East Nodaway River. Abandoned quarries are located in SW¼ NW¼ section 2, NE¼ NW¼ section 3, and SE¼ SW¼ section 3, all of Jasper Township. Inasmuch as the top of the Deer Creek limestone is but a few feet above water level, it is entirely unavailable under moderate stripping except in the bottomland or in the extreme lower slopes bordering the valley. Core drilling in section 3 has shown that in nearly all of the bottomland area the river has cut away part or all of the ledge. However, in the SE¼ SW¼ section 3 it is present on an area of about two acres, under an average overburden of 10 feet. The following section, from a core drill hole in the south bank of the river at this point, shows the nature of the Deer Creek and the beds beneath it:

	Feet	Inches
6. Limestone. In the lower 3 feet are three shale seams, each a few inches thick	13	6
5. Shale, black in the middle, gray above and below	2	3
4. Limestone	1	3
3. Shale, black	2	11
2. Limestone		10
1. Shale, varicolored, some beds soft and plastic	12	3

Low water level in Nodaway River is two feet below the top of No. 6 of this section. Above the top of this core drill hole the river bank shows in ascending order, 5 feet of shale, 1 foot of limestone, and 20 feet of glacial clay.

The Deer Creek limestone here (No. 6 of the foregoing section) is shown by laboratory tests to be hard enough for surfacing material or for aggregate and to be sound except for thin zones adjacent to the shale seams in the lower part. The principal difficulty in quarrying it is in the fact that it lies for the most part below water.

Shale

The Nodaway coal is mined at several points in the northwest part of the county. Most of the waste piles at these mines are well burnt and constitute a possible source of small quantities of road surfacing material. However, none of the mines is large, and no waste piles containing more than 1,000 cubic yards of material have been found. The most extensive recent mining has been near Carbon (sec. 12, Douglas Twp.).

Sand and Gravel

As a whole this county is not so much dissected by stream action as are others in that part of the state. Consequently there are fewer exposures of gravel and sand pockets in the glacial drift. All known prospects, some twenty in number, have been investigated, and the largest amount of gravel found available in any one was 600 cubic yards, in SW¼ NE¼ NW¼ section 26, Washington Township.

Where the Dakota sandstone appears in the west part of the county, it offers limited quantities of a rather fine sand, which might be used in asphaltic aggregate. The only exposures now known are near and south of the east quarter-corner section 31, Douglas Township.

Alluvial materials, so far as known, consist entirely of silt or very fine sand. Bridge soundings on the branches of Nodaway River indicate the presence of sand or fine gravel in the deeper alluvium, but thus far such materials have not been found available under moderate stripping.

APPANOOSE COUNTY

The bedrock of Appanoose County belongs entirely to the Des Moines series. The beds in the part of the county northeast of Chariton River are referred to the lower part of the Cherokee stage and are inconstant in occurrence and quality. Though not well exposed, they are known to consist of shales and sandy shales with subordinate amounts of sandstone. In the remainder of the county occurs a uniform and persistent series of shales, with associated thin limestones and one coal bed (Bain's "Appanoose Beds" [5]), which may be referred to the upper

[5] Bain, H. F., Geology of Appanoose County: Iowa Geological Survey, Vol. V, 1895.

part of the Cherokee. Deposits of the Chariton conglomerate, provisionally referred to the Pleasanton stage of the Des Moines series, appear at a few points near Centerville and Moravia.

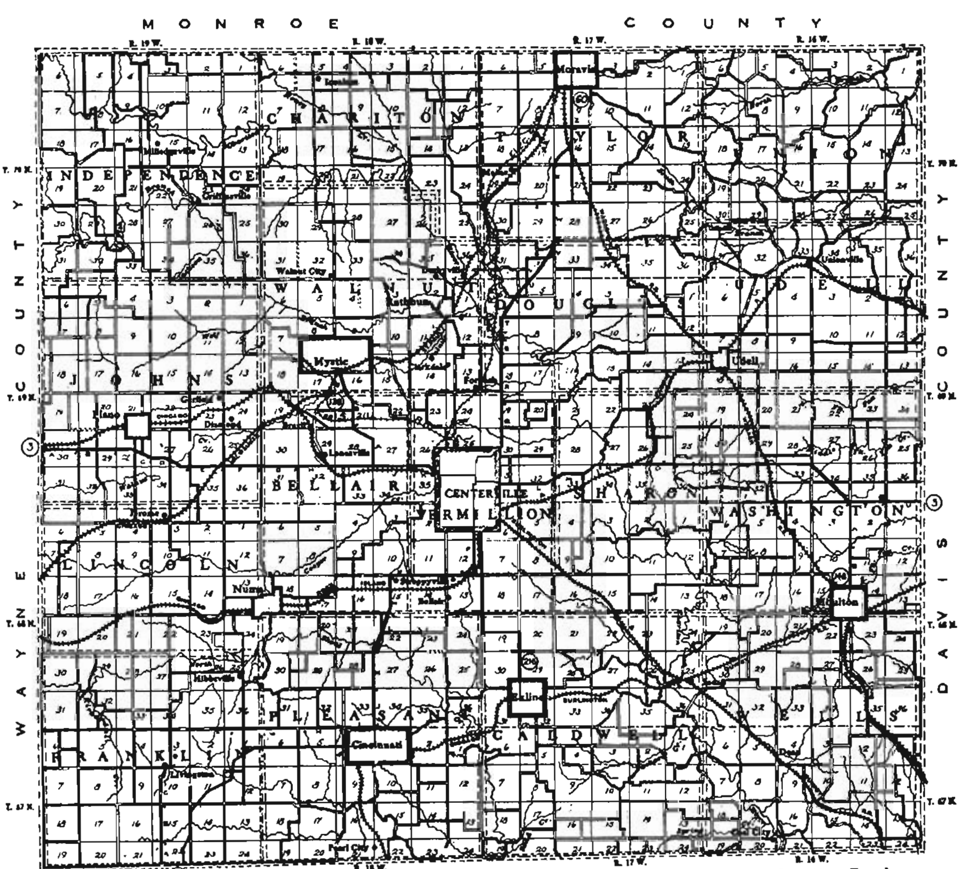
Underlying the Des Moines series are beds of the Ste. Genevieve and St. Louis formations of the Mississippian system. They are nowhere exposed at the surface in this county but are met at a depth of

IOWA GEOLOGICAL SURVEY. PLATE VIII

4

MAP OF
APPANOOSE COUNTY
IOWA

PRIMARY ROAD SYSTEM
COUNTY ROAD SYSTEM



500 feet in the mine of the United States Gypsum Company at Centerville.

Nebraskan and Kansan glacial drifts mantle the bedrock throughout the county with a total thickness which may in places exceed 100 feet. Exposures where the older drift can be definitely recognized are uncommon, but its presence may be safely inferred from numerous well records. The later drift appears at many localities in every township. A veneer of loess only a few feet thick covers the drift in the flat interstream areas, while near the larger valleys, where recent erosion has been active, the loess has been for the most part removed. Alluvial deposits of silt or fine sand are common in the valleys of the larger streams, but coarser materials are not known.

Limestone

The shaft of the United States Gypsum Company mine in the south part of Centerville penetrates 500 feet of Pleistocene and Pennsylvanian strata, which are followed by 50 feet of St. Louis limestone, 3 feet of gypsum, 4 feet of anhydrite (gypsum minus the water of crystallization), and 4 feet of gypsum. For the most part, only the lower bed of gypsum has been worked, leaving the anhydrite bed available in the roof of the mine on an area of about four or five acres. A few tests on the anhydrite show that it is suitable for road surfacing, but partly on account of inferior hardness, and perhaps also on account of the chemical effect of its sulphate composition, it is not recommended for use as concrete aggregate. If it is desired to use such material in concrete, further tests on its suitability should be made. The anhydrite is easily available, as its removal would make accessible the upper bed of gypsum. The limestone which lies above the gypsum in this mine has not been tested, but its appearance indicates that it is suitable for road surfacing, and that much or most of it is suitable for concrete or asphaltic aggregate. No attempt has been made to develop the limestone, as it could hardly compete in cost with shipped-in materials.

Limestones of the Des Moines series are known to appear only in the Appanoose beds, and are there quite uniform in occurrence and quality. The best exposures are in the west side of the valley of Chariton River and along the lower courses of its tributaries from the west. The following general section, condensed from Bain,[6] shows the sequence and character of the beds in this region:

6 Bain, H. F., Geology of Appanoose County: Iowa Geological Survey, Vol. V, p. 382, 1895.

		Feet
11.	Limestone, gray, subcrystalline, the "Floating Rock"	2–4
10.	Shale, argillaceous, different colors	12–30
9.	Limestone, heavy ledges, the "Fifty-foot Limestone"	4–10
8.	Shale, argillaceous, with some sandstone	32
7.	Limestone, the "Seventeen-foot" or "Little Rock"	1–3
6.	Shale, gray to black	7
5.	Limestone, different characters, the "Cap Rock"	2–4
4.	Shale, variable, some slaty	1–3
3.	Coal, with two seams of clay	2½–3
2.	Fire clay	1–6
1.	Limestone, the "Bottom Rock"	3½

It will be noted that the "Fifty-foot Limestone," No. 9 in the above section, is the only bed of more than local value for road work, and accordingly a careful study has been made of the exposures of this ledge in the area north and northwest of Centerville. A large number of exposures have been seen, the best being in SW¼ SW¼ section 24, Vermillion Township, where nine feet of limestone is available under an area of at least 1½ acres and is sound and hard, with a French Coefficient of 8.85. The same ledge is available and has been quarried at several other points. The "Floating Rock" and "Little Rock" ledges appear and have been quarried in a small way at a number of places near Centerville, Mystic, and Rathbun.

The "Fifty-foot Limestone" appears at numerous points in the county besides those north of Centerville that have been mentioned. For example, it is known to be five feet thick in SW¼ section 21, Pleasant Township (T. 68 N., R. 18 W.). In a mine shaft in SE¼ NW¼ section 2, Walnut Township (T. 69 N., R. 18 W.), it is 11 feet thick and 4 feet below the ground surface, though it fails to outcrop nearby. At a few points in section 31, Independence Township, it appears in various thicknesses up to 15 feet, but only small quantities are available. In this locality the stone is shaly and unsound along some of the bedding planes.

Shale

Appanoose County has for years been the seat of an extensive coal mining industry. The waste heaps at these mines form an extensive source of road surfacing material, which has already been widely used and which shows an important potential value for the future. Mine dumps with railroad connections are very numerous; in 1908 there were 62 of these. The railroad connection to many of these has since been removed, but nearly all are easily accessible to the public highway. Smaller dumps are entirely too numerous to mention. Mine slag is available in every township west of Chariton River and, except possibly for Franklin and Independence Townships, can be obtained in large quantities. No mines are known in the area east of Chariton River. In this connection, it must be remembered that this material has a wide range in quality, and by no means is all of it suitable for surfacing, even on roads of light traffic.

Sandstone and Conglomerate

Such sandstone as has been found in the county is not well enough cemented to be of value for crushing and is too fine of grain to be used as aggregate, except possibly in some of the asphaltic mixtures. Exposures are scattered and for the most part limited to the area east of Chariton River.

Channel deposits of conglomerate of Pleasanton age appear at a few points in the county. The component fragments of this conglomerate consist for the most part of hard and sound gray or white limestone apparently derived from the lower part of the Des Moines series. Associated with the limestone at many localities are numerous small particles of coal. The fragments are usually but little worn, indicating that they have not been transported far. They range in size from the lower limit of visibility up to several inches. The matrix is yellow to brown in color, of sandy, ferruginous, and calcareous composition, and is in places well indurated, while at other points it is soft and friable and breaks down readily under weathering. Though the conglomerate fragments themselves are suitable for concrete aggregate, the widely differing and in many cases undesirable character of the matrix and the abundant presence of coal particles make the rock of little or no value for that purpose. For surfacing work it is suitable except those zones which contain but few limestone fragments and a high proportion of soft easily-weathered matrix. No exposures have been seen where the matrix is soft enough to be completely broken down in crushing and screening, so that it might be screened out and wasted, as with sand or clay.

Known deposits of conglomerate in Appanoose County are as follows: in NW¼ NE¼ section 26, Pleasant Township (T. 68 N., R. 18 W.), a small quarry recently worked for agricultural lime and showing a bed about 15 feet thick; in SW¼ NW¼ section 1, Taylor Township, an abandoned quarry exposing a 15-foot bed; and in S½ SW¼ section 9, Douglas Township (T. 69 N., R. 17 W.), 14 feet of rather fine-grained conglomerate reported by Bain.[7] The writer has not examined

[7] Bain, H. F., Geology of Appanoose County: Iowa Geological Survey, Vol. V, p. 394, 1895.

this last-mentioned deposit, but the other two show at least several thousand cubic yards of material available under reasonable stripping. It should be mentioned here that, in view of the probable great range in quality of this material within short distances both horizontally and vertically, careful prospecting by the drill or other means is advisable before much money is spent on development of it.

Sand and Gravel

The central part of the county has been carefully examined for sand and gravel deposits, two of which have been found worthy of mention, as follows: south of center of section 29, Vermillion Township, 8,000 cubic yards of gravel suitable for road surfacing; and in SE¼ SE¼ section 32, Vermillion Township, a large deposit of fine clayey sand suitable for foundry work or perhaps for a filler in asphaltic aggregates, underlain by an unknown though probably large quantity of gravel. It may be that these two deposits are of the same age, having been laid down in a channel now filled and buried. At many points in this locality the till itself shows an unusually sandy or gravelly phase; this material compacts under highway traffic to a hard moisture-resisting surface.

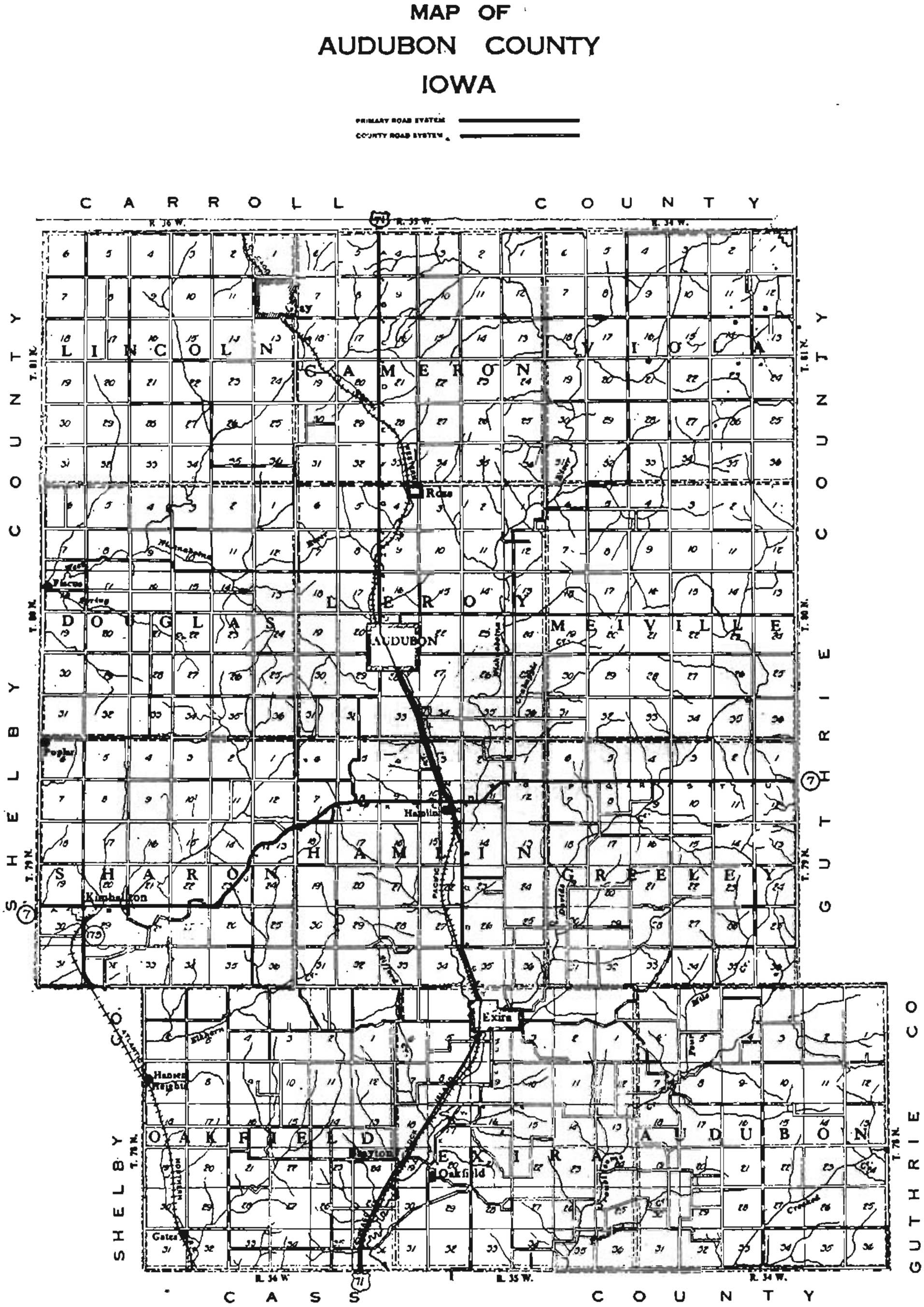
No complete survey of possible sand and gravel deposits in other parts of the county has been made, and it may be that such a survey would disclose other supplies of value equal to that of those mentioned.

AUDUBON COUNTY

With regard to the presence and availabiliy of road materials Audubon is one of the more barren counties in the state. No exposures of the indurated rocks are known, though it is possible that sandstones of the Dakota stage of the Cretaceous appear at a few points in the east part of the county. The Nebraskan and Kansan ice sheets spread a mantle of drift over the whole county, though the former is exposed only along the deeper valleys. Such gravel deposits as appear are within or upon this drift mantle. Loess covers the drift in all but the most sharply dissected areas. Alluvial deposits have been formed in the valleys of the larger streams, but those of most recent age and thus nearest the surface consist only of clay, silt, or very fine sand.

Sand and Gravel

Glacial gravels are perhaps as extensive in Audubon as in any other county of the Nebraskan-Kansan drift area. About twenty-five pros-


MAP OF
AUDUBON COUNTY
IOWA
CARROLL COUNTY
SHELBY COUNTY
GUTHRIE COUNTY
CASS COUNTY
SHELBY CO
GUTHRIE CO
LINCOLN
CAMERON
VIOLA
DOUGLAS
LEROY
MELVILLE
SHARON
HAMLIN
GREELEY
OAKFIELD
EXIRA
AUDUBON
Audubon
Exira
Hamlin
Kimballton
Brayton
Oakfield
Gates
Ross
Gray
Poplar
Hamlin
Viola

pects for this kind of deposit, distributed throughout all parts of the county, have been investigated. Most of them have been found to contain no gravel whatever, or to contain such a small quantity as to be not worth developing. The most valuable are listed below:

NW¼SW¼ sec. 29, Sharon Twp.----------------------6,000 cu. yds. available.
SE¼SE¼ sec. 30, Sharon Twp.-------------about 3,000 cu. yds. still available.
SE¼SW¼ sec. 24, Leroy Twp.----------------------1,000 cu. yds. available.
NE¼SE¼ sec. 5, Exira Twp.------------------------1,000 cu. yds. available.
SE¼SE¼ sec. 7, Exira Twp.-------------------------1,500 cu. yds. available.

The material in these deposits is quite similar, being a brownish iron-stained rather clayey gravel, most of it not very coarse and in some cases grading into a coarse sand. It is suitable for surfacing roads which carry only a medium or light traffic but is hardly of good enough quality for heavy-traffic surfacing or for concrete or asphaltic aggregate.

Soundings for a highway bridge over East Nishnabotna River near the southwest corner of the town of Exira (sec. 4, Exira Twp.) show a bed of sand and gravel 10 to 13 feet thick under 15 to 20 feet of soil and silt. The soundings cover an area 200 feet long and 50 feet wide. The sand and gravel are underlain by several feet of clay. The presence of such a deposit at this point suggests the possibility of finding others in the alluvium of this stream. Soundings in the alluvial deposits along the smaller streams of the county show only silt and clay, with very small amounts of sand or gravel.

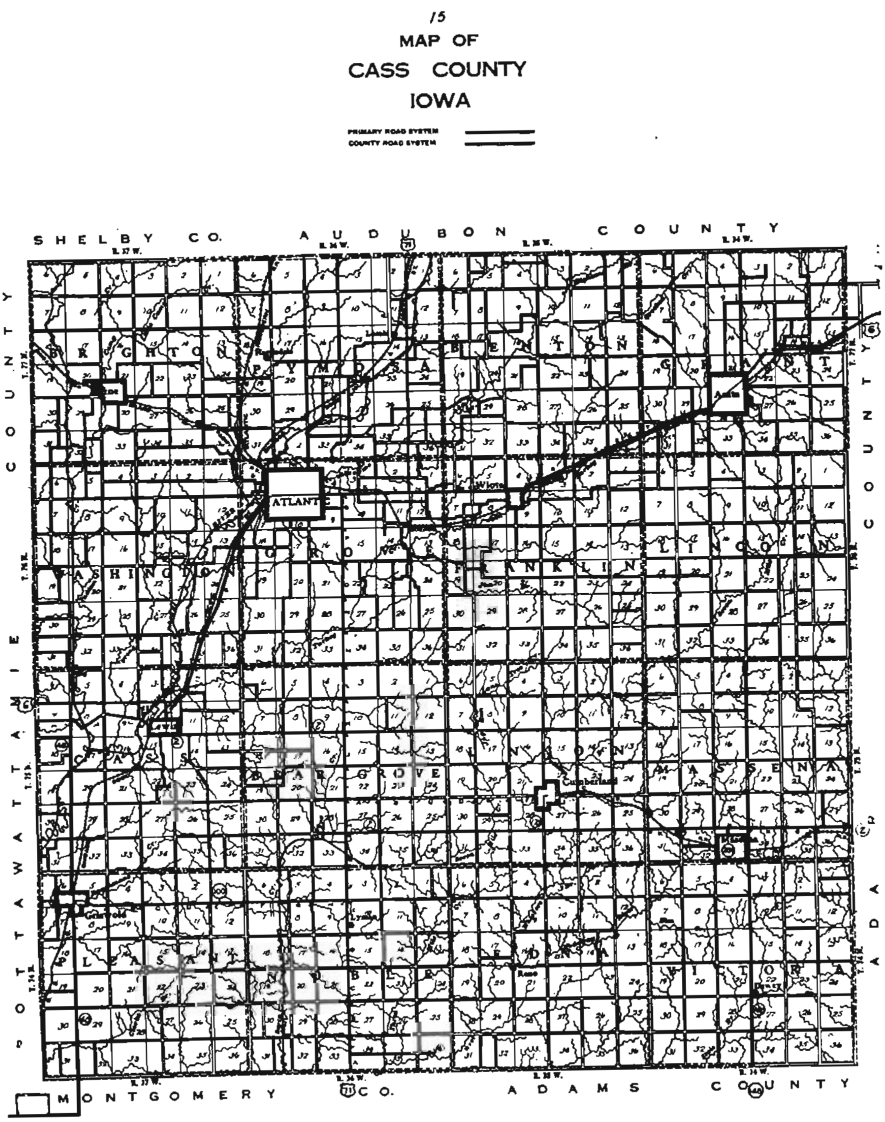
CASS COUNTY

In Cass County, the bedrock appears only in the south-central and southwest parts. A series of limestones and shales well exposed west and southwest of Lewis may confidently be referred to the middle portion of the Missouri series and probably represents the Oread and adjacent members of the Douglas stage. Another well-exposed series of limestones and shales near the southwest corner of Edna Township also may represent the Oread and associated beds, though it differs somewhat in detail from the sections at Lewis. A few scattered and very limited exposures northeast of Lewis are likewise provisionally referred to the Oread.

A fine-grained yellowish to reddish-brown, poorly indurated sandstone of the Dakota stage of the Cretaceous system is well exposed near Lewis and at several other points in the south-central and southwest parts of the county. The conglomerate which has been found associated with similar sandstone in Guthrie and Montgomery Counties appears to be lacking in Cass.

Glacial drift sheets of Nebraskan and Kansan age spread a mantle over the bedrock of the entire county, in different thicknesses up to more than 200 feet. The Nebraskan probably appears only in the deeper valleys, while the Kansan may be seen in almost every square mile in

IOWA GEOLOGICAL SURVEY. PLATE X



the county. Post-Kansan loess forms a veneer a few feet to 25 feet thick over the glacial drift in all but the most dissected areas.

Limestone

The following rock section seems to be general in sections 8, 17, and 19, Cass Township:

		Feet	Inches
10.	Shale, drab, clayey, with thin calcareous harder layers	5½+	
9.	Limestone, somewhat irregularly bedded, with thin shaly partings, yellowish gray, fine-grained, hard, with a few chert nodules	2–3	
8.	Limestone, one strong bed, light gray, fine-grained, hard and sound	1	2
7.	Shale, drab to dark gray	1	3
6.	Limestone, in three beds separated by shale seams 1 inch to 3 inches thick, very dark gray in color, fine-grained, very hard, with numerous large nodules of dark colored chert	2–3	
5.	Shale, buff to drab	2–3	
4.	Limestone, gray, fine-grained, hard		4
3.	Shale, drab, with 2 feet of very dark gray shale near the top	6	6
2.	Unexposed, at and below river level at southwest corner section 17; about	3	
1.	Limestone, hard, in several beds separated by seams of softer material, gray, somewhat granular or sandy. Known only from bridge soundings at southwest corner sec. 17	7+	

The whole of this section is now known only at southwest corner, section 17, but the middle members appear also in NE¼ NE¼ section 19, and at two points in the S½ section 8. On account of abruptly increasing overburden, Nos. 6, 8, and 9 are unavailable for quarrying except in small quantity. Number 1, being below river level, likewise can be worked only with difficulty.

Beds apparently the equivalents of Nos. 6 to 9 of the foregoing section have been uncovered in a new channel of Nishnabotna River in NW¼ NW¼ section 15, Cass Township, but are there also unavailable except in very small quantity. Tilton[8] has reported sections in NW¼ and in NE¼ NE¼ section 9, Cass Township, that are believed to include beds from the same horizon. From his descriptions it is obvious that nothing is now available at these two points, though at the latter there has been some quarrying in the past.

The following section has been worked out in a test hole and along a small ravine west and southwest of the Weeks quarry (Fox quarry in the older geological reports), in the NE¼ SE¼ section 36, Noble Township:

		Feet
25.	Limestone, buff	4
24.	Shale	10½
23.	Limestone, shaly, yellowish gray	¾
22.	Shale, green	4

[8] Tilton, John L., Geology of Cass County: Iowa Geological Survey, Vol. XXVII, pp. 192, 193, 1916.

21.	Shale, black	3
20.	Limestone, hard, sound, fine-grained, one strong ledge	4
19.	Shale	1
18.	Limestone, interbedded with thin, irregular seams of shale totaling perhaps 15 percent of the member. The limestone is hard and sound	4
17.	Limestone, crowded with fusulinids, hard and sound	2
16.	Shale	1
15.	Limestone, massive, hard, sound, crowded with segments of crinoid stems	2
14.	Shale	2
13.	Limestone, bluish gray, hard and sound, contains numerous segments of crinoid stems	1
12.	Shale	2
11.	Limestone, drab, hard and sound	2
10.	Shale	2
9.	Shale and sandstone	4
8.	Shale	4
7.	Limestone	1½
6.	Shale	½
5.	Limestone	1
4.	Shale	½
3.	Limestone	1
2.	Shale	12½
1.	Limestone	?

Numbers 15 to 20 inclusive of the above section constitute the only horizon of value, and these are the beds at one time worked in the Fox quarry and across the road to the east, in NW¼ SW¼ section 31, Edna Township, the old Phelps quarry. At the latter point, there is a tendency for Nos. 15, 16, 17, 18, and 19 to coalesce into a zone of irregular lenses or lumps of hard, sound limestone separated by soft shaly partings which in the upper part of the zone are thicker and more numerous. Number 20 and the limestone portions of Nos. 15 to 19 are suitable for concrete aggregate or surfacing stone. The strata at this point dip to the southwest, and overburden on the usable ledges increases abruptly, but it appears that by working a long narrow strip along the edge of the hill, 10,000 cubic yards or more might be obtained under an overburden nowhere more than 25 feet thick. At the old Phelps quarry approximately equivalent quantities are available.

Along West Nodaway River for one or two miles both east and west from the location just mentioned a few scattered outcrops show beds that apparently are equivalent to members of the preceding section. At no point, however, are the beds as well exposed or as easily available as in the two locations mentioned.

The favorable situation at Atlantic with regard to rail connections calls attention to the possibility of mining the deeply buried limestone ledges from a vertical shaft. The only information at hand which bears on this possibility is a record of a deep well boring near the depot, which penetrated a 15-foot ledge at 200 feet depth.

Sandstone

As was mentioned previously, the Dakota sandstone appears at numerous points in the south-central and southwestern parts of the county. It is available at several places in considerable quantity. However, it is too fine of grain to be broken down and used as aggregate, except possibly with a coarser aggregate in the asphaltic mixes, and it is not well enough indurated to be crushed and handled as crushed stone for surfacing or concrete work.

Sand and Gravel

A rather comprehensive survey of the glacial gravel deposits in this county has failed to show any of large size. The most valuable ones discovered are as follows:

NE$\frac{1}{4}$SW$\frac{1}{4}$ sec. 7, Noble Twp., 2,000 cu. yds. available.
NE$\frac{1}{4}$SE$\frac{1}{4}$ sec. 2, Grant Twp., 600 cu. yds. available.
NE$\frac{1}{4}$NE$\frac{1}{4}$ sec. 29, Union Twp., 800 cu. yds. available.
NW$\frac{1}{4}$SE$\frac{1}{4}$ sec. 32, Bear Grove Twp., 450 cu. yds. available.

The material in these deposits is all quite similar, with 70 to 80 percent passing the No. 4 screen, and 7 to 12 percent of silt and clay. In addition to these three, some 45 other gravel prospects, in all parts of the county, have been investigated.

In the vicinity of Lewis the valley of East Nishnabotna River is notably constricted by the presence in its sides of beds of Pennsylvanian shale and limestone and Cretaceous sandstone which have offered strong resistance to erosion processes. In the wider valley immediately downstream from this constriction, deposits of clean sand and fine gravel have been laid down, and some of this is available and even now is being utilized. About one mile west of Griswold (NE$\frac{1}{4}$ NE$\frac{1}{4}$ sec. 12, Waveland Twp., Pottawattamie County) a small pump in the river channel works a 15-foot bed of clean material with about 90 percent passing the No. 4 screen. Though the sand part of the material is rather fine, it has a ready market for local concrete work, for which it seems to be satisfactory. Well data nearby indicate that the bed extends beneath the bottomland on several acres to the west, under 15 to 20 feet of overburden. A bridge sounding near the center of the west line of section 16, Cass Township, Cass County, shows seven to nine feet of sand and gravel under about six feet of overburden. The area occupied by this deposit is not known. It is believed that systematic search in the bottomlands between Lewis and Griswold might reveal other supplies of similar nature.

CLARKE COUNTY

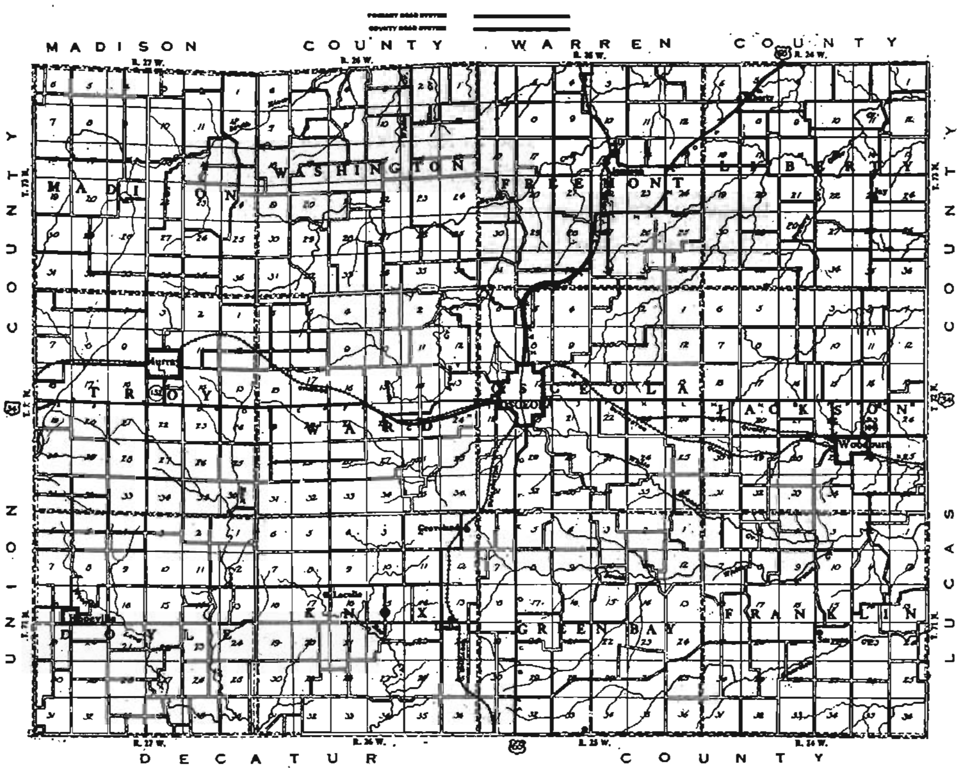
Strata of the Des Moines series form the country rock in the northeastern one-third of the county but are exposed only at very rare intervals and even there to an extremely limited extent. In the remainder of the county the uppermost consolidated rock is referred to the Missouri series. Exposures are few and positive correlations thus difficult to work out, but study of the local data and comparison with the sequence in the adjoining counties of Madison and Decatur indicate the succession and probable thickness of the members of the Missouri series to be about as follows:

Winterset limestone	12 feet
Galesburg shale	10 feet
Bethany Falls limestone	16 feet
Ladore shale	21 feet
Hertha limestone	14 feet

IOWA GEOLOGICAL SURVEY. PLATE XI

20

MAP OF
CLARKE COUNTY
IOWA



Upon the indurated rocks, the Nebraskan and Kansan drift sheets are found in a mantle ranging in thickness up to about 200 feet. Positive reference of most of the exposures of glacial materials in the county to one or the other of these drifts is usually difficult or impossible; however, Kay's studies [9] have indicated that the outcroppings in the lower slopes bordering a few of the deeper valleys are probably Nebraskan, while those in the higher uplands are Kansan. Loess is present at the surface in the less dissected upland areas, but its thickness is probably nowhere more than a few feet, and the areas where it has escaped removal by erosion are small.

Limestone

The Hertha, Bethany Falls, and Winterset limestones are known to outcrop in the county, most of the exposures being in the north part of Franklin and Green Bay Townships, the north part of Washington Township, and the northeast part of Ward Township, extending a short distance into adjacent parts of Washington and Osceola Townships. The Hertha limestone, as identified here, consists of two limestone members separated by a heavy bed of shale and is not known to be available by stripping except in very small quantity. The Winterset has not been found to outcrop in its full thickness at any point in the county, but the lower portion of it, much weathered, appears in conjunction with the Bethany Falls limestone in NE¼ NE¼ section 11, Ward Township. The Bethany Falls is reported to outcrop in NE¼ SW¼ section 14, Green Bay Township, but the exposure there is limited and now much obscured, and definite information as to availability of the stone is not at hand.

The only locality in Clarke County where limestone is now well exposed and easily available for quarrying is in sections 1, 2, 11, and 12, of Ward Township. The Bethany Falls limestone forms there an escarpment along both sides of the valley of Squaw Creek and the lower courses of its tributaries, and it is available by stripping in considerable quantity at several points. To the southwest it passes from sight beneath the bed of Squaw Creek and its tributaries, while to the east in section 6, Osceola Township, it has apparently been removed by pre-Pleistocene erosion. The following is a composite of two sections of the Bethany Falls, one near the center of SE¼ section 2, and the other one-fourth mile east of northwest corner of section 12.

9 Kay, G. F., and Apfel, Earl T., The Pre-Illinoian Pleistocene Geology of Iowa: Iowa Geological Survey, Vol. XXXIV, p. 207, 1928.

	Feet	Inches
8. Limestone, of granular texture, sound and hard. Not usually well exposed and believed to be missing at many points as a result of pre-Pleistocene erosion	4	
7. Shale, calcareous	1	3
6. Limestone, gray, hard and sound, in thin and rather wavy ledges, with three or four shale seams totaling perhaps 2 inches in thickness	3½–4	
5. Limestone and calcareous drab shale. About one third of the member, mostly in the middle part, is hard and sound gray limestone	1	3
4. Limestone, gray. A 4-inch zone near the middle and a 2-inch zone at the bottom are brown, soft, and unsound, but the remainder is gray, hard and sound	2	2
3. Shale, drab to buff, calcareous and hard, especially in the middle part	1	
2. Limestone, gray, medium grained, hard and sound, in several regular beds	3–3½	
1. Drab shaly limestone grading into calcareous shale	2+	

Bed No. 1 of the foregoing section represents the uppermost member of the Ladore shale.

Tests on the limestone members of the Bethany Falls in this county show that it is suitable for road surfacing or for concrete aggregate, if we except zones such as those noted in the section just given. It is now being worked for these purposes and also for agricultural lime by the Clarke County Lime Co., east of the northwest corner section 12, Ward Township. Their plant is of small capacity and may be characterized as being of the semiportable type. Other quarries have operated in this vicinity in the past.

Sand and Gravel

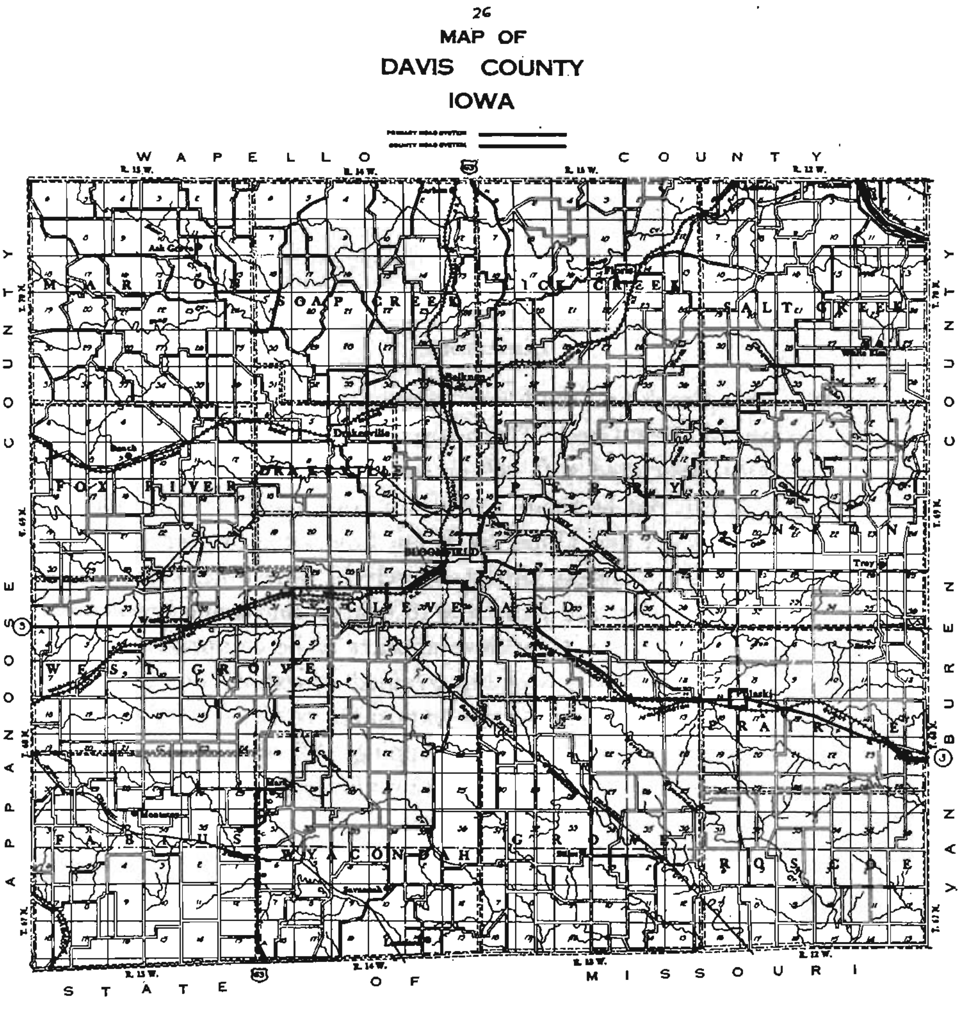
A comprehensive survey of all known gravel and sand prospects within the glacial deposits of the county has been made. While it is realized that such a survey can never be complete — that with the passage of time additional possibilities will always continue to be discovered — it is nevertheless believed that the best-known and most accessible deposits have all been investigated. Some 45 prospects, located in various parts of the county, have been examined. Most of them are found to be too small to be worth opening, but two exceptions are noted, as follows: In NE¼ NE¼ section 22, Knox Township, some 2,600 cubic yards of gravel suitable for road surfacing but with too high a clay content for concrete aggregate is available. Near the north quarter-corner of section 23, Fremont Township, about 11,000 cubic yards of similar material may be obtained.

Alluvial deposits are not extensive in Clarke County, as all of its streams rise within its borders and none attains large size. Such deposits as are found are derived from the glacial materials and thus consist almost entirely of silt or fine sand. Small short streams of high gradient that cut through unusually sandy or gravelly zones of the drift may carry small quantities of sand or gravel, but definite locations of any outstanding examples of such streams are not known.

DAVIS COUNTY

The formations of the Mississippian system underlie all the county but are exposed only in a small area bordering the valley of Des Moines River and the lower courses of its tributaries in sections 2, 11, 12, and

IOWA GEOLOGICAL SURVEY. PLATE XII



13 of Salt Creek Township. Exposures in these localities represent the St. Louis limestone and probably also the Ste. Genevieve. With the exception of this small area, the bedrock of the whole county is referred to the Cherokee stage of the Des Moines series, and it consists principally of shale, with subordinate amounts of sandstone and a few thin beds of dark-colored limestone. As is usual in the lower portion of the Cherokee stage, the deposits are lenslike in character, and individual beds show such differences horizontally as to make exact correlation of the various exposures difficult or impossible. Known outcroppings of any consolidated rock are limited to the three townships of Salt Creek, Lick Creek, and Soap Creek.

Glacial drift of Nebraskan and Kansan ages mantles the bedrock in various thicknesses up to 300 feet. The Nebraskan appears only along the lower sides of the deeper valleys, while the Kansan constitutes the higher upland slopes. A rather heavy clay, much of which may be Kansan gumbotil, forms the surface soil in the less dissected interstream areas, while near the major valleys it has been largely removed by recent erosion. Except in the valley of Des Moines River, alluvial deposits are small and consist almost entirely of silt or silty fine sand.

Limestone

Along Vesser Creek and the lower courses of some of its tributaries in $N\frac{1}{2}$ section 13, Salt Creek Township, are numerous exposures of limestones with associated soft yellow sandstones. The complete succession of beds can not be made out on any one point, but it appears that the Ste. Genevieve and Upper St. Louis limestones are represented. The Upper St. Louis consists almost entirely of limestone, some well-bedded and ranging in grain from fine to coarse, and some brecciated or conglomeratic. The Ste. Genevieve appears to be composed of soft sandstone in the lower part and fine-grained limestone in the upper part. The total vertical range of the exposures is about 35 feet, and moderate quantities are available by stripping. All of the limestone is suitable for road surfacing work, and the major part is probably satisfactory as a source of concrete aggregate.

In the bluffs bordering the valley of Des Moines River in sections 2, 11, and 12 of Salt Creek Township are scattered and limited exposures of beds similar to those just described. The bed of the river in this part of its course seems to consist almost entirely of solid limestone, which is locally covered with a thin bed of boulders, gravel, or sand.

A 4-foot ledge of black carbonaceous limestone of Pennsylvanian age overlies a coal seam which outcrops in the north bluff of Soap Creek near the point where it crosses the north line of section 6, Salt Creek Township. A test shows the material to be hard and sound. Only very limited quantities are available by stripping, while the thinness of the ledge makes mining rather expensive. An argillaceous limestone, or "cement rock," which appears in the same vicinity is unsound and thus not satisfactory for road or concrete work, though its chemical composition indicates that a fair grade of natural cement might be made by burning it.

Shale and Sandstone

The Pennsylvanian shales, which appear in a number of places in the north part of the county, are of no value for road work unless burned, as in a coal mine dump. There are a few coal mines near Laddsdale and Carbon, but they are small and their refuse piles offer only very limited quantities of surfacing materials.

Sandstones of the same age have been quarried in a small way in the area north and northeast of Belknap, but no beds sufficiently indurated to be of value for crushing and available in any workable quantity are known.

Sand and Gravel

No sand or gravel deposits within or upon the glacial till are known to be exposed in this county. This does not necessarily imply that none such is present. It is believed that if the same careful search were made in Davis as has been made in some of the other counties of southern Iowa, a number of sand or gravel pockets would be found, most of them small, but a few, perhaps, of usable size.

With the exception of Des Moines River, alluvial deposits of sand or gravel occur only in the beds of a few small streams of high gradient that may be actively cutting in sandy or gravelly zones of the glacial drift. Definite locations of any such small streams are not known. Material supplies originating from them would necessarily be of very small size.

A survey of Des Moines River channel from Des Moines to Keokuk reveals only two bars in Davis County, one in NW¼ SE¼ section 2, and one in NW¼ NW¼ section 12, Salt Creek Township; both on the northeast side of the river. Both of these bars are low, rising not over one foot above ordinary low water level. The upper one extends over 3 or 4 acres and the lower one over two acres. Both show fine gravel and coarse sand at the upper end, grading to a medium or fine sand at the lower end.

DECATUR COUNTY

The beds of the Des Moines series underlie the whole of the county and are found next beneath the unconsolidated materials in the eastern third. In the west two thirds they are overlain by the alternating limestones and shales of the Kansas City stage of the Missouri series. All of the Kansas City stage, except possibly the Chanute and Iola members, appears within the county, mainly along or near Grand River. The Bethany Falls, Winterset, and DeKalb limestones outcrop extensively and in places form conspicuous rock bluffs.

Upon the bedrock is a mantle composed of the Nebraskan and Kansan glacial drifts and of various thicknesses up to about 300 feet. Though differentiation between the two is often difficult, it may be said that the Nebraskan appears only in the lower slopes of the deeper valleys, while the Kansan is present on the upper slopes and in the higher uplands. Loess forms a veneer a few feet thick in the less dissected areas, while near the major valleys it has been very largely removed by recent erosion.

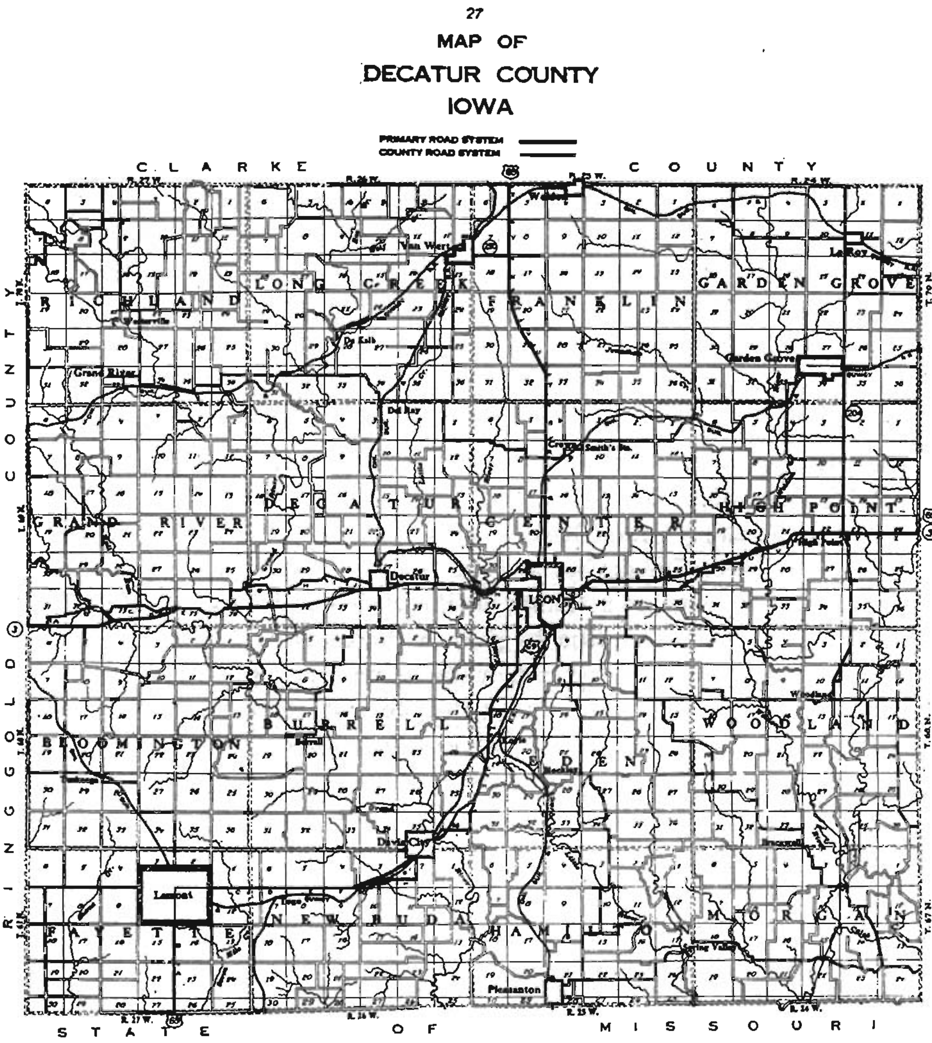
Limestone

The succession of the various members of the Kansas City stage of the Missouri series has already been given, in Chapter II of this report. A large amount of work has been done on the stratigraphy of the Missouri series in the county; but so many of the outcroppings lack continuity, and the various formations are so similar to each other in general character that positive correlation between all of the exposures is still incomplete. The correlations given in this chapter are the best that can be made on the basis of available information.

The Hertha and Bethany Falls limestones appear at a number of points in western Morgan and eastern Hamilton Townships, in the southeast part of the county. As this territory is at some distance from either railroad or main highway, no careful study has been made. Information at hand indicates a maximum exposed thickness of about five feet, while two test samples show a hard and sound stone, suitable for aggregate or for surfacing work. Quantities of 1,000 cubic yards or more are available by stripping, principally in sections 12 and 13 of Hamilton Township and sections 15 and 17 of Morgan Township.

Near Davis City are a number of good exposures and several old quarries. None of the quarries is now being operated, though one has been worked as recently as 1929. Nearly all of the prominent exposures may be referred to the Bethany Falls or to beds immediately above or

IOWA GEOLOGICAL SURVEY. PLATE XIII



below. The following section, in the quarry near north quarter-corner of section 10, New Buda Township, is typical:

	Feet	Inches
9. Limestone, gray, hard and sound	2	2
8. Shale and clay	1	2
7. Limestone, gray, hard and sound	1	1
6. Shale and clay	1	3
5. Limestone, gray, hard and sound	1	4
4. Limestone, similar to No. 5	2	11
3. Shale seam, wavy		2
2. Limestone, in several beds which are persistent but range in thickness from a few inches to a foot or more. The total thickness of the ledge runs nearly uniform. Between the beds are very thin zones of soft unsound marly limestone which undulate but pursue a general horizontal course. The limestone is gray in color and sound	8	5
1. Shale, gray and yellow above and black below	2	1

Number 1 is the uppermost member of the Ladore shale. The lower part of the Ladore may be seen in the creek bank below, and Bain has stated [10] that the Hertha (Fragmental) limestone at one time appeared in the bed of the creek beneath. As far as is now known, the Hertha is not now exposed at this point. The Bethany Falls here passes back beneath a low broad ridge and is shown by test holes to be available on an area of about 6 acres under a maximum overburden of 15 feet. The Winterset is reported to outcrop farther upstream, but details as to its character and thickness are lacking.

In the central part of section 35, Burrell Township, the Hertha has a thickness of 6 feet and the Bethany Falls has a thickness of 12 feet. The latter is available in considerable quantity near the center of the NW¼ section 35.

Exposures along Grand River are numerous and for the most part extensive between Davis City and the State Road bridge west of Decatur. Beyer [11] publishes a section on Pot Hole Creek (sec. 29, Burrell Twp.), in which the Hertha is given a thickness of 4 feet, and the Bethany Falls from 6 to 10 feet, while he reports [12] the Winterset as appearing farther upstream with a thickness of 15 feet. The Hertha and Bethany Falls members are well exposed along a small creek running south through sections 9 and 16 of Burrell Township. In sections 7, 8, 17, and 18, erosion has been especially active and both the Bethany Falls and Winterset members are well exposed under light cover, with large quantities available. In this locality a part of the Bethany Falls shows the nodular or fragmental appearance which characterizes it at

[10] Bain, H. F., Geology of Decatur County: Iowa Geological Survey, Vol. VIII, p. 280, 1897.
[11] Beyer, S. W., and Wright, H. F., Road and Concrete Materials in Iowa: Iowa Geological Survey, Vol. XXIV, p. 214, 1913.
[12] Beyer, S. W., idem, p. 215.

Bethany, Missouri. South of the highway bridge in NW¼ section 5, Burrell Township, are other exposures and an old quarry. In SE¼ SW¼ section 32, Decatur Township, is a limestone, probably the Bethany Falls, about 20 feet in total thickness (including five feet of shale in four beds), which is now being worked. Figure 1 is a view of the

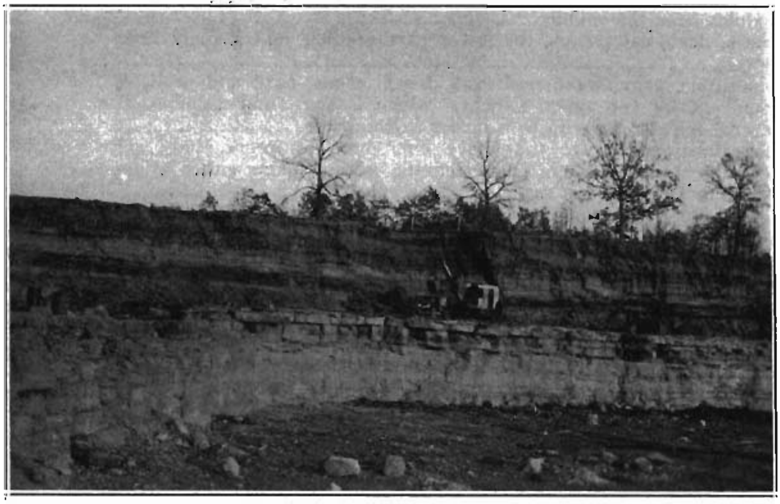


FIG. 1. — Sargent quarry in section 32, Decatur Township, Decatur County.

quarry here. Similar quantities have been found to be available in SE¼ SW¼ section 30, Decatur Township, and NW¼ NE¼ section 29, Decatur Township, both of these deposits being apparently referable to the Winterset, which is about 15 feet thick. At any of these locations mentioned the rock is easily available, and quantities up to 10,000 cubic yards or more can be obtained under not more than 15 feet overburden. The rock is for the most part hard and sound and suitable for aggregate or surfacing material; on the other hand, the presence of shale beds and thin zones of shaly unsound limestone between the ledges of harder limestone must be reckoned with.

On the lower course of Elk Creek, from its mouth as far west as section 34, Grand River Township, are other good exposures. The Bethany Falls, Winterset, and DeKalb limestones are represented, though the former appears only in the lower slopes along the last mile or so of the creek's course. The Winterset is well exposed downstream from SW¼ section 35, Grand River Township. The following section of it in SE¼ SW¼ is typical:

	Feet	Inches
11. Clay, glacial and residual	3	6
10. Limestone, yellow, weathered, has a somewhat earthy appearance. Contains several thin seams and zones of shaly material totaling perhaps 10 percent of the member	3	
9. Limestone, yellowish gray, medium grained, massive, hard and sound, fossiliferous	1	2
8. Shale, drab, calcareous, soft	1	
7. Limestone, hard and sound, gray, medium grained, fossiliferous, one bed when unweathered. With a thin discontinuous layer of chert nodules near the middle	2	8
6. Shale, drab, calcareous, the lower part grading into a shaly limestone	2	6
5. Limestone, gray, weathered drab, fossiliferous, hard and probably sound except for upper 4 inches, which is shaly and unsound. In several regular beds up to 6 inches in thickness	2	6
4. Limestone, similar to the above but somewhat more shaly and possibly unsound. There is no definite bedding plane either at the top or bottom of this member	1	8
3. Limestone, hard and sound, gray, medium grained, fossiliferous, in several beds up to 1 foot in thickness. A few small nodules of dark colored chert are noted in the lower part	4	6
2. Shale, gray to black, calcareous	2	
1. Unexposed to low water level in Elk Creek. Probably shale	5	

Numbers 1 and 2 represent the Galesburg shale, while the remainder of the section is referred to the Winterset. The exposure is almost continuous in the bluffs in S½ section 35, and large quantities are available. The limestone is all suitable for surfacing material (for which purpose some 28,000 cubic yards was removed in 1931 and 1932), and most of it is satisfactory for aggregate. The upper part of the Winterset appears and is available in moderate quantity at other points farther downstream; in E½ section 2; NE¼ section 11; along the north line of section 12; and at various places in E½ section 12, all in Bloomington Township; and in W½ section 7 and NW¼ section 18, Burrell Township.

The section previously given may be seen south of center section 2, Bloomington Township, where it is overlain in ascending order by 15 feet of dark gray calcareous shale with a 6-inch ledge of dark gray limestone in the lower part and by four feet of limestone in two ledges with a shale parting between. The shale is evidently the Cherryvale, and the limestone is the lower part of the DeKalb. The limestone is available in small quantity here and again farther upstream where it forms the bed of Elk Creek south of center NE¼ section 34, Grand River Township. A detailed section of it at that point is as follows:

	Feet	Inches
4. Limestone, dark gray, hard and sound, fine-grained, with an almost flinty texture showing on weathered surfaces	1	
3. Limestone, gray, fairly hard, but shaly and probably unsound, fine-grained, with numerous shale pockets		10
2. Shale, yellow to gray, soft		7

1. Limestone, gray to blue, hard and sound, medium-grained, fossiliferous	1	8

A section in the bank of the creek a few hundred feet south shows in ascending order above the top of the foregoing, about 5 feet of shale, 1 foot and 8 inches of limestone, 3 feet and 6 inches of gray shale, and about 5 feet of limestone interbedded with some shale. A more detailed section of this upper limestone and overlying beds has been obtained in SE¼ NE¼ section 34, as follows:

	Feet
6. Shale, drab	2
5. Limestone, soft, shaly	½
4. Shale, gray	½
3. Limestone, gray, medium-grained, fossiliferous, hard and sound	3
2. Shale, drab; about	½
1. Limestone, similar to No. 3	1

All of these strata are referred to the DeKalb. A few thousand cubic yards of the limestone (Nos. 1 and 3 of the foregoing section) is available at this point. The DeKalb again appears and is available in limited quantity near and south of center section 36, Grand River Township.

In the vicinity of DeKalb Station a complete general section of the beds has been worked out, as follows. Thicknesses are averages.

	Feet	Inches
13. Limestone, impure, hard, fine-grained, light gray when fresh but weathers rapidly and deeply to yellow. With numerous small crevices and cavities filled with drab shaly or marly material. Exposed in this thickness	3	
12. Shale, drab, calcareous		9
11. Limestone, hard, crystalline, gray, weathers brownish, probably one bed when fresh. With numerous small fossil forms	1	9
10. Shale, drab, calcareous, at some places a shaly unsound limestone	8	
9. Limestone, hard, crystalline, gray, weathers brownish, one bed when unweathered. With numerous small segments of crinoid stems and other small fossils	1	5
8. Shale, drab, calcareous, the lower part grading down to shaly and probably unsound limestone crowded with fusulinids	1	9
7. Limestone, gray, hard, crystalline, the upper part crowded with fusulinids. One bed	1	
6. Shale, drab, calcareous, the lower part grading below to a shaly unsound limestone	1	1
5. Limestone, gray, hard, crystalline. The lower part strongly fossiliferous, with segments of crinoid stems and other small forms	1	2
4. Shale, drab, calcareous, grading down to shaly unsound limestone	3	3
3. Limestone, dark gray, hard, crystalline. In beds of different thicknesses, fossiliferous. Certain beds show a pronounced tendency to weather out in large cubes	6	
2. Shale, drab above and gray below	1	5
1. Shale, dark gray to black, fissile. Exposed in this thickness	4	10

About 1½ miles southwest of DeKalb an imperfect exposure near an abandoned quarry shows some seven feet of limestone, which, for lack of intervening outcrops, can not be certainly correlated with the strata listed above. The beds seen there are described as follows: The lower two feet is a light-gray hard fine-grained limestone traversed by numerous cracks and with small cavities filled with a drab marly or shaly material; the four feet next above has a nodular or conglomeratic appearance and consists of small pellets of the same hard fine-grained limestone imbedded in a matrix of the same shaly material; above this are indications of a 6-inch ledge of limestone, gray weathering yellow, hard, crystalline, and fossiliferous. The lower two feet of the above strongly suggests No. 13 of the general section, but the exposure is too much limited and at too great a distance from the other outcrops to make this relationship certain.

With the exception of Nos. 1 and 2 of the general section, all of these strata are referred to the DeKalb. The succession of beds is in general similar to that west of Decatur, though the limestones are thicker and more numerous. The upper members of the general section appear in the bluffs east of Long Creek in NE¼ NW¼ section 28, and SE¼ SW¼ section 21, Long Creek Township, while the whole section may be seen in and near the west bank of the creek nearby. The upper members again appear along the north half of the west line of section 28. Limited quantities of rock are available in SE¼ SW¼ section 21, SW¼ NW¼ section 28, east of the creek, and near west quarter-corner section 28, west of the creek. The previously mentioned exposure 1¼ miles southwest of DeKalb (east of SW corner section 29, Long Creek Township) might also be worked for a limited quantity. It will be noted that the number and thickness of shale seams separating the limestone beds make hand working of any quarry necessary in order to produce satisfactory aggregate, or even surfacing stone.

Beds which apparently are the equivalents of the upper members of the preceding general section are well exposed in the bluffs south of Grand River at various points in sections 1 and 2, Grand River Township. Only limited quantities are available. The following is a typical section (N½ NE¼ section 1):

	Feet
4. Limestone, gray, hard, somewhat irregularly bedded. The upper part has a distinct nodular or conglomeratic appearance	6
3. Shale, drab	2
2. Limestone, one bed, gray, hard and sound, medium-grained, breaks off in large oblong blocks, and is conspicuous in the exposure	1½
1. Shale, dark gray to black	2

The following section is general on Sandy Creek west of Westerville:

	Feet
7. Limestone, one bed, yellowish, fine-grained, in places somewhat soft and shaly, shows a nodular or finely conglomeratic structure	1¼
6. Limestone, yellowish gray, medium hard, crowded with fusulinids	¾
5. Unexposed, about	2
4. Limestone, gray, medium-grained, hard, sound, usually in three strong ledges separated by very thin shaly partings. The lower and middle parts are crowded with fusulinids, the upper part less so. Other fossil forms also are numerous	3¼
3. Shale, drab above, dark gray below	6
2. Shale, dark gray, calcareous, with several thin beds, or lenses, none more than 3 inches thick, of dark-gray hard shaly limestone	6½
1. Shale and limestone, interbedded in about equal proportions	2

Beds Nos. 4, 6, and 7 of this section will yield small quantities of stone in SW¼ section 21, and SE¼ section 20, Richland Township. The succession appears south of the town of Grand River (SE¼ sec. 33 and SW¼ sec. 34, Richland Twp.), but the limestones are there almost entirely unavailable for quarrying.

A succession of strata in the west bank of Grand River at Westerville (SW¼ NE¼ sec. 21, Richland Twp.) evidently lies just below the beds of the foregoing section, as follows:

	Feet
5. Not well exposed. Signs of fusulina limestone at the top and of dark gray shale at the bottom; about	7
4. Limestone, one or two beds, dark gray, medium to fine grain, fossiliferous, hard, sound, a strong and persistent ledge	1¾
3. Limestone, two or three beds, dark gray, medium to fine grain, more shaly than the member above. Divided by irregular seams of shale so that it weathers out in lumps about 4 inches in diameter	1
2. Shale, drab above, dark gray below	2
1. Unexposed, to low water in Grand River, about	8

None of the limestone beds here is thick enough to be of any value for quarrying, except in very small quantities.

Sand and Gravel

Deposits of sand and gravel within or upon the glacial drift are known in this county, and a few have fairly large size, though most of them are unavailable. Most of those which have been discovered are at low enough level to be probably of Nebraskan age; this fact indicates a condition similar to that in Union county, where study [13] of the gravel deposits has shown them to be of that age. These glacial gravels show a large range in grading and nearly all contain enough clay and soft stone to preclude their use for concrete aggregate. They are, however, often found to be usable for road surfacing. The most important deposit, considering the amount of gravel available is in SE¼ SE¼ section 23, Burrell Township, where 5,400 cubic yards can

[13] Kay G. F., and Apfel, Earl T., The Pre-Illinoian Plestocene Geology of Iowa: Iowa Geological Survey, Vol. XXXIV, 1928.

be obtained. Open pits in NE¼ NE¼ section 28, Center Township, and in SW¼ SW¼ section 22, Richland Township, are now almost entirely worked out. In the SE¼ NW¼ section 35, Burrell Township, the bulk of a promising deposit lies beneath a cemetery. A terrace area of about two square miles extent in sections 1 and 2, New Buda Township, is apparently all underlain at an average depth of 20 feet by a 5-foot bed of coarse sand and fine gravel. This sand is, however, nowhere available under moderate stripping.

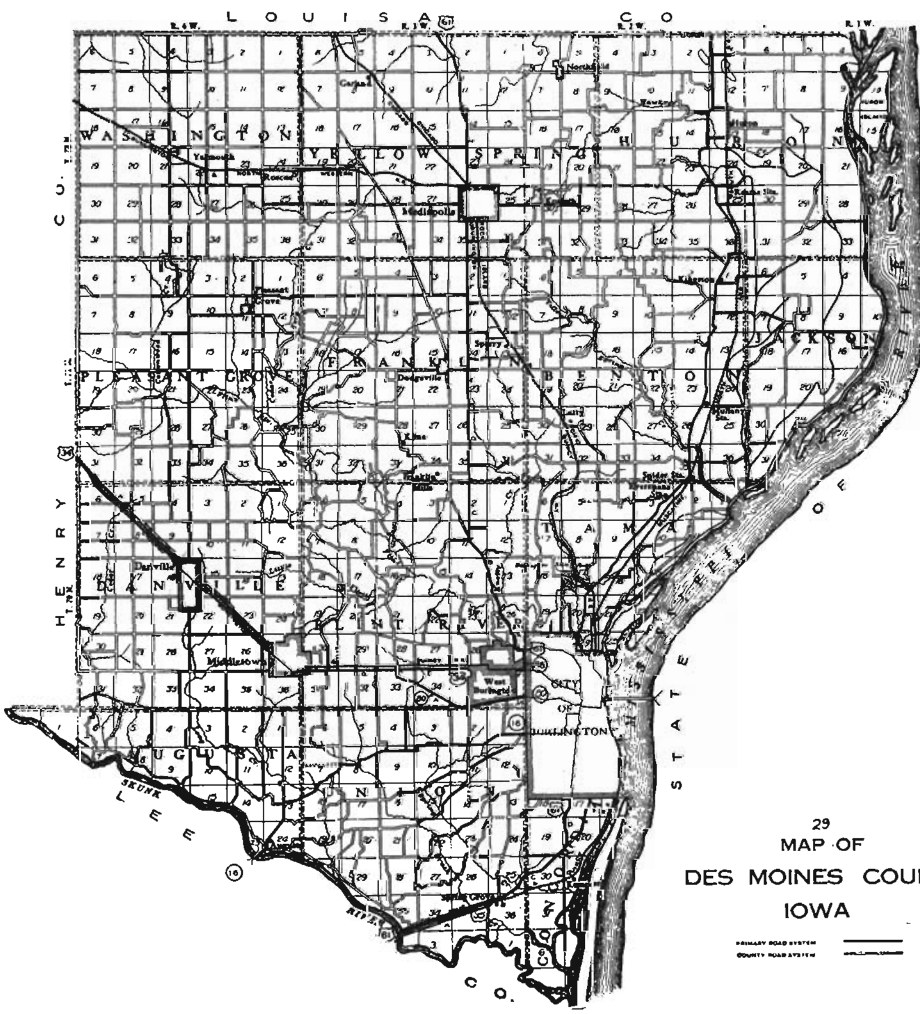
Besides the above, some twenty other gravel prospects have been investigated but not found to be worth opening. A careful visual survey of the bluffs bordering the valley of Grand River throughout its course in the county, and of Elk Creek from its mouth to section 34, Grand River Township, has disclosed a few possible sites for further examination, but none of these appears to be especially favorable.

Sand and gravel supplies of alluvial origin are not as a rule very extensive in this county. The larger streams have reached such a stage of maturity as to carry only silt and fine sand. However, a number of the medium-sized and smaller creeks have cut rather deeply into the glacial drift and a few of them into the underlying limestones, and they have accumulated along their courses bars of sand, gravel, and broken stone, in some places in fairly large amounts. Such an instance is seen in a small west-flowing creek on the south line of section 21, Eden Township. This stream, though very short, has cut through the Kansan drift down to a persistent layer of sand and gravel about one foot in thickness, probably of Aftonian age. During flood times, therefore, it carries considerable quantities of clean sand and a little gravel. Sand was formerly hauled from here to Blockley and there loaded on railroad cars and shipped out at the rate of three or four carloads per week. A typical small creek which deposits quantities of broken rock with the sand or gravel is that which runs southward through sections 9 and 16 of Burrell Township to join Grand River near the southwest corner of section 16. Other small creeks in the county, though perhaps not carrying as much material in proportion to their size as do the two mentioned, still have available deposits of clean sand and gravel that might be used for small improvement projects.

DES MOINES COUNTY

The greater part of the exposed consolidated beds in Des Moines county may be referred to the Osage group of the Mississippian system. The Kinderhook group appears in the lower bluffs and probably underlies the Mississippi valley flats north and south of Burlington. The Warsaw and Spergen formations and the St. Louis limestone occupy perhaps 30 square miles and are exposed in limited measure northwest of Augusta, where they are overlain by a few small outliers of Pennsylvanian strata, with a total area of perhaps 5 square miles. However, the best known and most conspicuous outcrops are of the Keokuk and Burlington limestones of the Osage group. The

IOWA GEOLOGICAL SURVEY. PLATE XIV



29
MAP OF
DES MOINES COUNTY
IOWA

Burlington takes its name from the city of that name, where it is easily accessible and where it was first studied.

Upon the indurated rocks is spread a mantle of glacial drift of various thicknesses but probably in very few places exceeding 100 feet. The surface drift is of Illinoian age, while Kansan and Nebraskan deposits lie beneath and are exposed in some of the deeper valleys. Loess overlies the glacial deposits on the flat uplands, but in the rougher areas near the larger streams it has been for the most part removed by recent erosion. Its thickness is almost nowhere more than 10 feet. The alluvium along most of the streams is of recent age and in many cases is being deposited even now. That of Mississippi River is an important source of road or concrete materials as will be explained later.

Limestone

Mississippi River Bluffs. — Rock forms the main part of the Mississippi River bluffs from the north county line south about eight miles (to sec. 12, Benton Twp.), and is exposed back to the west along the lower courses of the small tributary creeks. At many points only weathered material appears at the surface, but the fresh rock is found just beneath. The following section, obtained in SE¼ section 11, Huron Township, is typical for the north end of the area:

	Feet	Inches
13. Limestone, very coarse-grained, granular, strongly crinoidal, crumbles easily, with 9 inches of shale near the middle	3	
12. Shale, yellow		9
11. Limestone, brown, very soft		8
10. Limestone, coarse-grained, light buff to white, granular, crinoidal, one 3-inch chert band 2 feet from top	5	3
9. Limestone, similar to No. 10 except that it is bluish-gray in color	1	6
8. Shale, blue		1
7. Limestone, similar to No. 10	5	6
6. Chert nodules in limestone; 40 percent limestone	2–4	
5. Limestone, buff, fine-grained, upper half locally is hard, lower half is soft and locally contains a high percentage of chert; slightly crinoidal	2	
4. Limestone, buff, moderately hard, crinoidal, with a high percentage of chert in the lower third	9	
3. Limestone, buff, very soft, shaly	8	
2. Limestone, buff, massive, medium-grained, moderately hard, slightly crinoidal, magnesian	2	
1. Unexposed to bottom of bluff	20±	

Numbers 7 to 13 of this section may be referred to the Upper Burlington limestone, Nos. 2 to 6 to the Lower Burlington, and No. 1 probably to the uppermost strata of the Kinderhook. It will be noted that Nos. 7, 8, 9, and 10 constitute a zone of about 12 feet of coarse-grained crinoidal limestone, the zone most easily available and most quarried in the vicinity. It is suitable for road surfacing work and perhaps also for ordinary concrete work, though its rather granular and crumbly nature makes it somewhat soft and weak for use in high-strength concrete. It seems to be entirely sound and has been in the past used with satisfaction for building stone. The lower beds of the section given are in large part suitable for surfacing work but questionable for aggregate. Old quarries are known in SE¼ SE¼ section 11, NE¼ NW¼ section 14, and in SE¼ SE¼ section 14, Huron Township, all utilizing the crinoidal zone above mentioned. At many points fairly large quantities are available, though no one place is known where more than a few thousand cubic yards may be obtained under less than 15 feet of overburden.

The following section, obtained along a small creek in NW¼ section 1, Benton Township, is typical for that locality:

	Feet	Inches
15. Limestone, light buff to white, granular, coarse-grained, massive, crinoidal, medium hard	7	6
14. Limestone, brown, medium-grained, fairly hard, locally slightly sandy, weathers readily, crinoidal, contains numerous chert seams and nodules	8	0
13. Chert		6
12. Limestone, brown, coarse-grained, granular, fairly hard, one 2-inch chert band 3 feet from top	9±	
11. Limestone, yellow, hard, brittle, fine-grained, conchoidal fracture, contains a high percentage of chert	1	6
10. Limestone, same as No. 12	2	
9. Limestone, soft, sandy, medium-grained, unsound	1	9
8. Limestone, same as No. 12		9
7. Limestone, fine-grained, hard, brown, brittle, fractures easily	2	
6. Chert, white		4
5. Limestone, same as No. 12	1	9 to 6
4. Shale, sandy, yellow		8
3. Chert, white to gray	1 to 2	3
2. Limestone, yellow, fine-grained, soft and unsound, contains several bands and pockets of hard, brown, medium-grained limestone	6	
1. Limestone, reddish brown, coarse-grained, granular, hard, slightly crinoidal, contains numerous calcite crystals	4±	

This section apparently includes the full thickness of the Lower Burlington limestone at this point, while Nos. 14 and 15 are referred to the Upper Burlington. In section 36, Huron Township, and sections 1, 11, and 12 of Benton Township, these beds appear at a number of outcrops, though it is noted that Beds Nos. 3 to 11 show some local differences. As in the north part of Huron Township the crinoidal coarse-grained zone at the top is most easily available for quarrying though not obtainable in large quantity at any one point, except by heavy stripping. In quality the stone is in general similar to that occurring in section 11, Huron Township, and described above. No quarries are now known to be operating.

Preglacial or interglacial erosion has apparently cut out the rock in sections 14, 23, and 26 of Benton Township, along the Mississippi bluffs and along Yellow Spring creek as far upstream as section 22, Benton Township. Near the north line of section 35 the rock appears again and outcrops abundantly in that section and in the E½ section 34. The following is the general section:

	Feet	Inches
11. Limestone, light buff to white, granular, coarse-grained, medium hard, crinoidal	4+	
10. Chert		4
9. Limestone, medium-grained, yellow, soft	1	
8. Shale parting		
7. Limestone, buff to brown, coarse-grained, granular, medium hard, massive, strongly crinoidal	6	3
6. Shale parting		
5. Limestone, yellow, soft, medium-grained		9
4. Limestone, brown, medium-grained, sandy, massive, fairly hard, probably unsound	5	6
3. Limestone, light buff to white, hard, medium-grained, cracks and weathers badly	4	3
2. Limestone, yellow, fine-grained, hard, brittle, fragmental, contains high percentage of chert	5	
1. Limestone, very soft, shaly, buff at top shading into dark gray	9+	

It appears that Nos. 1 to 6 are referable to the Lower Burlington and Nos. 7 to 11 to the Upper Burlington. Much of the stone is of very questionable quality for aggregate though of value for road surfacing. Only limited quantities are available at any one point, unless under heavy stripping.

In Tama Township, exposures outside the city are very few, though an old quarry is reported as occurring in NE¼ section 17. No outcrops are known to exist in the Mississippi River bluffs.

The section at North Hill in Burlington (at the site of the Burlington Basket Co. factory) has been published by a number of writers and will not be repeated in detail here, as the beds are entirely unavailable for quarrying on account of surrounding permanent improvements. The typical succession is as follows:

	Feet
7. Limestone, brown, crinoidal, sound, medium hard	11
6. Limestone of different features but for the most part of good quality	8
5. Limestone, sandy or shaly	7
4. Limestone, curiously mottled or banded in brown and white on account of uneven dolomitization. Fairly hard but possibly unsound	7
3. Limestone, shaly	10
2. Sandstone, fine-grained, shaly	9
1. Shale, drab, calcareous. To river level	60 (app.)

All but No. 7 of this section are assigned to the Kinderhook.

A number of quarries have been worked in the city of Burlington in the past, but operations are all discontinued and now, on account of surrounding permanent improvements, resumption would be difficult or impossible. Both Upper and Lower Burlington limestones are represented.

The high bluffs fronting the river just south of Burlington show many good exposures of rock and a number of old quarries, all of which are now abandoned. The following section, near NE corner section 20, Concordia Township, (T. 69 N., R. 2 W.) is one of the most complete obtainable:

	Feet	Inches
36. Chert, white	2	6
35. Unexposed	1	6
34. Limestone, brown, hard, fine-grained, small percentage of chert, magnesian	1	6
33. Limestone, buff, coarse-grained, fairly hard, sound, strongly crinoidal		9
32. Chert, white		6
31. Limestone, brown, fine-grained, fairly hard, sound, magnesian	2	6
30. Limestone, coarse-grained, buff to white, fairly hard, sound, strongly crinoidal, with some chert nodules	7	
29. Limestone, buff, magnesian, fairly hard, sound, with numerous small pockets which weather out, giving a pitted surface	2	6
28. Limestone, buff to white, coarse-grained, strongly crinoidal, rather soft, unsound, with a few large chert nodules	6	3
27. Limestone, brown, medium-grained, slightly crinoidal, fairly hard, sound, upper 2 feet contains many thin seams of chert	4	3
26. Limestone, brown, hard, fine-grained, with high percentage of chert		8
25. Shale parting		
24. Limestone, fairly hard, sound, buff to white, coarse-grained, crinoidal	2	6
23. Limestone, differing in hardness, texture, and color, but mostly magnesian, some chert nodules, with several small geodic masses; weathers to an irregular pitted surface	7	6
22. Chert, white, very hard	1	2
21. Limestone, medium-grained, dark brown, slightly crinoidal, fairly hard, sound	2	10
20. Chert, white		6
19. Limestone, brown, hard, coarse-grained, crinoidal		9
18. Shale, yellow, calcareous	1	
17. Limestone, buff to white, coarse-grained, crinoidal, fairly hard, sound	2	6
16. Limestone, buff, soft, fine-grained, with a few chert nodules	1	
15. Limestone, buff, coarse-grained, fairly hard, sound, strongly crinoidal.	1	
14. Limestone, buff, rather soft, shaly and sandy, with layers of soft yellow shale in upper half, and numerous discontinuous chert bands, especially in the upper foot	16	
13. Chert, hard, white	1	5
12. Limestone, brown, medium-grained, soft, magnesian	2	
11. Limestone, buff, fairly hard, sound, medium-grained, crinoidal, with several chert nodules, and occasional bands or pockets of softer stone	11	
10. Limestone, buff, rather soft and earthy, but sound, sandy	4	6
9. Limestone, white, oölitic, hard, sound	2	
8. Shale, blue	1	
7. Sandstone, shaly, upper 3 feet gray and fairly hard, lower 1 foot buff and softer	4	

6. Limestone, consisting of nodular zones of light gray, hard, fine-grained stone, separated by bands of buff, softer, magnesian stone. Weathers to distinct banded appearance and shows some evidence of unsoundness	8	6
5. Limestone, drab to gray, fine-grained, soft, shaly and sandy	3	
4. Shale, yellow		6
3. Limestone, gray, fine-grained, soft, shaly and sandy, massive	10	6
2. Shale, gray		8
1. Limestone, buff to gray, fine-grained, soft, shaly and sandy, massive. To base of bluff	9	

Of the foregoing section, it appears that Nos. 1 to 10 are referable to the Kinderhook limestone, Nos. 11 to 27 to the Lower Burlington limestone, Nos. 28 to 34 to the Upper Burlington limestone, and Nos. 35 and 36 to the Montrose chert.

It is of interest to note that of eighteen samples from the various members of this section only one, representing Bed No. 9, shows a percentage of wear in the abrasion test of less than 8.0 and thus meets the State Highway Commission specifications for concrete aggregate. However, all of the limestones are probably suitable for road surfacing, and many of them may be used with satisfaction as concrete or asphaltic aggregate. The upper members of the section have been quarried at several places nearby, but at no point is more than a few thousand cubic yards available without exceeding 15 feet of overburden. The old quarry in the lower bluff about three-fourths mile south of this point has been worked until the overburden is at least 40 feet thick. The face includes Nos. 3 to 24 of the section just given.

The Kemper quarries were evidently at one time the seat of large-scale operations, but they are now abandoned. The quarry face included the lower 35 feet of the Lower Burlington limestone. The following is condensed from a detailed section obtained there:

	Feet	Inches
5. Limestone, differing in hardness, mostly brown and magnesian, much of it crinoidal, with several very cherty zones, and a 1-foot bed of soft cherty sandstone	12	
4. Sandstone, yellowish brown, soft, shaly	9	9
3. Limestone, brown, magnesian, much of it rather soft	4	9
2. Limestone, massive, medium to coarse of grain, crinoidal, fairly sound, ranging in color from light gray to brownish gray. No chert	9	
1. Limestone, brown, magnesian, fine-grained, rather soft. To quarry floor, which is about 5 feet above railroad track level	2	4

The limestones are suitable for surfacing, and the better part of them may be used for concrete aggregate, though tests show that none of the beds has a percentage of wear less than 8.0. Moderate quantities are still available by stripping.

From the above locality southwestward as far as Skunk River, the Mississippi River is at some distance from the bluffs and is separated from them by terrace areas, so that no rock is exposed. Spring Creek shows scattered outcrops of the Burlington and Montrose formations as far upstream as sections 11 and 3, Union Township. Limited quantities of stone, much of it rather soft, are available, especially in the west part of section 10 and the southwest quarter of section 11. Outcrops of similar strata are found on Brush Creek as far upstream as the northeast corner, section 21, Union Township.

Skunk River Bluffs. — Exposures in Des Moines County begin in the west part of Union Township and continue from there westward to the Henry County line. At Augusta, the Kinderhook and part of the Lower Burlington are below the limit of exposure, while the Keokuk appears in the higher slopes. The following section is adapted from one by Van Tuyl [14] and shows the general character of that part of the Burlington limestone which appears near Augusta:

	Feet
8. Limestone, gray weathering buff, soft, fine-grained	1½
7. Limestone, gray to brown, crinoidal, with a few thin chert seams	16–17
6. Limestone, brown, magnesian, medium-grained, cherty, with some seams of crinoidal limestone	8
5. Chert	1
4. Limestone, buff, soft, magnesian	1–1½
3. Limestone, light gray, crinoidal, cherty, with layers of soft, buff limestone	7½–8½
2. Limestone, bluish gray when fresh, weathering buff, fine-grained, soft, with occasional layers of brownish impure cherty crinoidal limestone ranging up to 2 feet in thickness	12½–13½
1. Limestone, gray, subcrystalline, cherty	4

Van Tuyl refers Nos. 1 and 2 to the Lower Burlington and the remainder of the section to the Upper Burlington. Moderate quantities are available at a few points, in some cases in conjunction with the overlying Keokuk beds. As usual the limestones are suitable for road surfacing but somewhat soft for first-grade aggregate.

The Montrose member here is in general lithologically similar to the upper Burlington, except for the presence of an increased amount of chert. It is well exposed on the lower courses of small creeks tributary to the Skunk River near and west of Augusta, and on Long Creek in the south part of section 18, Union Township. Considerable quantities are available for quarrying, although it is noted that a part of the stone is rather soft, and that in some zones the chert percentage is very high (75 percent of one eight-foot zone).

The upper Keokuk limestone is widely and abundantly exposed in the country north of Augusta, and it has been and still is quarried at

14 Van Tuyl, F. M., The Stratigraphy of the Mississippian Formations of Iowa: Iowa Geological Survey, Vol. XXX, p. 132, 1921-22.

several points. The most extensive workings were on the north bank of Long Creek north of center section 18, Union Township. At this point, the horizon worked included about 12 feet of coarse-grained gray hard sound limestone, in even beds, with finer-grained softer and possibly unsound stone between the beds; these softer beds totaled 10 to 25 percent of the entire body. Below the quarries is 15 feet unexposed but probably limestone or shaly limestone, and 15 feet of dark gray shaly and partly unsound massive limestone, to bottomland level. All of these beds are referred to the upper Keokuk limestone. Stone from the quarry horizon is still available in a quantity of many thousand cubic yards in this locality. Similar successions of beds are exposed and available for quarrying in moderate quantity at numerous points along the middle and lower courses of small creeks tributary to Skunk River in the eastern and central parts of Augusta Township.

A series of beds representing the Warsaw, Spergen, and Lower St. Louis formations is well exposed on Long Creek north of Augusta and along the middle courses of many of the smaller creeks northwest of Augusta. The following is a condensed composite section of strata visible in section 12, and the east half of section 11, Augusta Township.

	Feet
6. Limestone, light gray, fine-grained, conglomeratic, hard	6
5. Unexposed, an interval difficult to determine, but probably about	5
4. A zone which shows much local variation but is uniform in general character. The major part is a well-bedded yellow or buff sandy magnesian limestone, usually rather soft, and variable as to soundness. Associated are beds of buff cross-bedded dolomitic sandstone, yellowish fine-grained nonsandy limestone, light gray sandy limestone, or in fewer places, drab dolomitic shale or shaly limestone. Within the limits of any single exposure the beds are uniform in character and thickness and essentially flat-lying	25 (app.)
3. Shale, greenish or bluish, soft, an irregular but persistent bed, commonly unconformable with the members above and below	2–6
2. Limestone, conglomeratic, light gray, fine-grained, hard, an irregular but persistent bed	3 (app.)
1. Shale, greenish or bluish, soft, commonly not well exposed	25 (app.)

Number 1 of this section is referred to the Warsaw, and the higher members to the Spergen or lower St. Louis. The upper members are in many cases high in the slopes and thus available for quarrying in large quantity. The limestone beds and the harder part of the sandstones are suitable for road surfacing (except possibly on heavy-traffic roads), but they are commonly too soft or unsound to be desirable as a source of aggregate. They have been quarried in several places for building stone.

Both Lower and Upper St. Louis are well exposed farther west, principally along Cedar Creek. Details of the character of the formation have not been worked out, but it appears that the succession includes, in ascending order, a brownish magnesian member varying locally to a gray conglomeratic member, a gray conglomeratic or brecciated member, and an even bedded gray hard member. The two upper members are well exposed to a total thickness of 30 feet and have been quarried near Skunk River in the northeast part of section 1, Augusta Township (T. 69 N., R. 5 W.). They are available for quarrying there and at a few other points in the west part of Augusta Township. Most of the stone is of good quality for road-surfacing work and a part of it may be used for aggregate. As is often the case in the St. Louis, the beds are irregular and many of them differ in quality within short distances, both vertically and horizontally. Careful prospecting is thus advisable before any development is undertaken.

Miscellaneous Exposures. — Numerous outcroppings on and near Flint River and some of its tributaries may be referred to the Upper Burlington limestone, though the Lower Burlington appears in the lower bluffs at the west edge of Tama Township and the east part of Flint River Township. The best known section of the Upper Burlington is in the old quarry north of West Burlington (center NW¼ sec. 25, Flint River Twp.). The following beds are exposed:

		Feet	Inches
14.	Chert, white	1	6
13.	Limestone, coarse-grained, gray to buff, weathering white, fairly hard, sound, crinoidal, with numerous chert nodules	4	2
12.	Shale, yellow		8
11.	Limestone, buff, fairly hard, sound, coarse-grained, crinoidal, contains one 2-inch chert band 1½ feet from top and numerous small pockets of shale	3	6
10.	Chert, much weathered, and shaly limestone	2	
9.	Shale		3
8.	Limestone, buff, medium-grained, fairly hard, sound, crinoidal	1	
7.	Shale		3
6.	Limestone, fairly hard, sound, light gray, coarse-grained, massive, strongly crinoidal	4	9
5.	Shale, and soft shaly limestone with numerous chert nodules near the bottom	1	3
4.	Limestone, light gray, hard and sound, medium-grained, crinoidal, massive, with numerous stylolitic seams	8	6
3.	Shale parting		
2.	Limestone, coarse-grained, buff, fairly hard, sound, strongly crinoidal, massive	3	3
1.	Unexposed to quarry floor	6 (app.)	

Of seven samples tested from this point, only one, from the lower half of Bed No. 4, shows in the abrasion test a percentage of wear less than 8.0. However, the other limestone members are suitable for road surfacing or even for aggregate in concrete for ordinary uses or in asphaltic concrete. The coarse-grained crinoidal zone that characterizes the Upper Burlington limestone is typically shown here in Beds 2, 4, and 6, and tests on these beds well illustrate the usual nature of that zone (see Table III). The rock here is high in the hills and large areas are workable under 15 feet to 25 feet of overburden.

Other old quarry sites in the Flint River basin are in SE¼ section 19, Tama Township; SE¼ section 4, Flint River Township; SW¼ section 32, Franklin Township; SE¼ section 1, and E½ section 12, Pleasant Grove Township; NW¼ NW¼ section 16, Franklin Township; and west part of section 1, Danville Township. In any of these localities additional stone, suitable for ordinary purposes, can be obtained in moderate quantity. Both the white crinoidal stone and the brown granular stone are represented.

A few scattered exposures of the Upper Burlington limestone are present in the country north and southeast of Mediapolis, but details as to availability and quality of the stone are not known. Old quarries are located in SW¼ section 2, township 72, range 3; NW¼ section 6, township 72, range 2; and SE¼ section 36, township 72, range 3.

Sandstone

Keyes[15] has reported an outlier of Des Moines series sandstone about two miles north of Augusta. Examination of this locality indicates that the sandstone mentioned by him is a part of the previously described Spergen-Lower St. Louis horizon which is well exposed high in the bluffs on Long Creek. Sandstones are exposed in the southwest part of Danville Township and the northwest part of Augusta Township, and were formerly quarried in NW¼ section 30, Danville Township. They may be of St. Louis age, or, since they are in places associated with unquestioned Coal Measures strata, may be Pennsylvanian. In a county like Des Moines, with good limestone easily available, deposits of a rather soft sandstone such as this have little value for road or concrete work, and are therefore not described in detail.

Sand and Gravel

Glacial Deposits. — Definite locations of any glacial deposits in Des Moines County are not known, though it is probable that careful search would disclose a few. At the base of the Mississippi River bluff about

15 Keyes, C. R., Geology of Des Moines County: Iowa Geological Survey, Vol. III, p. 449, 1893.

4 miles north of Burlington (sec. 16, T. 70 N., R. 2 W.) a deposit of coarse clayey gravel about 25 feet thick has been and is still being worked. It is overlain by till, and its nature suggests a pre-Illinoian age. The quantity still available under moderate stripping is small.

Alluvial Deposits. — As in other counties where rock outcrops are numerous, small streams of high gradient, which are actively cutting through the lower glacial deposits and into the rock, carry small quantities of sand, gravel, broken limestone, and chert, which are deposited at favorable points in their channels. The quantity available at any one point is small, but such supplies have real value as a source of material for small local improvement projects.

Mississippi River is the only present known source of alluvial deposits of large size. This stream carries much sand in its channel. Its bottomlands are in large part underlain by heavy beds of sand or fine gravel, which in turn are overlain by 5 to 15 feet of silt and fine sand. One second-bottom, or terrace, deposit of gravel is known.

The Burlington Sand Company obtains sand or gravel from various points in the channel of Mississippi River near and north of Burlington. The material is pumped on barges and conveyed to its plant on the river bank at Burlington. The plant is of the usual type for washing and screening of sand and gravel, consisting essentially of revolving screens for separating the various sizes of material, which are conveyed by chute to the bins or recombined in any desired proportion. The plant capacity is about 300 tons per 10 hour day, of which at least three-fourths is sand. The sand is clean and sharp and of good quality for fine aggregate in concrete. The same company operates a plant of similar nature at Keithsburg, Illinois, about 20 miles north of Burlington.

One terrace deposit of gravel is known in N½ section 36, Union Township. This is but a few feet above the level of the surrounding bottomland and is probably a bar laid down at some time when the river flowed at slightly higher level than at present. It extends east and west for nearly the whole length of the section and has a maximum width of one fourth mile. The material composing it is under very light stripping and consists for the most part of sand with locally some gravel up to about one inch size. A large quantity of the coarser material has already been used for surfacing of the roads in that vicinity and as concrete paving material in Lee County.

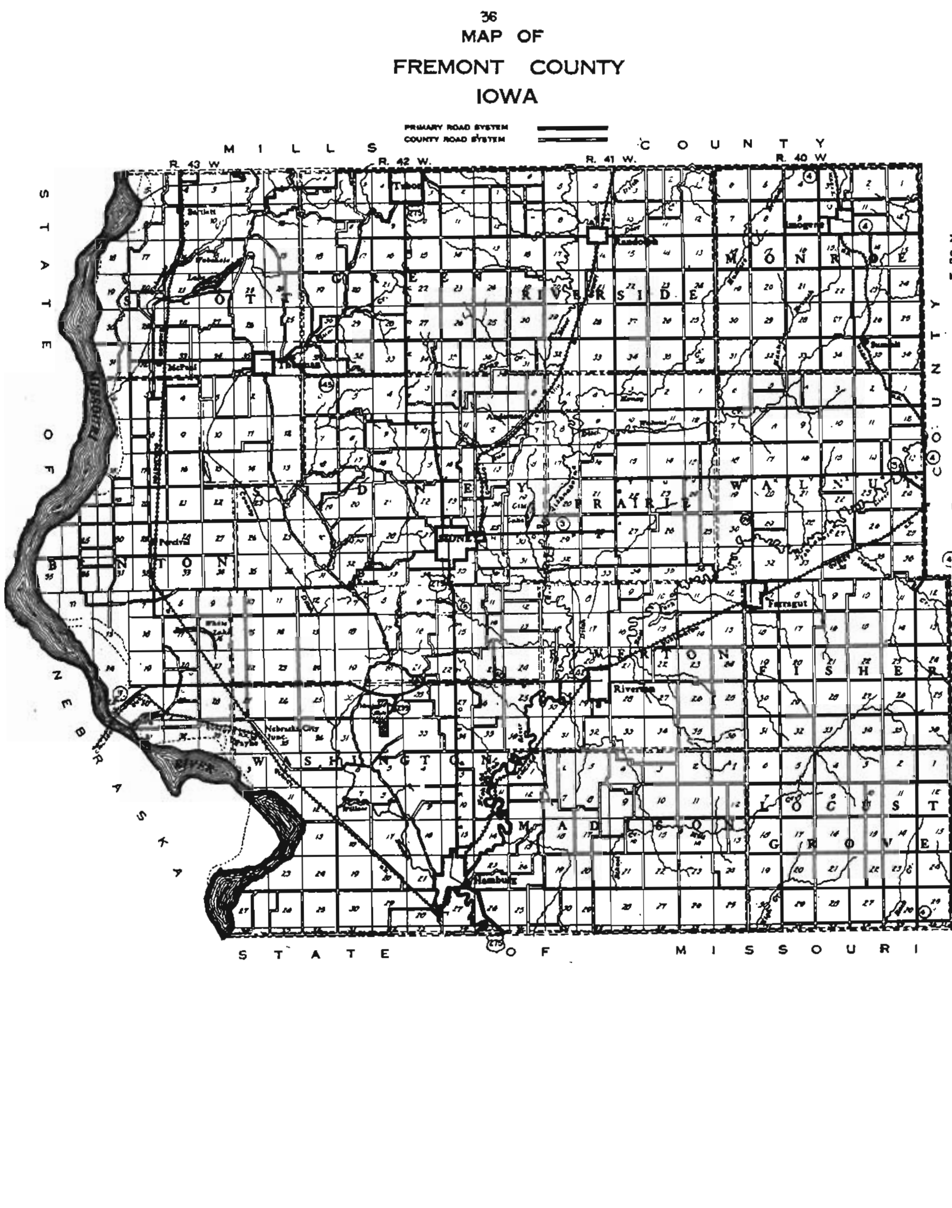
Higher and better-developed terraces are known in the south part of

Union Township, but these are in general underlain by a sand, much of it rather fine even for fine aggregate in concrete.

FREMONT COUNTY

All of the known exposed bedrock of Fremont County is referred to the upper portion (Shawnee and Wabaunsee stages) of the Missouri series, the strata constituting the uppermost members of the Iowa Pennsylvanian section. The presence of small patches of sandstone or conglomerate of Cretaceous (Dakota) age in the upland is suspected, as in the neighboring counties of Mills, Montgomery, and Page, but

IOWA GEOLOGICAL SURVEY. PLATE XV



these materials are nowhere well enough exposed to allow their sure identification.

Upon the indurated rocks, the mantle of glacial drift has a thickness ranging up to 200 feet or possibly more, the heavier deposit being in the east part of the county. Both Nebraskan and Kansan drift sheets are probably present. However, owing to the thickness of the overlying loess, exposures of glacial materials are limited to the deeper valleys where erosion is extremely active, and it thus seems probable that nearly all of the outcrops may be referred to the Nebraskan. It may be significant that in this county a high percentage of exposures of glacial materials shows well-defined zones or pockets of sand or gravel.

Loess is an important deposit in Fremont County. It is of post-Kansan age and forms a mantle over the earlier deposits that is almost unbroken except in the steeper and higher bluffs where present erosion is very active. This mantle ranges in thickness from about 100 feet on the bluffs bordering the Missouri River valley to about 20 feet in the east part of the county. The loess offers no materials for road or concrete construction but is of interest because it almost completely covers earlier formations which might contain such materials.

Limestone

The Thurman-Wilson fault cuts the Missouri River bluff near the southwest corner of section 23, Scott Township, passes northeastward and crosses Plum Creek in NW¼ NW¼ section 20, Green Township. Its extension beyond Fremont County is fairly well established a few miles south of Malvern and again at or just north of Red Oak. Inasmuch as the two parts into which the county is divided by the fault line show entirely different successions of strata, they may best be considered separately.

South of the Fault Line. — Outcroppings of bedrock are numerous near Hamburg and are found less frequently along Mill Creek south of Riverton and in the hills northeast, north, and south of Thurman. The heaviest limestone known is only some four feet thick, and it will thus be seen that little or no material is available. The two following sections indicate the nature of the strata:

General section near Hamburg (after Tilton)[16]

	Feet
14. Shale, blue and gray	20
13. Limestone, very dark gray, sandy, containing many small spheroidal	

[16] Tilton, J. L., The Missouri Series of the Pennsylvanian System in Southwestern Iowa; Iowa Geological Survey, Vol. XXIX, p. 260, 1919-1920.

	lumps, in places brecciated	1
12.	Limestone, blue, very sandy, almost a calcareous sandstone	1
11.	Shale, sandy, with two beds of sandstone. Yellow to blue in color	21½
10.	Limestone, dark gray, fossiliferous, in two layers	3
9.	Coal	1
8.	Shale, yellow and blue	31
7.	Limestone, gray, fossiliferous	½
6.	Shale, dark gray	3½
5.	Limestone, very dark gray	4½
4.	Shale, blue, weathering to yellow	8
3.	Limestone, weathered brown, in two or three layers	4
2.	Shale, gray, weathered	12
1.	Limestone, dark gray	1

All but Nos. 1 and 2 of this section are referred by Tilton to the Wabaunsee stage. Number 5 is the Tarkio limestone, which is well exposed in Page County.

The following section described by Tilton [17] shows the succession of strata south of Thurman (NW¼ NW¼ sec. 12, T. 69 N., R. 43 W.):

		Feet
9.	Limestone, bluish gray, of fine texture, arenaceous	½
8.	Shale, gray, not calcareous, part originally a black shale, grading into reddish shale above	10
7.	Limestone, blotched, jointed, numerous calcareous lumps up to ½ inch in diameter; a few shell fragments, joints of crinoid stems, and quartz grains	3
6.	Shale, bluish gray, soft; partly concealed	2
5.	Sandstone, grayish blue, of fine texture, calcareous; ripple-bedded above	3
4.	Shale, not well exposed	1
3.	Not exposed	4
2.	Limestone	3
1.	Shale, gray	3

Tilton correlates the limestone, No. 7 of this section, as the equivalent of the limestone, Nos. 12 and 13 of the section preceding.

North of the Fault Line. — Udden [18] has given a very complete description of the character and succession of the strata exposed in the Missouri River bluffs in section 23, Scott Township. Subsequent examination here, with more particular attention to the value of the rock for road or concrete work, gives the following section:

Udden's Section Nos.		Feet	Inches
13.	Limestone, blue, hard, brittle, fine-grained, irregularly bedded with shale, not well exposed. Percentage of wear 4.5, soundness satisfactory	1	10
13.	Shale		2½
13.	Limestone, dark gray, fossiliferous, hard, crystalline, coarse-grained. Percentage of wear 6.5, soundness satisfactory		9
12.	Shale		2½
12.	Limestone, dark gray, highly fossiliferous (fusulinids), medium soft, much weathered and probably unsound		6
12.	Shale, hard, drab	2	9

17 Idem, p. 250.

18 Udden, J. A., Geology of Mills and Fremont Counties: Iowa Geological Survey, Vol. XIII, pp. 144-146, 1902.

12.	Limestone, light brownish gray to drab, soft, fragmentary, interbedded with shale	1	3
12.	Shale, drab, hard	2	9
11.	Limestone, yellow, rusty, soft, oölitic		9
10.	Limestone, one ledge, light gray, hard, crystalline, fossiliferous (joints of crinoid stems noticeable). Percentage of wear 4.4, soundness satisfactory	3	5
9.	Shale, drab, hard, with thin layers of drab shaly limestone near the bottom	5	8
9.	Limestone, soft, drab, fossiliferous		3
9.	Shale, drab, hard, with thin layers of soft limestone near the bottom		10
9.	Limestone, soft, drab, fossiliferous		2½
9.	Shale, drab, hard	1	½
9.	Limestone, dark gray, hard, crystalline, of medium fine grain. Percentage of wear 3.8, soundness questionable	1	4
9.	Shale		7
9.	Limestone, light yellow, soft, weathered, probably unsound	1	5
9.	Shale, hard, drab		6
8.	Limestone, brownish gray, hard, brittle, crystalline, of medium fine grain, conchoidal fracture, with chert nodules, sparingly fossiliferous. Percentage of wear 4.5, soundness satisfactory	1	11
8.	Limestone, drab, shaly, fossiliferous (fusulinids)	1	
8.	Limestone, dark bluish gray, hard, crystalline		4
7.	Shale, drab, hard		5
7.	Limestone, light gray, soft, fossiliferous		1½
7.	Shale, drab, hard		9½
6.	Limestone, brownish gray, crystalline, with a few chert nodules, only sparingly fossiliferous. Percentage of wear 4.0, soundness satisfactory	1	2
5.	Shale, drab, hard	1	1
4.	Limestone, soft, weathered		3
4.	Limestone, gray, crystalline, with scattered chert nodules, and two 1-inch shaly partings. Percentage of wear 4.8, soundness satisfactory	1	11
4.	Limestone, one ledge, gray, hard, brittle, fine-grained, crystalline, with joints of crinoid stems. Percentage of wear 4.3, soundness satisfactory	1	3
3.	Limestone, gray, crystalline, with scattered chert nodules and several thin wavy shale partings. Percentage of wear 4.8, soundness satisfactory	1	7
2.	Limestone, gray, hard, crystalline, with thin shaly partings and a few chert nodules. Percentage of wear 4.8, soundness satisfactory	1	9½
2.	Limestone, drab, shaly, fossiliferous (fusulinids)		2½
1.	Limestone, brownish gray, medium-grained, hard, crystalline, fossiliferous, with a few thin shaly partings. Percentage of wear 6.0, soundness questionable or unsatisfactory	3	11½
1.	Limestone, drab, shaly, unsound, fossiliferous		11
1.	Limestone, dark bluish gray, very fossiliferous, with small pockets of calcite. Percentage of wear 5.6, soundness questionable or unsatisfactory	1	10
(These Beds Below Udden's Section)	Shale, hard, black and gray	1	11
	Limestone, dark gray, hard, crystalline, medium-grained, fossiliferous		11
	Shale, drab, hard	2	

The above section is so lengthy as to be rather cumbersome, but it is given in detail for the reason that in this part of the county the individual strata show persistence and uniformity and can ordinarily be recognized without difficulty wherever found.

Numbers 1 to 4 inclusive of the above section constitute the Deer

Creek limestone and Nos. 10 and 11 the Topeka (Meadow) limestone, both of which members are usually conspicuous where exposed. Where these beds are cut off by the fault near the southwest corner of section 23, Scott Township, the bottom of the Deer Creek is about five feet above the river bottomland level. To the north the strata decline gradually, so that the bottom of the Deer Creek is at bottomland level in SE¼ SW¼ section 14, Scott Township, and both the Deer Creek and the Meadow are below that level in section 14. Farther north, the beds rise again but do not outcrop in this county. Along the bluff as described, the Deer Creek is continuously exposed and is available in a long narrow strip. However, the bluff rises steeply, overburden being 20 feet or more within 50 feet of the outcrop, so that only limited quantities can be obtained without mining. The Topeka is hardly thick enough to be workable except in very small quantity.

Plum Creek first cuts into the Deer Creek limestone in the southwest quarter of section 17, Green Township. However, the Deer Creek is cut out by the Thurman-Wilson fault in NW¼ NW¼ section 20, Green Township, and is thus available in only a few small areas, those known being in NW¼ NW¼ section 20, on the west bank, and in SE¼ SW¼ section 17, on the east bank. At the latter point the stone was quarried for road surfacing stone in 1934. Only small quantities are now available here, and even those are under heavy overburden.

Mining. — Though lack of suitable rail connections may make it uneconomical to develop deeply buried limestones in this county by means of a vertical shaft mine, the presence of such limestones is still believed to be worthy of note. A deep drilling at Nebraska City, Nebraska, penetrated thirteen limestones, ranging in thickness from 15 to 60 feet, at depths of 215 to 940 feet. Other limestones of similar thickness have been encountered in deep drillings at points in Page County, which adjoins Fremont on the east.

Sand and Gravel

As previously mentioned, the loess obscures the glacial drift materials over most of the county, exposures being limited to the steepest slopes in the vicinity of the larger streams. The most important outcroppings of glacial till are along the Missouri River bluffs, and there a large number of sand and gravel pits have been opened in pockets within the till. All of these have been investigated in detail, as have also a number of others scattered through various parts of the county.

The largest amounts of available material found at any one place are 1,500 cubic yards of gravel in SE¼ NE¼ SW¼ section 9, Riverton Township, and 900 cubic yards of coarse sand in SW¼ SW¼ section 31, Walnut Township. The well-known pits in sections 30 and 31 of township 69 north, range 42 west, show only very small quantities of sand or gravel still available.

In Fremont as in Mills County a large part of the valley filling of Missouri River is sand, but in nearly all cases it is overlain by such a depth of silt or very fine sand as to make its development impracticable. One exception is in NW¼ NE¼ section 19, Benton Township (T. 68 N., R. 43 W.), where a sand of good quality for concrete work was formerly pumped out to a depth of 22 feet over an area of about one acre. Operations there are now discontinued, and it is said that the deposit is nearly all worked out.

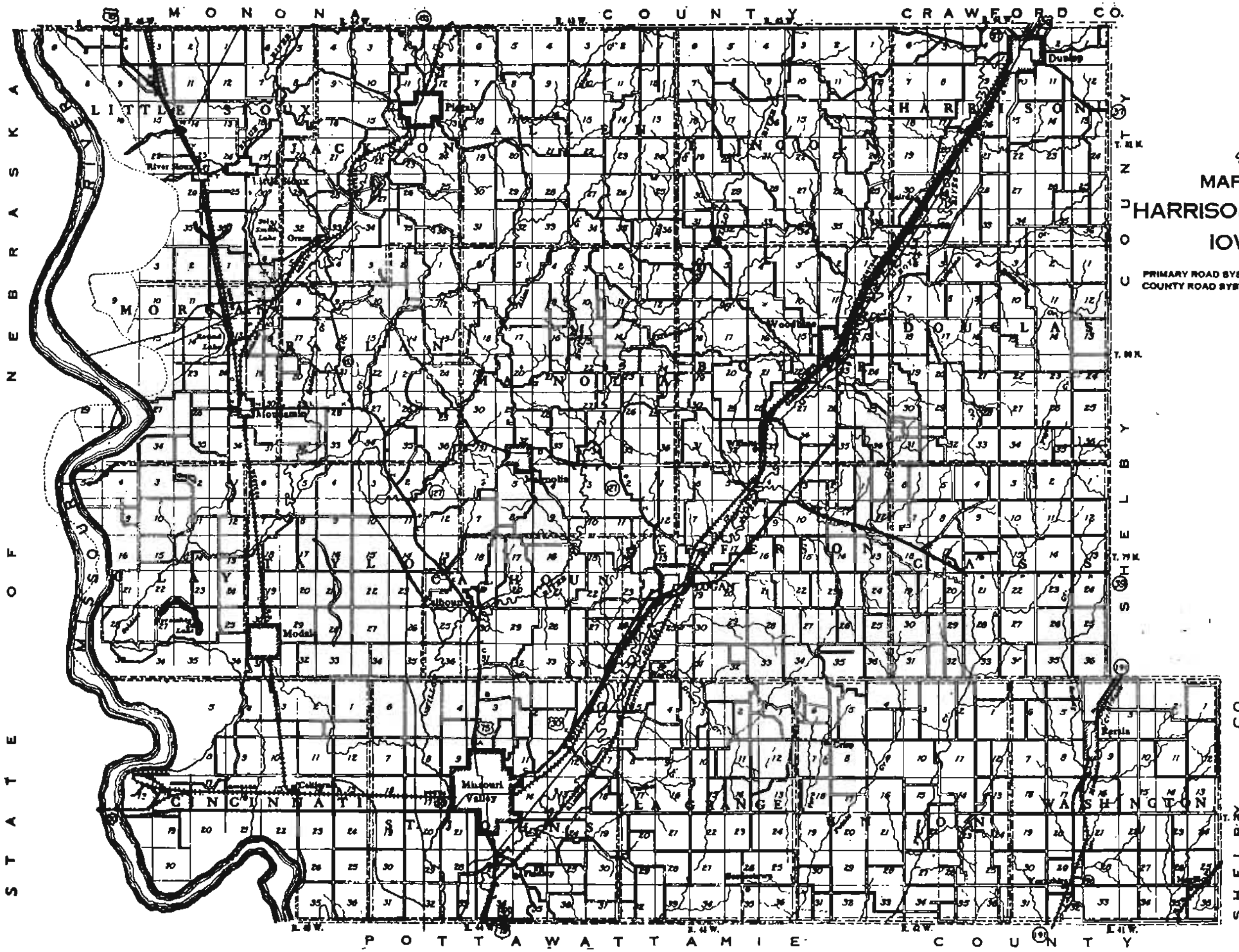
The valleys of both branches of Nishnabotna River are underlain by beds of sand and gravel, which, however, are usually so thin or so deeply buried as to be not workable under present conditions. A recent investigation of well data in these valleys, made with a view toward obtaining more definite information on such deposits, shows that the usual succession, from the surface downward, is 10 to 20 feet of silt or clay, 5 to 15 feet of fine sand, 2 to 15 feet of coarse sand or fine gravel, followed by clay (probably glacial till). The only point that was found where sand or gravel might be obtained under moderate stripping is in W½ SW¼ section 29, Walnut Township, where soundings for a bridge show 12 to 14 feet of sand and gravel under 3 to 4 feet of overburden. Nothing is known of the area that may be included by this deposit, though it may be rather large.

HARRISON COUNTY

A few limited and obscure exposures of bedrock along the channel of Boyer River near Logan and Woodbine represent the limestones and shales of the Pennsylvanian system, though whether these belong to the Des Moines series or the Missouri series is in some doubt.[19] The Pennsylvanian underlies the whole county. In the northeast part it may be overlain by Cretaceous deposits, though these are nowhere naturally exposed, even if present at all.

Glacial deposits of Nebraskan and Kansan age lie above the bedrock. Exposures are uncommon except in the steeper slopes near large valleys. In many places these drift deposits have a total thickness of 200

19 Tilton, J. L., The Missouri Series of the Pennsylvanian System in Southwestern Iowa: Iowa Geological Survey, Vol. XXIX, pp. 310-312, 1919-20.



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MAP OF
HARRISON COUNTY
IOWA

PRIMARY ROAD SYSTEM
COUNTY ROAD SYSTEM

PLATE XVI

feet or more, although they have wide limits of range from place to place.

As in other counties along Missouri River in western Iowa, loess is an important formation. It is of post-Yarmouth age and forms a surface mantle ranging in thickness from 100 feet on the higher bluffs facing the valley of the Missouri to about 15 feet in the eastern part of the county. In but slightly modified condition it forms most of the upper alluvium in the valleys of the larger streams. Constituting as it does an almost continuous mantle on upland and lowland, it effectually conceals the earlier deposits on all but the steepest slopes where erosion is most active, and even on those slopes it makes excessive overburden on whatever supplies of road or concrete materials may be present in the older deposits. Thus, though the loess contains none of the materials of interest for the purposes of this report, it is important because it almost completely covers the older deposits.

Limestone

A test pit in the bottom of the old quarry at Logan (SE¼ NW¼ sec. 19, Jefferson Twp.) shows the following succession of rock beds:

		Feet
6.	Limestone, gray, fine-grained, very hard, sound, fossiliferous, in even beds from a few inches to a foot thick, separated by thin fossiliferous shaly partings totaling perhaps 5 per cent. A two-inch band of black fossiliferous chert is 2 feet from the bottom	8¼
5.	Shale, drab, soft, fossiliferous	1¾
4.	Shale, black, strongly bituminous and almost a coal at the top, calcareous and harder below, with very few fossils	2¾
3.	Limestone, dark gray, shaly and unsound above, grading below into a harder and possibly sound stone, with few or no fossils	2¾
2.	Shale, gray, soft, fossiliferous	2½
1.	Limestone, hard, sound, light gray	5+

These beds are overlain by about 10 feet of sand, and that by 25 to 30 feet of loess clay. Number 6 of this section is available with 2 to 15 feet of overburden in a space about 300 feet long and 50 feet wide. Number 1 is at about river level and is said by the owner to be the ledge which makes rapids in the river at this point. Test holes across the river to the west show that the members of this section are not present there, being replaced by alluvial deposits of silt and sand.

Sand and Gravel

Deposits of sand and gravel are well known and have in the past been extensively worked at various points in the county. The best-known of these, the Cox pit at Missouri Valley, had at one time a face of 40 feet of sand and gravel. However, some thirty of these deposits have been investigated, and though there are a few points (e.g. NW¼ NE¼ sec. 23, Jackson Twp., and NE¼ NE¼ sec. 24, St. Johns Twp.) where thick beds of sand or gravel are still present, they are almost without exception under a prohibitive covering of loess and drift. At some points material has been available in the past but is now almost entirely removed. Recent surveys of all known glacial deposits showed only one where more than about 2,500 cubic yards of surfacing gravel is still available. This is in the form of three pockets exposed along the road through the central part of section 5, Little Sioux Township, which have available a total of 9,000 cubic yards of gravel under 10,000 cubic yards of overburden.

Other locations which show small quantities of gravel are as follows: southeast corner SW¼ section 14, Jackson Township, 2,000 cubic yards; SW¼ NE¼ section 21, Raglan Township, 2,500 cubic yards; NW¼ NW¼ NW¼ section 3, LaGrange Township, 650 cubic yards; in NE¼ NW¼ section 31, Little Sioux Township, 500 cubic yards; and at the north quarter-corner section 28, Boyer Township, 1,500 cubic yards. Should sand only be needed, a considerable quantity might be available in or near the Cox pit at Missouri Valley (NE¼ NE¼ sec. 24, St. Johns Twp.) or possibly at other points in the county.

Alluvial materials in Harrison County consist, except in the Boyer River valley, almost exclusively of silt and fine sand. Large quantities of coarse sand and fine gravel lie 30 to 50 feet deep in the bottomlands of Missouri River, but these are obviously unavailable. Bars in the channel of the Missouri, though large, consist of silt or of sand too fine for any purpose except possibly for filler in an asphaltic aggregate. Dune deposits in the Missouri bottomlands (principally near and west of California Junction) are of like fine-grained materials.

Boyer River, draining a territory which was once occupied in part by the Wisconsin ice sheet, has carried large quantities of sand and gravel and deposited them all along its course, the coarser materials farthest upstream and the finer materials below. Harrison County marks the lower limit of these deposits insofar as they are available for road building work. Two such deposits are definitely known to exist within the county.

The first is located near Woodbine, west of the center of section 23, Boyer Township, in the bottomlands of the river. It shows 7 to 10 feet of overburden and 12 to 20 feet of usable material, which lies on a hard layer that is probably solid rock (judging from an exposure of a ledge in the river channel nearby). Water stands about 15 feet below the ground surface. The material shows some range in grading, with an average of 72 percent passing the No. 4 screen, the finer material being at the top. It is of good quality, containing only a very small percentage of silt, soft stone, and shale. The deposit is estimated to cover 40 acres, of which about 3 acres has been worked out. At present there is no plant in operation.

A second deposit lies near the north quarter-corner of section 10, Harrison Township, and is known to occupy an area of about 8 acres. Tests have shown 10 feet average depth of stripping, and 18 feet of gravel, nearly all above natural ground water level. The material shows an average of 68 percent passing the No. 4 screen. The State Highway Commission now owns this deposit and it was opened and a small quantity of gravel for road surfacing work removed in 1934.

Deposits of similar character are present along Boyer River in the adjacent county of Crawford, and it is likely that systematic search would disclose others in Harrison County, especially in the northern half.

HENRY COUNTY

The Keokuk limestones and overlying Warsaw shales and impure limestones appear in three small areas, one extending along Skunk River from the south county line to Lowell and thence north two miles on Mud Creek, and the others north and south of Mount Pleasant, along Big Creek and Skunk River. The Spergen has been recognized by Van Tuyl [20] at one point in the first-mentioned area. Except for these areas, the St. Louis limestone underlies the whole county. It forms the uppermost consolidated rock in nearly all of that area except as overlain by the Ste. Genevieve. Pennsylvanian (Des Moines series) strata are present in a few small areas near the southern and western edges of the county, where they appear to occupy erosion channels in the Mississippian rocks. Such areas are all small and of no importance for the purpose of this report.

It appears from available information that Nebraskan and Aftonian glacial deposits lie next above the bedrock throughout most of the county. However, surface exposures definitely referable to those stages are difficult to find, and it may be that they are only a few feet thick. The Kansan drift sheet mantles the earlier deposits throughout the county

20 Van Tuyl, F. M., The Stratigraphy of the Mississippian Formations of Iowa: Iowa Geological Survey, Vol. XXX, p. 229, 1921-22.

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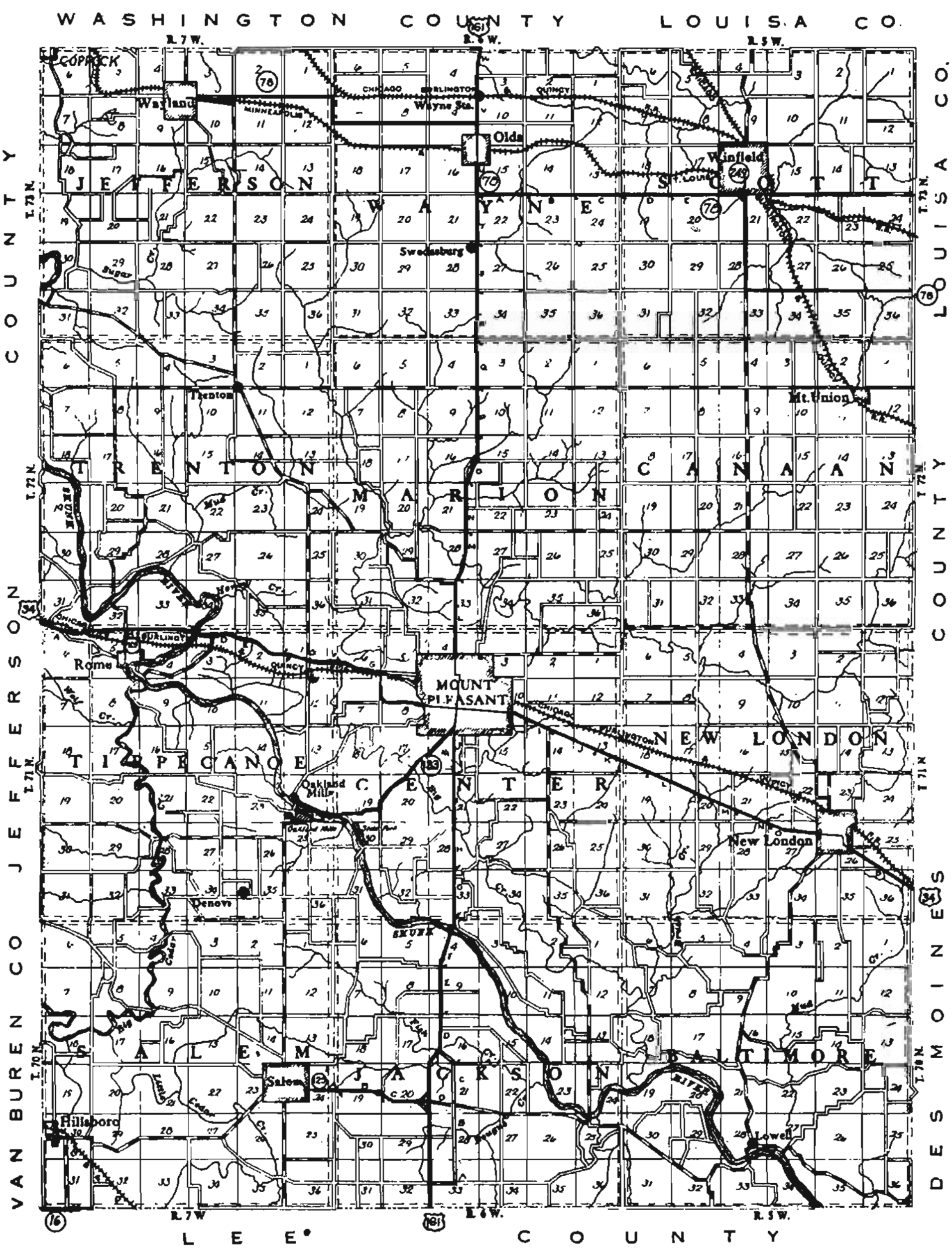
MAP OF HENRY COUNTY IOWA

PRIMARY ROAD SYSTEM
COUNTY ROAD SYSTEM



and is widely exposed in all parts. In the eastern part of Baltimore and New London Townships the Illinoian drift overlies the Kansan, its western boundary being marked by a moraine that is fairly well defined at some points and at others partly or completely obscured by the effects of erosion. A post-Illinoian loess a few feet thick mantles all of the Pleistocene deposits in the flat interstream areas, while in the more dissected country adjacent to the larger water courses it has been largely removed by recent erosion. The total thickness of loess and drifts is apparently at very few places in excess of 100 feet.

Alluvial plains are well developed in parts of the valley of Skunk River. They also occupy small areas along some of the lesser streams.

Limestone

In view of the fact that, in the few localities where the Keokuk limestone is exposed, the St. Louis also appears and is more easily available, it is hardly worth while to discuss in detail the nature of the Keokuk. As is true elsewhere, it consists of alternating beds, usually thin, of coarse-grained hard fossiliferous limestone, dark-colored shaly limestone, and calcareous shale. A composite section by Van Tuyl [21] in section 4, Jackson Township, shows, of 51 feet referred to the Keokuk, a total of 21 feet of shale. The Warsaw shows only materials unsuitable for road or concrete construction, and the Spergen is recognized at only one point, being there some four feet thick. The discussion which follows is therefore limited to the St. Louis and Ste. Genevieve limestones.

Savage [22] has published excellent general descriptions of the Lower St. Louis (his Springvale beds), the Upper St. Louis (his Verdi beds), and the Ste. Genevieve (his Pella beds), for this county. His descriptions, somewhat condensed, follow:

"The first or lower phase (Springvale) consists of magnesian limestones, usually occurring in massive layers. They are rather fine-grained in texture, yellowish brown in color, and dolomitic in character, ... The thickness of this division varies from over thirty feet in the southeastern corner of the county, near Lowell, to less than fifteen feet farther north and west. In the western portion of the county these layers become somewhat sandy in composition but even here the magnesian character still predominates and the yellowish brown appearance is maintained.

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21 Van Tuyl, F. M., The Stratigraphy of the Mississippian Formations of Iowa: Iowa Geological Survey, Vol. XXX, pp. 174-175, 1921-22.

22 Savage, T. E., Geology of Henry County: Iowa Geological Survey, Vol. XII, pp. 263-265, 1901.

"The second or middle division (Verdi) is recognized by the extreme variableness of its beds and its generally disturbed condition. It consists of irregular layers of sandstones and shales with an occasional bed of brecciated limestone near the upper portion. . . . It is for the most part a deposit near the margin of some troubled sea. . . (as indicated by) the presence of local layers which thin out rapidly within a short distance, the pockets of sand and shale, the numerous lenticular beds, the general irregular appearance of the strata . . . ripple marks . . . in the sandstone at numerous points, and the local development of oölitic limestone. The brecciated phase . . . occurs only near the upper portion of the division and is usually associated with nodules of chert. . . . Throughout much the greater portion (of Henry County) this division consists of sandstones interstratified with an occasional bed of shale or a thin stratum of limestone. The entire thickness of the deposits . . . would average about thirty feet, but at a few localities they reached a depth of fifty, and are throughout almost wholly barren of organic remains.

"The rock materials of the upper division (Pella) were laid down in deeper waters and in the lower portion consist of uniformly bedded, light gray limestones, very compact, and containing numerous fossils in the shaly bands between the layers. These beds grade upward into a softer, somewhat shaly deposit which weathers rapidly. . . . The strata of this division have been thrown into gentle folds, but the disturbance was not sufficient to cause more than a slight flexure of the beds. This phase, as developed in Henry County, reaches a maximum thickness of twenty feet."

Rock is exposed along all of the major streams of the county, though not continuously so, as in places they seem to occupy old channels, drift-filled, and only partly re-excavated. The areas of most extensive outcrop are as follows: in Scott Township north and west of Winfield; in the southwest part of Trenton Township and the north part of Tippecanoe Township, principally near Skunk River; along Big Creek and the lower course of its tributaries from its mouth to the southwest part of Marion Township; at intervals in the bluffs bordering the valley of Skunk River (though more extensively along tributary streams back a short distance from the main valley) from Rome to the southeast corner of the county; at numerous places near Little Cedar and Big Cedar Creeks through Salem Township; at intervals along Fish Creek and Bogue Creek in the central part of Jackson Township, and near Mud Creek in the central part of Baltimore Township; and at a few localities in the western part of Trenton Township and the western and northern parts of Jefferson Township.

An old quarry in SW¼ SE¼ section 4, Scott Township, shows the following succession of beds:

	Feet
6. Limestone, hard, sound, light gray, fine-grained, weathered into ledges 2 to 6 inches thick	3½
5. Sandstone, yellow to gray, moderately hard (percentage of wear 17.12) with numerous soft shaly pockets	2¼
4. Shale, yellow to gray, sandy	1¾
3. Limestone, drab, rather soft, shaly	1¾
2. Limestone, hard, sound, light gray, fine-grained, massive	6½
1. Quarry floor	

All of these strata are referred to the Upper St. Louis. Numbers 2 and 6 are suitable for concrete aggregate or road surfacing, and Nos. 3 and 5 have some value for the latter purpose. Savage [23] reports No. 2 to extend down to a total thickness of 10 feet and to be underlain by 2 feet of yellowish-brown magnesian limestone. Near this quarry, and again in the low bluff north of Crooked Creek in SE¼ section 6, and SW¼ section 5, moderate quantities of rock are available by stripping. An old quarry in similar strata in NW¼ SW¼ section 8, Scott Township, has possibility of extension.

The high bluff in the south bank of Skunk River in NE¼ SW¼ section 32, Trenton Township, shows the following approximate section:

	Feet
7. Clay, with occasional broken fragments of limestone	15
6. Limestone, hard, gray, well bedded	15
5. Limestone, hard, conglomeratic, poorly bedded	20
4. Limestone, brown, rather soft, in 1-foot beds	10
3. Limestone, brown and blue, soft	7
2. Limestone, sandstone, and clay, mixed	4–5
1. Limestone, gray and yellow, rather soft	4

Numbers 3 and 4 (and possibly 1 and 2) represent the Lower St. Louis, No. 5 belongs to the Upper St. Louis, and No. 6 to the Ste. Genevieve. Rock can be quarried here, though overburden is rather heavy. Savage's more detailed section,[24] in the east bank of the river in section 30, Trenton Township, shows 20 feet of strata, including a 3-foot bed of brownish shale and a 2½-foot bed of soft sandstone, the remainder being limestone. All of these beds represent the Upper St. Louis. Other exposures, with moderate quantities of available stone, are in SE¼ SE¼ section 11, Tippecanoe Township; near center SE¼ section 11, in N½ section 11, NE¼ NE¼ section 8, Tippecanoe Township; and in SW¼ SW¼ section 30, Trenton Township.

In a strip on both sides of Big Creek, ranging in total width from about two miles at its mouth in western Baltimore Township to one-

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[23] Savage, T. E., Geology of Henry County: Iowa Geological Survey, Vol. XII, p. 278, 1901.
[24] Savage, T. E., Geology of Henry County: Iowa Geological Survey, Vol. XII, p. 273, 1901.

half mile in the southeast part of Marion Township, rock exposures are both numerous and extensive. Outcrops are especially numerous in the territory north, northwest, west, and southwest of Mount Pleasant, and many quarries have been operated at intervals, some in recent years. Several good detailed sections for these deposits are published by Van Tuyl [25] and Savage [26] and will not be repeated here. The following section, general for a quarry which operated in 1931 in SW¼ NE¼ section 17, Center Township, shows the typical differences in the strata, even within short distances, in the Upper St. Louis, the member best developed in the Mount Pleasant locality:

	Feet	Inches
7. Clay, glacial and residual	1	
6. Limestone, gray to brown, hard, medium-grained, much weathered. This is well exposed at only one point, and an accurate description is therefore impossible. At other points in the quarry this member is only about 1 foot thick	3 (Max.)	6
5. Shale, green, plastic	1	6
4. Limestone, medium-grained, grayish brown, characterized by an abundance of brecciated chert. The fragments of chert are only slightly displaced from their original position in the nodules, and the interstices between them are filled with limestone	1	2
3. Limestone, in thin beds, lying in undulations conforming to the irregularities in the upper surface of the bed beneath. This bed is thinner where the member below is thicker, so that the total thickness of the two is quite uniform. The limestone is gray to brown in color, hard, probably sound, and of differing though usually medium fine grain	1 3	10 to 2
2. Limestone breccia, composed of angular fragments of various sizes of hard light-gray fine-grained sound stone, surrounded by a matrix of darker gray hard and sound stone. A few small veins and pockets of greenish shale are irregularly distributed through the bed. In some zones, instead of a breccia, is found a solid mass of fine-grained light-gray hard limestone. Across the small ravine to the southwest, this member is as much as 8 feet thick	2 3	6 to 6
1. Limestone, in regular and rather heavy beds. The bulk of the stone is a medium-grained, granular to subcrystalline, brown, fairly hard sound dolomite. The top 2 feet at several places shows a medium-grained gray hard sound nonmagnesian limestone. Other beds (none over 6 inches thick) show a soft brown earthy limestone. At the top of this member there is locally a 2-inch bed of shale. To bottom of exposure at quarry floor	6 (Max.)	

It is impossible to list all of the points in the hills adjoining and near the valley of Big Creek where rock may be quarried. Detailed prospecting work in the following locations has indicated that rock is available in thickness and quantity shown, under overburden in some cases as much as 10 feet: east of center section 6, Center Township, 42

25 Van Tuyl, F. M., The Stratigraphy of the Mississippian Formations of Iowa: Iowa Geological Survey, Vol. XXX, pp. 264-267, 1921-22.

26 Savage, T. E., Geology of Henry County: Iowa Geological Survey, Vol. XII, pp. 267-274, 1901.

feet of stone, 68,000 cubic yards available; W½ NE¼ section 18, Center Township, 20 feet of stone, 39,000 cubic yards available; NE¼ NE¼ section 28, Center Township, 18 feet of stone, 21,000 cubic yards available; and W½ SW¼ section 36, Center Township, 17 feet of stone, 20,000 cubic yards available. Other well-known exposures are in sections 30 and 31, Marion Township, section 17, Center Township, and sections 6 and 7, Baltimore Township. At any of these points nearly all of the stone is suitable for road surfacing work, and much of it may be used for aggregate. Both St. Louis and Ste. Genevieve formations are represented.

Outcroppings in sections 21, 28, 29, and 34, Marion Township, are provisionally referred to the Keokuk formation. They show beds of coarse-grained crinoidal limestone, alternating with unsound shaly limestone or calcareous shale. Though some of the exposures are extensive, the good beds are too thin to be quarried profitably, except in very small quantity.

The best-known exposures near Skunk River from Rome southeast (in addition to those showing Keokuk or Warsaw strata) are in SW¼ section 24, and east quarter-corner section 24, Tippecanoe Township; SW¼ NW¼ section 4, NW¼ NW¼ section 26, and NE¼ NE¼ section 25, Jackson Township; NW¼ SE¼ section 19, NW¼ SW¼ section 27, south of center section 33, and NE¼ SW¼ section 34, Baltimore Township. Detailed prospecting has been done in NW¼ NW¼ section 26, Jackson Township, and the following succession of beds is available:

	Feet
3. Limestone, hard, sound, light gray	6
2. Sandstone, brown and white, soft	5½
1. Limestone, gray, hard, sound, evenly bedded. To creek-level	18

These members evidently represent the Upper St. Louis limestone. Numbers 1 and 3 are suitable for aggregate or for surfacing work. The prospecting work indicates 40,000 cubic yards available under eight feet maximum thickness of overburden. It is probable that at the other points near Skunk River just mentioned similar rock is available, though perhaps not in such large quantity under such light overburden.

Savage's [27] section one mile east of Lowell shows the Lower St. Louis limestone to have there a thickness of about 36 feet and to consist of brown magnesian limestone, apparently suitable for road surfacing but very questionable for aggregate.

27 Savage, T. E., Geology of Henry County: Iowa Geological Survey, Vol. XII, p. 277, 1901.

The following section is condensed from one by Savage [28] at an old quarry near the southwest corner of section 22, Salem Township. This is the most complete section in the southwest part of the county, so far as is known:

		Feet
6.	Clay, reddish, with some gravel and small boulders	4
5.	Limestone, white, compact, fine-grained, fossiliferous, in layers 8 to 12 inches thick	3
4.	Limestone, fine-grained, similar to No. 5, in layers 3 to 7 inches thick, separated by clayey seams ½ inch to 1½ inches thick	9
3.	Limestone, yellowish, impure, in irregular layers 1½ to 2½ feet thick, nonfossiliferous, and containing numerous nodules of chert	6
2.	Limestone, coarsely oölitic	⅓
1.	Limestone, sandy, in layers 2 inches to 1 foot thick; exposed to the water's edge	3½

Savage refers Nos. 4 and 5 to the Pella and the lower members to the Verdi. Judging from his descriptions, nearly all of the beds are of value as a source of surfacing material, but for concrete aggregate, all except No. 5 are questionable and should probably not be used without testing. The upper part of this section reappears south of center section 35, Salem Township, and the lower part in NW¼ NW¼ section 26, Salem Township. Prospecting at the latter point has shown that a thickness of 16½ feet of rather unevenly bedded limestone (Upper St. Louis) is available to the amount of about 31,000 cubic yards under a maximum of 12 feet thickness of overburden. Other exposures in Salem Township are in SW¼ SW¼ section 3, SE¼ SE¼ section 21, east of center section 33, and SE¼ SE¼ section 35. At these points, and probably at others in the township, rock is obtainable in moderate quantity.

The best-known outcrops along Fish Creek are in SW¼ NW¼ section 20, Jackson Township. Some 10 feet of the Ste. Genevieve limestone has been removed from quarries there, though now the quarries have been so long abandoned that the faces are almost entirely sodded over. The Upper St. Louis, consisting of brecciated limestone with pockets and beds of shale, appears in considerable thickness farther downstream. Small quantities of stone are available. Farther east along Fish Creek are other, more limited exposures.

Outcroppings along Bogue Creek are numerous in sections 27 and 22, Jackson Township. A recently worked quarry in NW¼ NE¼ section 27 shows 10 feet of brecciated limestone, suitable for surfacing material, overlain by a few feet of soft incoherent sandstone. An older quarry was operated in SW¼ SW¼ section 27. Other surface ex-

28 Savage, T. E., Geology of Henry County: Iowa Geological Survey, Vol. XII, p. 269, 1901.

posures are known in NW¼ section 27 and NE¼ section 28, most of them showing the Upper St. Louis limestone. Moderate quantities of stone are available at several points.

The Keokuk and Warsaw formations are well exposed along the lower course of Mud Creek north of Lowell. In the higher bluffs, the St. Louis and Ste. Genevieve appear and are available in limited quantity. The same is true near Brush Creek in sections 31 and 32, New London Township, and section 6, Baltimore Township.

The St. Louis limestone is reported as occurring in NW¼ NE¼ section 3 and S½ SW¼ section 5, Jefferson Township, in the northwest part of the county, and Savage[29] has published sections of these occurrences. A few outcrops are known to occur in the west part of Jefferson and Trenton Townships. Skunk River, from Rome north, occupies an old drift-filled valley, only partly re-excavated by the present stream. Consequently exposures in and near its valley are scattered and limited in extent.

Sand and Gravel

A clayey iron-stained gravel, largely of residual origin, in many places forms a bed, usually one or two feet thick, upon the upper surface of the bedrock. This bed has been seen at numerous points, though everywhere under such heavy overburden as to render its development unprofitable. Glacial or interglacial gravels, though probably present at several points, have been examined only in SE¼ NW¼ section 7, Tippecanoe Township, in the south bank of Wolf Creek, where a 7-foot bed is present under 11 to 35 feet of overburden. The Illinoian moraine in New London and Baltimore Townships is loess-covered and shows no prominent gravelly hills. Where Mud Creek cuts it in the north part of Baltimore Township the drift is seen to be of an unusually sandy or gravelly composition and to contain small pockets of those materials. However, careful visual examination of the territory has failed to reveal anything available for development.

Mud Creek is a stream of high gradient, and as previously mentioned it cuts its upper course through the Illinoian moraine and its lower course through numerous exposures of bedrock. It thus carries important quantities of sand, gravel, and broken limestone, which are deposited in bars at favorable points along its course. The largest of

[29] Savage, T. E., Geology of Henry County: Iowa Geological Survey, Vol. XII, pp. 275-276, 1901.

these bars contain as much as several thousand cubic yards of material. A similar situation is found along Big Creek, where prospecting has shown some 15,000 cubic yards of material to be available in NE¼ SE¼ section 28, and NW¼ SW¼ section 27, Marion Township. At other points on Big Creek are other smaller bar deposits. Where a small creek from the south joins Skunk River in NE¼ NW¼ sec. 25, Jackson Township, deposition has formed a bar that contains several thousand cubic yards of sand, gravel, and broken rock. Probably many other small streams, especially in the southern half of the county, likewise carry limited quantities of similar materials.

At places in the channel of Skunk River are bars of sand or gravel. These are usually small, but many are large enough and show a good enough quality of material to be of value for local improvement projects. One such, in SE¼ NE¼ section 4, Tippecanoe Township, has been investigated. In the vicinity of Rome the extensive first and second bottomlands of the Skunk River valley are in many places composed of sand, at some points to a depth of several feet. The sand is rather fine-grained for any road or concrete uses, except possibly in an asphaltic aggregate. At greater depth is sometimes found a bed of gravel, which might be utilized if some inexpensive means were found for disposing of the overlying sand.

JEFFERSON COUNTY

The St. Louis and Ste. Genevieve stages of the Mississippian system underlie the whole county and form the uppermost consolidated beds in about 50 square miles in the northeast and southeast parts. The Spergen is recognized below the St. Louis at two points in Lockridge Township but probably is not continuous at that horizon. In the remainder of the county the country rock is Pennsylvanian sandstone or shale.

Both Nebraskan and Kansan glacial deposits are recognized in Jefferson County, though the former has been seen in only a few places. The combined thickness of Nebraskan, Aftonian, and Kansan is at few places greater than 125 feet. Upon the Kansan is a mantle of loess averaging about 12 feet thick, but in the rougher country adjacent to the more important streams it is largely removed by recent erosion. Alluvial deposits are rather small and consist mostly of clay, silt, or fine sand.

Limestone

Exposures of the Mississippian are common along and near Walnut

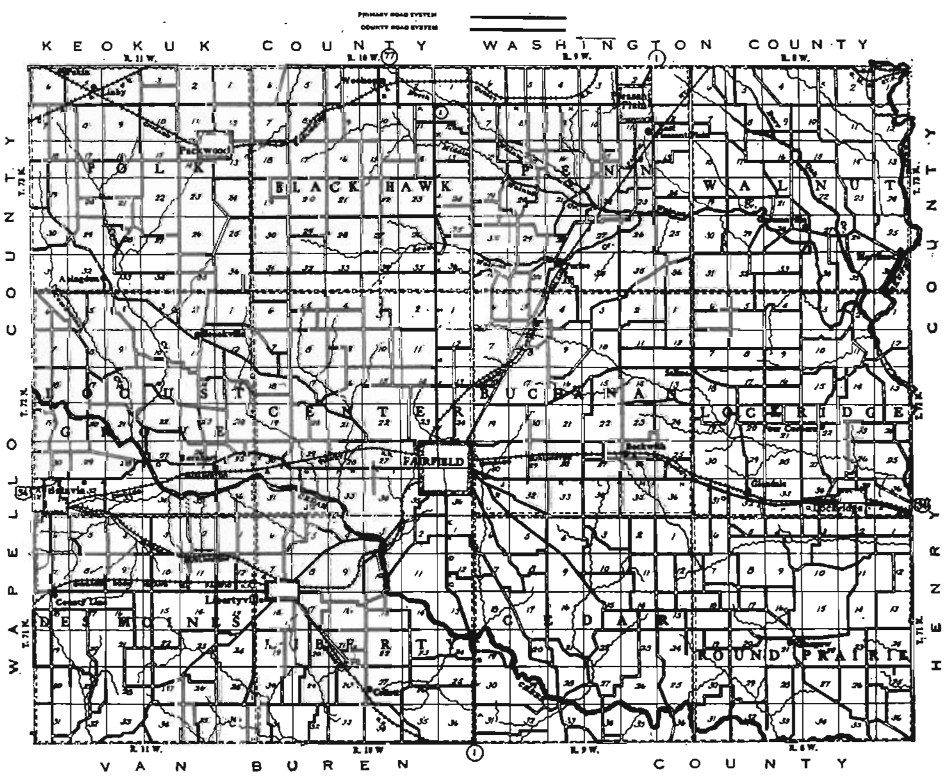
Creek in Walnut and the eastern part of Penn Townships, near Rocky Branch all along the south line of Walnut Township, near Skunk River and the lower course of its tributaries in eastern Walnut and Lockridge Townships, near Cedar Creek through Round Prairie and eastern Cedar Townships, and in scattered small areas east and south of Libertyville.

The Spergen is recognized at only two points (east of SW corner sec. 12, and near center NE¼ sec. 11, Lockridge Twp.) and consists of soft, generally massive sandstone of little importance to this report. Limestones of value are thus confined to the St. Louis and Ste. Genevieve stages.

Udden [80] has published excellent general descriptions of the St. Louis

IOWA GEOLOGICAL SURVEY. 51 PLATE XVIII

MAP OF
JEFFERSON COUNTY
IOWA



80 Udden, J. A., Geology of Jefferson County: Iowa Geological Survey, Vol. XII, pp. 386-390, 1901.

(his Springvale, Lower Verdi, and Upper Verdi beds) and the Ste. Genevieve (his Pella beds) formations. The following descriptions are condensed from his:

"The Springvale beds (Lower St. Louis) consist of soft dolomitic limestones interbedded with dolomitic marly shales and some sandstone of fine texture. The dolomite consists of an aggregate of crystals of minute but varying size. It frequently contains small lentils of green clayey materials, is here and there transversed by thin and curving fractures which have been filled with clear crystalline calcite, and occasionally contains a small admixture of fine sand. . . . In the limestones, impressions or imperfectly preserved fossil remains were noted.

"Above the magnesian limestones and shale just described, there is usually some exceedingly variable material most of which might be called mortar-rock as it consists of sand cemented together by a calcareous or magnesian matrix. The sand may be fine or coarse, the matrix may be calcareous or dolomitic, and the ratio between the sand and the matrix may vary to the exclusion of either one of the two. By an increase of clayey material either of these rock varieties may become shaly. Frequently the alternating thin seams have an unequal amount of matrix and sand. Finally, any of these variations and sediments may be brecciated and mingled with each other promiscuously. . . . The arenaceous (sandy) members just described change upward into brecciated, less sandy, and less frequently dolomitic limestone. At this horizon there are some very fine-grained calcareous ledges. . . . In the valley of Cedar Creek large lenses of a tough gray or almost black quartz . . . are seen replacing parts of certain ledges. . . . In the creeks draining into Skunk River there occurs near the top of this division a shaly or marly seam, usually about six inches in thickness, which can be recognized at points several miles apart. It lies between two ledges of solid limestone, which are sometimes slightly broken or brecciated. In correlating local sections this seam serves as an important landmark. . . .

"The Pella Beds (Ste. Genevieve). These consist mostly of heavy-bedded ledges of compact, calcareous limestone, alternating, especially above, with seams of greenish marly shales. Occasionally the limestone is slightly broken up and brecciated. Some ledges have a very fine texture. . . . The shales or marls are sometimes quite hard and stony. Fossils are common in the limestone and quite abundant in the marls."

Udden assigns to the Springvale beds a thickness of approximately 20 feet, to the Verdi about 60 feet, and to the Pella about 17 feet. The figure given for the Pella is probably greater than the average in the county, as the upper part of the formation has at many points been removed by post-Mississippian erosion. From observation of these strata it appears that stone of value for road surfacing may be obtained from any of the zones described by Udden, though probably not from the whole thickness of any of them. The upper part of his Verdi and the superjacent lower part of the Pella constitute the horizon of best quality. Many of the beds are usable as a source of aggregate.

In general, the strata described appear at some distance from rail transportation and they are at many places difficult of access from any centers of population or from main highways. Consequently there has been but little quarrying in the past, and so far as known very little is being carried on now. Therefore no more detailed description of the beds will be given. No place has been found where the available quantity of rock of satisfactory quality is sufficient to justify the erection of a large permanently located screening and crushing plant. However, there are numerous points where moderate quantities of satisfactory surfacing stone could be utilized by a portable or semiportable plant.

A few of the more easily workable locations are in NW¼ NE¼ section 10, NW¼ NE¼ section 11, and SW¼ SW¼ section 12, Lockridge Township; near center NE¼ section 34, Cedar Township; in E½ section 31 and SE¼ SE¼ section 29, Round Prairie Township; and near center section 30, Liberty Township. In addition to these, Udden [31] has published detailed sections of exposures of the Mississippian at the following points: SE corner section 24, southwest corner section 23, and NE¼ SE¼ section 21, Penn Township; SW¼ SW¼ section 26, southeast of center SW¼ section 20, SE¼ SE¼ section 19, and SW¼ SE¼ section 32, Walnut Township; SW¼ SE¼ section 3, NW¼ NW¼ section 3, NE¼ NW¼ section 8, SW¼ SW¼ section 10, NE¼ NE¼ section 14, NE¼ NW¼ section 24, and NE corner section 36, Lockridge Township; south of center section 5, SW¼ SE¼ section 34, near southwest corner section 34, NE¼ NE¼ section 32, and NE¼ SW¼ section 23, Round Prairie Township; northeast of center section 10 and NW¼ SE¼ section 9, Liberty Township; and near center section 25, Des Moines Township.

Sandstone

Coal Measures strata appear in every township but Polk and Black Hawk. They consist principally of shale and sandstone, the former being predominant. At most locations the sandstone is shaly, soft, and incoherent, but an exception is seen in the case of beds which appear in section 25, Locust Grove Township, and sections 3, 5, and 8, Des Moines Township. The best-known quarry was in NW¼ NW¼ section 25, the total thickness of sandstone there being about 30 feet. The

31 Udden, J. A., Geology of Jefferson County: Iowa Geological Survey, Vol. XII, 1901.

quarry operated only in the harder beds, from 5 to 12 feet thick. The stone is similar to that in Marion and Lucas Counties and is suitable for road-surfacing work, though probably not for aggregate. Moderate quantities are available.

A soft, incoherent yellow sandstone is well exposed in the bluff south of Cedar Creek in NW¼ section 19, Cedar Township, and NE¼ section 24, Liberty Township. It breaks down readily to a fine yellow sand, which has been used for foundry work in Fairfield.

Shale

Some mining has been carried on near Perlee and north of Lockridge, but the mines are small, and piles of burned shale from them are of little importance as a source of road surfacing material.

Sand and Gravel

Udden [82] has described outcroppings of glacial (or possibly preglacial) sands and gravels at southwest corner section 1, Walnut Township; NW¼ NW¼ section 12, Walnut Township; E½ SE¼ section 11, Lockridge Township; near southeast corner section 24, Round Prairie Township; and in SW¼ section 35, Round Prairie Township. The material is clayey and iron-stained and interbedded with sand. In section 24, Round Prairie Township, the beds are somewhat cemented together by a calcareous or ferruginous cement. Judging from Udden's descriptions, the material is unavailable or available in only very small quantity. A similar deposit in SW¼ SE¼ section 10, Buchanan Township, has been prospected and found to have about 1,000 cubic yards available. Systematic and careful search would probably disclose supplies of like nature at other points in the county.

Alluvial deposits, both on Skunk River and on the smaller streams, consist principally of fine sand and silt and are unimportant in this connection. Exceptions are often seen in some of the smaller streams, which, if cutting through a considerable thickness of glacial drift and indurated rock, have collected the sand, pebbles, and rock fragments into bars, sometimes of moderate size. Residents of the locality make use of them for small improvements.

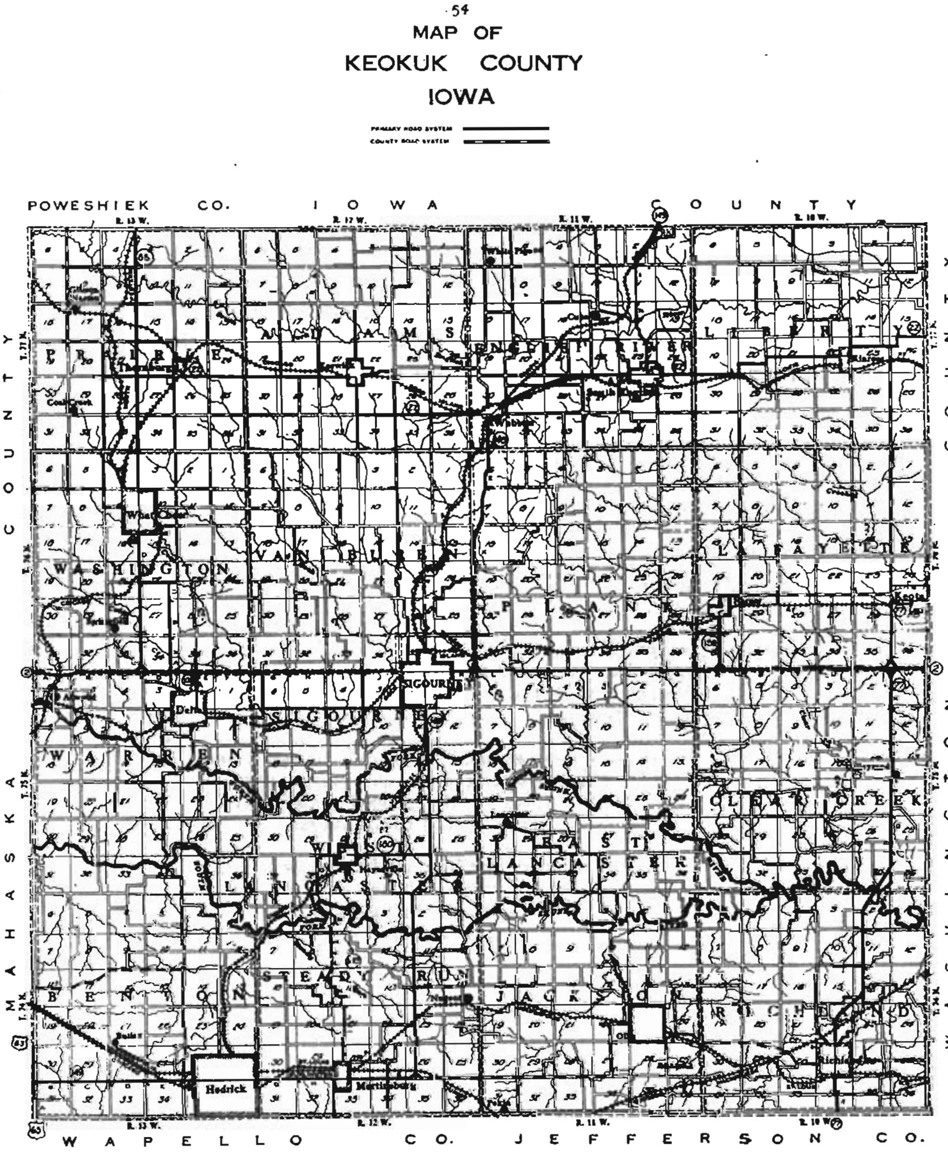
KEOKUK COUNTY

The bedrock in most of Keokuk County is of the Meramec stage of

82 Udden, J. A., Geology of Jefferson County: Iowa Geological Survey, Vol. XII, pp. 422-423, 1901.

the Mississippian system and includes the St. Louis and Ste. Genevieve limestones. The Keokuk appears at a few localities in the lower slopes near both branches of Skunk River and is believed to lie next beneath the drift in the northeast corner. In the latter locality it is known to be exposed at only one point and there to very limited extent.

IOWA GEOLOGICAL SURVEY. PLATE XIX



Above the Mississippian rocks, Pennsylvanian (Des Moines series) beds cover the northwest corner of the county and occupy scattered small outliers in other parts. It is probable that the Pennsylvanian is present also in the flat uplands of the southwest and southeast corners of the county, where, however, it is not exposed.

Upon the indurated rocks is a mantle of glacial drift of Nebraskan and Kansan ages. The Nebraskan is nearly everywhere concealed beneath the Kansan, the latter being widely exposed in every township. A layer of post-Kansan loess a few feet in thickness overlies the drift in the flat or gently rolling areas, while in the rougher country near the larger streams it has been largely removed by recent erosion. The loess is ordinarily not over 10 feet thick, and the total thickness of loess and drift at few points exceeds 150 feet.

Limestone

The Keokuk limestone has been recognized at a number of points near both branches of Skunk River. However, it is in general low in the hills and the slopes above it are steep and high. Old quarry workings in it are confined to the N½ section 10, Jackson Township, and N½ section 6, Richland Township. It is available for further development at these points and perhaps also in SE¼ section 5, and N½ section 11, Jackson Township, and near center section 13, West Lancaster Township. The best exposures are in section 10, Jackson Township, and the following section was obtained in SE¼ NW¼, in the west bank of Rock Creek:

	Feet	Inches
12. Limestone, buff, massive, magnesian, medium-grained, percentage of wear 25.3, soundness satisfactory. Chert seams and nodules constitute about 10 percent of the member. Included are several pockets of soft brown stone	4	4
11. Shale, drab, argillaceous	2	
10. Limestone, buff to gray, coarse-grained, crinoidal, massive, percentage of wear 7.6, soundness satisfactory, with large nests of calcite constituting about 5 percent of the member, and chert in the form of small nodules and irregular thin bands, about 2 percent	2	4
9. Shale, gray to drab		7
8. Limestone, gray, hard, sound, subcrystalline, medium-grained, massive, with a 5-inch chert band 2 feet below the top	3	
7. Limestone, gray, medium- to coarse-grained, crinoidal, percentage of wear 6.8, soundness satisfactory. Interbedded chert constitutes about 5 percent of the member. Included are pockets and irregular layers of shale and soft shaly limestone, constituting about 10 percent	5	6
6. Limestone, ash-colored, weathers drab, very soft, fine-grained, one bed	1	5
5. Limestone, bluish gray, fine-grained, and limestone, reddish gray, coarse-grained, in about equal proportions, grading into each other both horizontally and vertically. Percentage of wear 6.0 and soundness satisfactory. Included is 15 to 20 percent of gray chert in		

nodules and bands	5	
4. Shale, gray to buff, calcareous		10
3. Limestone, gray to buff, medium-grained, moderately hard		9
2. Shale, gray to buff, calcareous		4
1. Limestone, gray, massive, fine-grained, crinoidal in the lower part, hard, probably sound, with numerous thin irregular bands and nodules of chert	3	6

According to Van Tuyl,[33] who has published a section of the beds here, No. 1 has a total thickness of nearly eight feet. Above these beds the slope rises rather steeply, so that only limited quantities are available under moderate stripping. Mining of the lower beds, by means of tunnels back from the outcrop, might prove to be a profitable alternative. At the other locations mentioned, the Keokuk is even less easily available than in section 10, Jackson Township.

Nearly all of the outcrops of the St. Louis and Ste. Genevieve limestones are in the south half of the county, principally on or near the two branches of Skunk River. The best-known localities are as follows: Along Richland Creek north of Richland; on or near Clear Creek and Skunk River in the south part of Clear Creek Township; south of South Skunk River and near Rock Creek north, northwest, and west of Ollie; at various points south of South Skunk River and along tributaries to it from the south, in the north part of Steady Run and Benton Townships; near North Skunk River in Sigourney and Warren Townships; at a few points east and southeast of What Cheer; and along Bridge Creek north of Sigourney. Of these localities, the two last mentioned are the only ones where the Ste. Genevieve is known to appear.

Near Richland Creek in Richland Township are numerous rock outcrops, though none is of any great extent. It appears that here is a ledge of hard light-gray fine-grained limestone about three feet thick, underlain by sandy and magnesian beds, which are yellow to brown in color, massive, rather soft, and contain lenses and thin beds of hard fine-grained limestone. These lower beds are known to be about 25 feet thick and they are for the most part unsuitable as a source of aggregate or even of surfacing material.

In the southern part of Clear Creek Township a similar succession is found, though here the sandy and magnesian beds in places are as much as 40 feet thick. Locally they are well enough indurated to be of some value for surfacing on light-traffic roads. Owing to the thickness

33 Van Tuyl, F. M., The Stratigraphy of the Mississippian Formations of Iowa: Iowa Geological Survey, Vol. XXX, p. 179, 1921-22.

of the member it is well exposed and easily available for quarrying, particularly in sections 27, 28, 33, 34, 35, and 36, Clear Creek Township, and section 4, Richland Township. The lower part includes a series of soft shaly or sandy beds, weathered yellow or buff, of no value for road or concrete work, and extending downward perhaps 20 feet to the top of the Keokuk limestone.

The limestone part of these yellowish magnesian beds at some exposures has the form of a conglomerate of well-rounded fragments of hard gray fine-grained limestone or of light-gray chert, in a matrix of yellow or buff sandy magnesian stone. This facies is well shown in the upper part of an exposure in SW¼ SE¼ section 28, Clear Creek Township. In NE¼ NE¼ and again one fourth mile south of northeast corner section 29, Clear Creek Township, a conglomerate of similar nature with associated coarse-grained sandstone shows a thickness of a few feet. The upper part of the conglomerate is much weather-broken and grades upward into residual material containing much gravel and small boulders. The gravel has been worked in a small pit in NE¼ NW¼ and, with the underlying unweathered stone, may be available in additional limited quantity for road surfacing work.

The following general section of the St. Louis limestone is found northwest of Ollie:

	Feet	Inches
8. Limestone, gray, hard, compact, fine-grained, laminated	2	6
7. Sandstone, buff to yellow, massive, fine-grained	3½–5	
6. Limestone, gray, hard, compact, fine-grained		8
5. Limestone, brecciated, with a shaly or sandy matrix		8
4. Limestone, gray, hard, fine-grained, slightly brecciated	8–11	
3. Sandstone, soft, buff, shaly	2	
2. Sandstone, gray, moderately hard, fine-grained, massive	5	
1. Limestone, magnesian, granular, usually soft and shaly	20	

Beds Nos. 7 and 8 can not everywhere be seen and are in places apparently missing entirely. Again, No. 8 in some places appears in the form of large lenses in the upper part of No. 7, in which case No. 7 shows the maximum thickness given. Numbers 5 and 6 are usually present though not persistent in character. Sandstones Nos. 2 and 3 are persistent, and No. 2, being very resistant to erosion processes, is usually prominent in natural exposures. Number 1 is well exposed in only a few places, as it breaks down readily under weathering and tends to become covered with sod. Number 1 represents the Lower St. Louis limestone and the remainder of the section the Upper St. Louis.

Exposures of the various members of the preceding section are abundant in sections 10, 15, 22, 21, and the NE¼ section 20, Jackson

Township. Quarrying on a small scale has been carried on in the past at a few points. At present the most favorable sites for development (of bed No. 4 of the preceding section) appear to be in NE¼ SW¼ NW¼ and again in NW¼ SE¼ NW¼ section 22. At each of these points an area of one half acre may be worked with a probable maximum overburden of 15 feet.

The limestone member of the Upper St. Louis at Ollie is slightly thicker to the west. Bain [34] reports a 10-foot bed of gray fine-grained limestone near north quarter-corner section 12, Steady Run Township, though this thickness is no longer exposed. At the south end of the highway bridge here 10 feet of buff medium-grained magnesian limestone is exposed. It has a wide range in hardness and probably is usable only for road surfacing work. In the bluffs in section 11 and the W½ section 12, similar strata are present, though very poorly exposed. Near center SE¼ section 10, Steady Run Township, the following section may be made out:

	Feet
4. Limestone, white, hard, fine-grained	4
3. Unexposed. Probably shale or soft sandstone	4
2. Limestone, white, hard, fine-grained, with a few chert nodules and a few very thin shale partings	10
1. Sandstone, yellow to buff, soft	10

At this point moderate quantities of stone suitable for road or concrete work are available without difficulty.

North of center SW¼ section 13, Benton Township, the east bank of the small creek whose valley is followed by the railroad shows, in descending order, glacial clay increasing in thickness at a moderate grade from zero, 2 feet of limestone, 2 feet unexposed but probably sandstone, and 10 feet of limestone. At this point about one acre area is easily workable, and a good quality of stone may be obtained. Similar conditions are noted in the hills in sections 11 and 12, Benton Township, and in NW¼ section 7, Steady Run Township. At the latter point, there appears to be about 30 feet of soft white and yellow sandstone below the limestone member. Bain [35] reports 30 feet of imperfectly exposed limestone alternating with sandstone at the old Springvale mill site in NE¼ section 34 (T. 75 N., R. 13 W.). Other good exposures of limestone are known to be present farther west in the country south of South Skunk River, in White Oak Township, Mahaska County.

34 Bain, H. F., Geology of Keokuk County: Iowa Geological Survey, Vol. IV, p. 270, 1894.
35 Bain, H. F., Geology of Keokuk County: Iowa Geological Survey, Vol. IV, p. 271, 1894.

The St. Louis appears in many places near North Skunk River, south, southwest, and west of Sigourney. On account of the soft and easily weathered character of much of the rock, good natural sections are difficult to obtain. Also, quarry operations were limited in extent and are now entirely discontinued, so that there are no good artificial sections. The 10-foot limestone is present at some points along South Skunk River, while at others it can not be found. Following are a number of typical sections:

Section in NW¼ SE¼ section 13, West Lancaster Township

	Feet Approx.
3. Sandstone, buff, soft	30–40
2. Shale, drab, calcareous, and buff shaly limestone, with small nodular masses of quartz and chert. Poorly exposed, the thickness being somewhere between the limits given	10–30
1. Limestone, gray, hard, sound, crinoidal, thin-bedded. To river level	10

Number 1 is referred to the Keokuk, No. 2 represents Bain's [36] Springvale beds (Keokuk or Lower St. Louis), and No. 3 is evidently an Upper St. Louis sandstone. An 8-foot bed of hard dense limestone is reported to be present in the higher bluff to the south, where it may be quarried in limited quantity. Number 1 of the section given is also available in small quantity by stripping.

In NW¼ NE¼ section 14, Sigourney Township, the same three lower members appear in the north bank of the river, limestone being here more noticeable. The following is the section:

	Feet Approx.
3. Limestone and sandstone, buff, moderately hard, with small chert fragments and masses of white fine-grained limestone	10
2. Shale, drab, calcareous, and buff shaly, sandy soft limestone. Probably massive when unweathered	25
1. Limestone, coarse-grained, hard, gray, thin-bedded, crinoidal	2

Number 3 is partly usable for surfacing work, though not for concrete. It is available in limited quantity at several points in SE¼ section 10, NW¼ NW¼ section 15, and in the south part of section 15, all of township 75 north, range 12 west.

A limestone lying above the beds just described is widespread in sections 20 and 21 of township 75, range 12. Following is the approximate section in W½ NE¼ SE¼ section 21:

	Feet Approx.
4. Limestone, light gray, weathers white, hard and sound, fine-grained, nonmagnesian	10–15
3. Shale, drab, calcareous	5
2. Sandstone, principally soft, including a few feet of conglomeratic gray	

36 Bain, H. F., Geology of Keokuk County: Iowa Geological Survey, Vol. IV, pp .277-279, 1894.

	limestone and about 1 foot of sandstone recrystallized to almost pure quartz. Drab shale at bottom	20
1.	Limestone, brown, fine-grained, magnesian, fairly hard, sound, massive. To river level	20

Number 1 is for the most part suitable for road surfacing, but on account of overlying inferier beds it is difficult to work. Number 4 is suitable for road or concrete work and several thousand cubic yards is available under moderate stripping. In NE corner NW¼ section 20, a cliff above the river shows, in descending order, 5 feet of thin-bedded medium hard limestone, 5 feet unexposed, 10 feet of hard massive limestone, and 20 feet unexposed. Here also rock can easily be quarried from the upper limestones.

Farther west along North Skunk River are numerous exposures, particularly in sections 4, 8, 9 and 10, Warren Township. Details of the location and nature of the outcrops are incomplete, but one or two workable limestones appear to be present. In NE¼ NW¼ section 9, a 5-foot bed of limestone has three feet of sandstone above and an unknown thickness of sandstone below. Small quantities are available. Bain[87] reports a 2½-foot bed of limestone between two sandstones in NE¼ section 8. An old quarry near center section 9 shows the following approximate face section:

		Feet Approx.
6.	Clay, nearly all residual	3
5.	Limestone, massive, argillaceous	6
4.	Limestone, thin bedded, purer than the above, quite hard	3
3.	Limestone, massive, argillaceous	4
2.	Unexposed	8
1.	Limestone conglomerate, massive, much weathered	4

Accurate information as to the quality of this rock for road or concrete work is lacking. It may be that the upper strata represent the Ste. Genevieve. At this point a few thousand cubic yards of rock could be quarried without difficulty.

The Ste. Genevieve limestone was at one time exposed at several points east and southeast of What Cheer, principally in SE¼ section 11, SW¼ SW¼ section 12, NW¼ NW¼ section 13, and SW¼ section 35, Washington Township, and E½ E½ section 7 and NE¼ NW¼ section 17, Van Buren Township. At all of these points the exposure is now entirely or almost entirely obscured by overwash. North of the south quarter-corner section 35, Washington Township, about 15 feet of limestone under prohibitive overburden can be made out. It is possible that limited amounts of material are available at the other locations mentioned, though of what quality is unknown.

87 Bain, H. F., Geology of Keokuk County: Iowa Geological Survey, Vol. IV, p. 274, 1894.

Most of the outcroppings north of Sigourney show an Upper St. Louis sandstone, fine-grained and poorly cemented and having a thickness of 15 to 25 feet. Locally the sandstone contains thin beds or lenses of limestone, which is, however, almost entirely unavailable. Capping the sandstone is a limestone member a few feet thick that has been quarried in a small way and is still obtainable in moderate quantity at several points in sections 12, 13, 23, 24, 25, and 26, Van Buren Township. The maximum known thickness of this upper limestone member is in a quarry in NW¼ SW¼ section 13, recently worked

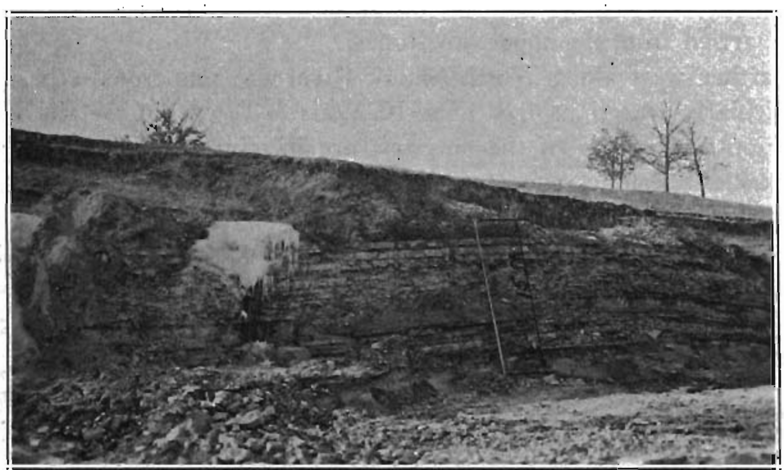


FIG. 2. — Ste. Genevieve limestone in County Quarry in section 13, Van Buren Township, Keokuk County. This shows the characteristic thin bedding and variable dips.

by the county (Figure 2). The detailed section of the face of this quarry is as follows:

		Feet
6.	Clay, glacial and residual	4
5.	Limestone, light gray, fine-grained, hard, sound, probably massive when fresh, but now much weather-broken into rather thin beds or blocks up to 6 inches thick. No fossils noted	6
4.	Limestone, gray to dark gray, medium-grained, hard, sound, one strong ledge	1
3.	Limestone, dark gray, fossiliferous, perhaps somewhat shaly, hard, but probably unsound, in several beds, with thin partings of black fissile shale	2
2.	Shale, bluish gray and very sandy above, drab and clayey below. In the middle there appears locally a 9-inch bed of hard gray medium-grained limestone	3½
1.	Limestone, gray, heavy-bedded, medium-grained, hard and sound, no fossils noted. On account of water in the quarry pit, only the upper 4 feet of this member can now be seen, but the quarry superintendent states that 7 to 8 feet is the total thickness	7

Though these beds show local dips, some of them rather sharp, they seem to be quite persistent as to character and thickness within the limits of the quarry. Numbers 1, 4, and 5 are suitable for aggregate or for surfacing material. Numbers 1 and 2 are believed to represent the St. Louis, while Nos. 3, 4, and 5 are tentatively referred to the Ste. Genevieve.

Scattered exposures near English River in the north part of the county are very limited in extent and show no stone available, either by stripping or by mining.

Mine Shale

At one time an extensive coal mining industry was carried on near What Cheer, but this has now almost entirely ceased. The waste piles from these mines have been and are still being utilized for surfacing material. Rather large quantities are yet available. The larger mines were in sections 3, 4, 5, 9, 10, and 15, Washington Township, and sections 33 and 34, Prairie Township. Smaller mines located near Thornburg, south of Delta, southwest of Richland, and north of Sigourney, have available only small amounts of possible surfacing materials.

Sand and Gravel

Small pockets and beds of oxidized, rather clayey gravel are found within or beneath the glacial deposits in many places. However, none is known to be large enough to have any value except for small improvements of a very local nature. In all, some thirty such deposits have been investigated. The largest supply discovered is north of center NW¼ section 20, Adams Township, where about 1,500 cubic yards has been removed, and 400 cubic yards still remains. About one fourth mile east of center section 6, Richland Township, the persistent layer of residual gravel and weathered and broken stone that overlies the Keokuk in many of its exposures is several feet thick and may be available in small quantity. Careful search might disclose other points in the county where this residual material would be workable.

Small streams of high gradient carry sand and gravel obtained from the glacial deposits, and, if they are cutting into the bedrock, they also carry much broken limestone and chert. All the supplies of such origin are small, but much of the material in them is clean, well sorted, and durable, overburden is light or altogether lacking, and the supply is replenished after each heavy rain. Consequently, for small local improvements, these deposits have been and will continue to be used quite extensively. Typical examples are along a small south-flowing creek in sections 19 and 30, Clear Creek Township, along the north-flowing creek in sections 12 and 13, Benton Township, or along Rock Creek in sections 10, 15, and 21, Jackson Township.

The surface alluvium of the two branches of Skunk River consists of clay, silt, or fine sand. The same is true of English River in the north part of the county. However, the lower alluvium along the Skunk at some places contains beds of gravel or coarse sand, some of which are heavy enough to warrant consideration as a material source. An example is about one fourth mile east of southwest corner, section 2, Steady Run Township, where soundings for a bridge show a bed of 34 feet of clean sound sand and gravel under 9 to 10 feet of overburden. The upper part of the deposit is mostly sand, while the lower part contains coarse gravel. The extent of the deposit is unknown but may be rather large.

LEE COUNTY

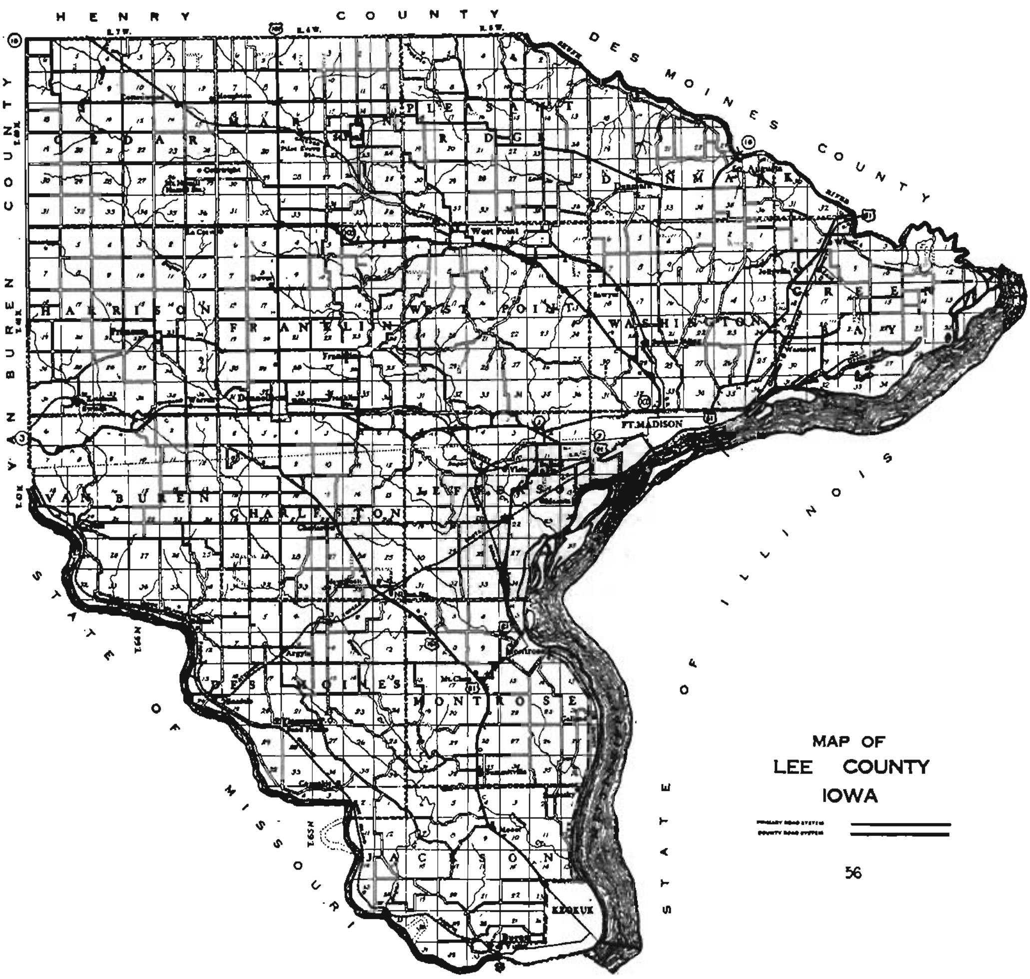
Except for the Kinderhook formation, the whole Mississippian section for southeastern Iowa is visible in Lee County. The Burlington appears in the lower slopes near Wever and Augusta and north and northwest of Denmark. The Keokuk may be seen in the higher slopes in the same locality and it forms the lower bedrock in the Keokuk-Montrose area. The Warsaw appears above the Keokuk in this latter area, and, in addition, its upper part is exposed at numerous places in conjunction with the overlying St. Louis in the western and north-central parts of the county. The Spergen appears locally beneath the St. Louis at many points where the latter outcrops.

The uppermost bedrock in a large part of the county is the St. Louis limestone, above which the Ste. Genevieve limestone and sandstone appear at some places. These beds form the highest exposures in the Keokuk-Montrose area and again in the hills south of Skunk River northwest of Denmark. They constitute the main bulk of the rock bluffs near Des Moines River and the lower courses of the small creeks tributary to it in the Croton-Belfast-Hinsdale locality. To them may be referred practically all of the exposures in the interior of the county, such being most numerous on East Sugar Creek and its tributaries.

Though the lowermost Pennsylvanian (Des Moines series) strata may be present beneath the unconsolidated beds in a large part of the less deeply dissected areas in the west, northwest and north parts of the county, exposures are few and limited in extent. They consist principally of shale, with some sandstone. Coal mining has been carried on only in very small scale, and burned shale from mine dumps is not known to be present in any usable quantity. Consequently the Des Moines series offers nothing of sufficient value to be mentioned further in this report.

Three glacial drift sheets, the Nebraskan, the Kansan, and the Illinoian, cover parts or all of this county. The Nebraskan has been recognized at only a few points but is believed to underlie the Kansan continuously throughout the area. The Kansan is widely exposed in the west part of the county, while in the Illinoian area its outcrops are

IOWA GEOLOGICAL SURVEY. PLATE XX



fewer. The Illinoian occupies that part of the county east of a line passing south from the north boundary to West Point and thence south-southeast to Mississippi River near Montrose. In this part of the county it forms most of the surface exposures except in the lower slopes of the deeper valleys. Kay [38] has described outcroppings of all three tills, with related interglacial materials, as being observed in the south part of Denmark and the north part of Washington Townships. Loess covers the earlier deposits with a layer from a few feet to 15 feet thick in the interstream areas, while on the steeper slopes it has been largely removed by recent erosion. The total thickness of unconsolidated deposits in Lee County at few places exceeds 100 feet, except as noted in the following paragraph.

Gordon [39] has shown that in preglacial time the course of Mississippi River lay somewhat to the west of its present course and that the old valley was excavated to a depth about 130 feet below the bed of the present river and was later filled with glacial and alluvial materials (Figure 3). His studies have indicated that the old valley had an average width of about six miles. At the same time the ancestral Des Moines River followed a course somewhat to the east of that in which it now runs, and its valley was excavated to an average width of about three miles and a depth in proportion to that of the Mississippi to which it was tributary. This valley was likewise refilled with unconsolidated materials. Information on the depth of the refilling of these two old valleys is meager, but a well record at Mount Clara (Sec. 16, Montrose Twp.) shows the highest bedrock to be 305 feet below the surface and about 245 feet lower than in the exposures at Montrose, two miles northeast. The accompanying map of the county shows the extent of these two valleys as mapped by Gordon. Their presence is of importance to this report for the reason that in the area occupied by them no rock is exposed at the surface.

Limestone

Examination of the map of the county shows that, by reason of the presence of the preglacial valleys just mentioned, rock outcrops are confined to certain rather definite areas. These are as follows: the Keokuk-Montrose area, three to four miles wide, extending along Mississippi River between those two points; the Croton-Belfast-Hins-

38 Kay, G. F., and Apfel, Earl T., The Pre-Illinoian Pleistocene Geology of Iowa: Iowa Geological Survey, Vol. XXXIV, pp. 148-151, 1928.

39 Gordon, C. H., Buried River Channels in Southeastern Iowa: Iowa Geological Survey, Vol. III, pp. 237-255, 1893.

dale area, with outcroppings along Des Moines River and lower courses of small streams tributary to it; the East Sugar Creek area, extending from the Fort Madison-Donnellson road northward to the central part of Marion Township, beyond which point the creek has not cut to bedrock; a small area along Lost Creek through the northeast part of Washington Township; and the Skunk River area, extending along that stream and the lower courses of its tributaries from Wever northwestward to the northeast part of Pleasant Ridge Township.

Keokuk-Montrose Area. — The Keokuk limestone is exposed in the lower part of the bluffs almost continuously from the mouth of Des Moines River to Montrose. Its top lies about 50 feet above water level in the river below the dam at Keokuk. Above the dam the water level is about 40 feet higher or near the top of the Keokuk formation. To the

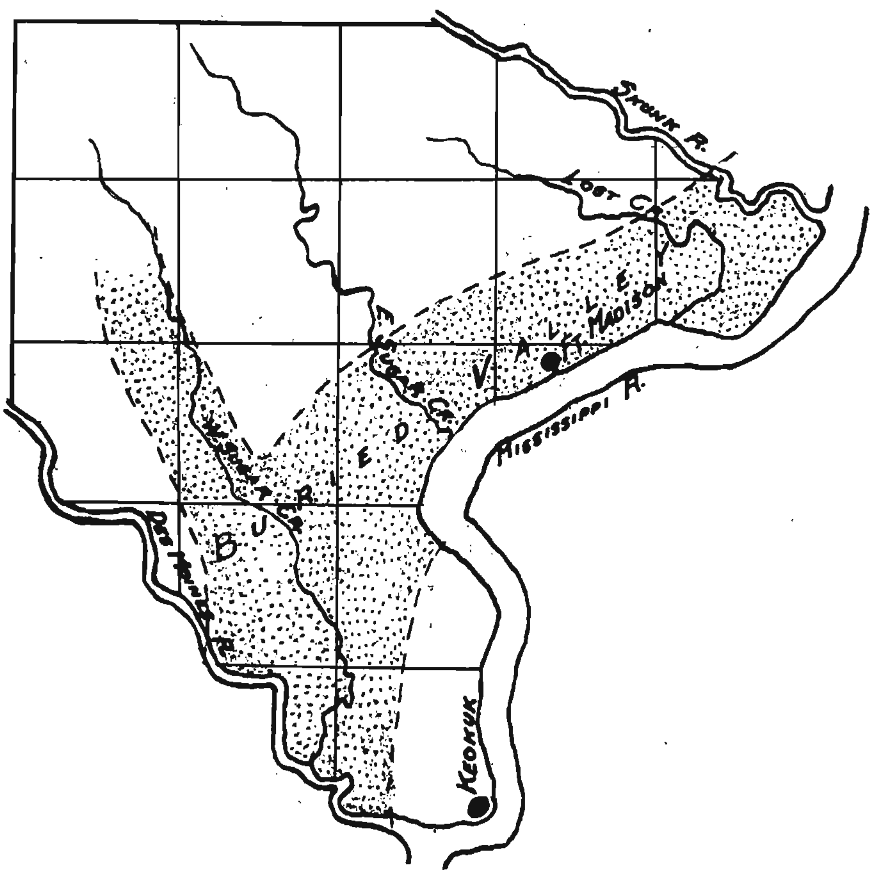


FIG. 3. — Map of Lee County showing buried valley (after Gordon).

north the beds rise gently until the top of the Keokuk is 25 feet above water level at Montrose. Natural exposures are thus confined to the upper part of the formation. However, quarrying operations have been extensive, and artificial sections reach down through the whole thickness of the Keokuk limestone proper (35 feet) and in some cases into the underlying upper part of the Montrose chert member.

A large number of good detailed sections of the Keokuk limestone at Keokuk and Montrose have been published. Careful examination of the sections previously published and of others obtained by the writer during a study of the Keokuk formation in this vicinity in 1929 indicates that while the beds are markedly uniform in thickness and general character, they show abrupt variation in detail, even within the limits of a single quarry opening. Consequently, no detailed sections will be given. Following is a general section for this area, as compiled from all available sources of information:

	Feet Approx.
7. The upper half of this member is a fair grade of limestone, and the lower half is in places a shale or shaly limestone	6
6. This zone is nearly all limestone, usually hard and sound, but locally shaly and of questionable soundness	10
5. Principally shale, or interbedded limestone and shale, locally cherty	3
4. Limestone, hard, and usually massive and sound. Locally with a moderate percentage of chert. Near Keokuk the lower half of this member contains geodic cavities lined or filled with calcite. Near Montrose a 1½-foot shale band occurs at the middle	12
3. Shale or shaly limestone. A rather persistent member	½–1
2. Limestone, massive, hard and sound, usually with very little chert	3
1. Limestone, with 10 to 50 percent of chert. The limestone is massive, hard, and usually sound, but the chert shows signs of unsoundness. Shale seams are thin or missing altogether. Except for the upper few feet, this zone is not visible near Keokuk or Montrose but may be seen on the opposite bluffs, between Hamilton and Warsaw, Illinois	35–40

Number 1 of this section is the Montrose chert member, while the remainder is the Keokuk limestone proper.

The rocks included in the Keokuk limestone proper may be divided into three general classes. The first is a coarse-grained massive gray crystalline hard sound limestone, strongly fossiliferous and with chert in fairly large nodules or continuous bands in different proportions up to 10 percent of the whole. The second is a dark gray, very fossiliferous, hard but in large part unsound shaly limestone, with chert in about the same range of proportion as in the first class, but appearing in smaller nodules or in the form of irregular veins and pockets. The third class is a dark gray fossiliferous calcareous shale. The first class is suitable for aggregate or for road surfacing work. The second class is of doubtful quality for either purpose, though for the most part fairly satisfactory for surfacing. The third class is of no value for road or concrete work. Analysis of five detailed sections near Keokuk shows that, of the beds exposed, these three classes average 38 percent, 53 percent, and 9 percent, respectively. Analysis of five detailed sections near and south of Montrose shows that, of the beds there exposed (including the upper half of the Montrose member in one section), the three classes average 58 percent, 33 percent, and 9 percent, respectively. At any particular location it is possible to set off for quarrying some part of the Keokuk in which the percentage of the first class of stone is considerably higher than the averages given. The maximum uninterrupted thickness of stone which is all of the first class is nearly everywhere in the neighborhood of 10 feet. It occurs in different horizons at different places, though usually in bed No. 4 or No. 6 of the general section.

Owing to the extent of former and present quarry operations, and also on account of the general steepness of the bluffs and the presence of overlying inferior stone, the Keokuk limestone has now become almost entirely unavailable by stripping, unless in small quantities (not to exceed a few thousand cubic yards). The only exceptions to this rule are in the bottoms of the present open quarries (which have for the most part reached down to or into the Montrose member) or in SW¼ SW¼ section 12, Montrose Township, across the road to the west of the abandoned Cameron & Joyce quarry. Mining of the more desirable beds from the outcrop is a possibility at numerous points, though it must be remembered that only the upper part of the formation is above water level above the Keokuk Dam.

During the 1931 season two plants operated in the Keokuk limestone. These were the Keokuk Quarry and Construction Co., near the mouth of Soap Creek at Keokuk, and the McManus Quarry Co., in NE¼ section 36, Montrose Township.

The first-mentioned quarry has a face about 44 feet high, of which the lower 12½ feet is referred to the Montrose and the remainder to the Keokuk limestone proper. The detailed section shows that the percentages of the three classes of stone are 44, 47, and 9 respectively. Recent workings are confined to the lower 16 feet of the face. The quarry is entirely surrounded by permanent improvements, so that the only possible extension is downward. Stone is loaded by hand on narrow-gauge cars, which are raised by cable on an incline to the primary crusher. The crushed stone passes through sizing screens of the cylindrical revolving type, oversize being returned to secondary crushers. The plant is electrically operated, and its capacity is estimated at 20 tons per hour.

At the McManus quarry, the face is 40 feet high and represents the full thickness of the Keokuk limestone proper. The detailed section shows that the percentages of the three classes of stone are 56, 37, and 7 respectively. The upper beds are worked by stripping and the lower ones by mining from the outcrop in a part of the quarry where overburden has become excessive. The stone is loaded by hand on trucks and hauled to the plant, which is of the usual type, consisting of primary and secondary crushers and revolving cylindrical screens for sizing. The plant is operated by steam generated at the site, and its capacity is estimated at 25 tons per hour. Extension of the quarry by stripping is limited to an area of not over one acre, but mining operations can be extended almost indefinitely.

In the Keokuk-Montrose area the Warsaw formation is exposed above the Keokuk almost continuously in the Mississippi River bluffs. This formation consists of geodiferous shaly unsound massive limestone and of massive soft calcareous fossiliferous shale in which are beds of fossiliferous shaly and magnesian, usually unsound limestone. None of these beds is of value as a source of road or concrete materials. The Spergen is represented by discontinuous and usually thin deposits of rather soft brown granular magnesian sandy limestone, almost entirely unavailable on account of not being found except where immediately overlain by the St. Louis limestone. Across Mississippi River, near East Fort Madison and Pontoosuc, the Spergen is better exposed and has been extensively quarried. In general it is not well enough indurated to be of value as aggregate or even as surfacing material, unless on light-traffic roads.

The St. Louis limestone forms a persistent though inconspicuous escarpment in the Mississippi River bluffs and stands 75 to 100 feet above water level in this area. Its maximum exposed thickness is about 30 feet (in Keokuk) and its minimum about 12 feet (near Montrose). The stone has some differences in character but is nearly all conglomeratic. The included fragments are of various sizes of light gray fine-grained hard, sound limestone, or of medium-grained buff to brown magnesian limestone of differing hardness. The matrix ranges in character from limestone to shaly limestone or shale and also differs in quantity. At Keokuk the upper part of the formation consists of the light gray fine-grained nonmagnesian stone and the lower part of brown magnesian stone. At other points the lower magnesian conglomerate is replaced by disturbed beds of granular magnesian stone, or the whole thickness of the formation is made up of a gray nonmagnesian conglomerate. On account of the differing and locally unsatisfactory character of the matrix, most of this material is unsuitable as a source of aggregate. For road surfacing work, most of it is satisfactory. Because of its extremely irregular structure it has been quarried at only a few points and even there in a small way. Being high in the bluffs, it appears well back along the small creeks tributary to the Mississippi and it is available in limited quantity at many points by stripping.

Croton-Belfast-Hinsdale Area. — Along Des Moines River from the county line between Croton and Farmington to the Santa Fe railroad near Hinsdale, rock outcrops are numerous or almost continuous. The exposures also extend up the small tributary creeks for distances up to about one mile. The general dip of the strata is to the south-southwest, so that practically the same succession of beds is repeated in all of the exposures. The top of the Warsaw is 15 to 25 feet above water level in Des Moines River. Above this the Spergen is well exposed near Belfast and Hinsdale, with a maximum thickness of about 30 feet, while near Croton it is entirely missing or only a very few feet thick. The Warsaw as exposed is a soft argillaceous shale. The Spergen includes an assemblage of beds that has a wide range in character, including a cross-bedded crinoidal limestone, a massive brown but rather soft dolomitic limestone, a brown, rather soft sandy dolomite, a fine-grained bluish soft sandstone, and a drab to bluish sandy shale. Differing thus so abruptly in both thickness and character, it is of much less economic importance than the overlying more dependable St. Louis limestone, and details of its exposures will not be given.

The bulk of the high rock bluffs that front Des Moines River and the lower courses of its tributaries in this area is made up of the St. Louis limestone. In places the Ste. Genevieve appears above the St. Louis, but its limestones are so thin in Lee County as not to deserve mention except in connection with the discussions of the lower formation.

The St. Louis limestone comprises three easily recognizable divisions. The first of these (Lower St. Louis) is a massive granular buff medium hard magnesian limestone, at many places in uniform and almost undisturbed beds but at a few points brecciated or conglomeratic. Its thickness is normally 20 to 25 feet. The second (brecciated division of the Upper St. Louis) consists of a poorly stratified or unstratified mass of limestone breccia, made up of angular fragments of all sizes of gray hard fine-grained limestone in a matrix of darker gray fine-grained limestone which is locally replaced by irregular veins and pockets of soft greenish shale. In places this division includes a few feet of calcareous shale or of greenish shaly unsound limestone. Its thickness is 10 to 15 feet. The third division (compact and granular division of the Upper St. Louis) is made up of heavy and rather persistent beds of compact or granular hard, sound gray nonmagnesian limestone, at some localities containing rather large amounts of quartz sand. Locally this limestone gives way in part or entirely to brecciated limestone similar to the underlying beds, or to a soft fine-grained sandstone. The thickness of this division is 10 to 20 feet. The basal Ste. Genevieve beds are predominantly soft fine-grained sandstone with subordinate amounts of sandy shale, or less commonly of limestone, the whole assemblage having a total thickness of 10 to 15 feet. Above these are rather thin-bedded, hard, sound fine-grained gray nonmagnesian limestones, ordinarily not over five feet in thickness. The limestones were probably originally about 20 feet thick, but they have suffered much from pre-Pennsylvanian erosion, so that at many points they are altogether missing.

Practically all of the Lower St. Louis stone in this area is suitable for road surfacing work, and in large part it is satisfactory for concrete or asphaltic aggregate. The abrasion test usually gives a percentage of wear from 5.0 to 8.0. The brecciated division is likewise nearly all suitable for surfacing. Its desirability for aggregate is questionable; at some points 90 percent or more is so usable, while elsewhere the percentage of good stone falls below 50. The individual fragments constituting the breccia are all hard and sound. The associated beds of shale or shaly limestone are usually unsuitable for any road or concrete work. The compact and granular division is nearly everywhere satisfactory for aggregate or for road surfacing. The basal sandstones of the Ste. Genevieve have no value except possibly in the finer part of an asphaltic aggregate. The limestone at the top of the Ste. Genevieve is in most of the exposures suitable for aggregate or surfacing stone, though to the west, in eastern Van Buren County, a part of it is a fossiliferous calcareous marl which breaks down rapidly under weathering.

Van Tuyl [40] has published a number of excellent detailed sections of the St. Louis and Ste. Genevieve in this area, and from these sections more detailed information as to the character of the strata is easily obtainable. One of the most extensive and representative sections now visible is at the State Penitentiary quarry at Croton (NW¼ NW¼ sec. 29, Van Buren Twp.). The following is the succession at this point:

	Feet
7. Limestone, light gray, weathered and much frost broken, hard, fine-grained, nonmagnesian. Appears only as a lens about 20 feet long near the north end of the quarry face. In the head of a ravine to the east, this member is seen to have a total thickness of 5½ feet	3
6. Principally a drab to buff soft massive sandstone. Included are two or three beds of drab sandy shale, some of which appear to be discontinuous. The shale beds or lenses are 1 foot to 2 feet thick	11
5. Sandstone, drab to yellowish, calcareous, hard, in one bed, which is persistent throughout the whole length of the quarry face	2
4. Limestone, gray, medium-grained, hard and tough, nonmagnesian, in fairly heavy and regular beds. The beds are slightly undulating and the lower surface of the member is somewhat irregular. Near the northeast end of the quarry face, almost the full thickness of this member is replaced by a mound of sandstone, whose lower surface is not visible. Still farther east, in a small ravine, the member is 15 feet thick and shows the same character throughout	9
3. Principally a drab calcareous shale, but including a few thin discontinuous seams of gray limestone	2
2. Limestone breccia, in which the included fragments are gray fine-grained hard and sound nonmagnesian limestone, angular in shape and of all sizes up to about 3 inches. The matrix is of different kinds. Most of it is a fine-grained gray limestone, similar to the included fragments but at some places of a slightly different shade of color. Running through it are irregular seams of greenish clay or soft shale. In parts of this member these seams are very thin or lacking altogether, but elsewhere they are very conspicuous and appear as pockets up to 1 inch in thickness	10
1. Limestone, buff, magnesian, massive, fairly hard and all sound. The texture ranges from granular to crystalline. The beds are slightly disturbed and broken. Some of the cracks formed by this disturbance are filled with the breccia from the member above, to a depth of a few feet below the general top surface of this member. To the quarry floor. In a ravine to the southeast this member was formerly exposed to a thickness of 21 feet	10

Number 1 of this section represents the Lower St. Louis, Nos. 2 and 3 the brecciated division, Nos. 4 and 5 the compact and granular division, and Nos. 6 and 7 the Ste. Genevieve. The suitability of this rock for road or concrete work is about as indicated in the paragraph preceding. About 80 percent of bed No. 2 as exposed here is usable for concrete aggregate.

Quarrying operations here are carried on mostly by hand, though

40 Van Tuyl, F. M., The Stratigraphy of the Mississippian Formations of Iowa: Iowa Geological Survey, Vol. XXX, pp. 240-247, 1921-22.

an air drill is used for drilling the blast holes. Rock is loaded by hand to small cars, which dump to the crusher. The screening plant is improved from time to time as available funds permit, so no detailed description of it will be given. Its capacity in 1931 was estimated at 15 tons per hour. Possible extension of the quarry is limited by the heavy overburden (bed No. 6) to an area of an acre or so. However, so high is the face that, even on this limited area, large quantities are available.

A similar deposit is well exposed in the bluff at a railroad cut just north of south quarter-corner section 29. Near the south end of this bluff the compact and granular division is missing (on account of post-St. Louis and pre-Ste. Genevieve erosion), and the space which it once occupied is filled with a soft Ste. Genevieve sandstone. However, to the north, the compact and granular division is available by stripping on an area of perhaps two acres. Above the Ste. Genevieve sandstone are faint signs of a thin Ste. Genevieve limestone and, still higher, is two to eight feet of soft Pennsylvanian sandstone.

Three samples have been tested from a 15-foot face of limestone of the compact and granular division in the SW¼ section 25, Van Buren Township. In the SE¼ section 2, Des Moines Township (T. 66, R. 7), nearly all of the St. Louis again appears, a section 39 feet high being obtained in it. In the NW¼ section 12 of the same township, the exposure is 20 feet high. The exposure at the old Santa Fe railroad quarry near south quarter-corner section 12 is now much obscured by overwash, but Keyes [41] gives a section of some 50 feet of rock here, including the St. Louis and beds beneath. At any of these points, as well as at many others in the bluffs, considerable quantities of stone, much of it of good quality, are available by stripping. Mining of the more desirable beds by tunneling back from the outcrop is a possibility which has already been successfully tried at Douds in Van Buren County, and which would be practical here.

West Sugar Creek. — Only one rock exposure along West Sugar Creek is known, and that is in SW¼ section 5, Charleston Township. At this point, some 25 feet of St. Louis stone was at one time visible, and it may be that moderate quantities are still obtainable. The lower part of this creek's course is entirely within an older and wider drift-filled valley and thus shows no rock outcrops.

East Sugar Creek Area. — Along East Sugar Creek and the lower

41 Keyes, C. R., Geology of Lee County: Iowa Geological Survey, Vol. III, p. 330, 1893.

courses of its tributaries, from the central part of Marion Township downstream to the point where it enters the preglacial Mississippi valley in section 5, Jefferson Township, rock outcroppings are numerous. All of the exposures seen may be referred to the St. Louis limestone or to the upper part of the Warsaw. At many places the slopes leading down to the rock outcrops are gentle, and at numerous points large quantities are easily available by stripping.

Exposures farthest upstream are in SE¼ NE¼ section 21, Marion Township, where an abandoned lime quarry shows the following section:

	Feet	Inches
9. Loam and clay	4–7	
8. Limestone, buff, soft, much weathered, unsound	1	
7. Shale, gray		3
6. Limestone, gray, hard, medium-grained, massive, nonfossiliferous, percentage of wear 3.2, soundness questionable	4	
5. Shale, gray		3
4. Limestone, gray, hard, fine-grained, in one bed, nonfossiliferous, conchoidal fracture. Percentage of wear 8.8, soundness questionable	1	3
3. Limestone, soft, shaly, unsound, with two shale seams, each 1 inch to 2 inches in thickness		9
2. Shale, gray		6
1. Limestone, gray, hard, fine-grained, massive, with a 1-inch shale seam 1 foot from the top, nonfossiliferous, conchoidal fracture. Percentage of wear 6.0, soundness questionable. To quarry floor and water	4	6

These beds are referred to the Upper St. Louis, though they are similar to the fossiliferous marls which are typical of the Ste. Genevieve. Tests indicate that about 60 percent of beds Nos. 1, 4, and 6 is sound. Judging from the appearance of the weathered stone, much of it, especially in the upper beds, is unsuitable even for road surfacing work. Overburden increases very gradually to the east, north, or south, and an area of several acres is easily workable. In SE¼ section 21, and S½ section 22, are limited exposures of similar beds, with moderate quantities available.

Along small southwest-flowing creeks in S½ section 23 and E½ section 26, Marion Township, beds similar to those just described, though showing less evidence of unsoundness, are well exposed and are available in large quantity with light stripping. In these localities there seem to be two zones of hard and sound stone, separated by a zone of shale and shaly unsound stone. The most complete section available is in an old quarry about one-fourth mile east of center section 26, as follows:

	Feet
5. Clay, red, residual, with much residual chert	2
4. Limestone, gray, hard, medium-grained, apparently sound, though somewhat weather-broken, fossiliferous. The difference in thickness is due to	

	erosion	6 (Max.)
3.	Shale, drab, calcareous, grading locally to a drab shaly or marly fossiliferous limestone	2–2½
2.	Limestone, gray, hard, apparently sound, of medium to fine grain, fossiliferous. In regular beds of moderate thickness	9
1.	Unexposed to floor of old quarry	2

The area quarried here was about one half acre. Stripping increases very gradually to the north, and it appears that perhaps five acres could be worked with six feet maximum depth of overburden.

Small openings high in the bluff in NW¼ NW¼ section 26, Marion Township, show a few feet of hard sound gray thin-bedded limestone. Below this are obscure indications of a brecciated limestone, a brown magnesian limestone, a weathered magnesian limestone showing many small solution cavities, and, at the foot of the bluff, a drab hard calcareous shale. It thus appears that all of the St. Louis is present here. Large quantities are easily available, though little can be determined as to the quality of the stone except by careful prospecting. The upper beds may be equivalent to those noted in the two preceding paragraphs.

Old quarry openings in NW¼ NW¼ section 36, Marion Township, show, in descending order, 12 feet of gray hard sound limestone, 3 feet unexposed but probably soft, and 5 feet of gray to brownish hard sound limestone. An area of several acres is easily workable. Benches above Sugar Creek, in N½ NE¼ NE¼ and W½ NE¼ section 35, show limited exposures of similar beds. Here also rock might be quarried. Through section 2, Franklin Township, rock is present in the slopes but is so covered by overwash from the overlying Pennsylvanian and recent deposits as not to be visible in natural exposures.

Through S½ section 3, E½ section 10, section 11, and W½ section 12, Franklin Township, the St. Louis limestone is present in large amounts and is exposed at a number of places. The most easily workable deposits are in SE¼ SW¼ and SW¼ SE¼ section 3, NE¼ NW¼ and NW¼ NE¼ section 10, SE¼ NW¼ section 11, and SW¼ SE¼ section 11, at any of which points quantities running up into tens of thousands of cubic yards are easily available by stripping. At the last-mentioned location some 50 feet of rock is exposed on an area of about 15 acres under a maximum stripping of 20 feet. It may yield an estimated total quantity of over one million cubic yards. The best section available in this territory is a composite of three obtained near the north quarter-corner section 10, as follows:

		Feet
8.	Sandstone, yellow to brown, very soft	2–5
7.	Limestone, hard, sound, gray, fine-grained, massive when fresh but	

	weathers to thin beds	5
6.	Alternating beds of hard sound fine-grained gray limestone, soft gray shaly limestone, and gray shale. Good limestone constitutes about 75 percent of the member	4½
5.	Limestone, gray, hard, sound, fine-grained, massive when fresh but weathers to small blocks of irregular shape. In the upper 2 feet are two 1-inch shale seams	9
4.	Limestone, gray, hard, sound, rather fine-grained, in several beds, including a 2-inch shale seam and a 4-inch seam of soft yellow granular limestone	4½–5
3.	Limestone, buff to brown, magnesian, rather fine-grained, massive, quite hard, sound	4½
2.	Limestone, gray, massive, hard, probably sound, locally with a small amount of chert, with persistent shale seams totaling about 15 percent of the whole	7
1.	Limestone, rather irregularly bedded, differing in character, partly brecciated. Color ranges from gray to buff. Most of the stone is sound and fairly hard, but included are small pockets and thin irregular seams of shale and a few zones of soft buff magnesian stone. To water level in the branch of Sugar Creek in E½NW¼NE¼ section 10	11

All of these beds except No. 8 are referred to the St. Louis. The whole succession as described is usable for road surfacing work, and the larger part of it is satisfactory for aggregate.

Keyes [42] mentions locations of old quarries or good rock exposures in NE¼ section 20, NE¼ NE¼ section 18, NW¼ NW¼ section 30, and SW¼ SW¼ section 30, West Point Township, and in NE¼ NE¼ section 25 and in SE¼ SE¼ section 13, Franklin Township. The sections as described by him range from near the top of the St. Louis down to the upper part of the Warsaw. Most of the exposed rock is limestone, though in NE¼ section 20 a 10-foot bed of sandstone is included. Outcroppings rise as much as 65 feet above Sugar Creek, and large quantities are available with moderate stripping.

Similar beds are shown in the following, combined from two detailed sections obtained in and near two old quarries about 1,000 feet apart, near center NE¼ section 30, West Point Township (thickness approximate):

		Feet
13.	Clay, glacial and residual	5
12.	Sandstone, gray to drab, soft	½
11.	Shale and limestone, the former predominating	11
10.	Limestone, gray to drab, coarse-grained, rather soft, in two beds separated by a shale parting	2½
9.	Limestone, gray, hard, sound, rather thinly bedded	2½
8.	Limestone, gray, massive, irregularly bedded, differing in texture, but generally hard and sound	8½
7.	Limestone, light gray, usually medium to fine of grain, hard, sound, in several beds, separated by shale partings of various thicknesses up to 6 inches	7
6.	Limestone, gray, soft and earthy above, harder below	2½
5.	Limestone, gray, massive, irregularly bedded, distinctly conglomeratic in places, with irregular thin veins and pockets of soft shaly limestone, but for the most part hard and sound	10½

42 Keyes, C. R., Geology of Lee County: Iowa Geological Survey, Vol. III, pp. 335-337 and 385-386, 1893.

4.	Limestone, buff, magnesian, a wide range in hardness and soundness but suitable for surfacing material	2
3.	Shale, yellow	½
2.	Limestone, buff, rather soft (percentage of wear 10 to 15), sound, magnesian, weathers to a sandy texture	7
1.	Unexposed to base of bluff	15

It appears that Nos. 2, 3, and 4 represent the Lower St. Louis, while the remainder of the section is referred to the Upper St. Louis. It will be noted that here, as at Montrose, a compact and granular division is not readily set off from an underlying brecciated division. A face of rock over 40 feet high is available here on about four acres with a maximum overburden of 12 feet. The whole face is satisfactory for surfacing material and large parts of it are usable as aggregate.

The Lower St. Louis has been quarried near center section 32, West Point Township, and in NW¼ section 5, Jefferson Township (T. 67, R. 5). The operations were on a small scale and extended to a depth of only a few feet. The exposures there are now almost entirely obscured by overwash. The Upper St. Louis also appears in NW¼ section 5, and NE¼ section 6 of the same township and is available in limited quantity.

Lost Creek Area. — Outcroppings near Lost Creek represent the lower part of the Keokuk limestone, ranging down through the Montrose chert to the Upper Burlington limestone. Keyes[43] gives the following quarry section in SE¼ NW¼ section 12, Washington Township, and refers the whole succession of rock beds to the Upper Burlington limestone (evidently extended to include the Montrose chert).

		Feet
5.	Drift	4
4.	Limestone, crinoidal, brownish, thinly bedded, with some chert	1½
3.	Limestone, white, rather soft, somewhat cherty in places	½
2.	Limestone, yellowish	1⅓
1.	Limestone, hard, brown, crinoidal, heavily bedded	2

Reports mention other outcroppings in NE¼ NE¼ section 11, SW¼ section 3, and SE¼ section 4, Washington Township. Like the one described, these show a large proportion of soft material of little value except possibly for surfacing on light-traffic roads. Moderate quantities are available.

Skunk River Area. — Numerous exposures of rock occur in the bluffs south of Skunk River and along the lower courses of small creeks tributary to it from Wever to the Henry County line. The beds range from the Lower Burlington to the St. Louis. The general dip is to the

43 Keyes, C. R., Geology of Lee County: Iowa Geological Survey, Vol. III, p. 327, 1893.

southwest, so that the higher beds appear to greater extent farther upstream.

The following section of the Lower and Upper Burlington limestone in NE¼ section 25, Denmark Township, is condensed from one published by Van Tuyl.[44]

	Feet
8. Limestone, soft, buff, not everywhere present	1
7. Limestone, light gray, crinoidal, with some small nodules and thin irregular discontinuous seams of chert	17
6. Limestone, compact, dense, brownish, nodular, cherty, magnesian, nonfossiliferous	8
5. Chert, crinoidal	1
4. Limestone, soft, buff, magnesian	1–1½
3. Limestone, buff to whitish, crinoidal, cherty	7½–8½
2. Limestone, fine-grained, soft, bluish gray, weathers buff, iron-stained, with occasional layers of brownish impure cherty crinoidal limestone up to 2 feet thick	12½–13½
1. Limestone, gray, subcrystalline, very cherty in the upper part	4

Bed No. 7 has been quarried in a small way in section 25, and fairly large quantities are still available in section 25, north half section 26, and south half section 23. The stone is suitable for road surfacing work but a large part of it is rather soft for concrete or asphaltic aggregate. Similar beds may be made out in the low bluff north of Wever (SE¼ sec. 32, T. 69, R. 3 W.), where the thickness is about 6 feet and a small quantity could be quarried. Between these two points other deposits are exposed.

At South Augusta the Montrose chert overlies the Burlington in the higher bluffs and is available in large quantities by stripping. Van Tuyl[45] reports some 11 feet of crinoidal, very cherty limestone in NE¼ section 25, Denmark Township. This lies above the section for the Burlington previously given. More complete sections of higher strata in the Keokuk formation are abundant farther upstream. Van Tuyl[46] has described a succession of alternating limestones and shales in NW¼ section 17, Denmark Township, which total some 36 feet in thickness. Of this succession, 33 percent is stone of the first class, as mentioned in the descriptions of this formation in the Keokuk-Montrose area; 46 percent is of the second class; and 21 percent is of the third class. It will thus be noted that road or concrete materials are unavailable in the Keokuk formation, unless in very small quantity.

The Lower St. Louis limestones, and associated beds which are

44 Van Tuyl, F. M., The Stratigraphy of the Mississippian Formations of Iowa; Iowa Geological Survey, Vol. XXX, pp. 127-128, 1921-22.

45 Van Tuyl, F. M., The Stratigraphy of the Mississippian Formations of Iowa: Iowa Geological Survey, Vol. XXX, p. 162, 1921-22.

46 Van Tuyl, F. M., The stratigraphy of the Mississippian Formations of Iowa: Iowa Geological Survey, Vol. XXX, p. 162, 1921-22.

probably of Spergen age, appear in the upper slopes near the branches of Deeds Creek in sections 18 and 19, Denmark Township. These beds consist chiefly of a rather soft brown granular limestone, with minor amounts of gray or brown brecciated limestone. Material which may be used for surfacing light-traffic roads is available at several points, principally in the south half of section 18. The Upper St. Louis is almost entirely missing, though in some places a bed of a few feet of brown Pennsylvanian sandstone overlies the Lower St. Louis.

Similar conditions are found in the northeast part of Pleasant Ridge Township, along Hell Hollow, and smaller creeks tributary to Skunk River. However, the white limestones of the Upper St. Louis appear in a few places, and have recently been quarried near center SW¼ section 13. Following is the quarry section.

	Feet
5. Clay, glacial and residual	3–6
4. Limestone, coarsely granular, almost oölitic, hard, sound, gray or greenish-gray, in even beds 1 foot or more in thickness. A few small masses of fine-grained hard gray stone are included. Due to weathering, vertical cracks or chimneys filled with clay, extending through or even below this member, are frequent	7–10
3. Limestone, irregularly bedded, chiefly a gray hard sound fine-grained stone which is commonly brecciated or even conglomeratic. Irregular veins, pockets, or beds of greenish clayey or sandy shale constitute perhaps one-fourth, or one-third of this member	5–6
2. Limestone, brown to dark gray, hard, sound, of crystalline texture, in one or two fairly even beds, with a few small pockets of stone similar to Number 3	4
1. Limestone, yellowish-brown, fine-grained, softer than Number 2, in one or two even beds. Exposed only at one point	2

Numbers 1 and 2 represent the Lower St. Louis, and Numbers 3 and 4 the Upper St. Louis. A large part of the stone available at this point has already been removed. Moderate quantities are available at other locations, principally in west half section 1, west half section 12, and NE¼ section 14. However, here as on Deeds Creek, the bulk of the exposures reach only up to the Lower St. Louis, in some places overlain by a few feet of Pennsylvanian sandstone.

The compact limestones of the upper part of the Upper St. Louis are more extensively exposed in sections 2 and 3, and NE¼ section 11, Pleasant Ridge Township. Particularly favorable quarry sites are available in NE¼ NE¼ section 11 and SW¼ SW¼ section 3. A natural exposure in the south creek bank at the former location gives the following approximate section.

	Feet
3. Limestone, gray, hard, evenly bedded	5
2. Shale, soft, drab, perhaps not everywhere present	2
1. Limestone, gray, hard, somewhat irregularly bedded, locally conglomeratic	15

Numbers 1 and 3 of this section are suitable for road surfacing stone, and a large part of them is suitable for aggregate. Large quantities are available.

Sand and Gravel

As in other counties of southern Iowa, the glacial till of Lee County contains a number of pockets of sand or gravel, most of them of small size. A few such have been prospected, as for instance in section 1, township 66, range 7; section 24, township 66, range 7; and section 7, township 65, range 5; but nothing was found which was considered to be worth opening. Boulder deposits that are apparently of early glacial age and that include much residual matter derived from the decay of the underlying limestones are fairly extensive in Keokuk (SE$\frac{1}{4}$ SE$\frac{1}{4}$ sec. 25, T. 65, R. 5) and again in NW$\frac{1}{4}$ section 32, and SW$\frac{1}{4}$ section 29, West Point Township. The parts of these deposits that are sufficiently free from clay are suitable for road surfacing work, but, on account of the overlying till, only small quantities are available. Other subglacial sands and gravels (e.g. in sec. 30, T. 65, R. 5) are also almost entirely unavailable.

Gravel or coarse sand terraces along Des Moines River in Lee County are unknown, although near Croton and Vincennes (Sand Prairie) extensive terrace areas are underlain by silt and fine sand. One large terrace area appears in the Mississippi River valley in this county. It occupies a strip a mile or more in width, nearly all of the way from Fort Madison to Montrose. Pits have been opened in sections 10, 11, and 14 of Jefferson Township to depths as much as 40 feet, of which 10 to 25 feet is above water. The material includes 10 to 15 percent retained on the No. 4 screen and is clean and sound, though the sand portion is rather fine. The large bottomland area in Green Bay Township is underlain by sand and fine gravel, though at such depth as to make its working by stripping impracticable.

On account of backwater from the Keokuk dam, sand or gravel is not now deposited in the Mississippi River channel above Keokuk. At Keokuk, the Keokuk Sand Company pumps from the river bottom a good grade of sand for fine aggregate in concrete. This is taken out below the dam and especially near the mouth of Des Moines River. By means of small openings in their pump discharge line a part of the finer material is wasted, and the resulting product is of good quality and is extensively used in road and concrete work.

Des Moines River in a large part of its course along the border of Lee County is in a narrow valley bounded by rock bluffs and has sufficient velocity to carry sand, gravel, and rock fragments, which are deposited in bars along the channel. The material in most of these bars is clean, hard and sound, and much of it is usable for concrete aggregate. The grading differs, but the quantity of coarse gravel in any one bar is usually limited to a few thousand cubic yards or less. The quantity of sand or fine gravel is large, as some of the bars are as much as a mile long. Such bar deposits have been prospected in section 19, township 67, range 7; section 2, township 66, range 7; section 14, township 65, range 6; and section 3, township 65, range 6.

Other bars of considerable size are known to be present at the following points:

W. of center sec. 29, T. 67, R. 7	Bar of gravel and sand on west side of river
E. of center SE¼ sec. 3, T. 66, R. 7	Low bar of gravel and coarse sand on south side of river, 4 acres in area
W. of center NW¼ sec. 12, T. 66, R. 7	5-acre bar of gravel and sand on west side of river
SW¼ sec. 13, NW¼ sec. 24, and NE¼ SW¼ sec. 24, all of T. 66. R. 7	15-acre bar of gravel and sand on east side of river, about one mile long
SE¼ SE¼ sec. 24, T. 66, R. 7, and SW¼ SW¼ sec. 19, T. 66, R. 6	6-acre sand bar on east bank
N. of center sec. 30, T. 66, R. 6	5-acre bar of gravel and sand along west bank, one half mile long
W. of center sec. 32, T. 66, R. 6.	10-acre bar on east bank, one half mile long, mostly sand
SW¼ sec. 11, T. 65, R. 6	15-acre sand bar on east bank
S. of center NW¼ to NE¼ SW¼ sec. 23, T. 65, R. 6	6-acre sand bar on east bank, one half mile long
SW¼ SE¼ sec. 23, T. 65, R. 6	10-acre bar on west bank and bed of river nearby shows sand and gravel, some very coarse
NE¼ NE¼ sec. 26, T. 65, R. 6 and NW¼ NW¼ sec. 25, T. 65, R. 6	3-acre high sand bar on north bank
SE¼ NE¼ sec. 25, T. 65, R. 6 and NW¼ SW¼ sec. 30, T. 65, R. 5	10-acre high sand bar on south bank
NE¼ SW¼ sec. 32, T. 65, R. 5	5-acre sand bar on south bank

NE¼ SE¼ sec. 33, T. 65, R. 5 and NW¼ SW¼ sec. 34, T. 65, R. 5	4-acre sand bar on north bank.

In addition to these the locations of some twenty other smaller bars are known.

Small deposits of sand, gravel, broken limestone, and chert are common along many of the smaller streams and constitute an important source of material for local improvements.

LOUISA COUNTY

The Kinderhook formation underlies the whole of the county but is exposed only along the lower slopes in a narrow strip of territory southwest of Iowa River. The Burlington limestone underlies most of the area southwest of Iowa River. The weathered lower beds of the Keokuk limestone appear above it in a few small areas, and at one point (SE¼ SW¼ sec. 32, T. 73, R. 3) a few feet of the St. Louis is recognized. Pennsylvanian shales and associated sandstones occupy some small outliers in the west part of the county but exposures are few and offer nothing to the road builder.

Three drift sheets, the Nebraskan, the Kansan, and the Illinoian, have overspread parts or all of the county. The Nebraskan, with subsequent Aftonian deposits, appears to be present throughout the whole county but is exposed at only a few points. The Kansan is exposed widely in the western part and at fewer places in the Illinoian area. The Illinoian is the surface drift over all of the county east of a north-south line passing through the west half of range 4 west. Post-Illinoian loess veneers the uplands to a depth of 8 to 20 feet. The total thickness of Pleistocene deposits is usually less than 200 feet west of Iowa River and from 200 to 500 feet east of that stream.

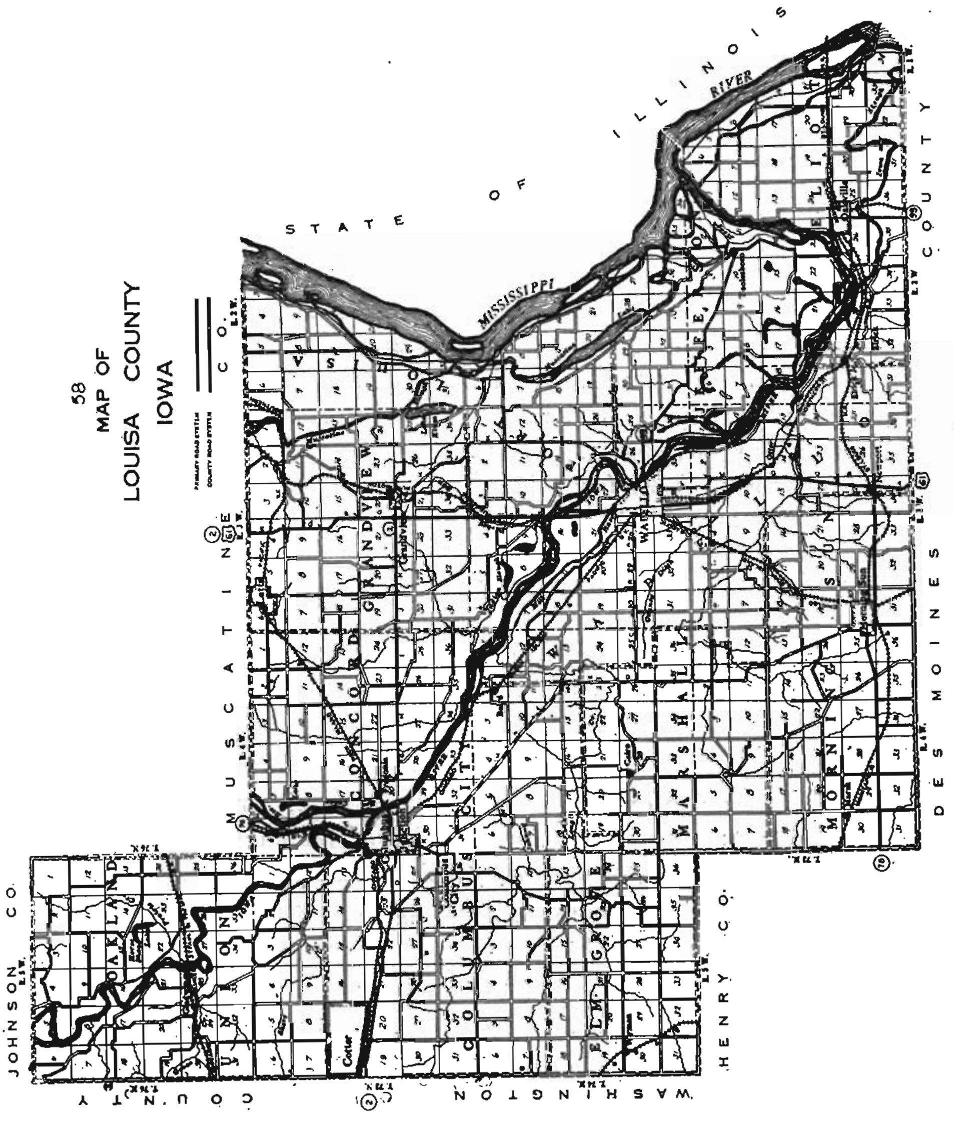
Along the larger streams, and particularly in the extensive lowland areas bordering Iowa and Mississippi Rivers, the loess, and at many points the Illinoian or even the Kansan, is largely eroded away, and the remnants are covered by the alluvium. This alluvium is of post-Illinoian or even Recent age and consists principally of sandy silt or fine sand, which may be locally piled up by recent winds into broad low dunelike deposits.

Limestone

The three limestone formations (Kinderhook, Burlington, and Keokuk) that are most abundant in the county succeed each other conformably and without any abrupt lithologic change. It therefore seems advisable to consider all three as a unit. Outcrops of any kind of consolidated rock are limited to the area southwest of Iowa River.

Rock underlies the lower and middle slopes of the hills south of Iowa River near Oakville and Elrick. One of the most complete and representative sections in this locality is that at the old Anderson

IOWA GEOLOGICAL SURVEY. PLATE XXI



quarry in SW¼ SW¼ section 29, township 73, range 2, which follows:

		Feet
15.	Limestone, massive, coarse-grained, light gray to white, crinoidal, with stylolitic seams in the lower part. Percentage of wear 6.4, soundness satisfactory	7
14.	Limestone, similar to the above, but with several seams of white chert	2
13.	Limestone, similar to No. 15, except that stylolitic seams were not noticed. Percentage of wear 13.3, soundness satisfactory	5
	Floor of Anderson quarry	
12.	Unexposed. Chiefly limestone	7
11.	Limestone, soft, buff, magnesian	2½
10.	Limestone, coarse-grained, hard, buff, crinoidal	1
9.	Limestone, soft, buff, magnesian	2
8.	Shale, yellow, with numerous calcareous nodules	2
7.	Limestone, soft, buff, magnesian. Some layers and zones are locally harder and might be suitable for concrete aggregate. Average percentage of wear 19.3. Soundness satisfactory	11
6a.	Shale parting	
6.	Limestone, buff, fine-grained, magnesian. In two ledges, the upper one 3 feet thick. Percentage of wear 14.1. Soundness satisfactory	8
5.	Limestone, gray to buff, coarse-grained, crystalline. Weathered surfaces show an oölitic texture. Percentage of wear 5.6. Soundness satisfactory	3
4.	Limestone, buff, granular, magnesian, has a sandy appearance and may contain some silica. Percentage of wear 6.2. Soundness satisfactory	3
3.	Limestone, soft, buff, irregularly bedded, unsound. Weathered to irregular nodular masses	3½
2.	Shale, sandy, ash-colored	5±
1.	Shale, sandy at the top, clayey below, gray to drab. This thickness exposed to the creek level. A thin carbonaceous seam a few feet above the Creek	15

Number 1 is best exposed near the highway bridge about 1,000 feet north of the quarry. Numbers 3 to 15 may be seen in and below the quarry. Numbers 1, 2, and 3 are well exposed in the east bank of Smith Creek about one fourth mile south of the quarry. Numbers 1 to 6a represent the Kinderhook, Nos. 7 to 12 the Lower Burlington, and Nos. 13 to 15 the Upper Burlington. It will be noted that the Upper Burlington horizon is the one of greatest value, though the softer magnesian beds of the Lower Burlington may be usable as surfacing material on light-traffic roads. In the upper part of the Kinderhook another zone is fairly satisfactory as a source of surfacing material. At the old quarry face, stripping is 11 feet, increasing to 27 feet at a point 150 feet back. It is possible that some of the cherty crinoidal limestones of the Montrose formation are present in this 27 feet, though there are no surface indications of their presence.

Other exposures south of Oakville are not so complete as the foregoing but show signs of similar beds. The softer strata weather back rapidly, leaving usually a steep rock-strewn slope, on which no ledges can be seen in place. At several points, small quantities of Upper Burlington stone can be obtained.

To the west of the Oakville-Elrick area, the zone of harder magnesian stone extends from the Kinderhook up into the lower part of the Lower Burlington. The following section at the Louisa County quarry (NW¼ NW¼ sec. 23, T. 73, R. 3) shows this characteristic:

	Feet	Inches
19. Chert		6
18. Limestone, brown, hard, crinoidal, coarse-grained		3
17. Yellow shale	1	
16. Limestone, same as No. 18	1	
15. White chert		6
14. Limestone, same as Nos. 16 and 18	1	
13. Yellow shale	1	6
12. Limestone, same as Nos. 14, 16, and 18	1	
11. Yellow shale		3
10. Limestone, brown, hard, medium-grained, crinoidal, contains several thin chert bands	1	6
9. Yellow shale		8
8. Brown limestone, fine-grained, gray limestone and chert interbedded	1	2
7. Limestone, brown, hard, crinoidal, contains several chert and calcite nodules	10	6
6. Limestone, brown, medium-grained, crystalline, oölitic in the upper part	4	
5. Limestone, soft, shaly	2	8
4. Shale parting		
3. Limestone, same as No. 6	4	6
2. Shale parting		
1. Limestone, mottled brown and black, apparently owing to uneven dolomitization. Contains numerous calcite nodules	2	6

Numbers 1 to 6 represent the Kinderhook, and the remainder of the section is Lower Burlington. The limestones are suitable for road surfacing work, but many of them are rather soft for use as aggregate (average percentage of wear estimated 9.0). Overburden at this site is not excessive, but it will be noted that the beds above No. 8 show such a high proportion of shale as to require special handling of some kind. In the NE¼ section 23, and at various points in section 22, township 73, range 3, and northwest corner section 27, township 73, range 3, the white crinoidal Upper Burlington stone is extensive and can be quarried in large quantity at various points. For instance, investigations in NE¼ SW¼ section 22 show an area of about one acre where the Upper and Lower Burlington are available with 12 feet maximum thickness of overburden.

A complete succession of beds from the top of the Kinderhook to the bottom of the St. Louis may be seen along Honey Creek in sections 28 and 32 of township 73, range 3. The following section may be seen in SW¼ SW¼ section 28:

	Feet	Inches
8. Clay, glacial and residual, with chert fragments. Signs of drab shale in the lower part	6	
7. Chert and limestone, with two thin shale seams. The chert is prin-		

cipally at the top and bottom and constitutes about 60 percent of the member	2	3
6. Limestone, coarse-grained, crinoidal, fairly hard	2	
5. Shale, buff, calcareous		5
4. Limestone, light gray to buff, crinoidal, sound and fairly hard. With pockets or lenses of buff magnesian fine-grained stone. The lower 6 feet shows several stylolitic seams. In moderately heavy beds. With two chert bands in the upper part, each ranging from less than an inch to 8 inches in thickness	15	
3. Limestone and chert, in irregular masses. At least 50 percent chert	2	
2. Limestone, soft, buff, shaly. With some harder zones, especially near the top. Locally much thicker	3	6
1. Shale, buff to brown, sandy, grading locally into a soft buff earthy magnesian limestone. With a few scattered chert nodules. At the creek level west of center SW¼ is a thick layer of chert	4	6

A bed of soft buff earthy limestone with a maximum thickness of 12 feet may be seen below No. 1 of this section in the NW¼ SW¼ and SW¼ NW¼ section 28. It grades locally in the middle part to a coarse-grained crinoidal soft buff limestone. This bed, with Nos. 1 to 3 of the preceding section, represents, apparently, the full thickness of the Lower Burlington. Numbers 4, 5, and 6 represent the Upper Burlington, while No. 7 is referred to the Montrose. In an old quarry in NW¼ SW¼, No. 4 of this section is split by a 3-foot zone of shale, soft shaly limestone, and chert, leaving three feet of better stone above and nine feet below.

The Stewart quarry (Figure 4), at southwest corner section 28, repeats the upper members of the foregoing section and continues it somewhat higher. The following is the succession of beds:

	Feet
6. Limestone, brown, soft, granular, with one or more heavy bands of chert. Grades above into residual clay filled with rock fragments	5
5. Shale, drab to buff	2
4. Limestone, differing in character both horizontally and vertically. About half is a brown medium-hard crinoidal limestone, one third is white chert in heavy bands, and the remainder is soft buff or drab shaly limestone or calcareous shale	5
3. Limestone, light gray, coarse-grained, crinoidal, sound, medium-hard, in regular and rather heavy beds, with a few discontinuous chert bands	5
2. Limestone, brown, crinoidal, fairly hard, grading into brown soft granular magnesian limestone	1¾
1. Limestone, as No. 3, but with no chert noted. Exposed	6

Numbers 1, 2, and 3 of the above section correspond to No. 4 of the preceding, and No. 4 of this section indicates the differences that may be expected in the zone of Nos. 5, 6, and 7 of the preceding. Van Tuyl's [47] section of the Keokuk near the north line of the SW¼ section 28, shows beds similar in general to Nos. 4, 5, and 6 of the Stewart quarry section and extending about four feet higher.

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[47] Van Tuyl, F. M., The Stratigraphy of the Mississippian Formations of Iowa: Iowa Geological Survey, Vol. XXX, p. 177, 1921-22.

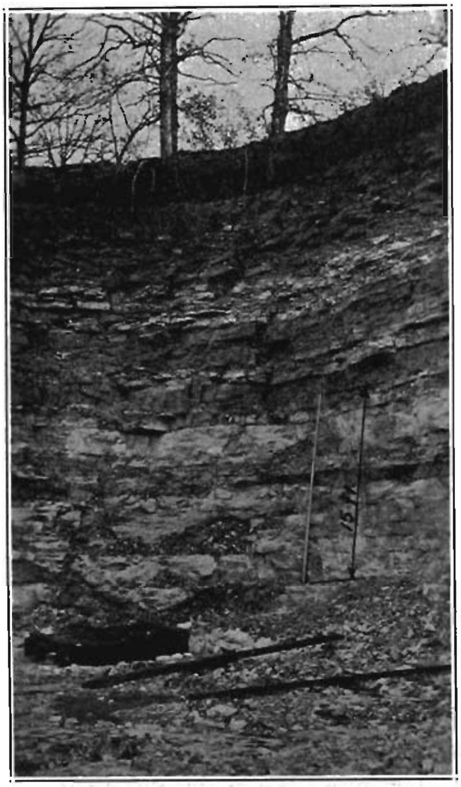


FIG. 4. — Quarry face two miles east of Morning Sun.

Numbers 1, 2, and 3 of the Stewart quarry section appear in the bed and lower banks of Honey Creek in NE¼ NE¼ section 32, township 73, range 3. Scattered outcrops at various points in E½ section 32, with a vertical range of about 50 feet above these limestones, show soft brown or drab granular limestones with a small amount of chert in the lower part and evidently represent the upper Keokuk and possibly the Spergen or Lower St. Louis formations. About one foot of light gray conglomeratic limestone (Upper St. Louis) is visible in SW¼ SE¼ section 32, but is entirely unavailable for quarrying.

It will be noted from the descriptions given in the preceding paragraphs that No. 4 of the section in SW¼ SW¼ section 28 is the only zone showing any considerable uninterrupted thickness of stone that might be of value for road or concrete work. Even this bed, in NW¼ SW¼ section 28, is so split as to leave only some nine feet of satisfactory stone. The most desirable quarry locations are, therefore, in the SW¼ SW¼ section 28; SE¼ SE¼ section 29; and NE¼ NE¼ section 32. At these points only limited quantities are available by stripping, although mining from the outcrop may prove practicable. Tests on the stone from this zone show in most cases a percentage of wear from 9.0 to 12.0 and soundness satisfactory. The soft yellow or buff dolomitic stone, which constitutes such a large part of the exposed strata here, may have some value as surfacing material on side roads, but under moderate or heavy traffic it may be expected to pulverize quickly to a fine-grained, dolomitic sand.

A succession of beds similar to those just described may be made out along the creek that is followed by the railroad north from Morning Sun. The uppermost Kinderhook beds appear in section 17, township 73, range 3, but do not show the zone of hard brown stone found in the Louisa County quarry. The Lower Burlington is, as usual, soft, yellow, and possibly unsound. The zone of fairly hard crinoidal stone in the Upper Burlington is best exposed in NW¼ NE¼ section 19, township 73, range 3, where a thickness of four feet is exposed. It is available by stripping only in small quantity. The following section, in the west bank of the creek west of southeast corner section 14, is representative for the northeastern part of township 73, range 4.

	Feet
3. Limestone, buff, weathered, grading above into residual clay, cherty, mostly soft and granular, but with a few thin zones of hard brown subcrystalline crinoidal limestone	8
2. Chert, white	1
1. Limestone, as No. 3, to creek bed	5

These beds evidently represent the Lower Burlington. They appear at short intervals along the creek through section 14, and the NE¼ section 23, township 73, range 4, but, being under rather heavy overburden, they are available at any one point in only limited quantity. Further, a large part of the stone is rather soft, even for road surfacing work. The light gray crinoidal stone of the Upper Burlington is not now exposed, though Udden [48] has reported it as having a thickness of eight feet in NE¼ NE¼ section 14.

A small north-flowing creek in NW¼ NW¼ section 9, and SW¼ SW¼ section 4, of township 73, range 4, cuts through ledges of yellow cherty limestone and white crinoidal limestone. Five feet of the latter is exposed and is available in limited quantity at a small old quarry near center SW¼ section 4. Small and indistinct exposures in section 3, township 73, range 4, are reported.

48 Udden, J. A., Geology of Louisa County: Iowa Geological Survey, Vol. XI, p. 78, 1900.

On Long Creek rock appears in sections 3, 12, 13, and 14, and NW¼ section 23, township 74, range 5, and sections 32 and 33, township 75, range 5. In the southeast part of this territory the exposures show shale and soft sandstone, evidently from the upper part of the Kinderhook. They are overlain by as much as 20 feet of rock, which consists principally of brown magnesian granular medium-hard limestone. With this upper stone are associated thin bands of white chert and a few bands of yellowish coarse-grained crinoidal stone. These beds evidently represent the Lower Burlington. The brown magnesian limestone is easily quarried at several points, as it is well up in the bluffs above the creek. Near the north quarter-corner section 13, township 74, range 5, large quantities are available with moderate stripping. A test at that point shows a percentage of wear of 11.4 and soundness satisfactory.

To the southwest the exposures reach up into the Upper Burlington, as will be noted from the following section at the Louisa County quarry in SE¼ SW¼ section 14, township 74, range 5.

	Feet
5. Clay, glacial and residual, with rock fragments	2+
4. Limestone, light gray to brownish gray, coarse-grained, crinoidal, fairly hard, somewhat weathered to thin beds, but probably massive when fresh. An irregular zone near the middle consists of soft brown granular stone and constitutes about 10 percent of the member	6 (Max.)
3. Limestone, soft, buff, granular. At the west end it is almost hard enough for surfacing work	2
2. Limestone, as No. 4, but without any noticeable soft zone	4½
1. Limestone, as No. 3. To quarry floor	3-5

All of this section, except possibly No. 1, may be referred to the Upper Burlington. Fairly large quantities are available by stripping. Beyer [49] reports some 20 feet of yellowish, badly disintegrated soft cherty limestone above 12 feet of white crinoidal stone at an old quarry near the northwest corner of section 23, township 74, range 5. Judging from his descriptions, this 20 feet is of poor quality, even for road surfacing work. Its presence tends to make for heavy overburden on the white crinoidal stone in the vicinity.

A similar succession of strata farther north is typified by the following section, in the north bank of Long Creek, due south of the north quarter-corner section 3, township 74, range 5.

	Feet	Inches
9. Limestone, white, coarse-grained, crinoidal, hard and dense		8
8. Chert, white. Weathered and not well exposed		6
7. Limestone, crinoidal, fairly hard, in several beds, possibly with		

[49] Beyer, S. W., Geology of Quarry Products of Iowa: Iowa Geological Survey, Vol. XVII, p. 414, 1906.

	shaly partings between	2	
6.	Chert, white, with a thin seam of brownish crinoidal limestone		10
5.	Limestone, sandy, magnesian, yellow, soft. Softer and shaly above, but harder below. A few nests of calcite in the lower part	3	6
4.	Limestone, white or brownish, coarse-grained, crinoidal, sound and mostly hard. In several slightly uneven beds, with a few nodular masses of white chert	5	3
3.	Chert, white, with local thin seams of brownish crinoidal limestone. Fades out to the west		8
2.	Limestone, brown, massive, sound but rather soft, with thin crinoidal zones and a few chert nodules. In the upper part are lenses of hard brown crystalline limestone. The lower part is the softer	6	
1.	Unexposed, to low water in Long Creek	2	

Number 2 is referred to the Lower Burlington and the upper members to the Upper Burlington. Udden [50] mentions a 5-foot bed of yellow, partly disintegrated crinoidal limestone in an old quarry face above the top of this section. This bed is not now well exposed, but it appears that perhaps two thirds is a white crinoidal, fairly hard stone and the remainder a soft earthy buff stone. A sample of the crinoidal white stone of this bed, and also of Nos. 4 and 7 of the section just given, shows a percentage of wear of 10.6 and soundness satisfactory. Moderate quantities are available by stripping.

Similar rock is obtainable at other localities in section 3 and sections 32 and 33 of township 75, range 5, but ordinarily with more difficulty or under heavier overburden. Scattered exposures in sections 22 and 27 of township 75, range 5, and in section 16, township 76, range 5, are very limited in extent and show no available rock.

Sand and Gravel

Glacial Materials. — A bed of interglacial sand with some gravel appears at intervals along the Mississippi valley bluffs in the southern part of Port Louisa Township, and from well records it seems to be quite persistent throughout the uplands farther west. It is marked in the bluffs by a series of large springs and where best exposed (west of center sec. 7, T. 74, R. 2) has a thickness of 20 feet. The material has a wide range both in coarseness and in clay content, but much of it is suitable for road surfacing work. It is, however, not known to be commercially available anywhere, on account of the great thickness of overlying drift clay. Of similar nature and possibly of the same age is a deposit of 30 feet of fine sand underlain by 10 feet of coarse gravel, which outcrops in the creek bluff one half mile south of the town of Gladwin. The sand here is overlain by an average of 20 feet of drift clay.

50 Udden, J. A., Geology of Louisa County: Iowa Geological Survey, Vol. XI, p. 80, 1900.

Some deposits of clayey sand in the northeast part of the county lie nearer to the surface and probably are of Illinoian age. Most of them are high enough in position to be commercially available, but nowhere so far as yet seen are they coarse enough to be of value for road surfacing or clean enough to be washed and used as fine aggregate. Examples are found in sections 10, 11, and 21, Grandview Township.

Mississippi River Deposits. — Almost inexhaustible supplies of coarse sand and fine gravel lie in the channel of that part of Mississippi River which borders Louisa County. At Port Louisa these materials have been pumped and used for building the main levee which protects the lower end of Muscatine Island. The material there has about 85 percent passing the No. 4 screen. The Mississippi Sand and Gravel Company pumps similar material at Keithsburg, Illinois, east of Oakville, and, wasting a part of the finer sand, produces concrete aggregate for local trade and for shipping to nearby points. Its plant is electrically operated and is said to have a capacity of 50 tons per hour.

Most first-bottom deposits in the valley consist of 10 to 20 feet of silt and fine sand, underlain by coarse sand and fine gravel, but toward the northeast corner of the county, on Muscatine Island, the material is coarser and stripping is not so great. Extensive deposits of this type are commercially utilized on a large scale on Muscatine Island a few miles beyond the northern border of the county.

Terrace or second-bottom formations in the valley are comparatively rare but where found usually contain sand or gravel. Two conspicuous examples are known, in the Great Sand Mound, in the extreme northeastern corner of the county, and in an area north of Iowa River one mile west of Oakville. The first-mentioned deposit consists almost entirely of sand and has never been exploited commercially on account of the proximity of coarser materials easily available. The deposit at Oakville has been extensively worked in recent years. It shows on an area of five acres or more 1 foot to 12 feet of overburden, and gravel ranging in thickness up to 35 feet. The gravel is clean and composed of hard and sound pebbles and is of satisfactory quality for surfacing or for aggregate.

Iowa and Cedar River Deposits. — A survey of the channels of Iowa and Cedar Rivers shows a large number of bars. Almost without exception these consist of sand, ranging in grading from fine to coarse, but nearly everywhere clean and sound and satisfactory for use as fine aggregate. The quantity available is in most cases large, and overburden is light or altogether lacking. Coarser materials (10 to 20 percent retained on a No. 4 screen) are found in limited quantity at bars in the following locations:

NE¼ NW¼ sec. 6, T. 76, R. 5	North bank
SW¼ NW¼ sec. 5, T. 76, R. 5	West bank
NW¼ SW¼ sec. 5, T. 76, R. 5	West bank
SW¼ NW¼ NW¼ sec. 27, T. 76, R. 5	East bank
NW¼SE¼ sec. 27, T. 76, R. 5	South bank
SW¼ NW¼ SW¼ sec. 26, T. 76, R. 5	Old channel on south bank
SE¼ NW¼ sec. 35, T. 76, R. 5	Bars around small island near west bank
SE¼ NE¼ sec. 27, T. 74, R. 3	East bank
SE¼ NE¼ sec. 11, T. 73, R. 2	East bank
SW¼ SW¼ sec. 1, T. 73, R. 2	East bank

It will be noted that most of these locations are in Iowa River above its junction with the Cedar. Besides the locations listed, some seventy other bars are known to be present in these streams. None of the bars is being worked, except in a small way to supply local needs.

First-bottom deposits are very widespread and the usable material is nearly everywhere under light stripping. It consists predominantly of sand, which is fine to coarse and mostly clean and sharp. In some places beds of fine-grained gravel appear, as for example southeast and north of Wapello and near Columbus Junction. It is believed that sand suitable for fine aggregate in concrete can be obtained at intervals all along the valleys of Iowa and Cedar Rivers within the county.

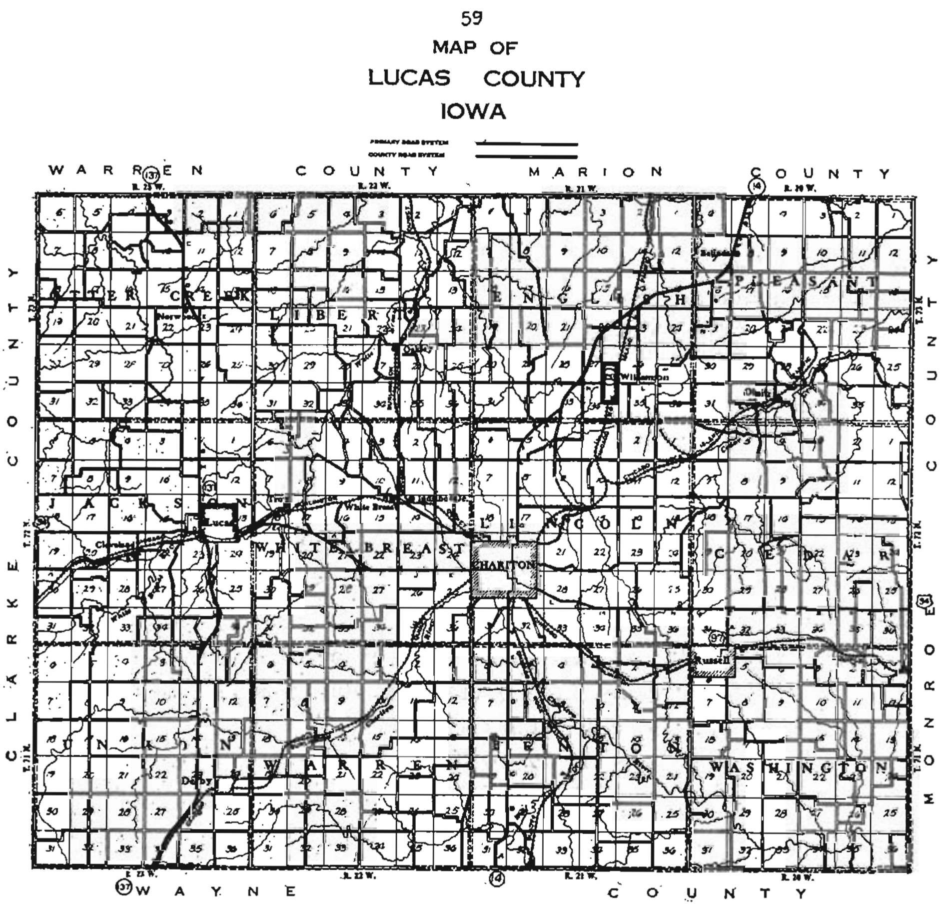
As is true in the Mississippi valley, terrace deposits are not numerous, and those known consist principally of fine sand. The "Wapello Prairie," west of Wapello, usually considered as terrace, is not known to have anywhere available sand or gravel coarse enough to be of value even as fine aggregate in concrete, though it might be used in asphaltic mixtures. A small gravel terrace, probably formed in glacial time, has been seen on the east bank of Cedar River one mile north of Fredonia. No great quantity of road material is available.

Deposits along the Smaller Streams. — Many of the smaller creeks and intermittent streams, having cut deep into the glacial drift, or even at places into the underlying rock, have collected important quantities of sand, pebbles, and broken rock to form bars along their courses. Most of these bars are small, but in some places, as in SE¼ section 30, township 75, range 4, they contain a few hundred cubic yards of gravel and sand. Any one deposit of this type is of only very local interest, but in their aggregate they constitute a source of road or concrete material which should not be overlooked.

LUCAS COUNTY

The Des Moines series constitutes the country rock throughout the county, exposures being limited, however, to the north and east parts. All three stages of the Des Moines are represented, but most of the exposures are referable to the Cherokee. Both Nebraskan and Kansan drift sheets, with related interglacial materials, spread a mantle of various thicknesses, from nothing to nearly 400 feet, upon the consolidated beds. The Nebraskan appears only in the lower slopes, as along Whitebreast Creek and in lesser measure near Chariton River,

IOWA GEOLOGICAL SURVEY. PLATE XXII



while the Kansan is widely exposed in almost every square mile of the county. Loess, ranging in thickness from a few feet to 15 feet, covers the less dissected uplands, while near the larger valleys it has been largely removed by recent erosion. Alluvial deposits are not of wide extent and, where found, consist of clay or silt, with minor amounts of sand and gravel.

Limestone

Two thin limestones are known to be exposed in the north part of the county. One is 4½ feet thick, light gray in color, massive, and usually hard and sound, and appears in limited extent in E½ section 4, English Township, near southeast corner section 16, English Township, SE¼ section 16, Lincoln Township, and at a few scattered points near Chariton River in Washington Township. Only very small quantities are available at any one point. The other limestone is 2½ to 3 feet thick, very dark gray in color, strongly fossiliferous and hard, but not everywhere sound. It is best exposed in the "Swede Hollow" neighborhood, in sections 3 and 4 of Whitebreast Township. It also is available only in very small quantity. A limestone that probably belongs to the same or a similar horizon has been found in various coal mines in the north part of Lucas and the south part of Marion Counties, and it has been quarried there to a small extent in connection with the coal mining operations. It has been crushed at Melcher, in Marion County, for use as an asphaltic aggregate.

A very limited exposure on a high hillside about one fourth mile south of the northeast corner of section 21, Liberty Township, shows a Mississippian limestone, which is much weather-broken and slumped so that the beds show steep dips in all directions. A small quarry has been opened and perhaps 100 cubic yards removed. Judging from the position and location of this rock, it is probably a glacial boulder. However, its extremely large size leads to the suspicion that it may be the almost-buried remnant of some high Mississippian peak; if such is the case, the quantity of available stone might be rather large.

In the east part of Pleasant Township the top of the Mississippian is only 70 to 100 feet below the ground surface in the deeper valleys. A coal prospect hole about 8 miles north of Chariton and 4 miles west showed 46 feet of limestone beginning at a depth of 218 feet. Other prospect holes or wells have reached limestone, usually at a depth of not more than a few hundred feet. Mining of these limestones from a vertical shaft is a possibility worthy of mention.

Sandstone and Conglomerate

Though the Des Moines series strata consist predominantly of shale, they include minor amounts of sandstone. Ordinarily the sandstone beds are from a few feet to 10 feet thick, but they are not well enough indurated to be of value for crushing and are too fine of grain to be broken down to their component particles and used as sand. An exception is seen in the case of a continental (channel) deposit of sandstone of Pleasanton age that extends north and south across Pleasant Township and has been traced northward into Marion County. The deposit has been recognized in sections 3, 10, 15, 22, and 27, Pleasant Township. Apparently its width nowhere exceeds one half mile. Following are brief descriptions of the more important exposures.

The following detailed section was worked out in NW¼ NW¼ section 3, at a quarry on the south bank of a small east-flowing tributary to Columbia Creek. The section was made before the quarry was opened:

	Feet	Inches
5. Sandstone, hard, gray, medium-grained, massive	6	
4. Shale, gray to yellow		8
3. Sandstone, moderately hard to hard, gray to buff, medium to fine of grain	5	1
2. Alternating beds, none more than 1 foot thick, of hard gray sandstone, soft shaly sandstone, and gray or brown shale, usually sandy. Hard sandstone constitutes 39 percent, soft sandstone 23 percent, and shale 38 percent	9	7
1. Sandstone, moderately hard to hard, gray to brown, medium to fine of grain, with a 1-inch seam and a 2-inch seam of shale. The lower part of this member at some places contains granules and small pebbles of black shale	13	6

Test samples from these beds show a percentage of wear of about 11.0 for No. 1, of 3.9 for No. 3, and of 5.7 for No. 5. The extreme and abrupt differences in character of these beds are illustrated by the fact that in working about 100 feet back from this exposure, Nos. 3, 4, and 5 were almost entirely replaced by soft buff sandstone or soft sandy shale. A further illustration of this range in character may be had by comparison with Lugn's [51] section at this point, which shows principally soft sandstone and sandy shale, with only minor amounts of hard sandstone. Only small amounts of usable stone are available here except under heavy overburden.

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[51] Lugn, A. L., Geology of Lucas County: Iowa Geological Survey, Vol. XXXII, p. 168, 1925-26.

In the bluffs west of Columbia Creek and in the courses of its tributaries in section 3, sandstone exposures are numerous and some of them are extensive. In SE¼ SE¼ SW¼ nearly 20 feet of fine-grained, but only moderately hard sandstone can be made out. It is under very light stripping on an area of one or two acres.

Between the two forks of Carruthers Creek (sometimes known as Flint Creek), in SE¼ section 10, sandstone is well exposed and available by stripping in fairly large quantity. The vertical range of exposure is nearly 50 feet. At this point, coarse-grained hard sandstone and conglomerate alternate with finer-grained hard sandstone, or fine-grained softer sandstone. Between 50 and 75 percent of the rock is usable for road surfacing work, and some beds are satisfactory even for aggregate.

Sandstone outcroppings are common in NE¼ section 15, along Carruthers Creek and a small creek tributary to it from the south, at a level about 60 feet above the creek. In general the thickness of any uninterrupted exposure of sandstone is about six feet. There is evidence of much greater thickness of sandstone but in separate ledges with intervening shale seams. Only limited quantities are available at any one point by stripping. The material seen is for the most part rather fine-grained and well indurated.

Along the small creeks and ravines in SE¼ section 22 are other extensive outcroppings. A small ravine in SE¼ NW¼ SE¼ shows a continuous exposure of about 40 feet of beds of different kinds of which about 60 percent is hard sandstone, 10 percent is conglomerate, 15 percent is soft sandstone, and 15 percent is shale. Small quarries have been worked, and large quantities of material are easily available in the area just north of this exposure. More limited exposures in W½ SE¼ SE¼, and SW¼ NE¼ SE¼ indicate similar beds but these are separated by seams of soft yellow or white shale.

South of center section 27 are small abandoned quarry workings and a few limited natural exposures of sandstone, which is of medium to coarse grain and usually quite hard. Only small quantities appear to be available under moderate overburden.

The general character of the rock at all of these points is similar. Where it is of medium or fine grain, the grains are composed almost entirely of quartz in a calcareous and ferruginous matrix. In the better indurated beds the matrix seems to include some siliceous material as well. In the conglomerate phase the pebbles are composed principally of hard sound gray fossiliferous limestone with subordinate amounts of quartz or chert. They are well rounded and of all sizes up to 2 or 3 inches. The matrix is in many places more ferruginous and neither as strong nor as durable as in the finer-grained material. The coarse beds, and also the fine beds, if they are sufficiently well cemented, are suitable for road-surfacing work. Where the matrix is more siliceous and thus stronger and more durable, the material is almost like a quartzite and is satisfactory for use as aggregate. However, rock of this latter class is not abundant.

Mine Shale

A rather extensive coal mining industry has been carried on in Lucas County. A number of supplies of burned mine refuse are available in the vicinity of Lucas and near and northeast of Williamson, and some of these are still being replenished by the mining operations. The locations of the largest of these are as follows:

SW¼ NW¼ sec. 22, Pleasant Twp.	Old Tipperary mine dump, about 140,000 cubic yards, part of the pile not well burned, with much dark-colored limestone on the surface.
One fourth mile west of center sec. 32, Pleasant Twp.	Old Olmitz mine dump, about 5,000 cubic yards, well burned.
NE¼ NE¼ sec. 24, English Twp.	Indiana Consolidated Coal Co., mine now working, dump burning and being built up.
Near E quarter-corner sec. 23, English Township	Central Iowa Fuel Co., mine now working, dump burning, and being built up, but now having over 100,000 cubic yards volume.
SE¼ SW¼ sec. 1, Lincoln Twp.	Central Iowa Fuel Co., mine now working, dump burning, and being built up.
NW¼ NE¼ NW¼ sec. 9, Lincoln Twp.	30,000 cubic yards, well burned, abandoned mine of Central Iowa Fuel Co.
SE¼ NW¼ sec. 13, Jackson Twp.	3,000 cubic yards, very well burned, and with large masses of clinker.

Besides these present or former shipping mines a number of smaller ones without railroad connection are present east and west of Lucas, northeast of Norwood in the northeast part of Pleasant Township, northeast of Chariton, and near the county line east of Russell. At these latter points only very limited quantities of surfacing materials are obtainable.

Sand and Gravel

Glacial and interglacial sands and gravels are widely exposed in Lucas County, though no supplies of any great size have been located. Some fifty such deposits, located in nearly all parts of the county, have been investigated by a prospecting party, and a number of other locations have been seen and judged not worthy of further examination. As far as is now known, the largest gravel deposit contains some 2,000 cubic yards, and some deposits of sand undoubtedly have a greater yardage. Perhaps ten gravel deposits of 500 or more cubic yards are now known to be present in various parts of the county but principally in Jackson, Lincoln, and Benton Townships. There are at least as many smaller deposits each containing 100 to 500 cubic yards. No one of these supplies is of more than local interest, but in their aggregate they constitute a source of material for improvement of secondary roads which should not be overlooked.

In a few cases, where an outcrop of soft or moderately hard sandstone has been exposed to the weather for many years, the broken fragments appear similar to gravel, and interested parties have reported such outcrops as indications of a gravel bed.

Sand and gravel bars along the streams are nowhere of more than local importance. Since glacial time none of these streams has had sufficient energy to carry any large quantity of coarse material for any distance. Consequently, the bars of gravel and coarse sand are found only on the smaller tributaries, and the larger creeks carry nothing but fine sand and silt. Nevertheless all of the small streams have cut their valleys in the glacial till and in some places into the bedrock, and in the aggregate a considerable quantity of sand and gravel is moved by them each year. One well-known instance of this type of deposit is in SW¼ NE¼ section 17, Whitebreast Township, where a small stream has deposited in one bar about 500 cubic yards of clean sand and gravel, all usable for building work and perhaps one third of it usable for road surfacing. Sand is hauled from here to the town of Lucas, and the supply, being replenished by the stream each year, is practically inexhaustible.

IOWA GEOLOGICAL SURVEY. PLATE XXIII

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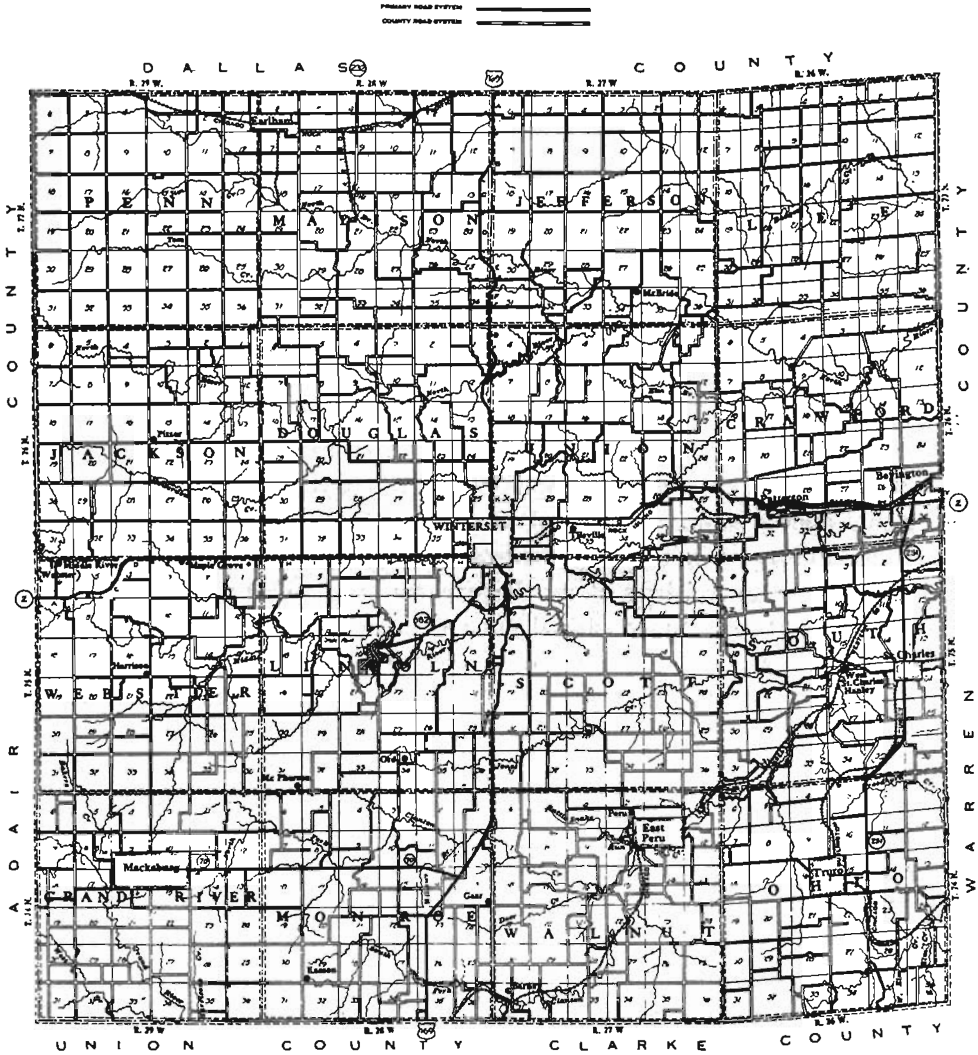
MAP OF
MADISON COUNTY
IOWA



MADISON COUNTY

The upper part of the Des Moines series (Pleasanton stage) underlies the whole county and forms the highest consolidated beds over approximately the eastern one third. In the remainder of the county the country rock is of the Kansas City stage of the Missouri series. The lower beds of the Lansing stage also appear in the middle and higher slopes in Webster Township and the south part of Jackson Township, but, as they show only thin limestones, they are of no importance to the purposes of this report.

Nebraskan and Kansan drift sheets are present in the county. The former is exposed at only a few places, in the lower slopes bordering the deeper valleys, while the latter is the surface drift. In regions of less active erosion the Kansan till is overlain by several feet of gumbotil and that by 5 to 15 feet of post-Kansan loess. The total thickness of unconsolidated deposits at few places exceeds 125 feet, even in the highest uplands.

Shale and Sandstone

Both sandstone and shale are present in considerable quantity in the Des Moines series as this is exposed in the eastern part of the county. However, the sandstone is too soft to be crushed for road or concrete work and too fine-grained to be broken down to its component particles and used as sand, except possibly as the finer part of an asphaltic aggregate. Shale is of no value except when burned, as in coal mine dumps. A few mines have been worked in Madison County, but they are all small in size, and their waste heaps are thus of little importance as sources of surfacing materials.

Limestone

The beds of the Kansas City stage, as exposed in Madison County, show remarkable uniformity and persistence of character and of thickness except as affected by preglacial or recent erosion. General descriptions of the various formations, showing their characteristics in some detail, can therefore be made, and typical detailed sections are thus unnecessary. Below are described the various formations of the Missouri series which are found in the county.

The Hertha limestone is 3 to 5 feet thick, is in one bed when unweathered, and is light gray, fine-grained, hard, and nearly all sound. Most of the member is rather irregularly bedded, this feature in many cases being so pronounced as to divide it into small rounded nodules of light gray fine-grained limestone, surrounded and separated by veins of greenish-gray shaly unsound limestone. On account of this characteristic the term "Fragmental Limestone" was formerly applied to the member. Previous reports have included in the Hertha two beds of limestone separated by a bed of shale. However, the exposures now visible show that the lower limestone is only 1 foot to 3 feet thick and that it is separated from the upper limestone by 10 feet or more of shale or sandy shale. Consequently, it is believed to be more logical to refer these lower beds to the Pleasanton stage and to consider the bottom of the 5-foot member here described to be the base of the Missouri series.

The Ladore shale is 18 to 21 feet thick. The lower one third is at many of its outcrops a sandy shale with some zones ranging to a soft sandstone or sandy limestone. The middle third is a drab clay shale. Three or four feet from the top is a very persistent bed of hard, very dark gray fossiliferous limestone about six inches thick. Above this is a clay shale, black below and drab above.

The Bethany Falls limestone is 20 to 23 feet thick and is divided into three parts, separated by seams of shale and shaly limestone. These seams are 1 foot to 1½ feet thick and lie about 9 feet and 16 feet respectively from the bottom. The limestone is light gray in color, weathers gray, and is rather fine-grained, hard and sound except for zones about two inches thick next to the shale seams. In most places the top two feet is a soft yellow earthy nodular limestone, useless for aggregate and in some places very soft even for road surfacing work. The bedding is somewhat wavy but otherwise regular. When unweathered, each of the three parts appears as one solid ledge. The limestone of this member is of good quality for concrete aggregate or for road surfacing, except as noted. The upper part is at some points partly or entirely missing, because of preglacial or recent erosion.

The Galesburg shale is 9 to 10 feet thick and consists entirely of a drab clay shale, except for a 3-foot zone starting a few feet below the top and consisting of black thin-bedded fissile or slaty shale.

The Winterset limestone commonly shows two parts — the lower 6 to 7 feet thick and the upper 4 to 9 feet thick. The lower part is one bed (when unweathered) of fine-grained light gray, sparingly fossiliferous hard limestone. Most of it is sound, though a few indefinitely limited zones of shaly softer unsound stone appear. A few small nodular or irregular masses of iron oxide are present in this lower part in most places. The upper part is one bed where it is only four feet thick and in two or three heavy beds separated by seams of yellowish calcareous shale where it is thicker. The shale seams constitute about one fifth of the thickness of this part. The limestone is rather coarse-grained, gray when fresh, weathering brownish, fossiliferous, hard and sound. A persistent characteristic is the presence of a layer of discontinuous large nodules of dark-colored fossiliferous chert in the lower half of one of the heavy beds in the upper part.

The Cherryvale shale is about 15 feet thick and is drab and clayey above, dark gray to black in the middle, and bright yellow and strongly calcareous below. The upper zone locally includes one or two limestone beds.

The DeKalb includes a succession of alternating limestones and shales and is best described by the following general section:

	Feet
7. Alternating thin beds of hard brownish coarse-grained sound limestone and yellowish shaly limestone, in about equal proportions	8
6. Limestone, mostly massive, but locally with soft shaly zones in the lower part. Light gray in color, rather fine-grained, hard and sound except as noted; fossiliferous, with fusulinids, crinoid stems and various brachiopod types conspicuous. In the upper 3 feet are a few thin layers of nodules of light colored fossiliferous chert. Part or all of the member is at some places slightly speckled with iron oxide	10–11
5. Shale, drab, strongly calcareous and with zones of yellowish fossiliferous limestone above, darker gray or black and fissile below. Near the bottom are usually one or two thin ledges of very dark gray hard shaly limestone, very fossiliferous, in some places almost a breccia of brachiopod shells and other forms	6–7
4. Shale, dark gray, soft, clayey; at some places black and fissile in the upper part	6–9
3. Limestone, coarse-grained, massive, hard and sound, gray to brownish-gray, everywhere crowded with fusulinids, and with smaller numbers of other fossil forms noticeable. No chert found	1½–2
2. Alternating rather thin beds of hard yellowish gray or dark gray limestone, and soft shaly limestone or calcareous shale, all strongly fossiliferous. This member, though persistent in general character, differs much in detail from place to place	13–16
1. Limestone, yellowish gray, very fossiliferous, rather irregularly bedded and in some places showing a nodular structure, probably massive when unweathered	3

For convenience of description, Nos. 1, 2, and 3 may be designated as the Lower DeKalb limestone and Nos. 6 and 7 as the Upper DeKalb limestone.

A succession of shales and thin limestones nearly 40 feet thick can be made out above the DeKalb in the west part of the county. It includes the Chanute shale, the Iola limestone, and the Lane shale. The heaviest limestone is 2½ feet thick and lies about 5 feet above the top of the DeKalb.

Other limestones are not over 1 foot thick. Included in this succession is a zone of dark red shale near the middle and, in the lower part, a gray or drab shale filled with small rounded calcareous nodules.

The Hertha limestone is exposed in the hills north of South River in sections 26, 27, and 28, Ohio Township, though at few places and usually obscurely. Limited quantities are available along some of the tributary creeks, as in SW¼ SE¼ section 28. At a few exposures the lower part of the Bethany Falls limestone is represented in the form of small limestone boulders on the higher slopes. Broadhorn Creek, in the northeast part of Ohio Township, exposes only Des Moines series strata.

The Hertha limestone appears in the form of loose limestone boulders and scattered obscure exposures high in the hills above Clanton Creek at numerous points in the central part of South Township. It is usually much weathered and almost entirely unavailable for quarrying, though several small quarries near St. Charles and Hanley have worked a 3-foot limestone ledge lying 10 to 20 feet below it. The Hertha is much better exposed and is available in limited quantity at several points along Jones Creek in sections 17, 18, 19, and 20, South Township, and near Clanton Creek in sections 31 and 32, South Township, sections 5 and 6, Ohio Township, sections 35 and 36, Scott Township, and sections 1 and 12, Walnut Township. The lower part of the Bethany Falls limestone appears first in section 12, Walnut Township, and section 35, Scott Township. From there upstream the Bethany Falls is abundantly and well exposed, forming a distinct escarpment in the bluffs bordering the valley of Clanton Creek and appearing at the same level in the lower courses of the small tributary creeks. The exposures are especially good in sections 10, 11, and 15, Walnut Township, and large quantities have been removed, while still larger quantities are yet available. The largest quarry is near northeast corner section 10, where a small crushing and screening plant was formerly connected by a spur track to the Chicago Great Western R. R. but now is operated only intermittently to supply the local trade. The Hertha also appears in these sections but being low in the slope it is almost entirely unavailable. The Winterset limestone is present in the form of scattered limestone boulders or obscure exposures high in the hills and is probably available in limited quantity at several points. The Bethany Falls limestone continues upstream on Clanton Creek through sections 22, 27, and 28. Walnut Township, being lower and lower in the valley and thus not so well exposed. In NE¼ SE¼ section 28 it underlies a large benchlike area between the creek and the railroad and is available in considerable quantity. At this point the Hertha is below the creek level. Apparently the Bethany Falls dips below the creek east of Barney (sec. 31, Walnut Twp.) and the Winterset near or just west of Barney. In any case, outcroppings on Clanton Creek west of section 28, Walnut Township, are scattered and most of them are obscure. In the territory between Barney and Peru the Winterset is probably as extensive as the Bethany Falls, though details of exposures of it are lacking. The Lower DeKalb limestone is also present at some places in the higher slopes, but on account of the availability of the more desirable Bethany Falls and Winterset ledges it is quarried but little.

The north fork of Clanton Creek shows but few rock exposures through sections 16, and 17, Walnut Township. In sections 18 and 7, Walnut Township, and section 12, Monroe Township, outcroppings are more common. The Bethany Falls is present as far west as section 7, where the creek cuts through it. About 9,000 cubic yards is available in N½ NE¼ section 18, Walnut Township, and in small quantity at other points in sections 18 and 7. The Winterset is most easily available near center NE¼ section 12, Monroe Township, or at a few points in section 7, Walnut Township, but the valley here is narrow and bound by steep slopes, so that only small quantities are available at any one point without removing an excessive thickness of overburden. Near the northwest corner section 12, Monroe Township, the Winterset disappears below the creek level.

Detailed information about the strata along Jones Creek through sections 22, 23 and 24, Scott Township, is lacking, but it is probable that the Bethany Falls limestone is available at a few points.

Outcroppings of the Missouri series on Middle River may be seen as far east as section 26, Union Township, and continue at short intervals to the west county line. The whole section for the county is represented.

The easternmost exposures of bedrock are in sections 26 and 27, Union Township, and show the Hertha limestone though not in many places in its full thickness. In sections 27 and 34 the Bethany Falls is present above it, and from this point westward the Hertha is almost entirely unavailable under moderate stripping, the reason being that the resistance of the overlying limestones to erosion gives rise to steep unbroken slopes from the lowlands up to the level of the highest rock exposures. The Hertha appears in many natural exposures near Winterset (e.g. sec. 6, Scott Twp., and sec. 1, Union Twp.) but lies lower and lower in the slopes to the west, until it is cut through by Middle River at the State Park in SE¼ NE¼ section 16, Lincoln Township.

The lower part of the Bethany Falls limestone appears first in sections 27 and 34, Union Township, and within a mile to the west it has practically its full thickness. The Winterset Limestone Co. has conducted rather extensive recent quarry operations in NE¼ NE¼ section 33, Union Township. The local trade is supplied, and rock is furnished also for the manufacture of portland cement at the Penn-Dixie plant near Des Moines. For the local trade, the rock is loaded by hand (shale and soft shaly limestone being thus sorted out) and hauled in small cars on narrow-gauge track to the crusher, a Williams hammer mill. From the crusher the rock passes to the screens, which are of the cylindrical revolving type, oversize being returned to the primary crusher. The plant is operated by gasoline power, and its capacity is estimated at 25 tons per hour. Crushed stone for all road or concrete purposes is made. Rock shipped to Des Moines for cement making is loaded with a power shovel direct to the railroad cars.

From this point westward the Bethany Falls limestone is exposed commonly or almost continuously and is conspicuous in the hills bordering both sides of the valley of Middle River and the lower courses of its tributaries as far west as SE¼ section 17, Lincoln Township, where it passes beneath the river. At numerous points it is easily available in quantities ranging from a few thousand to 50,000 cubic yards or even more. It is impossible to list all of the locations where it might be quarried; a few typical ones are in sections 6 and 8, and SW¼ section 18, Scott Township, and S½ section 1, NW¼ section 22, SE¼ section 10, and W½ section 16, Lincoln Township.

The Winterset limestone appears above the Bethany Falls first in sections 5 and 6, Scott Township, and from that point westward to NW¼ section 17, Lincoln Township (near which point it passes beneath Middle River), it is exposed as widely and as commonly as is the Bethany Falls. Being somewhat thinner than the Bethany Falls, it is not available in as large quantities as is the lower limestone, but it may be quarried at a large number of points. Some of the best known of these are in NW¼ section 6, Scott Township, SE¼ section 1, NW¼ section 22, SW¼ section 16, and near center section 17, Lincoln Township. No quarries were known to be operating in it during the 1932 season.

The Lower DeKalb limestone, including, as it does, some shale and being rather thin bedded, is much less resistant to erosion than are the Bethany Falls and Winterset members, and it is consequently much less abundantly and plainly exposed. It has not been observed on or near Middle River east of sections 15 and 22, Lincoln Township, though the weathered lower part of it may be present in the higher slopes a mile or so farther east. It may be distinguished in its position between the Winterset and the Upper DeKalb in W$\frac{1}{2}$ section 17, Lincoln Township, and it is found above the Winterset along the small creeks in W$\frac{1}{2}$ section 22, W$\frac{1}{2}$ section 20, and as far back as center section 30, all of Lincoln Township. Farther west, it is low in the slopes and has very few exposures. Apparently it passes beneath the river somewhere in the eastern part of Webster Township. Quarrying on a small scale has been carried on in it intermittently at several points (e.g. SW$\frac{1}{4}$ NW$\frac{1}{4}$ sec. 22, Lincoln Twp.), operations being usually confined to the massive fusulina-bearing limestone at the top (No. 3 of the section described).

The Upper DeKalb limestone is present as far east as SW$\frac{1}{4}$ section 16, Lincoln Township and, being resistant to erosion, is exposed at several places from there westward to section 7, Webster Township, where it dips beneath Middle River. It has been quarried in a small way at several points, though no quarries are now operating. The best-known exposures are in SW$\frac{1}{4}$ SW$\frac{1}{4}$ section 8, N$\frac{1}{2}$ SW$\frac{1}{4}$ section 16, E$\frac{1}{2}$ W$\frac{1}{4}$ section 17, and N$\frac{1}{2}$ SW$\frac{1}{4}$ section 17, Lincoln Township, and in SE$\frac{1}{4}$ NW$\frac{1}{4}$ section 23, SW$\frac{1}{4}$ SW$\frac{1}{4}$ section 10, S$\frac{1}{2}$ SE$\frac{1}{4}$ section 9, NW$\frac{1}{4}$ NE$\frac{1}{4}$ section 8, and SW$\frac{1}{4}$ SE$\frac{1}{4}$ section 5, Webster Township. At any of these points, and probably at many others as well, quantities ranging from a few thousand to 10,000 or more cubic yards are available by stripping.

Cedar Creek, which runs through the southeast part of Douglas Township and the south part of Union Township, shows conditions of exposure very similar to those along Middle River to the south. The Hertha appears in sections 26 and 27, Union Township, but within a short distance it is overlain by the Bethany Falls and is thus nearly unavailable. The Bethany Falls is visible and easily obtainable at numerous points in sections 19, 20, 21, 28, and 29, Union Township, and N$\frac{1}{2}$ section 25, Douglas Township, dipping beneath the creek in NW$\frac{1}{4}$ section 25. Quarrying on a small scale was carried on during the 1931 season near center NE$\frac{1}{4}$ section 25, Douglas Township, and near center

NW¼ section 20, Union Township. Quantities ranging up to 50,000 cubic yards or more are obtainable at several points. The Winterset appears at several points in section 19, Union Township, and section 25, Douglas Township, but it is not available in large quantity at any one point, nor has it been recently quarried. The DeKalb limestone is not known to appear.

Limestone outcrops near North River at intervals throughout its course in Douglas Township and in sections 6, 7, and 8 of Union Township. The Hertha limestone is exposed to the east at a few places, but in a short distance it underlies Bethany Falls and is thus nearly unavailable. The Bethany Falls appears in section 7, Union Township, and may be seen at intervals from there westward to the west line of Douglas Township. Details of the exposures are lacking, but it is probable that important quantities are available at several points. Near southeast corner section 12, Douglas Township, it has been quarried for surfacing on the primary road which passes that point. To the northeast, in SE¼ section 12, and SW¼ section 7, it is still available in fairly large quantity. At this point the Winterset limestone is present above it, though not everywhere in its full thickness. Exposures of the Winterset extend at intervals along the valley westward at least as far as the west line of Douglas Township, with moderate quantities available at several points.

The North Branch of North River does not show outcroppings of the Missouri series until the southwest part of Jefferson Township is reached. In that territory the Hertha and the Bethany Falls limestones appear together so that the Hertha is exposed at fewer places and is almost entirely unavailable. Outcroppings along the North Branch and its tributaries and also along small creeks running eastward to Raccoon River near Van Meter extend as far west as the west line of Madison Township. In Madison Township the glacial materials are thin (not commonly more than 50 feet), and the consolidated beds appear well up in valleys of even the smaller creeks. Practically all of the exposures represent the Bethany Falls limestone, although the lower part of the Winterset, much weathered, appears obscurely at a few points. The Bethany Falls has been extensively quarried in N½ N½ section 9, SE¼ section 4, NW¼ section 18, NE¼ section 5, and S½ section 16. At any of these localities considerable quantities of stone are still available. The last-named is the location of the quarry of the Hawkeye Portland Cement Co. A large share of the quarry output is shipped to Des

Moines and used in the plant there for the manufacture of portland cement, and the remainder is crushed and screened at the quarry and sold for various purposes. The quarry is worked in three lifts, corresponding to the three divisions of the Bethany Falls, as described earlier in this chapter. The rock is loaded by steam shovels on cars handled by small locomotives on standard-gauge track. The cars dump to the primary crusher, a 30-inch gyratory, from which the rock passes to one or both of two smaller gyratory crushers for finer crushing. After crushing, the dust is screened from the rock by means of vibrator screens. Facilities are provided for loading on railroad cars on a spur track connecting with the Rock Island Railway in SW¼ section 4, Madison Township. The plant is new and well equipped, is electrically operated, and has an estimated capacity of 100 tons of crushed rock per hour, the largest in southern Iowa. Both concrete aggregate and road surfacing stone are produced. Figure 5 is a general view of the operations at this plant.

FIG. 5. — General view of Hawkeye Portland Cement Co. quarry at Earlham showing steam shovels working in different quarry lifts.

In the southwestern part of the county Grand River has cut a deep valley which, however, shows no bedrock exposures.

Sand and Gravel

Pockets of sand or gravel within the glacial till of Madison County are, as in other counties of southwestern Iowa, small and of uncommon occurrence. One, in SE¼ SW¼ section 30, Jefferson Township, has been found to contain about 5,000 cubic yards of a fair grade of road surfacing gravel. Others contain only a few hundred cubic yards. In all, some twelve prospects of this type, principally in the eastern half of the county, have been investigated in detail. It is probable that other pockets of sand or gravel exist in the drift, but there is no reason for believing that any of them will yield any great quantity of usable road material.

Alluvial deposits in Madison County consist for the most part of silt and fine sand. However, bars of limited extent in Middle River near Patterson, Winterset, and Webster are reported to have been utilized locally for mortar and plastering sand. Gravel bars are unknown, except in some of the more vigorous streams, which, in cutting through the glacial clay and the Missouri limestones, have accumulated at various points in their channels small quantities of mixed broken stone, gravel, sand, and clay. One such deposit in SE¼ SW¼ section 19, Union Township, is believed to cover about one acre, and it is probable that systematic search would disclose others of equal or even greater value.

MAHASKA COUNTY

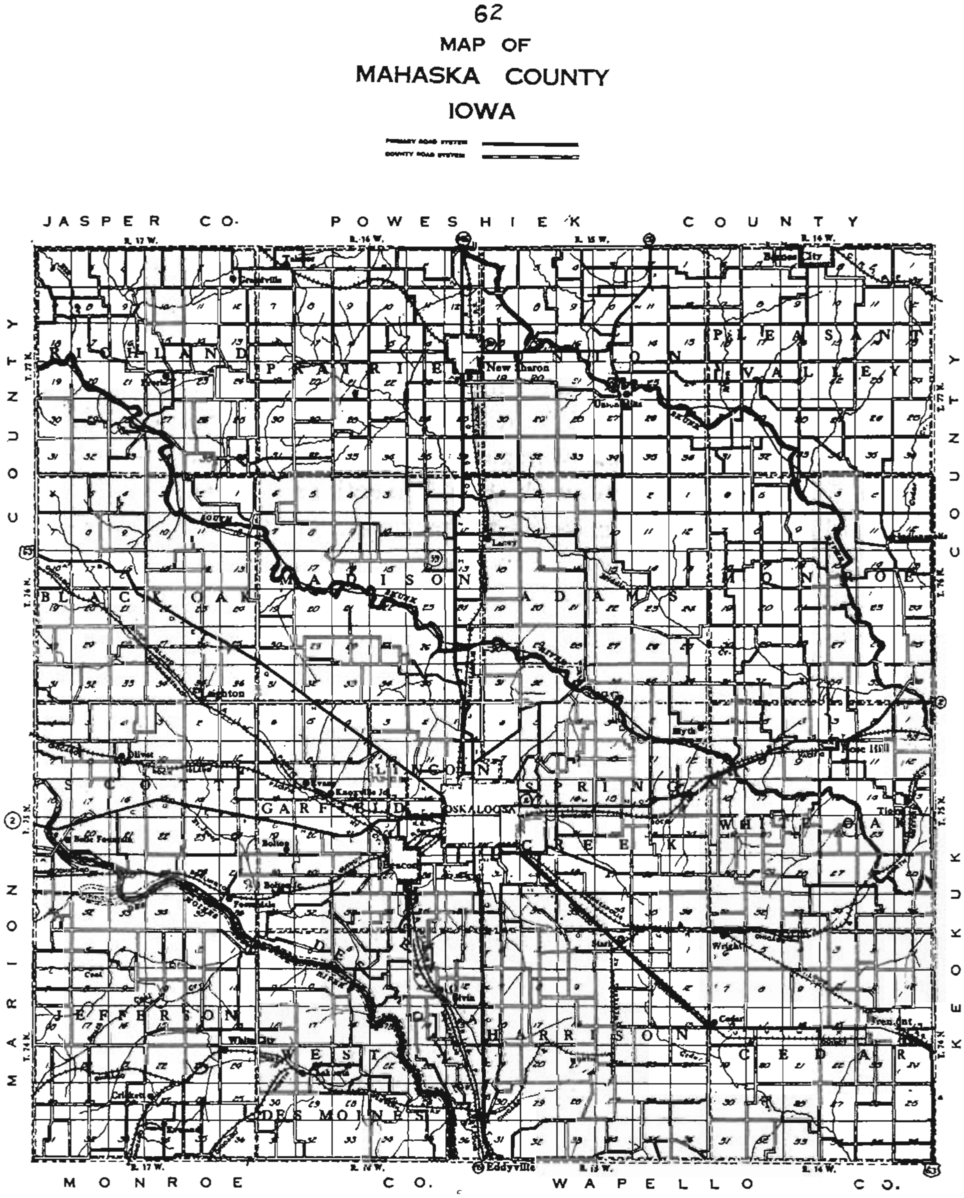
The entire county is underlain by the St. Louis and Ste. Genevieve limestones, which, however, appear at the surface only in narrow belts along Des Moines, South Skunk, and North Skunk Rivers and the immediate lower courses of a few of their tributaries. Elsewhere the country rock is of Pennsylvanian (Des Moines series) age. The unconsolidated deposits include the Nebraskan drift, Kansan drift, loess, and alluvium. The Nebraskan has few exposures but, from information in this and adjoining counties, it is known to be present throughout most or all of the county. The Kansan forms the surface drift. Loess covers the older materials with a mantle not commonly more than 10 feet thick and in the rough areas near the larger streams mostly removed by recent erosion. Alluvium is extensive on the larger streams, reaching a thickness as much as 40 feet in some places along Des Moines River. The total thickness of unconsolidated deposits differs extremely but in few places exceeds 150 feet.

Limestone

According to Van Tuyl,[52] both the Ste. Genevieve and the St. Louis

52 Van Tuyl, F. M., The Stratigraphy of the Mississippian Formations in Iowa: Iowa Geological Survey, Vol. XXX, pp. 277-278, and 299-300, 1921-22.

IOWA GEOLOGICAL SURVEY. PLATE XXIV



formations are represented in the exposures of the Mississippian in the county. However, the outcroppings are much more limited and scattered than in such counties as Van Buren or Lee, and the stratigraphic relationships of these two formations are but imperfectly understood. It thus seems undesirable to attempt in this paper to distinguish between the two when discussing the different localities where rock is exposed.

As before stated, the Mississippian appears only along Des Moines, South Skunk, and North Skunk Rivers, and the immediate lower courses of some of their tributaries. A former limited exposure near Cedar Creek in Cedar Township is now entirely obscured. These three areas or belts of outcrop may be considered separately.

Des Moines River Belt. — Rock appears at a few points along the course of Des Moines River, but, except near Eddyville, the beds are low in the banks and almost entirely unavailable. Near Bellefontain are interbedded sandstones and limestones, the former predominating and both usually deeply overlain by Pennsylvanian or younger deposits. The sandstones are too fine of grain and too poorly indurated to be of value for road or concrete work. Bain [53] mentions an exposure of 12 feet of limestone in section 18, Scott Township, and the same thickness in NE¼ section 1, Jefferson Township.

Near and north of Eddyville rock outcrops are numerous. Quarries have been worked in NE¼ SE¼ section 14, and NW¼ SW¼ section 13, and again near center section 13 of East Des Moines Township. A composite section obtained by clearing the old quarry face at two points and extended by core drill holes in the old quarry floor is as follows:

	Feet
4. Sandstone, soft, fine-grained, locally removed by erosion	5
3. Limestone, compact, fine-grained, light gray, hard (percentage of wear 5.0 to 6.6), sound, the upper 4 to 5 feet rather thin-bedded and much weather-broken to small oblong blocks, the remainder more massive and resistant to weathering, with a 3-inch shale seam near or just below the middle	10½–12
2. Shale, bluish gray, soft, with a few thin lenses of limestone	5½
1. Limestone, thin-bedded, shaly, with shale seams separating the beds	4

Number 3 of this section is suitable for road or concrete work, while Nos. 1 and 4 are undesirable for either purpose. In this locality large quantities of rock are available, but material under less than 15 feet of overburden is almost entirely removed in the former quarry operations.

Bain [54] mentions a similar thickness of limestone in NW¼ section 23, East Des Moines Township. Exposures in the south-central part

53 Bain, H. F., Geology of Mahaska County: Iowa Geological Survey, Vol. IV, pp. 330-331, 1894.

54 Bain, H. F., Geology of Mahaska County: Iowa Geological Survey, Vol. IV, p. 332, 1894.

of section 35, West Des Moines Township, show a limestone ledge 6 to 11 feet thick, with several feet of shale or sandstone above and five feet or more of a massive sandstone below. Moderate quantities are available for quarrying but almost none with less than 10 feet of overburden. In sections 25 and 26, no rock exposures are found. In the north part of the township the Mississippian rises only a few feet above the river and is apparently almost entirely unavailable.

South Skunk River Belt. — Only obscure exposures occur in the west part of the county, and these show almost nothing available. The first outcrop of value is in SW¼ section 25, SE¼ section 26, and NE¼ section 35, of Madison Township, in the bluffs south of the river and along a small tributary creek from the south. The following section has been worked out in W½ NE¼ section 35:

	Feet
10. Limestone	2
9. Shale	2½
8. Limestone, gray, hard, crystalline	3
7. Shale	3
6. Limestone, gray, hard	3
5. Shale	1/10
4. Limestone, gray, hard, rather irregularly bedded. The lower foot is much streaked with iron oxide	8
3. Sandstone interbedded with some limestone and shale	1
2. Limestone, yellowish	½
1. Sandstone	4+

Numbers 4 and 6 constitute a zone of rock that is available in limited quantity with rather heavy overburden and is shown by tests to be suitable for aggregate or for surfacing stone. The upper beds here are much weathered, and the lower ones are now very poorly exposed.

About five feet of hard white fine-grained limestone may be seen about one-fourth mile west of center section 33, township 76, range 15. Limited quantities are available. The exposure is now much obscured, and it may be that five feet is considerably less than the full thickness of limestone here. Bain [55] gives the following general section along Spring Creek in SE¼ section 33, and in section 4, township 75, range 15:

	Feet
5. Limestone, thin-bedded, with fossiliferous marls	2
4. Limestone, compact, gray	2
3. Limestone, fine-grained, white	10
2. Sandstone, calcareous	4
1. Unexposed to river level	10

Some obscure exposures in SW¼ SW¼ section 2, township 75, range 15, south of the river, show small quantities of limestone available.

[55] Bain, H. F., Geology of Mahaska County: Iowa Geological Survey, Vol. IV, p. 328, 1894.

Probably more and better exposures of the Mississippian limestones occur in White Oak Township than in all the rest of the county. The same horizon seems to be represented in all of the exposures, though it shows a wide range in character even in some cases within the limits of a single quarry. Following is a general section:

		Feet
4.	Limestone, light gray, medium to fine of grain, fossiliferous, hard and sound except at the top, which is locally shaly; usually in heavy and regular beds. Scattered small pyrite crystals are generally characteristic	3–6
3.	Beds with extreme range in character, consisting principally of sandstone and shale. Sandstone, where present, is fine-grained and soft and usually appears in the upper part of the member, though locally it constitutes practically the full thickness. The shale is drab to brown or greenish in color, calcareous, and includes some thin lenses or plates of light gray fine-grained hard limestone. In places where this member is thin, the limestone is thicker in proportion, so that it constitutes the major part of the member	½–7
2.	Limestone, gray to dark gray, rather fine-grained, nonfossiliferous, hard, sound, locally conglomeratic in the upper part, often divided into two parts by a seam of calcareous or sandy shale which may be as much as 3½ feet thick but is usually not more than 1 foot	3½–7½
1.	Principally sandstone, fine-grained, yellowish, soft but including thin zones of hard calcareous sandstone or of hard gray limestone. The soft sandstone usually constitutes half to three quarters of the member. Bain[56] gives this member a thickness as much as 35 feet	15+

The fossiliferous character of No. 4 suggests the reference of it and No. 3 to the Ste. Genevieve, while the lower beds may represent the St. Louis. However, this correlation cannot be considered positive. The limestones are suitable for aggregate or for road surfacing, except where parts of them are shaly and unsound.

The members of the foregoing section form an escarpment in the lower bluffs north of the river at short intervals in sections 17, 16, 15, 23, and south of the river in section 16. In general, the two limestones show about average thickness, and the shale and sandstone between are thick and persistent. Moderate quantities are available by stripping in SE¼ SW¼ section 14, NW¼ NW¼ section 15, and SE¼ NE¼ section 17, and at several points in S½ section 16.

Along the small creeks tributary to the river from the south in the southeast part of the township are numerous exposures and a few old quarries. The deposits in sections 34 and 35 are especially good. In recent years, Mahaska County has operated a quarry in SE¼ SW¼ section 34. The section at that place shows a higher proportion of limestone than any other observed in the township and is therefore given in detail as follows:

		Feet
7.	Clay, glacial and residual, with weathered shale and broken limestone fragments	5–10

[56] Bain, H. F., Geology of Mahaska County: Iowa Geological Survey, Vol. IV, p. 329, 1894.

6. Shale, dark gray, calcareous, fossiliferous	½–2
5. Limestone, dark gray, medium to fine of grain, noticeably fossiliferous (principally small brachiopod shells), hard, questionably sound, in several regular beds separated by thin seams of black fissile shale. Next to these shale seams are zones of dark shaly unsound limestone	1½
4. Limestone, in two or three beds separated by shaly partings about 1 inch thick, light gray, rather fine-grained, hard, sound, nonfossiliferous except for a few joints of crinoid stems and broken shell fragments in the lower foot	4¾
3. Principally shale, green and soft, or dark brown, hard and fissile. Included are lenses of hard gray fine-grained limestone, which in the west end of the quarry replace nearly all of the shale but elsewhere constitute perhaps 25 percent of the member	⅓–1½
2. Limestone, very similar to No. 4, except that no fossils are noted	5½
1. Drilling to this depth below the quarry floor shows limestone, sandstone, and shale, in alternating beds, the limestone constituting about 60 percent of the total thickness. Sandstone lies next below No. 2	14

The quarry face is about 500 feet long, and the beds for this distance show persistence in thickness and character, except as noted. The hill above the quarry face is not steep, and while a large quantity of rock has been removed, much more is available. Only half a mile from here, in SE¼ SE¼ section 34, and again in SE¼ NE¼ section 35, the shale bed (No. 3 of the above section) is thicker, and the usual sequence, as given in the general section, is seen. At these points also, 50,000 cubic yards or more might be obtained.

North Skunk River Belt. — Bain [57] mentions the occurrence of six feet of good limestone at old quarry workings in SE¼ NW¼ section 1, Prairie Township. Judging from his description, overburden was heavy. The limestone is now entirely obscured by overwash. From this point downstream as far as Union Mills the only definite exposures show Pennsylvanian strata, and it is probable that the top of the Mississippian is below river level.

At Union Mills (SE¼ sec. 23, Union Twp.) about six feet of limestone is to be seen in the bed of the river. It is not available except with heavy stripping and even then only in small quantity.

Bain [58] mentions the occurrence in NE¼ NW¼ section 4, Monroe Township, of 12 feet of imperfectly exposed limestone interbedded with sandstone. His section [59] in SW¼ section 15, Monroe Township, is as follows:

	Feet
6. Limestone, gray, subcrystalline, with interbedded fossiliferous marl layers	10
5. Unexposed	11
4. Limestone, ash-gray, compact	1
3. Sandstone, soft, yellow	1
2. Limestone, as above	2
1. Sandstone, as above	2

57 Bain, H. F., Geology of Mashaska County: Iowa Geological Survey, Vol. IV, p. 324, 1894.
58 Idem, p. 325.
59 Idem, p. 326.

Details as to the quantity of stone obtainable and thickness and character of overburden are lacking, but judging from the conditions at Union Mills and in Keokuk County between Atwood and Delta, the available quantity is not large.

In NW¼ SE¼ section 35, Monroe Township, limestone appears low in the bluff south of the river, but the available quantity is small. Other exposures of rock in the south part of Monroe Township show only Pennsylvanian beds.

Sandstone

The sandstones mentioned in the foregoing discussions of the Mississippian formations are nearly all too soft to be crushed for aggregate or surfacing material and too fine-grained to be broken down and the resulting sand used for aggregate, unless in asphaltic mixtures. Harder zones are known to exist in sections 23 and 34, White Oak Township, and may be present at other points, but they are apparently nowhere more than a few feet thick. Pennsylvanian sandstone appears commonly, in many places several feet thick, but also too soft and too fine-grained to be used for road or concrete work. A large deposit of channel sandstone, similar to that at Red Rock, in Marion County, extends along the bluffs south of Des Moines River in sections 32 and 33, Jefferson Township (T. 75, R. 17). The bed is in places 50 feet or more in thickness. Little is known of the quality of the stone, but, as at Red Rock, there may be zones that are well enough indurated to have some value for crushing and use as road surfacing material.

Mine Shale

Mahaska County has been and still is the seat of an extensive coal mining industry. Scattered mines are reported from east of New Sharon (secs. 8 and 9, Union Twp.) in NW¼ section 6, White Oak Township, at Olivet (sec. 9, Scott Twp.) and near Evans (sec. 13, Scott Twp. and SW¼ sec. 19, Garfield Twp.), but the most extensive operations have been near and south of Oskaloosa and in the south half of Jefferson Township.

Large dumps, showing well-burned material, are present in section 12, East Des Moines Township. Other localities where mining has been extensive are near Beacon (secs. 22, 26, and 27, Garfield Twp.), southeast of Oskaloosa (secs. 30 and 31, Garfield Twp. and sec. 5, Harrison Twp.), and northeast of Eddyville (secs. 28, 29, and 33, Harrison Twp.).

The largest mines in Jefferson Township were located in SW¼ SW¼ section 13; west of center SE¼ section 19; NW¼ NE¼ section 25; NE¼ NW¼ section 27; SW¼ SW¼ section 28; NW¼ NW¼ section 30; SE¼ NW¼ section 33; NE¼ NW¼ section 34. The quantity of mine shale available at some of these locations is not known, but it ranges up to 10,000 cubic yards at the locations seen. Much of the material is not uniformly or well burned.

Sand and Gravel

On account of the abundance of sand and gravel in Des Moines River, no detailed survey of the glacial gravels in Mahaska County has been made. However, gravels of Nebraskan, Aftonian, or Kansan age are about as common as in the other counties of southern Iowa. The best-known instance is near southwest corner section 35, Madison Township, where a deposit of rather clayey but quite coarse reddish-brown gravel has been worked for several years. In 1925 some 25,000 cubic yards of gravel was found in this bed, but a large part of this has since been removed. What appears to be a still larger deposit of similar material is present in the bluff north of Skunk River valley in NE¼ NE¼ section 12, Black Oak Township, and NW¼ NW¼ section 7, Madison Township. However, at this point, the only material under a moderate thickness of overburden is rather fine for surfacing work and too clayey to make good aggregate. A smaller deposit is known in NW¼ SE¼ section 25, Union Township, also under heavy overburden.

River gravels along the Des Moines so far overshadow any of the small sand or gravel bars found on either branch of the Skunk, or on any of the smaller creeks, that these latter will not be given more specific mention, though some of them are of value as sources of small quantities of material for local projects.

Sand and gravel, the former nearly always predominating, are known at a number of points in the channel and beneath the bottomlands of Des Moines River within the county. The most important bars are as follows:

Near center sec. 19, T. 75, R. 17	7-acre bar of gravel and coarse sand on the east bank, rising as much as 10 feet above low water
SE¼ SE¼ sec. 28, T. 75, R. 17	Sand bar on the north bank about 1,000 feet long

S½ NE¼ sec. 1, T. 74, R. 17	8-acre bar of coarse sand and fine gravel on north bank, prospected and found 160,000 cubic yards of material
NW¼ SW¼ sec. 6, T. 74, R. 16	5-acre bar of coarse sand and fine gravel on south bank, prospected and found 70,000 cubic yards of material
South of center sec. 6, T. 74, R. 16	3-acre low bar of gravel and sand on south bank
SE¼ SW¼ sec. 5, T. 74, R. 16	4-acre low bar of gravel and sand on north bank
SE¼ SE¼ sec. 5, T. 74, R. 16	5-acre gravel bar on south bank
NE¼ NW¼ sec. 9, T. 74, R. 16	Bar on north bank shows 5,000 cubic yards of gravel above low water
NW¼ NW¼ sec. 15, T. 74, R. 16	6-acre bar of sand and fine gravel on west bank
NW¼ SW¼ sec. 15, T. 74, R. 16	5-acre sand bar on east bank, mostly rather low
NE¼ SE¼ sec. 22, T. 74, R. 16	East bank, 1-acre bar of sand and fine gravel, rising about four feet above low water
SE¼ NE¼ sec. 26, T. 74, R. 16	2-acre bar of sand and fine gravel on south bank
NW¼ NW¼ sec. 36, T. 74, R. 16	1-acre bar of rather coarse gravel on east bank
SW¼ SW¼ sec. 36, T. 74, R. 16	1½-acre bar of gravel on east bank, prospected and found about 20,000 cubic yards of material

Almost without exception the gravel and sand in these bars is clean, sound, and well-graded. It is usually suitable for concrete aggregate and, if coarse enough, for road surfacing work.

In the bottomlands are other deposits, commonly showing a few feet of silt overburden, then sand to water level, with coarser sand or gravel below. The best-known are those worked by the Wilson Sand and Gravel Co. in NW¼ SW¼ section 28, Scott Township, and by the Concrete Materials Corporation near north quarter-corner section 26, East Des Moines Township (loading plant in SE¼ SW¼ sec. 25, East Des Moines Twp.).

At the Wilson plant is found 1 foot to 4 feet of black silt overburden, 8 to 15 feet of sand above water, and 5 to 40 feet of sand and gravel below water. About three acres has been worked over and much more is easily available. The material is clean, sound, and usually well graded, but locally it contains a large proportion of sticks, clay balls, or pebbles of black carbonaceous shale. It is excavated by a pump dredge, the discharge pipe from which feeds the main screen at the top of the plant. The screen is of the cylindrical revolving type. The gravel passes from the screen through a revolving screw washer to a storage bin, and the sand passes through a wooden settling tank to another bin. A third bin is used for whatever mixtures of sand and gravel are desired. Facilities for ground storage and reclamation of sand are provided. The plant is electrically operated and has track connection to the Chicago, Burlington & Quincy railway nearby. Its capacity is estimated at 50 tons per hour, mostly sand. Both road surfacing gravel and concrete aggregate can be produced.

The plant of the Concrete Materials Corporation is one of the largest and best-equipped plants in southern Iowa. The deposit worked is very similar to that at the Wilson plant. The material is excavated by pump dredge, which discharges to a preliminary plant consisting of a screen for separating the sand from the gravel. As there is usually an excess of sand, provision is made for wasting it back into the pit from this plant. Gravel, and sand as needed, discharge from this plant to cars on an industrial railway and are hauled to the main plant about

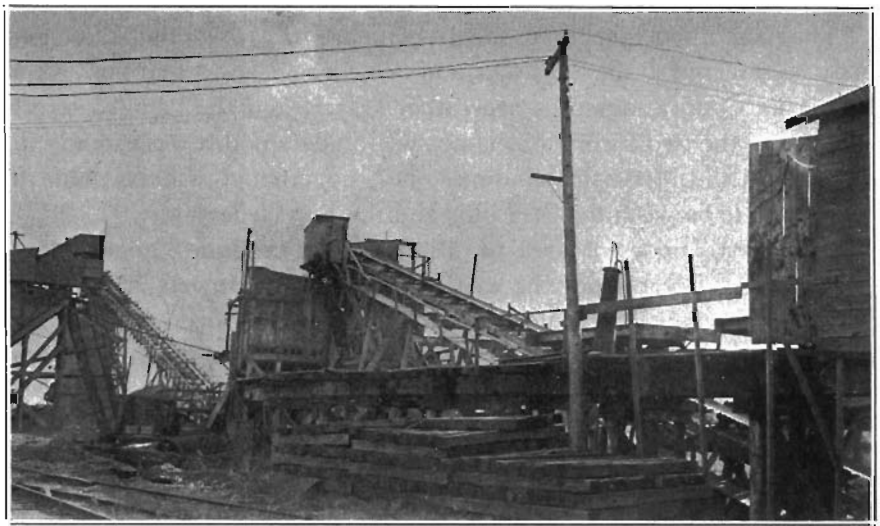


FIG. 6. — Concrete Materials Corporation, Eddyville. General view of the screening and washing plant.

1½ miles distant. At this plant are additional screening facilities for sizing the gravel, screw washers for cleaning it, and a settling tank for further cleaning of the sand. Material is loaded on cars on a spur track connecting with the Minneapolis & St. Louis railroad. Provision is made for ground storage and reclamation of any of the materials produced. The plant is electrically operated, and its capacity is estimated at 100 tons per hour, about half being gravel and half sand. Sand or gravel suitable for any road or concrete purposes can be produced. Figure 6 is a general view of the main plant.

MARION COUNTY

The exposed bedrock in all of Marion County is of Pennsylvanian age except for narrow belts of Mississippian formations that follow the main valleys in the northeastern part. Upon the bedrock is a mantle of Kansan and Nebraskan drifts and of post-Illinoian loess. The loess ranges in thickness up to 15 feet, and in the rough areas near the larger streams it is largely removed by recent erosion. At very few places does the total thickness of unconsolidated materials exceed 125 feet. Alluvium is extensive in the valleys of Skunk and Des Moines Rivers and appears in lesser measure along the smaller streams. On Des Moines River it contains large quantities of sand and gravel.

Limestone

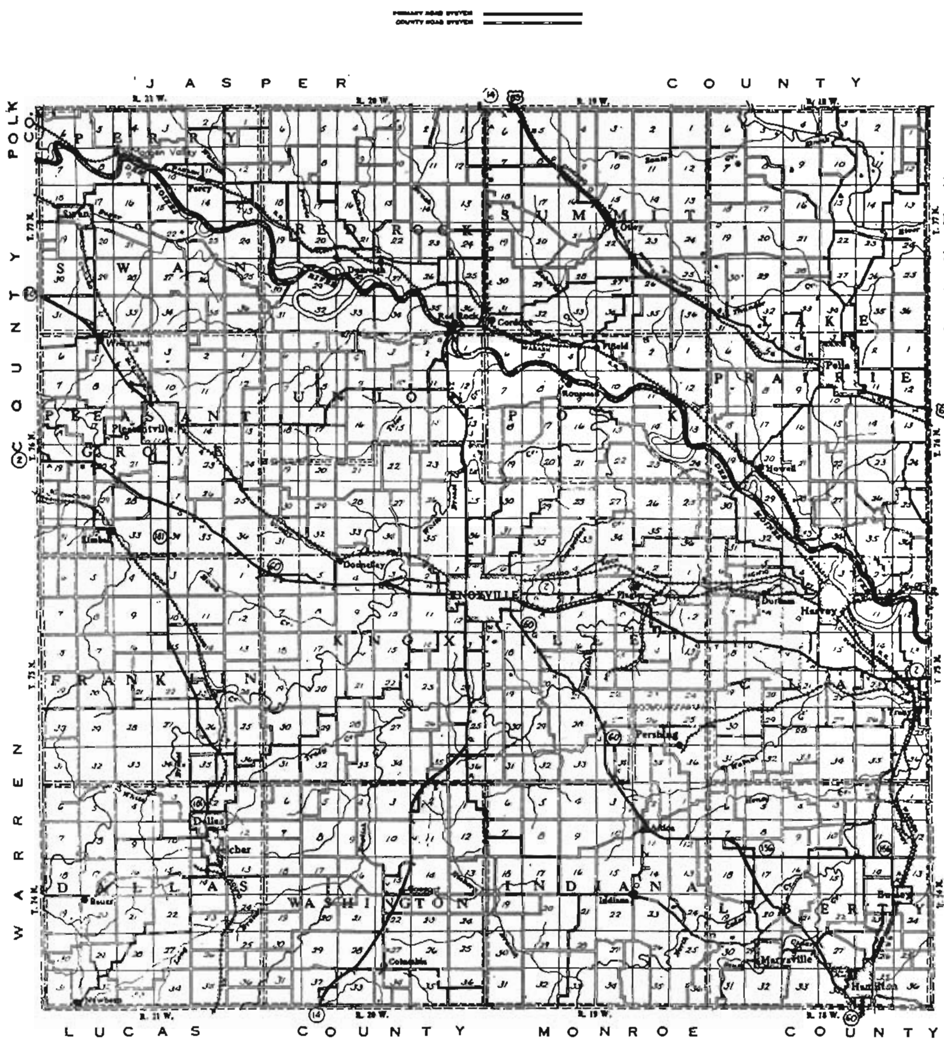
The most important limestone deposits are of Mississippian age and may be referred to the St. Louis and Ste. Genevieve formations. As in Mahaska County, outcrops are rather scarce, and the detailed stratigraphy of the two formations is not well understood. Consequently, in describing the Mississippian limestones, no attempt will be made to differentiate between the St. Louis and the Ste. Genevieve.

The most important area of Mississippian outcrop extends along Des Moines River from the east county line to Howell, up English Creek as far as Flagler, along other creeks a short distance west and south of Tracy, and in a narrow belt from Harvey north nearly to Pella. The best-known and most extensively developed deposit is in N½ SE¼ section 35, Clay Township. A number of detailed sections at this point have been published.[60] The following is one obtained by the writer:

60 E.g., Miller, B. L., Geology of Marion County: Iowa Geological Survey, Vol. XI, p. 143, 1900.

IOWA GEOLOGICAL SURVEY. PLATE XXV

63
MAP OF
MARION COUNTY
IOWA



	Feet	Inches
10. Clay, glacial and residual	3+	
9. Limestone, one bed. Light gray, fine-grained, with distinct conchoidal fracture; percentage of wear 4.92; soundness satisfactory	2	2
8. Limestone, similar to the above but with numerous horizontal lamination planes along which it weathers to thin plates. Percentage of wear 5.82; soundness questionable	4	3
7. Shale, drab, calcareous		2
6. Limestone, one bed, gray, weathers yellowish, medium-grained, fossiliferous; percentage of wear 5.66; soundness satisfactory	1	6
5. Limestone, one bed, similar to the above	1	8
4. Limestone, gray, finer-grained than the above. The lower 1 or 2 inches is darker colored and possibly unsound. Percentage of wear 5.94; soundness questionable	1	3
3. Shale, drab, calcareous	1	6
2. Limestone, not visible in the quarry face but reported to have been found in a small pit below the quarry floor	4 (Approx.)	
1. Sandstone, yellowish, soft	20+	

Though only clay appears above the rock at the point where this section was obtained, most of the old railroad quarry here was worked back to a point where the limestone was overlain by 10 to 20 feet of shale and sandy shale with one or two thin limestone beds. It appears, in fact, that nearly all of the rock available here by stripping has been removed.

A succession of beds similar to those just described appears in whole or in part at various points in this territory. As the rock is low in the valleys, often only the upper part, Nos. 8 and 9 of the section given, may be seen. Known points of outcrop are in the central part of section 23, NW¼ SE¼ section 21, SE¼ section 13, center N½ section 15, S½ SW¼ section 11, SW¼ section 4, and SE¼ section 5, all of Clay Township. The last named location is the site of another extensive old quarry, from which all the material under light overburden has been removed, though large quantities of rock could still be obtained by stripping a thickness of 10 to 20 feet. Other locations are in SW¼ SW¼ section 1, township 75, range 19; and also in SW¼ NE¼ section 30, NW¼ NW¼ section 20, NW¼ NW¼ section 27, SE¼ SE¼ section 9, SE¼ SE¼ section 34, and SW¼ SW¼ section 35, all of township 76, range 18. At any of these points only small quantities are obtainable before excessive overburden is encountered.

In Lake Prairie Township (T. 77, R. 18), north and northeast of Pella, are a number of other limestone exposures and several old quarries. The limestone appears to be much thinner, the maximum thickness reported being four feet, with shale and sandstone both above and below. Only small quantities are available.

The Pennsylvanian of Marion County includes several limestone beds, none of which is over four feet thick. They have been quarried in a small way at a number of points in the south and central parts of the county, but they are of little or no importance as sources of road or concrete materials. A ledge of black and carbonaceous, but hard and sound limestone was worked at a coal mine at Melcher (NW¼ sec. 14, Dallas Twp.), where it lay between two beds of coal and was therefore removed in connection with the mining operations. A similar ledge, from 2½ to 3½ feet thick, lies above the coal in a strip pit in SE¼ section 2, township 75, range 19, and has been crushed for road work as the pit is extended.

Sandstone and Conglomerate

The Mississippian sandstones, as was mentioned in No. 1 of the section given for SE¼ section 35, Clay Township, are too soft and too fine-grained to be of any particular value for road or concrete work. The early Pennsylvanian beds include numerous sandstones, many of which are fairly hard but only a few feet thick. Some of them have been quarried in a small way in the south part of the county. The quantity available at any one point is small and insufficient to justify setting up even a small portable crushing or screening plant.

Thick deposits of sandstone, ranging locally to conglomerate, which apparently were laid down in late Des Moines time in channels cut into the early Des Moines beds, are well-known in the county and have at times supported an important quarry industry. Most of these deposits range widely in character within a short distance; thus a hard well-cemented calcareous sandstone grades into a firm calcareous conglomerate or into a soft sandy shale, or, if the sandstone persists, it may show abrupt changes in the degree of induration. This, together with the fact that the beds show inconstant and often rather steep dips, makes accurate estimation of the extent and value of any deposit very difficult without careful and expensive prospecting work.

The best-known of these channel deposits is well exposed in the old Red Rock quarries north of center section 35, Red Rock Township. It consists almost entirely of yellowish to reddish fine-grained ferruginous sandstone. The bed is nearly 100 feet thick and has been traced by natural exposures and well records through an area 11 miles long (north-northeast to south-southwest) and as much as 3 miles wide. Large quantities are easily available. In general it may be said that this sandstone is not well enough indurated to be of value for road or concrete work. However, the face of the Red Rock quarries shows numerous ill-defined zones of hard sandstone, in places almost quartzitic, which is suitable for road surfacing work. Most of these zones are small, the largest seen containing perhaps 500 cubic yards. At other exposures of the Red Rock sandstone, as at southwest corner section 17, NW¼ NW¼ section 5, NE¼ NE¼ section 7, and SW¼ SW¼ section 5, Polk Township, these more indurated zones are not as noticeable as at Red Rock.

What may be an extension of the Red Rock deposit or may be an entirely separate deposit of about the same age has been traced from SW¼ section 25, township 76, range 20, to the NW¼ section 2, township 75, range 20. It ranges in thickness up to nearly 75 feet and is exposed at numerous places in the middle or higher slopes leading down to Whitebreast Creek. Typical sections are as follows:

Section in NE¼ NW¼ SW¼ section 25, township 76, range 20

	Feet	Inches
9. Conglomerate of rounded pebbles of hard gray fine-grained limestone, ½ inch to 2 inches in diameter in a ferruginous matrix which is usually soft and unsound	2	10
8. Sandstone, gray, hard, coarse-grained		8
7. Shale, gray to buff, with fragments of soft buff coarse-grained sandstone		10
6. Conglomerate, similar to No. 9	6	4
5. Shale, gray to buff, siliceous		6
4. Sandstone, gray, hard, coarse-grained, with several limestone pebbles. Percentage of wear 6.6; soundness questionable (on account of the ferruginous matrix)	3	4
3. Shale, gray, calcareous	4	
2. Conglomerate, similar to No. 9, but with numerous small pockets of shale in the matrix	6	
1. Shale, gray, fissile in the lower half	3	

Section in SE¼ NE¼ NE¼ section 35, township 76, range 20

	Feet	Inches
8. Sandstone, medium- to coarse-grained, gray, massive; percentage of wear 6.8, soundness satisfactory	11	9
7. Shale		9
6. Sandstone, brown, soft, fine-grained	4	3
5. Sandstone, gray to buff, medium-grained, massive. Percentage of wear 7.4; soundness satisfactory. To floor of old quarry	19	
4. Sandstone, similar to No. 5, but containing seams and zones of soft sandstone	17	(Approx.)
3. Unexposed, probably sandstone	11	(Approx.)
2. Conglomerate of large limestone pebbles in a buff ferruginous matrix	2	(Approx.)
1. Shale, black, fissile	4–6	

Section in SE¼ SW¼ SE¼ section 35, township 76, range 20

	Feet	Inches
13. Sandstone, buff, hard, coarse-grained, ferruginous. Percentage of wear 19.0; soundness satisfactory	1	9
12. Shale, gray to buff, with thin layers of very soft sandstone in the lower part	1	9

	Feet	Inches
11. Sandstone, gray to brown, medium-grained. Percentage of wear 15.0; soundness satisfactory	2	9
10. Sandstone, soft		4
9. Sandstone, gray to brown, coarse-grained, massive. Percentage of wear 17.1; soundness satisfactory	8	6
8. Shale, buff		4
7. Sandstone, similar to No. 9	1	3
6. Sandstone, very soft		3
5. Sandstone, moderately hard, coarse-grained		8
4. Sandstone, buff, soft, with two 1-inch layers of black shale in the upper foot	3	6
3. Unexposed	32 (Approx.)	
2. Sandstone, moderately hard, coarse-grained	6	
1. Shale, gray to black, fissile	10	

Section in NE¼ NW¼ section 2, township 75, range 20

	Feet
2. Conglomerate, imperfectly exposed, with rounded pebbles of limestone, iron oxide, and chert, from 1/16-inch to ½-inch in diameter, in a matrix of iron oxide. Percentage of wear 8.76; soundness satisfactory	15 (Approx.)
1. Shale	2+

These four sections are given for the purpose of illustrating the differences in what is obviously a continuous deposit. At any of these points, and at others in the locality as well, quantities ranging from 1,000 to 25,000 cubic yards or more are obtainable by stripping.

Other thick sandstones are present south of Knoxville, as follows: NE¼ section 24, township 75, range 20, 15 feet of alternating sandstone and shale in about equal proportions; west of center section 17, township 75, range 20, 10 feet of rather soft reddish-brown sandstone; and west of center section 20, township 75, range 20, 60 feet of soft sandstone. Near Columbia (NW¼ NE¼ sec. 21, and W½ SW¼ sec. 34,

Fig. 7. — View of the quarry face near SW. corner section 21, Dallas Township, Marion County.

Washington Twp.) are fairly hard sandstones from 5 to 10 feet thick. Near SW corner section 21, Dallas Township, a 12-foot bed of calcareous fine-grained conglomerate and coarse-grained sandstone is

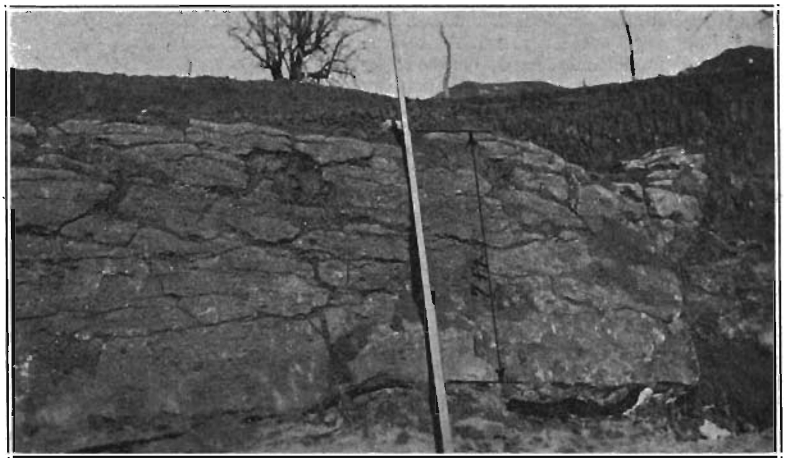


FIG. 8. — Detail of part of quarry face shown in figure 7 showing weathering of upper part of conglomerate and unconformity with shale and coal below.

available to the extent of 40,000 cubic yards or more, with light stripping. Tests show a percentage of wear of 8.3 and soundness satisfactory. Figure 7 is a view of the quarry opening at this point, and Figure 8 shows a part of the quarry face in more detail.

Mine Shale

Coal mining has been carried on rather extensively in Marion County, and at the dumps of the larger mines large quantities of surfacing material are available, as follows:

NW¼ NW¼ sec. 24, Dallas Twp.	50,000 cubic yards of well-burned shale
NW¼ NW¼ sec. 14, Dallas Twp.	Large mine recently in operation and shale dump now burning

W. of center sec. 4, Perry Twp.
SW¼ NE¼ sec. 22, Red Rock Twp.
NW¼ SW¼ sec. 26, Red Rock Twp.
SW¼ NW¼ sec. 27, Red Rock Twp.
SW¼ NW¼ sec. 27, Summit Twp.
SE¼ NE¼ sec. 3, Knoxville Twp. (T. 75, R. 19)
NE¼ SE¼ sec. 4, Knoxville Twp. (T. 75, R. 19)

S½ sec. 25, T. 75, R. 19
(at Pershing)
NE¼ NE¼ sec. 20, Liberty Twp.
NE¼ NE¼ sec. 22, Liberty Twp.
SW¼ SE¼ sec. 26, Liberty Twp.
Center sec. 27, Liberty Twp.

Besides these, numerous other mines, either abandoned or operating, are located in the vicinities of Otley, Pella, Knoxville, Bussey, Marysville, and Melcher, where limited quantities of satisfactory surfacing materials may be obtained.

Sand and Gravel

As in other counties of southern Iowa, Marion County has some pockets of sand or gravel in the drift, most of them too small to be usable but a few larger. However, where such are present, they are overshadowed in importance by the gravels along Des Moines River and by the limestone and sandstone deposits in various parts of the county, and they need not be considered further in this study.

The small streams of high gradient that cut to the bedrock have along their courses small deposits of sand, gravel, and broken stone, which are of some value for local improvements. The lower alluvium of Skunk River in the northeast corner of the county contains much sand and some gravel, usually under prohibitive overburden. However, these supplies are of little importance as compared with the extensive deposits of sand and gravel found along Des Moines River.

The largest and most valuable bars in Des Moines River are briefly described as follows:

NW¼ SW¼ sec. 9, T. 77, R. 21	10-acre low bar on north bank, gravel at upper end, remainder sand
SE¼ SE¼ sec. 15, T. 77, R. 21	5-acre bar on south bank, gravel at the upper end, remainder sand
SW¼ SW¼ sec. 14, T. 77, R. 21	5-acre high bar on north bank, coarse gravel in upper third, remainder sand
NE¼ NW¼ sec. 23, T. 77, R. 21	4-acre bar on south bank, one acre of gravel at upper end, remainder sand
E½ NE¼ sec. 23, T. 77, R. 21	15-acre bar on north bank, fine gravel in upper part, remainder sand
SW¼ NE¼ sec. 30, T. 77, R. 20	1-acre high gravel bar on north bank
SE¼ NE¼ sec. 30, T. 77, R. 20	10-acre high bar on north bank, gravel at upper end grading to fine sand at lower end

N. of center NW¼, sec. 29, T. 77, R. 20	12-acre high bar on south bank, gravel in upstream part, remainder sand
SE¼ NE¼ sec. 29, T. 77, R. 20	15-acre high bar on north bank, coarse gravel at upper end, grading to fine sand at lower end
NE¼ SW¼ sec. 28, T. 77, R. 20	6-acre high bar on south bank, mostly coarse sand
SE¼ SE¼ sec. 28, T. 77, R. 20	8-acre bar on north bank, mostly fine gravel and coarse sand
SE¼ NE¼ NE¼ sec. 34, T. 77, R. 20	5-acre low bar on north bank, mostly coarse gravel
N½ SE¼ sec. 35, T. 77, R. 20	Large bar on north bank has been extensively worked and most of the coarse material removed
SW¼ SW¼ sec. 36, T. 77, R. 20	Bar on north bank, prospected and found to contain 24,000 cubic yards of gravel
NW¼ SW¼ sec. 6, T. 76, R. 19	High but rather small bar of sand and gravel on south bank
SE¼ SE¼ sec. 5, T. 76, R. 19	Bar on south bank, prospected and found to contain 20,000 cubic yards of fine gravel and coarse sand
NW¼ SW¼ sec. 10, T. 76, R. 19	Bar on south bank, prospected and found to contain 13,000 cubic yards of fine to coarse gravel
SW¼ NW¼ sec. 11, T. 76, R. 19	High bar on south bank, 5 acres area, mostly coarse to fine gravel
NE¼ NW¼ sec. 13, T. 76, R. 19	7-acre bar on south bank, sand except at upper end, which is gravel
E½ SW¼ sec. 13, T. 76, R. 19	20-acre low sand bar on north bank
SW¼ SE¼ sec. 19, T. 76, R. 18	3-acre bar on north bank, ranges from coarse gravel at upper end to sand at lower end
Center NE¼ sec. 30, T. 76, R. 18	Bar on south bank, prospected and found to contain 88,000 cubic yards of gravel, ranging from coarse to fine
NW¼ SW¼ sec. 29, T. 76, R. 18	3-acre low bar on north bank, fine gravel and medium to coarse sand
NE¼ NW¼ NE¼ sec. 32, T. 76, R. 18	2-acre high bar on north bank, gravel at upper end, remainder sand
NW¼ SE¼ sec. 33, T. 76, R. 18	Rather low bar of coarse gravel on south bank, four acres, now being worked for road materials

SE¼ SW¼ sec. 34, T. 76, R. 18	6-acre bar on north bank, largely gravel
E½ SE¼ sec. 34, T. 76, R. 18	5-acre bar on south or west bank, largely gravel
SW¼ NW¼ NW¼ sec. 2, T. 75, R. 18	6-acre bar on north bank, gravel at upper end, remainder sand
NE¼ NE¼ sec. 13, T. 75, R. 18	10-acre bar on north bank, mostly sand and fine gravel

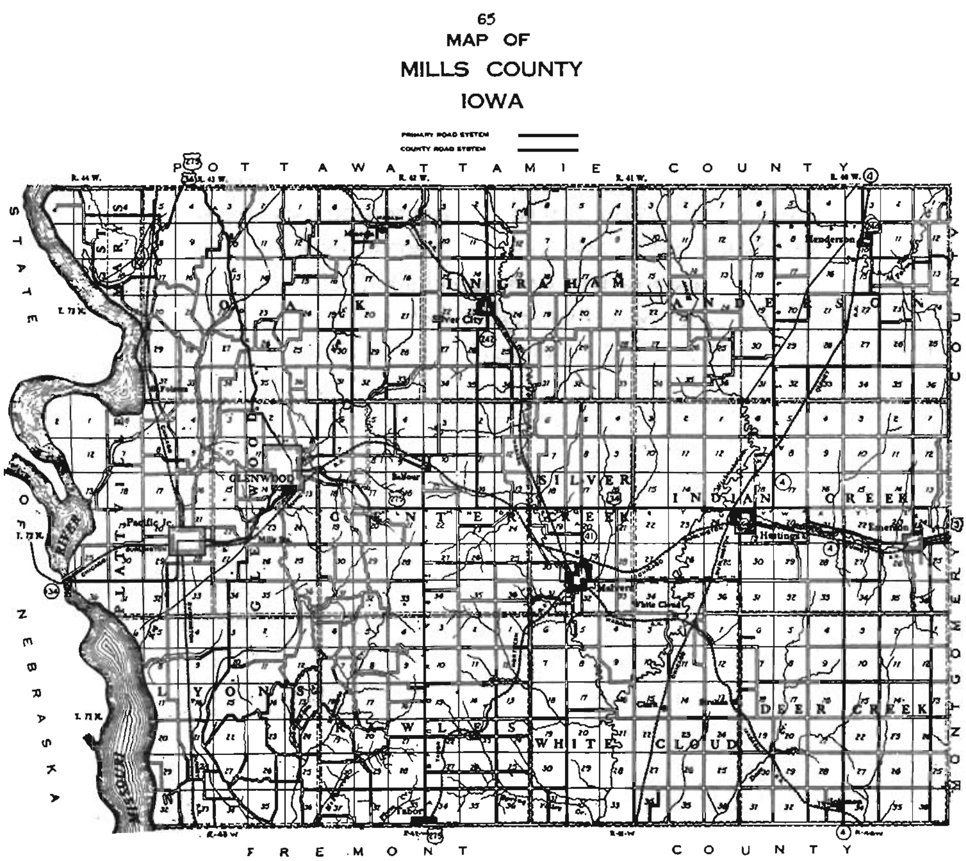
The material in all these bars is very similar, usually clean, hard, and sound, and suitable for any road or concrete purposes. Occasional streaks of silt, or thin beds containing sticks, shale, or coal, are objectionable features.

Most of the Des Moines River bottomlands are underlain by a few feet of black silt, thence sand to about water level, and thence coarse sand or fine to coarse gravel to bedrock, which is 5 to 40 feet below water. The material is very similar to that in the bars, though many of the deposits are more uniform and dependable. Supplies of this type have been developed in NW¼ SW¼ section 20, township 76, range 18, E½ section 3, township 75, range 18, SW¼ SE¼ section 5, township 76, range 19, and NW¼ NW¼ section 32, township 77, range 20. At the first location the deposit extends 8 to 10 feet below water and has been worked on an area of about 3 acres. At the second location is the plant of the Harvey Sand and Gravel Co. The deposit extends 10 feet or more below water. It is excavated by pump, which discharges direct to the revolving screens. Oversize material is usually wasted. The screens discharge to small bins, from which cars on a spur track to the Rock Island railway are loaded. The plant capacity is estimated at 50 to 75 tons per hour, about three fourths being sand.

MILLS COUNTY

Strata of the Douglas and Shawnee stages of the Missouri series underlie the whole county and include all of the exposed bedrock, except for two small outcroppings of Cretaceous sandstone south of Henderson and a few other scattered sandstone outcrops, which are doubtfully referred to the Cretaceous. Imperfectly exposed silts and fine sands beneath the glacial deposits in the Missouri River bluffs are younger than the Cretaceous and older than the earliest Pleistocene, but their exact age is doubtful and of no importance to the purposes of this report. Both Nebraskan and Kansan drifts are represented in the glacial deposits, the former appearing at only a few points in the lower slopes. Loess mantles the older formations except where it has been removed by recent vigorous erosion. The loess is important to this report, not because it offers any material of value for road or concrete work, but because it so completely conceals the older deposits, which might otherwise expose material supplies of value. The thickness of the glacial deposits ranges from 0 to about 75 feet in the west part of the county and from 0 to about 200 feet in the east part. The loess ranges in thickness up to 100 feet or more in the west part and up to about 25 feet in the east part. Alluvial deposits are extensive in the valleys of Missouri and West Nishnabotna Rivers and appear to lesser extent on the smaller streams. The upper part of the alluvium consists mainly of a more or less modified loess, while at greater depths are

IOWA GEOLOGICAL SURVEY. PLATE XXVI



extensive deposits of fine or coarse sand. In the northwest part of the county alluvial deposits in the Missouri River valley reach a thickness of about 100 feet.

Limestone

Rock exposures are numerous in the high bluffs east of the Missouri River valley throughout most of Lyons Township. The following general section, typical for this territory, has been worked out in E½ section 16:

	Feet	Inches
34. Limestone, dark gray, hard, fossiliferous	2	2
33. Shale, drab, with a thin seam of dark limestone		6
32. Limestone, dark gray, hard		7
31. Shale, drab above, dark gray below	3	
30. Limestone, dark gray, hard, fossiliferous		4
29. Shale, drab	4	3
28. Limestone, yellow, soft, earthy	1	
27. Limestone, gray, weathers toward brown, hard, fossiliferous; one bed, prominent in natural exposures	3	2
26. Shale, gray, with two 3-inch seams of limestone, 4 feet and 5½ feet from the top, respectively	6	10
25. Conglomerate of irregular masses of gray limestone in a matrix that is chalky above and shaly below	2	6
24. Shale, gray	1	
23. Limestone, hard, brown, with chert nodules. In two beds, with a 2-inch shale parting	2	
22. Shale, gray, sandy	1	3
21. Limestone, hard, brown		4
20. Shale, gray above and black below	1	6
19. Limestone, hard, gray, one bed	1	3
18. Shale, blue to black	1	2
17. Limestone, light gray, hard, somewhat unevenly bedded. With scattered nodules of dark colored chert in the upper part	5	6
16. Limestone, brown, shaly, hard when first exposed, but breaking down under the weather	3	8
15. Shale, drab		10
14. Limestone, as above		10
13. Shale, drab	2	
12. Limestone, hard, gray, fossiliferous, but shaly and probably unsound		11
11. Shale, gray above and black below	2	2
10. Limestone, gray, hard, fossiliferous, shaly and possibly unsound	1	10
9. Shale, gray above, with a dark layer near the bottom. The lower part sandy	7	2
8. Sandstone, yellow to buff, calcareous, differing in induration	5	8
7. Not well exposed, but apparently gray and black shale	12	6
6. Limestone, hard, gray	1	3
5. Shale, gray to drab	1	10
4. Limestone, as No. 6, but somewhat shaly in lower part	1	6
3. Shale, gray and drab	7	6
2. Limestone, hard, gray, sound, fossiliferous	1	10
1. Shale, gray; to bottom of exposure		6
Total	90	4

Numbers 14, 15, and 16 in some places coalesce into one bed similar to No. 16, and these beds, together with No. 17, constitute the main ledge of rather extensive former quarry workings in SE¼ section 16.

This section may readily be correlated with others at this locality previously published,[61] though it extends several feet both higher and lower than the earlier sections. Numbers 14, 15, 16, and 17 represent the Deer Creek (Forbes) limestone, and Nos. 27 and 28 the Topeka (Meadow) limestone. Both of these limestones are prominent in the bluffs, being traceable from SW¼ section 10, to SW¼ section 27. They dip persistently to the south and in section 34 are below the bottomland level. On account of the great height and steepness of these bluffs, only limited quantities of stone are available at any one point by stripping, either from the Deer Creek or from the Topeka. However, a long narrow area of either may be thus worked. A possible alternative in the case of the Deer Creek limestone is mining from the outcrop, which would be practicable at several points. The upper half of the Deer Creek (No. 17 of the section described) is of good quality for any road or concrete uses, but the lower half shows a distinct tendency toward unsoundness and should never be used where durability under severe conditions of exposure is necessary. The main bed of the Topeka (No. 27 of the section described) is of good quality for any road or concrete uses.

A series of ledges that apparently are referable to the Deer Creek limestone was at one time exposed and quarried west of the center of section 5, White Cloud Township. Quarrying has been discontinued as stripping became excessive, and only the top of the upper ledge is now visible. The following is condensed from Udden's [62] section at this point:

		Feet
6.	Shale, marly	½
5.	Limestone, grayish, cream-colored, in three or four strong ledges, crowded with fusulinids, with a layer of gray to black fossiliferous chert about 14 inches below the top	6
4.	Limestone, grayish blue, compact	⅔
3.	Concealed	2
2.	Limestone, yellow, fine-grained, fossiliferous, breaking into thin small irregular slabs 1 inch to 3 inches thick	2
1.	Limestone, quarried but now concealed	3 (Approx.)

The minimum overburden here is 18 feet. Mining is a possibility, though the ledge is rather thin for that purpose. A possible part of this section of beds appears in the Silver Creek drainage ditch in SE¼ section 31, Silver Creek Township, only two feet of stone being visible above water. What may be the same zone is reported to be shown in a

61 E.g., Tilton, J. L., The Missouri Series of the Pennsylvanian System in Southwestern Iowa: Iowa Geological Survey, Vol. XXIX, p. 253, 1919-20.
62 Udden, J. A., Geology of Mills and Fremont Counties: Iowa Geological Survey, Vol. XIII, p. 157, 1902.

very limited exposure near north quarter-corner section 36, Rawles Township. Here also no stone is available unless under very heavy overburden.

An exposure in the bed and north bank of Keg Creek near the southeast corner of section 22, Glenwood Township, shows some seven feet of gray limestone crowded with fusulinids and inclosing a few nodules of fossiliferous chert. This bed is underlain by three feet of yellow shale and shaly limestone. A test on the limestone shows 4.46 percentage of wear and soundness satisfactory. Some quarrying has been done here, and only about 2,000 cubic yards is now available by stripping.

The following section has been dug out in NW¼ NW¼ section 29, Oak Township (T. 73, R. 43), only the two upper members being naturally exposed.

	Feet	Inches
10. Limestone, soft, yellow, weathered	1	
9. Limestone, gray, with chert nodules at the top. Percentage of wear 3.8; soundness satisfactory	4	4
8. Shale, gray, soft		2
7. Limestone, dark gray to black, fossiliferous, hard, with a few chert nodules	1	
6. Shale		2
5. Limestone, dark gray. Percentage of wear 4.12; soundness questionable	3	5
4. Shale, dark gray, calcareous, very hard above, softer below	7	7
3. Limestone, light gray. Percentage of wear 4.84; soundness satisfactory	1	6
2. Shale, gray, soft	1	4
1. Limestone		

These beds are obtainable here in an area of about two acres under a moderate thickness of overburden.

On account of lack of intervening outcrops, it is impossible to make a positive correlation of the limestones in the two locations last mentioned with the section in Lyons Township. Probably both lie beneath the Lyons Township succession of beds.

In this part of the state, where road materials are scarce, mining of the deeply buried limestones of the Missouri series from a vertical shaft may be given consideration. The log of the city well at Glenwood shows a 24-foot limestone ledge at a depth of 203 feet, a 25-foot ledge at 289 feet, a 20-foot ledge at 550 feet, a 43-foot ledge at 595 feet, and a 27-foot ledge at 764 feet. This well was drilled in a rather high upland. Should further testing show that one or more of these ledges is of good quality, it might prove worth while to develop them by mining from a vertical shaft.

Sandstone

At two points near Henderson (S½ NE¼ sec. 22, and near SW corner sec. 14, Anderson Twp.), the Cretaceous strata may be seen as a 5-foot bed of fairly hard sandstone underlain by clay and sandy clay. The sandstone is not sufficiently indurated to be of value for road surfacing or coarse aggregate in concrete when crushed, and it is too fine of grain to be usable as fine aggregate. Very limited exposures of similar sandstone are reported as occurring at various other points in the county. No conglomerate beds similar to those in Montgomery County have been found.

Sand and Gravel

On account of the thickness of the overlying loess, exposures of the glacial till are relatively few, and it is only to be expected that sand and gravel of this origin should assume but little importance in this county. Small quantities have been taken from the till at a number of points, principally along the Missouri River bluffs, but in every case nearly all of the available material has already been removed. About thirty locations have been prospected in detail, and the largest quantity available at any one point is 1,400 cubic yards, in SE¼ SW¼ section 30, Silver Creek Township.

Some of these sands and gravels are cemented into a rather soft sandstone or conglomerate by calcium carbonate precipitated from percolating ground waters. Elsewhere the proportion of calcareous matrix is so much larger that pebbles or sand grains are almost excluded, and the deposits may be characterized as calcareous tufa. Some such deposits east of center section 10, Lyons Township, are known to be as much as 15 feet thick and some in SE¼ NE¼ section 34, Lyons Township, are 20 feet thick. This material is easily available, but on account of its light and friable nature it has little value for any road or concrete purposes.

As has been mentioned previously, the upper alluvium in all the valleys consists principally of modified loess clay. In most cases this extends down about to the level of the stream bed, where it is underlain by sand. On Nishnabotna River most of this sand is rather fine, even for fine aggregate in concrete. Ordinarily it is 10 to 30 feet thick and is underlain either by glacial clay or by bedrock. On Missouri River the upper sand is very fine, but a coarse sand with some small gravel lies 10 to 40 feet down (below the bottomland ground level) and usually extends to bedrock. The depth of bedrock below the surface in the Missouri bottoms ranges from about 100 feet at the north county line to about 75 feet at the south county line. It is thus seen that an immense body of this coarse sand is present and available, though with rather heavy overburden.

Since the sand in the Missouri River bottomlands in Mills County has probably originated from Platte River more than from the Missouri, an investigation has been made of well records in the territory in Mills County opposite and just below the mouth of the Platte. This territory includes Platteville Township, the southwest part of Glenwood Township, and the northwest part of Lyons Township. The accom-

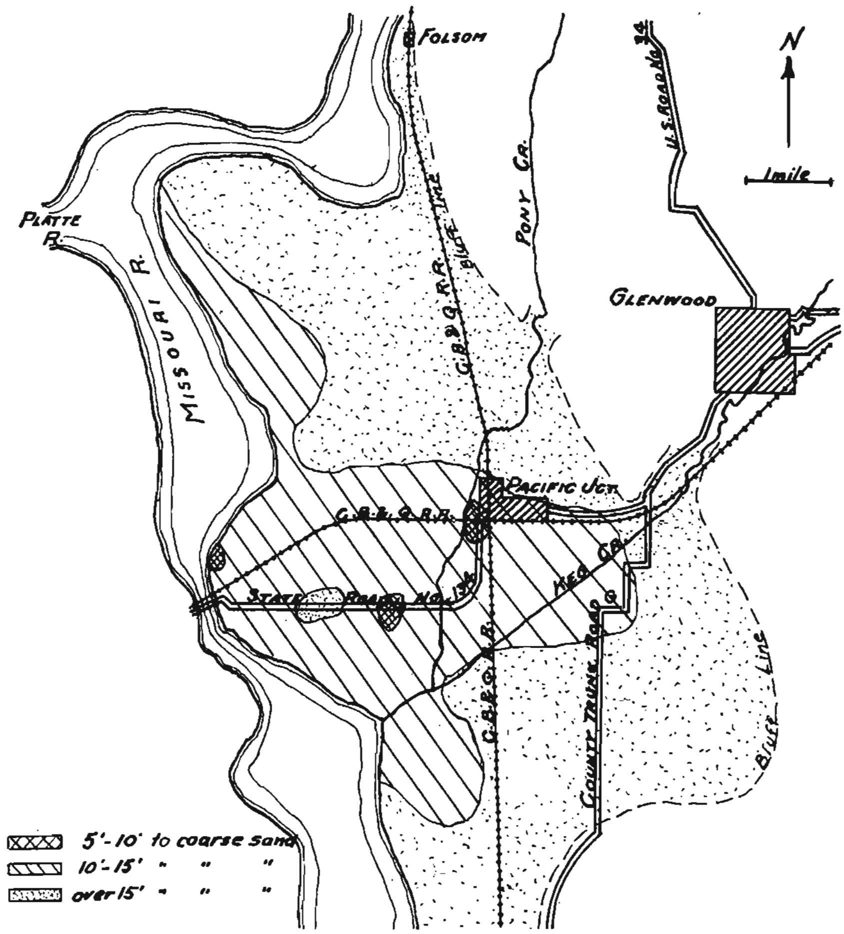


FIG. 9. — Map of the western part of Mills County showing the depth to coarse sand in Missouri bottomlands.

panying map of this area (Figure 9) shows, by appropriate symbols, the depths below the surface to this coarse sand.

In section 25 and E½ section 26, Platteville Township, and SW¼ section 22, Glenwood Township, a number of deep borings have been made to determine the depth and quality of the sand. These holes show 7 to 36 feet of overburden (in only 3 holes out of 34 was this more than 20 feet), consisting of clay and silt in the upper part and fine sand below. Beneath this the sand extends to bedrock, which is 95 to 100 feet deep, or to the bottom of the hole where this does not reach to bedrock. Most of the sand is fairly coarse, with 2 to 10 percent retained on a No. 4 screen, but with it are veins of medium fine or fine sand. The presence of thin streaks and scattered pebbles of black lignite in amounts ranging up to 15 percent is an objection to the use of the material as aggregate for portland cement concrete; however, this lignite is light in weight, and careful washing, with equipment now available and in common use, should be adequate to remove it. None of the sand is coarse enough to be of value as surfacing material except by screening out a large part of the finer sizes.

MONROE COUNTY

The upper Mississippian limestones underlie the whole county and appear at many places in the northeast part of Pleasant Township. In all except this small area, beds of the Des Moines series form the country rock. A mantle of glacial materials on the bedrock represents both the Nebraskan and the Kansan ice invasions, though the deposits of the former are not exposed so that they can be recognized with certainty, their presence being inferred from well records and from conditions in adjoining counties.

Post-Kansan loess veneers the uplands in various thicknesses up to about 20 feet, but in the rougher areas near the larger streams it has been largely removed by recent erosion. Alluvial deposits are not very extensive and consist almost entirely of silt and fine sand, except in the extreme northeast corner of the county, in the Des Moines River valley, where large deposits of sand or fine gravel are present. The total thickness of unconsolidated deposits in few places exceeds 100 feet.

Limestone

The following section from Beyer and Young [63] is typical of the

[63] Beyer, S. W., and Young, L. E., Geology of Monroe County: Iowa Geological Survey, Vol. XIII, p. 364, 1902.

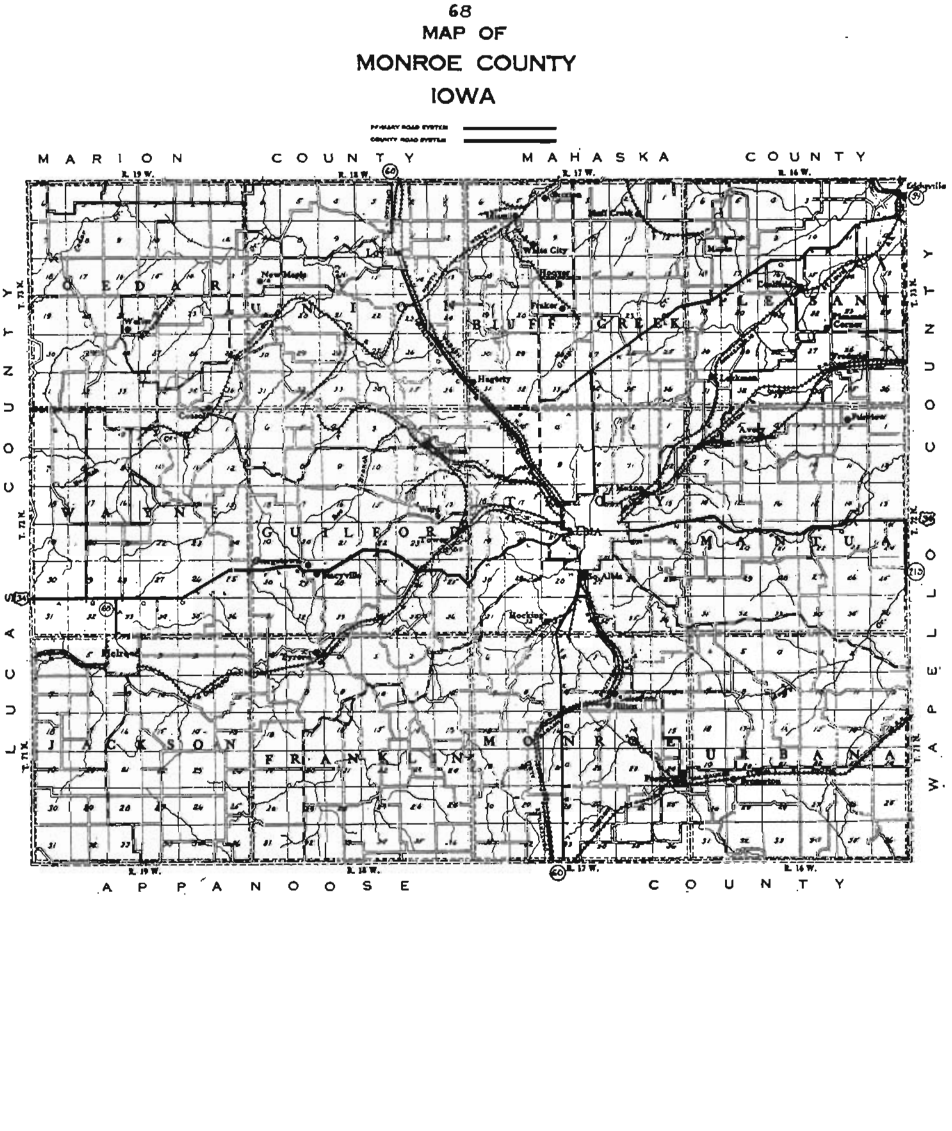
Mississippian rocks exposed in the northeast part of Pleasant Township:

		FEET
7.	Drift and surface wash	5
6.	Shale, arenaceous, with calcareous cement	7
5.	Limestone, compact, brittle, containing pyrite balls	3
4.	Limestone, oölitic, evenly bedded, with broken shell fragments	3½
3.	Marl, fossiliferous	½
2.	Limestone, compact, lithographic, softer below	4
1.	Sandstone, in heavy beds, some cross-bedded. Exposed	25

This section is very similar to that in the south part of Mahaska County and, except for Nos. 1 and 7, may be referred to the Ste. Genevieve formation. Number 1 probably represents the Upper St. Louis.

The limestone horizon described forms an interrupted low escarpment in the bluffs along the west side of the Des Moines River valley

IOWA GEOLOGICAL SURVEY. PLATE XXVII



in section 1 and appears at intervals along Gray and Miller Creeks in sections 2 and 12, all of Pleasant Township. In general, only small quantities are available at any one point with moderate stripping. Physical tests on the stone have not been made but, judging from its nature in adjoining parts of Mahaska and Wapello Counties, it is suitable for surfacing work or for concrete aggregate.

The Pennsylvanian strata of Monroe County show a few beds of limestone, but, so far as known, none of these is more than two feet thick.

Sandstone

The Mississippian sandstone in the northeast part of Pleasant Township, which was mentioned in the foregoing section, is too soft to be of value for crushing and too fine-grained to be broken down and have value as sand. The same may be said of the Pennsylvanian sandstones, of which a number are known to be present, in thicknesses ranging up to about 30 feet. Channel deposits of sandstone or conglomerate, of Pleasanton age, are reported as being present in section 3, Monroe Township, but quarry workings there are now long abandoned, and natural exposures are overgrown and covered with sod.

Mine Shale

For many years Monroe County has been the seat of an extensive coal-mining industry, and the waste heaps of these mines, many of them long abandoned, form an important source of road surfacing materials. The following list gives the locations of the more important mines and, where known, the approximate quantities of burnt shale available:

Pleasant Township:	
North of center sec. 7	Quantity 6,000 cu. yd. in 1932
NW¼ SE¼ sec. 16	Quantity 5,000 cu. yd. in 1932
NW¼ SW¼ sec. 33	Mine operating and pile being built
Bluff Creek Township:	
NE¼ NW¼ sec. 2	Quantity 30,000 cu. yd. in 1932
NW¼ SW¼ sec. 5	Quantity 5,000 cu. yd. in 1932
Near center SE¼ sec. 6	Quantity 10,000 cu. yd. in 1932
¼ Mi. N of center sec. 8	Quantity 50,000 cu. yd. in 1932
NW¼ NW¼ sec. 12	Quantity 4,000 cu. yd. in 1932
SE¼ NW¼ sec. 16	Quantity 10,000 cu. yd. in 1932
West of NE corner sec. 36	Quantity 15,000 cu. yd. in 1932

Union Township:	
SE¼ NE¼ sec. 23	Quantity 16,000 cu. yd. in 1926
SW¼ NW¼ sec. 23	Quantity 21,000 cu. yd. in 1926
Wayne Township:	
NE¼ SW¼ sec. 3	Quantity 82,000 cu. yd. in 1926
Guilford Township:	
Center sec. 2	
SE¼ SE¼ sec. 3	
NE¼ SW¼ sec. 11	
Troy Township:	
NW¼ SW¼ sec. 33	Quantity 20,000 cu. yd. in 1932
Mantua Township:	
NE¼ SE¼ sec. 3	
SW¼ NW¼ sec. 11.	Quantity 7,000 cu. yd. in 1926
NW¼ NW¼ sec. 13	Material very poorly burned
West of center sec. 16	
Center NE¼ sec. 23	Quantity 25,000 cu. yd. in 1931
NW¼ SW¼ sec. 23	
Monroe Township:	
NE¼ NE¼ sec. 4	Quantity 25,000 cu. yd. in 1932
NW¼ NE¼ sec. 5	Quantity 100,000 cu. yd. in 1932
NW¼ NW¼ sec. 9	Quantity 80,000 cu. yd. in 1932
SW¼ SW¼ sec. 10	Quantity 32,000 cu. yd. in 1926
SE¼ SW¼ sec. 24	

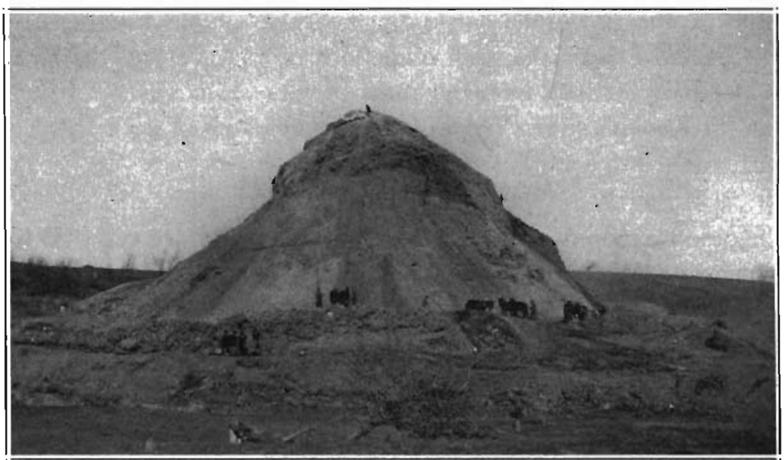


FIG. 10. — Coal mine dump near Albia.

Figure 10 shows one of the larger mine dumps near Albia.

It must be kept in mind that the material in these waste heaps differs in quality depending upon the degree of burning, and that not all of it is satisfactory for road surfacing work.

Sand and Gravel

The glacial gravels are present in Monroe as well as in other counties of southern Iowa, but no point has been found where they are in sufficient quantity to be worth developing. Extensive prospecting has been done in sections 22 and 23 of Wayne Township, where there are noticeable surface showings of gravel, but it appears that the material there is of rather poor quality and unobtainable except with very heavy stripping. Terrace-like areas in the valleys of English and Sand Creeks in Wayne Township and of Cedar Creek in Union Township are evidently the terminations of low broad ridges of glacial drift, in some cases upheld by beds of sandstone or shale. Certain dunelike formations near Buxton show sand that is too fine and clayey to be of value, except possibly as filler in an asphaltic aggregate.

Except along Des Moines River, alluvium in Monroe County is scarce and consists principally of silt or fine sand. Even along the short streams of high gradient, small deposits of gravel and broken rock are less numerous and less extensive than in many of the southern Iowa counties. In section 1, Pleasant Township, the Des Moines River bottomlands are underlain by sand and fine gravel, which, however, on account of the proximity of more easily available supplies in the nearby parts of Mahaska and Wapello Counties, has not been developed. A survey of bars in the channel of Des Moines River from Des Moines to Keokuk shows none of the larger or more permanent ones.

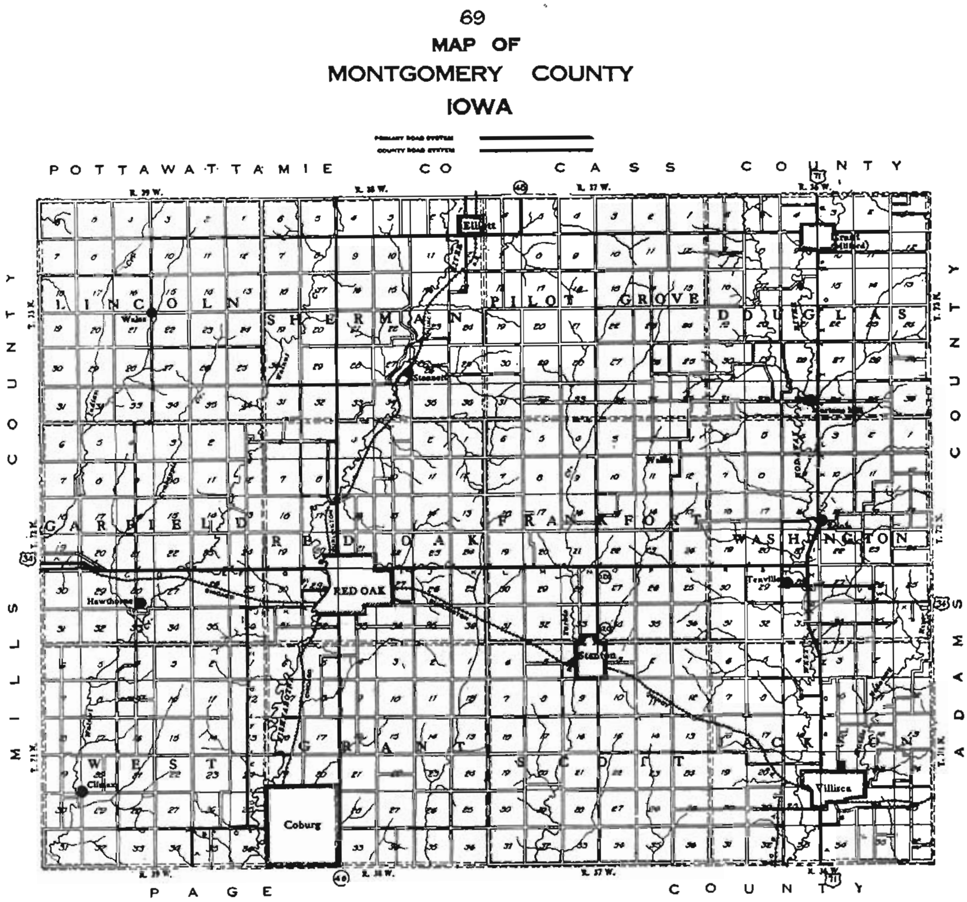
MONTGOMERY COUNTY

The oldest exposed rocks of Montgomery county are referred to the Shawnee and Wabaunsee stages of the Missouri series and consist principally of shale, with comparatively thin limestones and one or two thin coal seams. Outcrops are scarce and very limited in extent except near Stennett. In the higher uplands the Missouri series beds are overlain by the Dakota sandstone and conglomerate of Cretaceous age, which is locally as much as 100 feet thick and is commonly and extensively exposed near Red Oak and Coburg.

Two glacial drift sheets of Pleistocene age, the Nebraskan and the Kansan, are found upon the consolidated rocks. Extensive areas along Walnut Creek, East Nishnabotna River, West and Middle Tarkio

Creeks, and West Nodaway River lie below the level of Kay's Aftonian gumbotil plain, and the surface drift in them is therefore mapped by him [64] as Nebraskan. In the higher interstream areas the surface drift is Kansan. Post-Kansan loess covers the drift deposits with a mantle ranging in thickness from about 35 feet at the west to 10 feet at the east, but on the steeper slopes it has been largely removed by recent erosion. Alluvial deposits, consisting of silt, sand, or gravel, occupy rather large areas in the wider valleys. Most of the alluvium is of late Pleistocene or Recent age. The total thickness of all the unconsolidated deposits differs widely, ranging up to about 200 feet.

IOWA GEOLOGICAL SURVEY. PLATE XXVIII



64 Kay, G. F., and Apfel, Earl T., The Pre-Illinoian Pleistocene Geology of Iowa: Iowa Geological Survey, Vol. XXXIV, Plate II following p. 14, 1928.

Limestone

The rock formation that is widely exposed in the Stennett locality shows unusual uniformity of thickness and character and thus may be adequately described by the following general section:

		Feet
17.	Limestone, yellow, rather soft and earthy	1
16.	Limestone, light gray, fine-grained, hard, sound, evenly-bedded, fossiliferous	3
15.	Limestone, very dark gray, fine-grained, irregularly bedded, fossiliferous, hard and sound below, grading above to a calcareous shale	2½
14.	Shale, gray to drab, with a 4-inch limestone bed 2 feet from the top	8
13.	Limestone, gray, very hard, sound, one ledge, very resistant to weathering, and prominent in natural exposures	1½
12.	Shale, the upper two thirds yellowish gray, the lower one third dark gray to black	4
11.	Limestone, gray, weathers yellowish, has the appearance of one massive bed when fresh, but upon weathering shows thin zones of shaly unsound limestone or calcareous shale which divide the member into several ledges from ½ foot to 2 feet thick. These unsound shaly zones are of various thicknesses up to about six inches, and are nearly always present at the top and bottom of the member, where they mark a transition into the adjacent shale beds. A layer of disconnected nodules of dark-colored fossiliferous chert two to four inches thick is characteristic of a zone about two feet below the top. The whole member is strongly fossiliferous, fusulinids being conspicuous. As a rule the whole member is suitable for road surfacing stone, but the unsound zones make its use for aggregate difficult	6–7½
10.	Shale, gray, darker below	¾
9.	Limestone, dark gray, hard, sound, fine-grained	½
8.	Shale parting, very thin	
7.	Limestone, yellowish gray to brownish gray, fusulinid-bearing, one massive bed when fresh, but on weathering shows numerous zones of shaly material that is unsound. These unsound zones constitute about half of the member but are usually absent from the upper 2 or 3 feet. A layer of disconnected nodules of dark gray chert near the top is characteristic, and scattered chert nodules appear lower down. This member is of questionable quality, even for road surfacing work, except in the upper part	6½–7
6.	Limestone, dark gray, hard, sound, with chert near the bottom	2–2½
5.	Shale parting, very thin	
4.	Limestone, dark gray, hard, sound	1–1¾
3.	Shale, brown, calcareous	¼
2.	Limestone, gray, rather soft, shaly, unsound	2
1.	Shale, hard, gray above, black below	3+

Numbers 11, 12, and 13 of this section are well exposed in and near the old quarries at Stennett. A more recently opened quarry in W½ SW¼ section 17, Red Oak Township, shows Nos. 7 to 11 inclusive. The lower members are not known to be naturally exposed anywhere in the county now but have been found in test pits below the floor of this quarry and in a quarry in N½ NW¼ section 3, Red Oak Township. Numbers 2 to 11 inclusive are referred to the Deer Creek limestone of the Shawnee stage.

This series of beds forms a prominent and almost continuous bench in the bluffs on the east side of the East Nishnabotna River valley through sections 23 and 26, Sherman Township, and in the bluffs on the west side of the valley through sections 22, 27, 34, and 33, Sherman Township. Numerous quarries have been worked here in the past, and a number of sections have been described by Lonsdale.[65] In general it may be said that overburden is rather heavy if any considerable quantity of stone is to be obtained. Smaller quantities are obtainable at various points in SE¼ section 22, or at other points in sections 23, 26, and 27.

Beds of the same horizon appear along the tributaries of East Nishnabotna River near Stennett, especially through the central part of section 26; SE¼ SE¼ section 21; SW¼ SW¼ section 22; and NW¼ section 27, all of Sherman Township. In these places they are low in the bluffs and in general are unavailable for quarrying. A bottomland area of about one acre north of the small creek near center SE¼ SE¼ section 21 appears to be underlain at a depth of a few feet by No. 11 of the general section. If such is the case, quarrying would be easy. Careful search beneath the bottomlands of these tributary creeks might reveal other small areas that are underlain by these limestones.

During the 1932 season, some 20,000 cubic yards of surfacing stone was taken from a quarry in N½ NW¼ section 3, Red Oak Township. Prospecting there shows that an area of about four acres is underlain by No. 13 and lower members of the general section with 2 to 15 feet of stripping.

Number 11 and lower members of the general section form an indistinct escarpment along the bluffs facing the East Nishnabotna River valley through NW¼ SW¼ section 17, Red Oak Township. During the 1932 season, some 10,000 cubic yards of surfacing stone was taken from here. Fairly large quantities are still available, though under rather heavy overburden.

In addition to the locations described there have been quarries or rock exposures in SW¼ SE¼ section 5, Red Oak Township; SE¼ NE¼ section 1, Garfield Township; and SW¼ SW¼ section 9, Red Oak Township; but at these points the strata are now entirely obscured.

A few scattered exposures and small abandoned quarries are located in the southern part of the county, as for instance in NE¼ section 30, West Township; NE¼ NW¼ section 31, and SE¼ SW¼ section 34, Grant Township; at three points in section 20, Scott Township, and at one

65 Lonsdale, E. H., Geology of Montgomery County: Iowa Geological Survey, Vol. IV, pp. 383-453, 1894.

or two points near Villisca. At all of these places the ledges quarried were only a few feet thick, and they are now almost entirely obscured by overwash. It appears that nothing is now available, either by stripping or by mining.

Near and northeast of Grant, rock has been quarried in SW¼ NW¼ section 10, NW¼ SE¼ section 3, and NE¼ SW¼ section 3, all of Douglas Township. No quarrying has been done here in recent years, and the exposures are so obscured by slumping that the sequence of beds can not be seen. It appears that in every case the work was abandoned on account of excessive stripping, and no location in this vicinity where rock is available is now known. The following is condensed from Beyer's [66] section at the Berry quarry near the south edge of section 3:

	Feet
6. Soil, loess, oxidized drift, sand, and gravel	5
5. Shale, plastic, gray to yellow	1½
4. Limestone, shaly, fossiliferous, laminated	1
3. Shale, soft, yellow	1–2
2. Limestone, weathered, nodular, yellow, marly, with flint nodules	1⅔
1. Limestone, one ledge, yellow to gray, fossiliferous, with flint nodules	3½

Beds 1 to 4 inclusive may be the equivalents of No. 11 of the Stennett section, but this correlation can not be considered positive.

In a county such as Montgomery, where limestones of good quality and thickness are not present at the surface, the plan of mining deeply buried ledges by means of a vertical shaft becomes worthy of consideration. Consequently, it may be of interest to note that the record of a prospect hole at Red Oak shows a 13-foot limestone ledge at a depth of 291 feet, a 23-foot ledge at 355 feet, and a 14-foot ledge at 525 feet. Details of the character of the stone are not known, and, if it were planned to develop these ledges, core drilling should be done in order to determine their nature.

Sandstone and Conglomerate

The major part of the Dakota formation in this county is sandstone containing a few small lenses of clay and locally capped by a conglomerate of various thicknesses. Most of the sandstone is so incoherent that it can be excavated by pick and shovel. It is thus a source of sand rather than of crushed rock. The sand is fine-grained and of no value for road or concrete work, except possibly as the finer part of an asphaltic aggregate. It is well exposed and easily available in

[66] Beyer, S. W., and Williams, I. A., Geology of Quarry Products of Iowa: Iowa Geological Survey, Vol. XVII, p. 512, 1906.

large quantity at numerous points near Red Oak and thence southward along both sides of the valley of East Nishnabotna River to the Page County line. At Red Oak its total thickness is about 100 feet, but elsewhere it is thinner. It appears also at a few points south of Elliott and near Middle Nodaway River in the central part of Washington Township and the southwestern part of Douglas Township.

The sandstone contains a few pebble bands, but as a rule the coarser material lies at the top of the deposit, forming a cap which has a thickness ranging from 1 foot up to about 30 feet. This capping of coarser material has been observed at numerous points near and south of Red Oak, its greatest size being in sections 17 and 20, Grant Township. In SW¼ section 17 it makes an almost continuous exposure in the points of the ridges leading down north and northwest to the valley. The conglomerate ranges in thickness from 5 to 30 feet and is underlain by sandstone at some points and by shale at others. Some 25,000 cubic yards was removed in 1932 (Figure 11) and prospecting has shown

FIG. 11. — Cretaceous gravel in the State pit south of Red Oak.

about 175,000 cubic yards still available under moderate stripping. The material is composed of well-rounded pebbles of quartz, flint, and chert, most of them one-half inch or less in diameter, surrounded by a ferruginous clayey sand. In certain veinlike streaks, which may extend in any direction, the proportion of iron oxide in the matrix is larger so that it is firm and rocklike in character, even to the extent of breaking through rather than around the pebbles when fractured. Not many of these streaks are more than a few inches thick. On account of the rather high percentage of clay, the material is hardly satisfactory for concrete aggregate, though it may be used in the bituminous mixtures. It is an excellent surfacing material.

The deposit in section 17 extends northward through the NW¼ section 17, but it is there only some four feet thick, is underlain by sandstone with a few pebbly streaks, and is thus available in only very small quantity. For a short distance to the southeast its thickness is maintained (25 feet thickness and perhaps 50,000 cubic yards available in NW¼ SE¼ sec. 20, Grant Twp.), but to the southwest, in SE¼ SE¼ section 18, and NE¼ NE¼ section 19, it is only 10 feet or less. Farther south and north it has been observed at various points in the bluffs on both sides of the East Nishnabotna River valley but nowhere with a thickness of more than six feet. A small amount is available at Coburg (SE¼ SW¼ section 30, Grant Twp.). At other points in the county where the Dakota appears, the capping of coarse material is very thin or not present at all.

Sand and Gravel

As might be expected in an area where the bedrock contains a large proportion of sandstone, the glacial gravels are here somewhat more important than in most of the counties of southern Iowa. Several deposits have been found, two of which are of rather large size. Some 14,000 cubic yards of gravel was once available in SE¼ SE¼ section 33, Washington Township. This was too clayey for concrete work but was of satisfactory quality for road surfacing. During the 1932 season a large part of it was removed. Some 9,000 cubic yards of similar material is present in SE¼ NW¼ section 16, Douglas Township. Of twenty other prospects of the same kind that have been examined, none was found to contain more than 100 cubic yards of available gravel. Deposits of fine sand on the hills east of Middle Nodaway River in Douglas Township may be of glacial origin or may be blown up by the prevailing westerly winds from the valley flats in much the same manner as loess is deposited.

A few of the short streams of high gradient in the area near Stennett show along their courses several small bars of broken rock, gravel, and sand. Similar streams in other parts of the county carry limited quantities of sand or gravel. Many of these deposits, though small, are large enough to be of value for local improvement projects.

The lower alluvium of Nishnabotna and Nodaway Rivers at numerous places in southwestern Iowa consists of sand and fine gravel which begins usually at or just below the stream bed. The valley of the Nishnabotna in Montgomery County shows a rather narrow and thin belt of alluvium because of the presence of bedrock in its sides and bottom from the central part of Sherman Township southward. Beds of sand or gravel are not so numerous or extensive along this part as in the wider valley near and above Elliott. For example, a bridge sounding near Red Oak, west of northeast corner section 29, Red Oak Township, shows 11 feet of sand and gravel beginning 16 feet below the surface, while soundings near Elliott, between sections 2 and 11, Sherman Township, show 16 feet of sand and gravel, overlain by 6 feet of fine sand and that by 8 to 12 feet of silt and clay. Well data at other points in the valley indicate that these sounding records are typical for their respective localities. Small quantities of sand for local consumption are pumped from the river channel about two miles north of Coburg, but the thickness of the deposit thus utilized is unknown. Information as to the Nodaway River valley is more meager, but it is reported that, in straightening the channel between Grant and Villisca, sand and gravel were penetrated at several points. This valley is wide and well-developed, and conditions in it are believed to be similar to those in the Nishnabotna near Elliott.

PAGE COUNTY

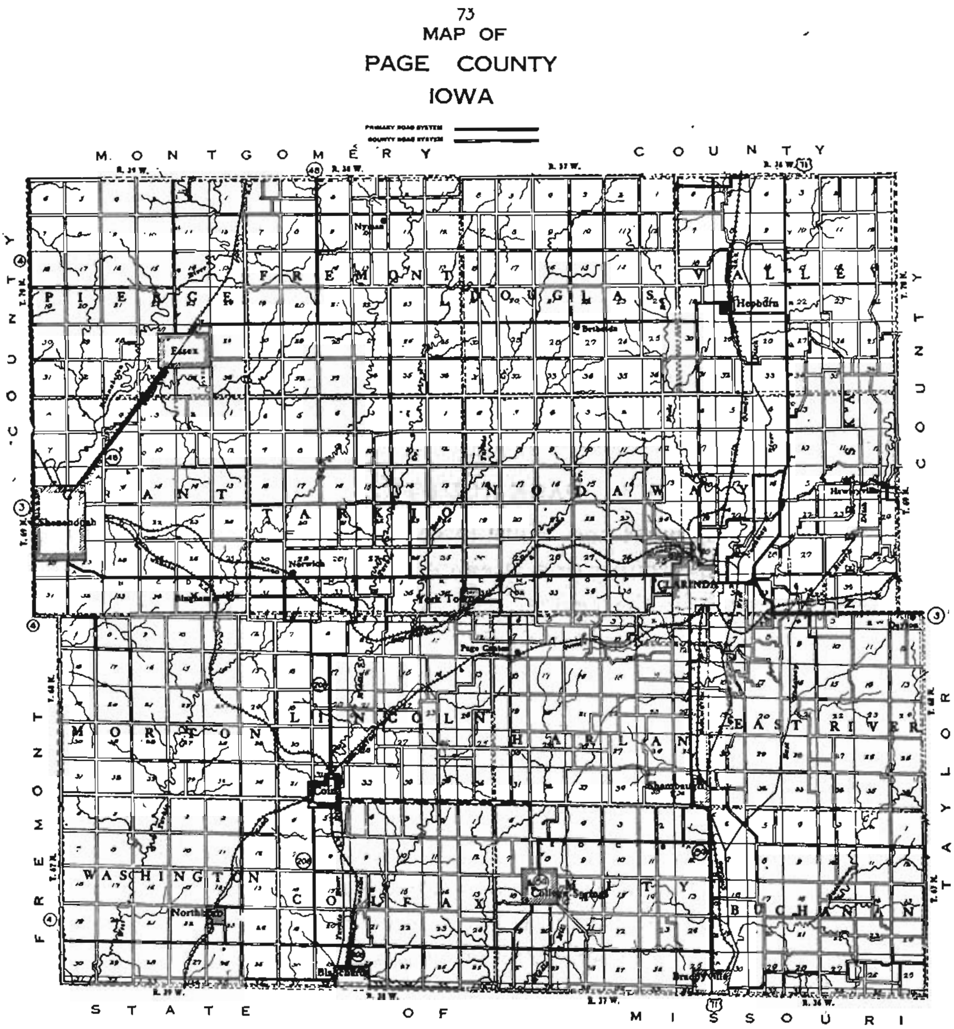
Rock of the Shawnee and Wabaunsee stages of the Missouri series underlies the whole county and is exposed at intervals near and south of Clarinda and, in the central part, along the branches of Tarkio River. Data regarding wells in the higher uplands indicate the presence of outliers of Cretaceous (Dakota) sandstone above the Missouri series beds, but the newer formation is known to be exposed at only one point and even there very obscurely. Both Nebraskan and Kansan drift sheets are present and widely exposed, the former in the lower slopes leading down to the deeper valleys and the latter in the higher uplands. There is evidence that the combined thickness of the two drift sheets is at many places 200 feet or more. Post-Kansan loess mantles the drift in thicknesses up to 20 feet, but where erosion is active this loess has been largely cut away. Alluvial deposits are widespread along Nishnabotna and Nodaway Rivers and to lesser extent on the Tarkio.

Limestone

A persistent series of limestones and shales, known as the Tarkio limestone, is commonly exposed and has been extensively quarried in Lincoln, Tarkio, Fremont, and southeastern Pierce Townships. The limestones are so thin and separated by such thicknesses of shale as to be unavailable except in very small quantity at any one point. The following general section is adapted from Smith:[67]

	Feet
9. Limestone, crowded with fusulinids	1
8. Shale	3-5

IOWA GEOLOGICAL SURVEY. PLATE XXIX



67 Smith, Geo. L., Carboniferous Section of Southwestern Iowa: Iowa Geological Survey, Vol. XIX, pp. 634-635, 1908.

7. Limestone, soft, earthy	$\frac{2}{3}$
6. Shale parting	$\frac{1}{2}$
5. Limestone, dark bluish gray, hard, sound, fine-grained	$1\frac{1}{3}$
4. Shale	7–12
3. Limestone, shaly, soft	$1\frac{1}{2}$
2. Shale	$3\frac{1}{2}$
1. Limestone, as No. 3	2

It will be noted that the maximum uninterrupted thickness of limestone is two feet, hardly sufficient to justify opening a quarry and installing a crushing plant. The best exposures are in section 36, Pierce Township, sections 24, 25, and 36, Fremont Township, and sections 10, 15, 22, and 27, Tarkio Township.

In the valleys of the two branches of Nodaway River are a number of exposures of limestone beds, which belong to the formation next below the horizon of the Nodaway coal. They are composed of some 45 feet of alternating limestones and shales, about one fourth of the thickness being limestone. The heaviest single limestone bed of this formation was found in a diamond drill hole at Clarinda to have a thickness of six feet. This bed is reported to occur at a depth of about eight feet over a considerable area of bottomland east of the center of section 18, East River Township, but it is not exposed either at that point or at any other known point within the county. Outcroppings of thinner ledges are found at several other localities, notably near Braddyville, southeast of Clarinda, and near Hawleyville. With the possible exception of the ledge in section 18, East River Township, none of the deposits shows a sufficient uninterrupted thickness of limestone to justify its development for road or concrete work.

The unusually good rail transportation facilities at Clarinda, combined with the lack of nearby surface exposures of limestones of good quality and thickness, make the possibility of mining from a vertical shaft worthy of consideration. The record of a core drilling in the northeast part of the town shows 18 feet of limestone beginning 97 feet from the surface, 22 feet beginning at 219 feet, 16 feet beginning at 413 feet, 19 feet beginning at 505 feet, 22 feet beginning at 578 feet, and 31 feet beginning at 610 feet. Other core drillings at College Springs and Coin show limestone ledges 13 to 20 feet thick, at depths of 250 to 400 feet. Inasmuch as the cores from these holes are now unavailable, the quality of the stone is unknown, but the fact of its presence is of interest to the purpose of this report.

Mine Shale

The Nodaway coal has been and is now being mined at numerous points near Clarinda. However, nearly all of the mining operations are on a very small scale, and at many of them the waste heaps are not burned, so that little or no road surfacing material is obtainable from them.

Sand and Gravel

For a county traversed by valleys as deep as those of Page, this county has relatively few steep slopes, such as those that commonly show exposures of glacial gravels. The reason for this fact is seen in the pronounced maturity of the drainage system, the slopes being worn down until they are now comparatively gentle. The covering of loess, thicker to the west, also conceals many exposures which would be plainly visible in a county farther to the east.

The Highway Commission has made an examination of all gravel and sand deposits of this type within the county that could be found by advertising in local weekly newspapers, inquiry from residents, or field observation in the most likely regions. In all, some forty-five prospects were investigated and the largest deposit found, in NW¼ SE¼ section 13, Amity Township, has 1,400 cubic yards. A few others, containing from 150 to 550 cubic yards each also were located. It is not believed that all the available deposits of glacial gravel have been examined, but, on the other hand, it is certain that all of those best known were seen, and the probability of finding others is therefore small.

As is the case in the northeast part of Montgomery County, deposits of fine sand are present on the hills east of the Nodaway River valley near Clarinda. These are of glacial or possibly of eolian origin. This sand is easily available in large quantity but is too fine for any road or concrete use except possibly as the finer portion of asphaltic aggregate.

Alluvial deposits at the surface in Page County consist almost entirely of silt and fine sand. Beds of coarse sand and fine gravel, some of them of considerable thickness, lie in the valleys of the larger streams at depths of 15 to 40 feet. The best known example is at the location of the new Shenandoah city well in NW¼ NW¼ section 19, Grant Township, where 20 to 22 feet of sand and gravel is found under 17 to 19 feet of soil and clay. A small quantity of sand for local consumption is pumped from the river about one mile north of Shenandoah, the deposit being 12 feet or more in thickness. At

Essex the valley is narrower, alluvial deposits are shallower, and sand and gravel beds are much thinner. Along Nodaway River, conditions are believed to be very similar to those on the Nishnabotna.

POTTAWATTAMIE COUNTY

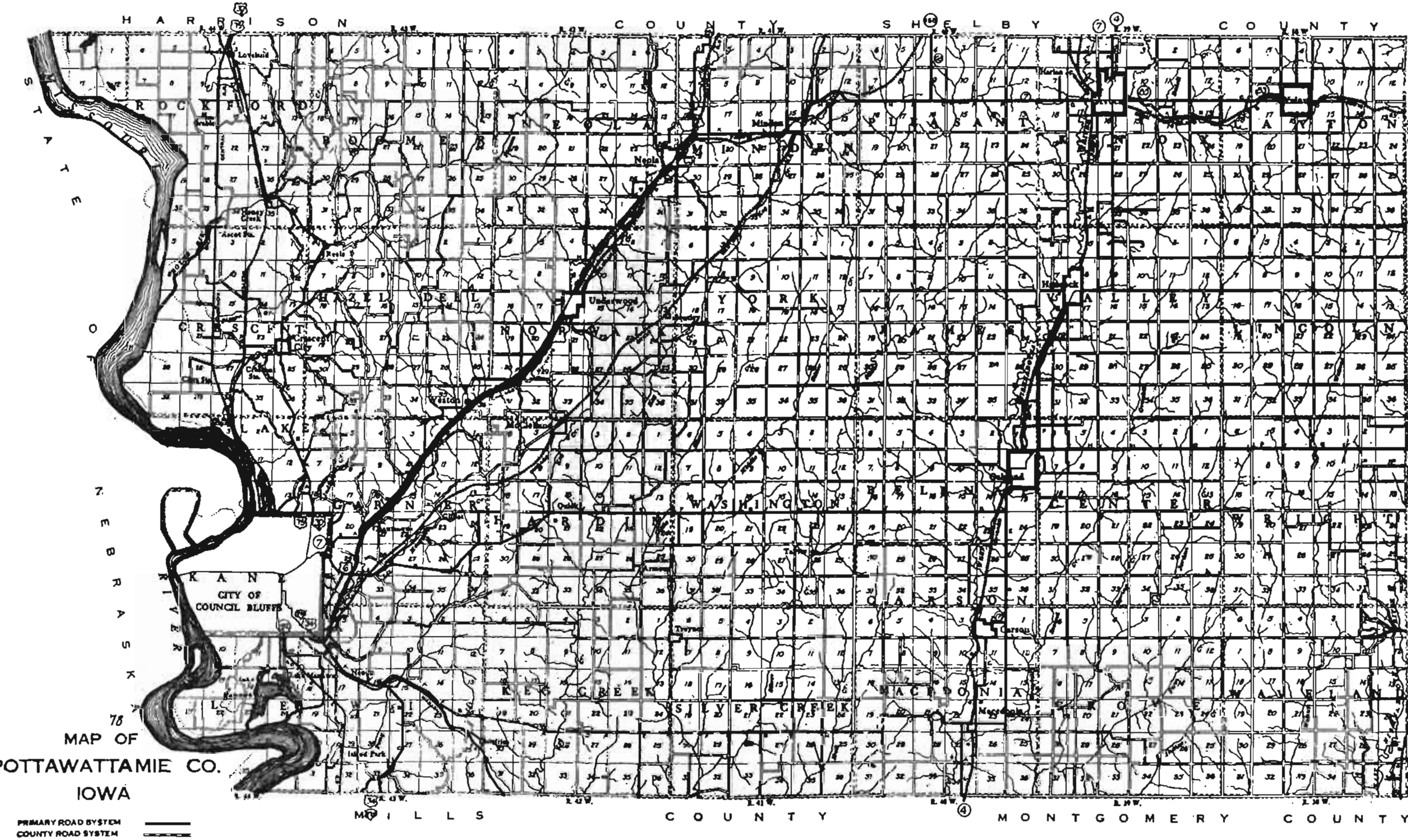
The oldest exposed bedrock in the county belongs to the Missouri series. Outcroppings near Macedonia and Carson apparently represent the Deer Creek limestone of the Shawnee stage; while a few near Crescent and Council Bluffs are tentatively assigned to the Lansing stage. Cretaceous (Dakota) sandstone appears at several points along East Nishnabotna River in the extreme east part of the county and also at a few scattered localities farther north and west. Well records indicate that it is generally present above the Missouri series beds in the high upland areas east of West Nishnabotna River, in various thicknesses up to 100 feet or more.

Both Nebraskan and Kansan drift sheets are represented in the county. All of the main valleys have cut below the level of the Aftonian gumbotil plain and the heavy loess covering on the higher uplands obscures nearly all the older materials. Loess is an important deposit, commonly reaching thicknesses of 100 feet or more in the first bluffs east of the Missouri River valley and about 40 feet in the eastern part of the county. Though it offers no material of value for road or concrete construction, it is important to the purpose of this report on account of its almost complete coverage of the older formations. Alluvium is extensive along the smaller streams and consists in its upper part of silt and fine sand with coarser materials below. The total thickness of unconsolidated deposits is at many places 300 feet or more.

Limestone

Recent prospecting and quarrying operations near Macedonia and Carson have revealed the following to be the succession of beds there:

	Feet
10. Limestone, much weathered, with a large proportion of residual chert, which has come either from this member or from others formerly present above it	1
9. Limestone, hard, bluish gray, fine-grained, with small veins or pockets of calcite, fossiliferous, irregularly bedded, grading below into a brown or yellowish hard calcareous shale	1½–2½
8. Limestone, bluish gray, hard, sound, fine-grained, one bed	½
7. Limestone, shaly, grading into a calcareous shale, drab, weathers yellowish	2–3½
6. Limestone, bluish gray, fine-grained, hard, sound, crystalline, sparingly fossiliferous, with numerous small nodular zones of dark blue limestone	1½
5. Shale, drab to gray, calcareous	3½–4



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MAP OF
POTTAWATTAMIE CO.
IOWA

4.	Limestone, gray, weathers light yellowish, medium-grained, in several beds, some even and regular, and some lenticular, separated by seams of drab shaly limestone or calcareous shale of various thicknesses up to 6 inches, and totaling 10 to 15 percent of the member. The whole member is fossiliferous, the shaly partings especially so. A band of nodules of dark colored fossiliferous chert about 5 feet below the top is persistent. The lower 2 feet is one strong hard ledge	12–13½
3.	Shale, dark gray	2–3
2.	Limestone, gray, hard, sound, one strong ledge	1
1.	Shale, gray to black	2+

The strong similarity of this section to that at Stennett, in Montgomery County, suggests the reference of these beds to the Deer Creek limestone. Numbers 5 to 9, and the upper part of 4 are the only ones usually found in the natural exposures.

Of the section just given, No. 4 is the only bed thick enough and of quality good enough to be worth quarrying in any but very small quantity. The whole bed may be used as road surfacing material, and a considerable part is suitable for aggregate. It is nowhere easily available by stripping but is known to be present under a few acres in NW¼ NW¼ section 23 and W½ SW¼ section 14, Macedonia Township, with 10 to 25 feet of overburden. The same beds appear at several other points near Macedonia and Carson but are nowhere else available by stripping, even as easily as in sections 23 and 14. Old quarries were worked in NW¼ section 27, and SW¼ section 22, Macedonia Township, and in SE¼ SE¼ section 3, and SE¼ NE¼ section 3, Carson Township, as well as in sections 23 and 14, Macedonia Township. At any of these points there is possibility of obtaining stone by mining from the outcrop, taking the lower part of Bed No. 3 and leaving the upper part as a roof. However, the rock thus available would be rather thin for most economical working and is also low in the valleys, where surface or ground waters might be expected to give trouble in a mine.

The following general section in the Missouri River bluffs near Crescent is condensed from one published by Udden:[68]

		Feet
5.	Limestone, yellowish gray, compact, regularly bedded, medium-grained	5
4.	Shale, yellow	2
3.	Limestone, yellowish gray, rather soft	2
2.	Shale, blue, fossiliferous	5
1.	Limestone, one ledge, rather fine-grained, compact, fossiliferous	3

Of these beds only No. 5 is now exposed, and even it is much weathered. There is one old quarry here, but at no point is any quantity of rock available by stripping. On account of the thinness of the ledges

[68] Udden, J. A., Geology of Pottawattamie County: Iowa Geological Survey, Vol. XI, pp. 227-228, 1900.

mining is likewise impracticable. A bed said to be the equivalent of No. 5 of this section was at one time quarried along the bank of Mosquito Creek near the west quarter-corner of section 21, Garner Township, but there is now no exposure at that point.

Well drillings at Council Bluffs have shown the presence of a 20-foot ledge of hard limestone about 150 feet below the lowlands. At a depth of 100 feet is another ledge of about the same thickness but showing a large proportion of shaly and unsound material. In this county, where local supplies of sand, gravel, or rock are scarce and shipped-in materials are expensive, the possibility of mining one of these ledges by means of a vertical shaft may be worth considering.

Sandstone

The Cretaceous sandstones and clays appear at many places in the bluffs bordering the East Nishnabotna River valley in the southeast part of Wright Township. Small outcroppings are known also in section 1, Wright Township, and section 28, Grove Township. The sandstone is so incoherent as to be readily broken down by pick and shovel or by the natural weathering agencies and therefore has no value for crushing. The sand of which it is composed is too fine-grained to be usable for road or concrete work except possibly as the finer portion of an asphaltic aggregate. The conglomerate phase found in Montgomery County is not known to be present here.

Sand and Gravel

As previously mentioned, Pottawattamie County has relatively few exposures of glacial material and thus offers little opportunity for discovery or development of the glacial gravels. However, the till, where exposed, commonly shows pockets or beds of sand or gravel. The gravel in many of the deposits seen is evidently of residual origin, being left behind while moderately strong currents of water washed away the finer materials. Locally, some of the gravel has been cemented by iron oxide or calcium carbonate into a fairly hard conglomerate. Many of the deposits are poorly sorted and contain pockets or lenses of clay, and none of the material can be considered suitable for any but road surfacing work.

As the till is nearly everywhere overlain by many feet of loess, it is only at a few places that any quantity of gravel is obtainable by stripping. A number of pits have been opened along the bluffs bordering the valley of Missouri River and several at other points in the county, but these are almost without exception completely worked out. Recent surveys have revealed two remaining deposits, each containing about 3,000 cubic yards of gravel. One is south of the center of section 29, Center Township, and the other in the NE¼ SW¼ section 9, Grove Township. About 15 prospects have been investigated unsuccessfully.

The upper alluvium of Pottawattamie County consists almost entirely of silt or fine sand, even along the smaller streams of high gradient. Many beds of gravel or coarse sand occur at greater depth and thus under heavy or prohibitive overburden. For instance, the Missouri River bottomlands are underlain by sand- and fine-grained gravel beginning ordinarily at a depth of about 50 feet. Along West Nishnabotna River the usual succession, in descending order, is as follows: 12 to 15 feet of silt, 4 or 5 feet of fine sand, 1 to 3 feet of gravel or coarse sand, and thence glacial clay. Terraces in this valley show the gravel or coarse sand at about the same elevation and thickness but overlain by a greater thickness of fine sand. On the East Nishnabotna conditions are somewhat more favorable. Sand, with about 10 percent retained on the No. 4 screen, is pumped from the river channel to a depth of 20 feet, in SE¼ SE¼ section 1, Waveland Township. The bottomland near this point shows the same bed beginning at a depth of 15 to 20 feet. Farther south, as in section 26, Waveland Township, the sand and gravel is only some five feet thick and is thus unavailable.

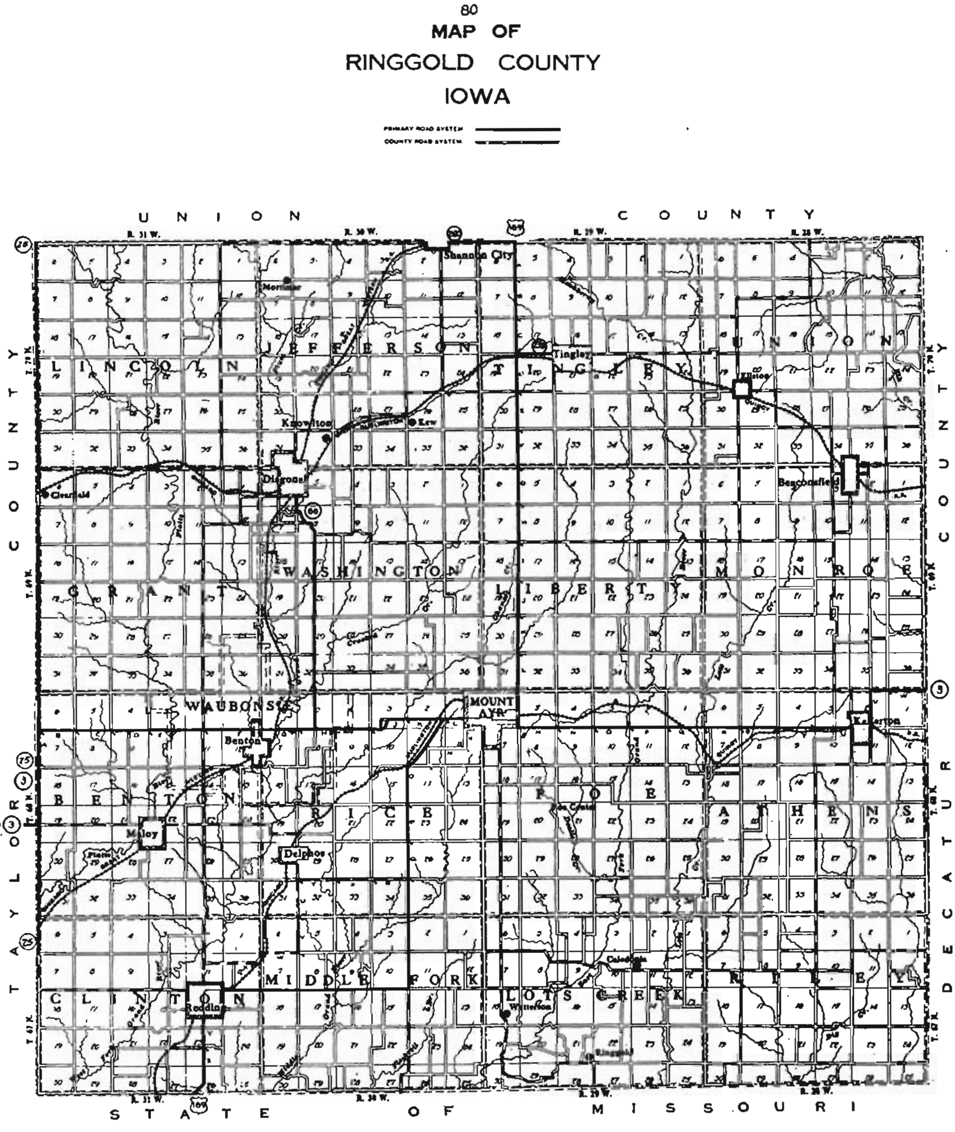
RINGGOLD COUNTY

A few obscure exposures of shales and limestones in the northeast part of Union Township and the southwest part of Lots Creek Township evidently represent the Missouri series, and probably one of the earlier stages. Elsewhere in the county the indurated rocks do not appear. Both Nebraskan and Kansan drift sheets are present, the former appearing in the lower slopes along the major valleys, while the latter is seen in the higher uplands. Loess covers the drift with a mantle ranging up to about 10 feet in thickness, but in areas of active erosion it has been almost entirely cut away. The alluvium consists principally of silt and fine sand and is not extensively present except on a few of the major streams. The total thickness of unconsolidated deposits is in places as much as 300 feet.

Limestone

Obscure exposures in section 1, Union Township, and sections 19, 20, 29, and 30, Lots Creek Township, show interbedded limestones and shales, the latter predominating. So far as known, the limestone beds are in no case more than three feet thick and, appearing near the

IOWA GEOLOGICAL SURVEY. PLATE XXXI



base of high and steep bluffs, are entirely unavailable in such a quantity that they might be developed for road or concrete work.

A test pit in SW¼ SE¼ section 19, Lots Creek Township, gives 10 feet of hard sound limestone, in even beds including an 8-inch layer, two 2-inch layers, and two or three 1-inch layers, of drab calcareous shale. The limestone begins at about 8 feet below the river bottomland level and lies entirely below natural water level. Below the limestone is 1½ feet of calcareous shale. On account of the presence of water in and above the workable ledge, quarrying is very difficult.

In view of the scarcity of limestone at the surface, information as to deeply buried ledges which might be mined from a vertical shaft is of interest. Such information about Ringgold County is very meager. However, the record of a deep well two miles west of Tingley shows a 9-foot limestone bed 234 feet deep, a 20-foot bed at 262 feet that contains two feet of shale, and a 20-foot bed of impure limestone at 294 feet. These are evidently the limestones of the Kansas City stage of the Missouri series, which appear at the surface about 20 miles to the east, in Decatur County.

Sand and Gravel

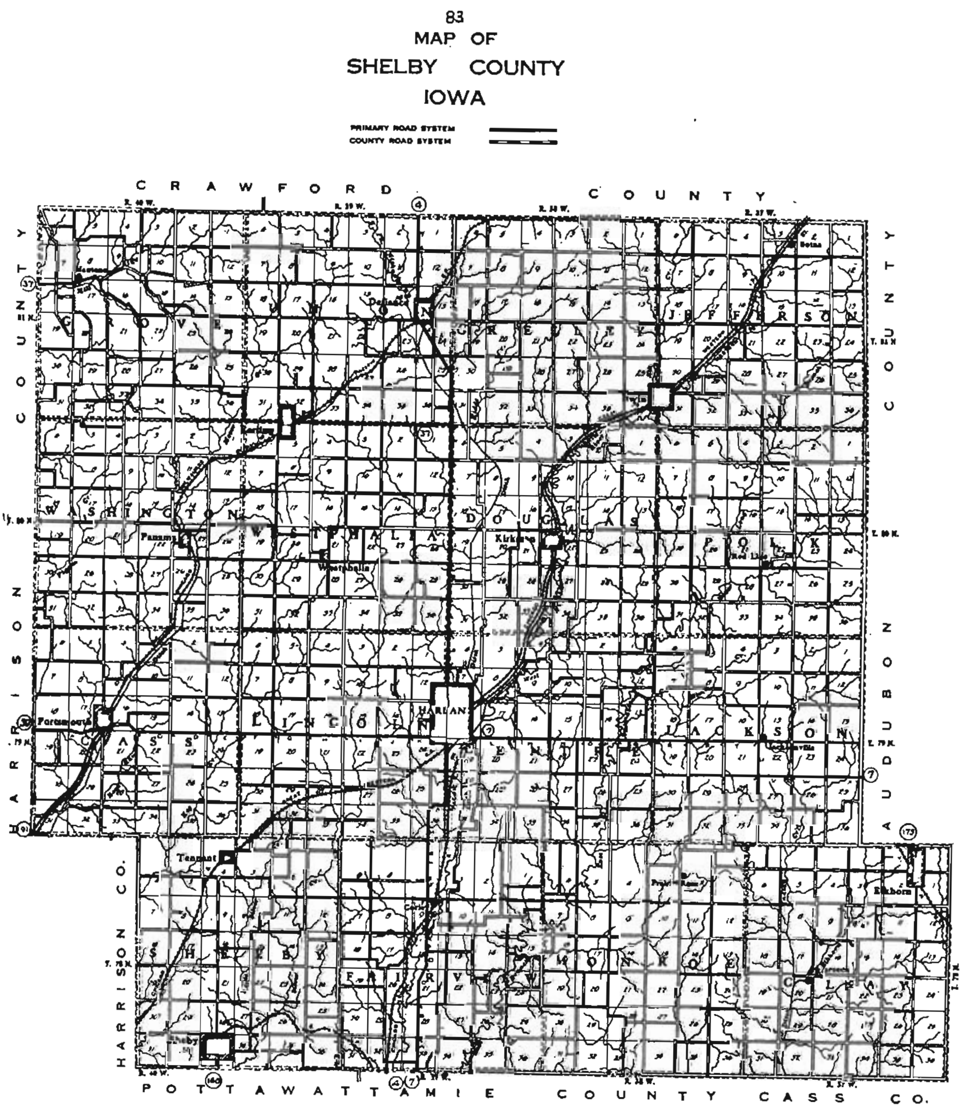
Careful surveys of the glacial gravels made by the State Highway Commission in the years 1926, 1927, and 1928 and covering some fifty locations have revealed very little available gravel. The largest deposits found are as follows: NE¼ SE¼ section 9, Washington Township, 1,600 cubic yards; NE¼ NE¼ section 36, Grant Township, 350 cubic yards; NW¼ SE¼ section 6, Rice Township, 700 cubic yards; and SW¼ NW¼ section 13, Rice Township, 400 cubic yards. The gravel from these deposits contains too much clay and inferior stone to be used for concrete work, but it is suitable for surfacing on any except the heavy-traffic roads.

So far as is known, the alluvium along the larger streams consists almost entirely of silt and fine sand. However, a number of the smaller streams of high gradient (for example, Sandy Creek in the northeast part of Union Township) are now actively cutting in the drift and carry small quantities of sand and gravel obtained from it. This sand and gravel appears at favorable points in the channel, usually in quantity ranging from a few cubic yards up to about 100 cubic yards and is easily available for small improvement projects. An advantage in working such deposits lies in the fact that they are in many cases replenished after each heavy rain.

SHELBY COUNTY

The indurated rocks do not appear in Shelby County. Both Nebraskan and Kansan drift sheets are represented, exposures of the former

IOWA GEOLOGICAL SURVEY. PLATE XXXII



being confined for the most part to the valley of Nishnabotna River and the immediate lower courses of its tributaries. Loess is generally present in the uplands in thicknesses ranging up to about 25 feet, but in areas of active erosion it is almost entirely cut away. Alluvial deposits, consisting of silt, sand, and small amounts of fine gravel, are extensive in the Nishnabotna River valley. The total thickness of the unconsolidated deposits may in places reach 300 feet or more.

Sand and Gravel

A recent survey by the State Highway Commission, covering some fifty prospects for deposits of glacial gravel in all parts of the county, reveals only one of usable size. This is located near the center of the SW¼ section 29, Clay Township, and shows some 6,000 cubic yards of available gravel. The material contains too much clay to be used in concrete but is fairly satisfactory for road surfacing.

As in other counties of southern Iowa, small streams of high gradient that are actively cutting in the drift carry small quantities of sand and gravel. This is deposited at favorable points in the channels and is there available for local improvement projects.

The Nishnabotna River bottomlands in NE¼ section 19, Center Township, show 10 to 17 feet of coarse sand and fine gravel beneath 10 to 26 feet of silt and clay overburden. Below the gravel is glacial clay. The material is clean and suitable for concrete work, though it contains very little coarse gravel and is thus of little value for road surfacing except by screening out the excess sand. Near Corley, in SE¼ section 9 and SW¼ section 10, Fairview Township, a similar deposit has a thickness of 12 to 20 feet under 9 to 16 feet of overburden. In view of these two known occurrences it seems probable that sand and small quantities of gravel might be available, though with heavy stripping, at other points in the bottomland from Harlan to the Pottawattamie County line.

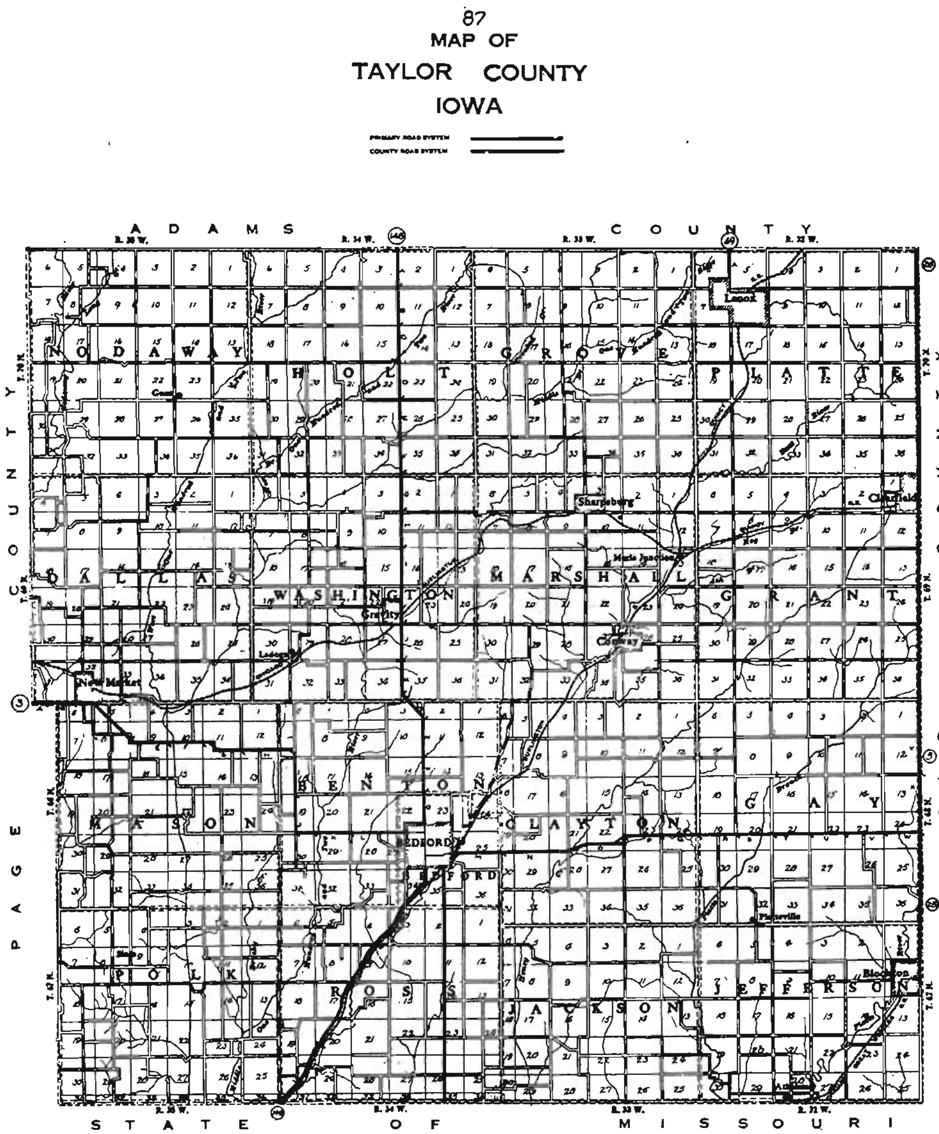
TAYLOR COUNTY

The few obscure exposures of bedrock at Bedford and in the southwest part of Nodaway Township evidently represent the Shawnee stage of the Missouri series, which probably underlies the whole county. Nebraskan and Kansan drift sheets are present, forming most of the surface exposures, the former in the deeper valleys and the latter in the higher slopes. Post-Kansan loess mantles the drift in various thicknesses up to about 20 feet in much of the upland, but in the rougher areas near the major streams it has been for the most part cut away by recent erosion.

Limestone

An outcrop of three feet of limestone above low water level in the

IOWA GEOLOGICAL SURVEY. PLATE XXXIII



east bank of One Hundred and Two River near the center SE¼ section 26, Bedford Township, is known from nearby well records to be the top of the Deer Creek limestone, here some 12 feet thick. This bed underlies fairly large areas of bottomland to the east at depths of 6 to 20 feet and to the west at somewhat greater depth. However, the limestone is overlain by a bed of water-bearing sand from 2 to 10 feet in thickness, thus making it extremely difficult to quarry, either by stripping or by mining. An abandoned quarry near the east quarter-corner section 26 probably was worked in this ledge, but the quarry pit is now filled with water and no rock is visible.

A few obscure exposures of a limestone ledge one foot to two feet thick may be seen near East Nodaway River in sections 28 and 29, Nodaway Township, and section 7, Dallas Township. The rock is unavailable in any quantity usable for road or concrete work.

A deep drill hole at Bedford showed a 25-foot limestone ledge at a depth of 125 feet, a 20-foot ledge at 420 feet, a 21-foot ledge at 495 feet, a 15-foot ledge at 535 feet and a 15-foot ledge at 600 feet. Nothing is known of the quality of these limestones, but in a county such as this, where rock is unavailable by stripping, the possibility of mining stone by means of a vertical shaft may be worth considering. Twelve feet of Deer Creek limestone was found in this well, beginning at a depth of 38 feet.

Mine Shale

The Nodaway coal has been and is still being mined at a number of points near New Market. Most of the operations are on very small scale, and but one with rail connection is known (in NW¼ SE¼ sec. 32, Dallas Twp.). The waste heap here shows (in 1933) some 25,000 cubic yards of well-burned shale, apparently suitable for road surfacing work.

Sand and Gravel

Sand and gravel pockets within the glacial drift are numerous, a survey recently completed by the State Highway Commission revealing about 85 prospects of this class. However, these are invariably small, most of them not being worth opening. The largest found are as follows: N½ SW¼ section 28, Clayton Township, 1,500 cubic yards; SE¼ NW¼ section 20, Ross Township, 1,700 cubic yards; west of center NW¼ section 14, Jefferson Township, 700 cubic yards. The gravel has too much clay and soft stone to be utilized for concrete work, but it is suitable for surfacing on light-traffic roads.

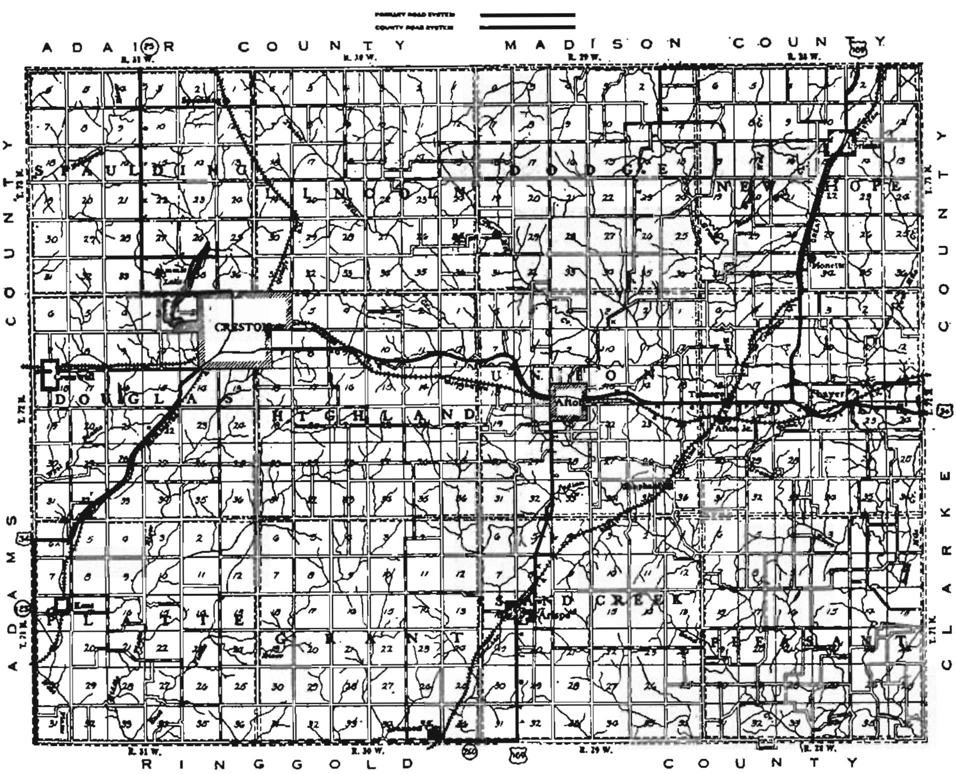
Alluvial deposits as known in the county consist almost entirely of silt and fine sand, undesirable for road improvement. A possible exception is the case of some of the short streams of high gradient that are cutting actively in the drift and thus are carrying sand and gravel. This is deposited in small bars in and near their channels and is available for local improvement projects.

UNION COUNTY

Bedrock outcrops are confined to the townships of Union, Jones, and Pleasant, and are referred to the Missouri series, probably representing one or more of the three earlier stages. These beds underlie the whole county. The mantle of glacial drift which covers them is of

IOWA GEOLOGICAL SURVEY. PLATE XXXIV

88
MAP OF
UNION COUNTY
IOWA



Nebraskan and Kansan ages, the earlier drift (Nebraskan) appearing at many points in the lower slopes bordering the deeper valleys and the later forming the exposures in the higher uplands. A mantle of loess with thicknesses ranging up to about 15 feet overlies the drift in the flatter upland areas, but in a considerable part of the county near the larger streams it has been partly or entirely removed by recent erosion. Alluvial deposits of silt or sand with small amounts of gravel are fairly extensive in the valleys of a few of the larger streams. The total thickness of unconsolidated materials is in few places less than 50 feet or more than 200 feet.

Limestone

On account of their scarcity, and the obscurity of most of them, the bedrock outcrops of Union County cannot be definitely correlated with those of adjoining counties and in some cases not even with each other. However, several horizons can be identified.

The uppermost recognizable zone is represented in an exposure in the east bank of Grand River at the southwest corner section 28, Jones Township. The section here includes, in ascending order above low water level, four feet of gray to black shale, eight feet of alternating beds of shale and fossiliferous limestone in about equal proportions, and ten feet of beds much obscured by slumping but apparently nearly all drab shale. The limestone beds are 1 foot to 1½ feet thick. Obviously, nothing is available here for quarrying in any quantity, either by stripping or by mining. The section here shown is repeated in the south bank of Grand River west of the north quarter-corner section 4, Pleasant Township. An obscure exposure of shale north of center of section 30, Jones Township, may represent one of these beds. A 3-foot bed of limestone in the lower part of the south bank of Three Mile Creek one fourth mile west of the northeast corner section 15, Union Township, may be of a younger horizon. Here also nothing is available for quarrying.

A succession of beds along a small south-flowing creek in NW¼ SE¼ section 33, Jones Township, evidently is not far above or below those at the southwest corner section 28. The following is the section:

	Feet
4. Limestone, evenly bedded, massive when fresh but weathering to thin wavy plates; granular texture, hard, sound, gray to yellowish or brownish in color, sparingly fossiliferous. Some zones are filled with small specks of iron oxide. Gray or buff chert is conspicuous, both in well-shaped nodules ranging in thickness up to 4 inches and in small angular fragments that total perhaps 5 percent of the member	5

3. Shale, yellow to drab, calcareous, hard	1
2. Limestone, light gray, fine-grained, hard, probably sound, in several distinct beds separated by shale seams which constitute about 20 percent of the thickness of the member. The top is a nodular shaly limestone grading into the member above	2½
1. Shale, drab, calcareous, hard, almost a shaly limestone	1½

Number 4 of this section is satisfactory for surfacing material and perhaps also for aggregate. It is available in limited quantity by stripping in the bed and banks of the small creek here but is too thin for profitable mining. Along other ravines in SE¼ section 33, the same zone is obscurely exposed and may be available for quarrying in small quantity.

A succession of beds which appear to lie about 25 feet below those just described is represented by the following section in the south bank of Grand River near the line between sections 3 and 4, Pleasant Township:

	Feet
3. Limestone, nodular or fragmental, yellowish gray, rather fine-grained, mostly breaking down under weathering to small calcareous pellets or lumps but with a few zones that are massive and sound. Sparingly fossiliferous	5
2. Limestone, gray, weathers yellowish, medium-grained, hard, sound, in several beds, very fossiliferous, with fusulinids predominant	4
1. Unexposed to low water level in Grand River. The upper 3 feet is drab shale	4–10

The difference in thickness of No. 1 is the result of the dip of the strata from the west end of the exposure to the east end. Number 2 is suitable for any road or concrete purpose. Parts of No. 3 are suitable also, but the larger part of it is undesirable for aggregate and of questionable quality even for surfacing. If No. 3 is usable, small quantities are available along the bluff here, with heavy stripping, or, by leaving No. 3 as a roof, No. 2 might possibly be mined from the outcrop.

The same beds as those just described appear in the west bank of a small north-flowing creek near center NE¼ section 4, Pleasant Township, but here practically nothing is available for quarrying unless by mining. East of center NW¼ section 3, Pleasant Township, the same beds appear just above water in the east bank of the river, the upper two feet of No. 3 having been removed by glacial erosion. A small quantity might be quarried here. Farther upstream, west of southeast corner section 33, Jones Township, No. 2 is below water, and No. 3 appears in the east bank of the river just above low water level. An obscure exposure along a small south-flowing creek about one fourth mile north of southeast corner section 2, Pleasant Township, indicates the same beds, but apparently nothing is available.

The following section is condensed from a composite section of three exposures, one in NW¼ SE¼ section 35, Jones Township, one in SW¼ NE¼ section 35, and one in NE¼ SE¼ section 3, Pleasant Township. These beds may lie next below or above the limestone mentioned in the preceding paragraph or may possibly be in part equivalent to that limestone.

	Feet
6. Limestone, gray, hard, sound, fossiliferous, medium to fine of grain, in two or three strong even beds	3
5. Shale, drab to dark gray, calcareous, with a few thin zones of limestone	8
4. Limestone, irregularly bedded or of nodular structure, gray, fine-grained, hard, one bed when fresh, weathers for the most part to small calcareous pellets. Some zones are sound and durable	4
3. Shale, not well exposed	2
2. Limestone, gray, medium to fine of grain, hard, sound	1
1. Unexposed to low water level in Four Mile Creek, about	2

Number 6 is probably the only bed worth quarrying, and even it is so thin as to make its use at any of the locations mentioned almost impracticable.

Alternating shales and fossiliferous limestones are exposed along a small north-flowing creek in SW¼ NW¼ section 35, Pleasant Township, none of the limestones being as much as two feet thick. These are apparently the equivalents of the upper beds which appear along Sandy Creek in sections 20 and 21, Richland Township, Decatur County. Practically nothing is available here for quarrying.

Shaft mining of the limestones of the Kansas City stage of the Missouri series, which apparently underlie the exposed rocks of Union County, is a possibility that may be worth considering here, where surface limestones have few exposures and are available only with difficulty. Information as to the depth, thickness, and character of these deeply buried ledges is not available but could be obtained at reasonable cost by core drilling. It is estimated that the base of the Missouri series is about 400 feet below the upland at Creston or about 200 feet below the valley of Grand River near Afton Junction.

Sand and Gravel

Numerous pockets of sand or gravel lie within or between the two glacial till sheets. Most of these are rather small, but a few have a volume as great as 100,000 cubic yards. The largest of these deposits occurring in Union County were the two formerly worked by the railroads (C. G. W. R. R. in NE¼ SW¼ sec. 19, Jones Twp., and C. B. & Q. R. R. in SE¼ NE¼ sec. 22, Jones Twp.), and a privately owned pit worked for the Chicago Great Western Railroad near center section 30, Jones Township. Several thousand cubic yards of material are still available in the first mentioned of these three. In the second practically all of the material under moderate stripping has been removed, but it may be that considerable quantities are still available with 25 to 60 feet of overburden. The face of the third now shows 8 feet or more (probably about 20 feet, judging from the depth of the pit) of gravel, under some 35 feet of clay.

A few thousand cubic yards of rather poor surfacing gravel has been taken from an open pit near northeast corner section 16, Union Township, and more is obtainable at this point. At least 16,000 cubic yards of a rather fine gravel was formerly available in SW¼ SW¼ section 4, Union Township (the deposit worked in 1932 for county road surfacing), and a few thousand cubic yards could still be obtained in NE¼ NE¼ section 8, Jones Township. A few other smaller pockets are known.

The material in these deposits is not uniform in character, but a large share of it is suitable for road surfacing work. On account of the content of clay and soft and disintegrated stone, it is not suitable for concrete aggregate.

Besides the above-mentioned gravel deposits, some seventy other locations have recently been examined by the Highway Commission, but no material was found to be available. These locations are in all parts of the county, but the majority are in Union and Jones Townships. In addition, gravel prospects are reported to be present south of Twelve Mile Creek in the west part of section 36, Pleasant Township, and in the east bank of Grand River west of the southeast corner section 33, Jones Township, but these have not been investigated in detail. It appears probable that systematic search in the lower slopes along the larger valleys would disclose other prospects, some perhaps of usable size.

A few of the larger streams of the county, while cutting their valleys in the glacial materials, have sorted these materials and have concentrated sand and gravel in certain favored locations. Deposits of this type consist principally of sand and are usually under heavy overburden. However, they are as a rule more uniform and dependable than the upland deposits and are therefore worthy of mention.

A bottomland area of about 10 acres along Grand River in E½ SW¼ SW¼ section 17, Jones Township, contains about 8 feet of gravel and coarse sand under 11 feet of overburden. The material is of such quality that by washing it could be made suitable for concrete aggregate.

Other possible deposits of similar nature are present in the Grand River bottomlands in E½ NE¼ section 19, Jones Township, and in the Twelve Mile Creek bottomlands near center NW¼ section 35, Pleasant Township. Neither of the latter two has been investigated in detail, and it may be that gravel or sand from them is entirely unavailable.

Along some of the short streams of high gradient are small bars of sand and gravel washed out of the drift, which may be of interest as sources of material for small local improvement projects.

VAN BUREN COUNTY

The indurated rocks of the county belong to the Osage and the Meramec series of the Mississippian system and to the lower part of the Des Moines series of the Pennsylvanian system. Of these, the Osage series, consisting of the Burlington and Keokuk formations, is exposed only in an anticline rising above Des Moines River near Bentonsport and Bonaparte. The Meramec series consists locally of the Warsaw beds and more extensively of the Spergen, St. Louis, and Ste. Genevieve limestones. It appears along the bluffs of Des Moines River and the lower courses of its tributaries for the whole length of its course within the county and in a small area adjacent to Cedar Creek in the northeast corner.

The Des Moines series underlies the upland areas throughout the remainder of the county and is known to be exposed in every township except Jackson. Though the Des Moines covers such a large part of the county, it is in most places thin and consists almost entirely of shales. Sandstone and limestone beds are too thin to be economically quarried, and coals are not thick enough and persistent enough to have supported any extensive mining industry. Consequently, the Des Moines offers little or nothing of value as a source of road or concrete materials, and it need be mentioned no further in this report.

Overlying the bedrock are two glacial till sheets, the Nebraskan and the Kansan. The former is not well exposed in the county, but its presence is known from well records and from outcroppings in neighboring counties. The thickness of the glacial deposits differs widely; over most of the county it is commonly less than 50 feet while in some parts of the southwest one fourth it is 200 feet or more. Covering the glacial materials in most of the flat interstream areas is a bed of post-Kansan loess with thicknesses ranging up to 10 feet. Alluvial deposits along the major streams are widespread and in many places assume economic importance as a source of road-building material.

Limestone

The formations of the Mississippian that appear in Van Buren County are, in ascending order, the Burlington, Keokuk, Warsaw, Spergen, St. Louis, and Ste. Genevieve. Of these the Burlington appears only in a very small area low in the bank of Des Moines River east of Bentonsport and is there entirely unavailable for quarrying. The

IOWA GEOLOGICAL SURVEY. PLATE XXXV

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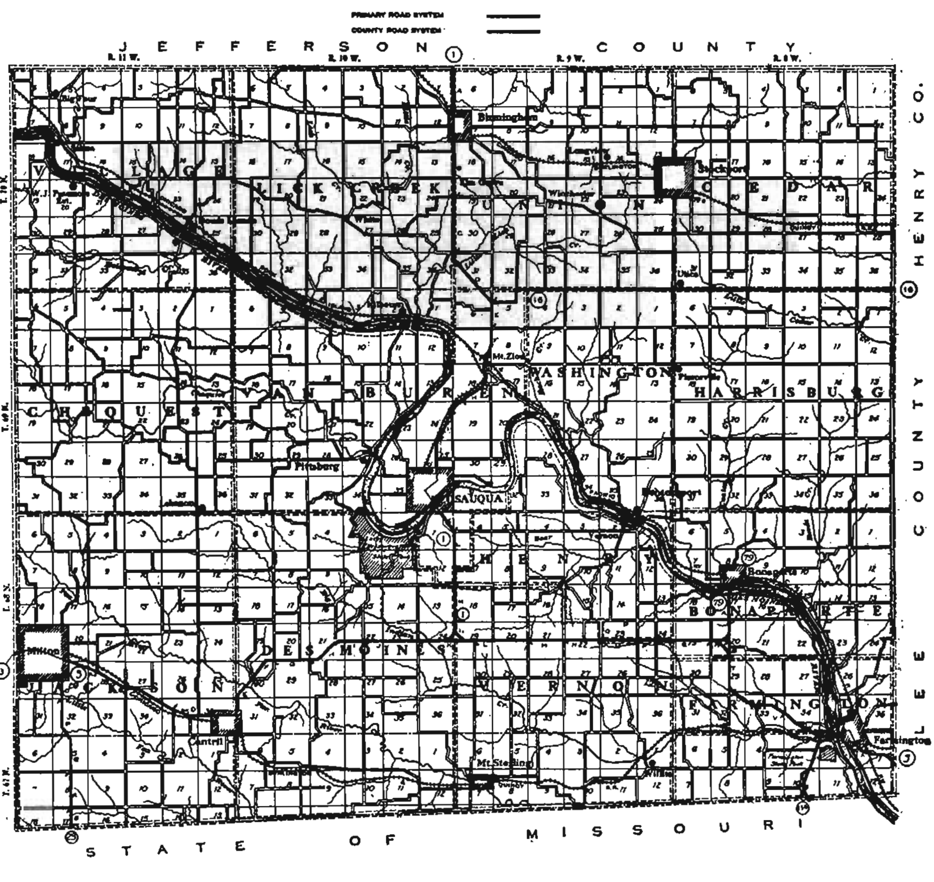
MAP OF
VAN BUREN COUNTY
IOWA



Warsaw shows little or nothing of value to the road builder. The Spergen is recognized only with difficulty, being at most points very similar to the overlying Lower St. Louis. Most of it is more shaly than the Lower St. Louis, for which reason it is of little value for road or concrete work. Consequently, the discussion in this chapter is limited for the most part to the Keokuk, St. Louis, and Ste. Genevieve formations.

The areas of availability of these various formations are included in a strip along Des Moines River and the lower courses of its tributaries; they reach back several miles from the Des Moines valley in the case of the larger streams, such as Indian, Reed, and Chequest Creeks. A small area in the northeast corner of the county, adjacent to Cedar Creek, also has some available rock. These areas may be considered in order, beginning at the lower end of Des Moines River, at the southeast corner of the county.

Farmington Area. — From the southeast corner of the county up stream to a point several miles above Farmington the top of the Keokuk limestone is a few feet to 10 feet above river level, and it is thus available for quarrying only with difficulty. During times of low water it may be obtained in limited quantity in the bed and banks of the river, usually with little or no overburden.

The St. Louis limestone is widely exposed in the middle bluffs near Farmington and northward along Des Moines River and westward along Indian Creek as far as the north quarter corner, section 5, Farmington Township, where it passes beneath the creek. At some localities the Ste. Genevieve is exposed with it. At many places in the higher bluffs, Pennsylvanian strata are present. Generally the St. Louis is not available in large quantity by stripping at any point along Des Moines River, as the bluffs at many points are high and steep, and overburden increases abruptly in going back into the hill from the outcrop. Stripping for small quantities of stone or mining from the outcrop is easy at numerous points. Most of the stone is good surfacing material, and a large part may be used as aggregate.

Extensive terrace-like areas on Indian Creek are upheld by rock, and in these the limestone is available in large quantity by stripping. To the east the Warsaw shale is the underlying material, but farther upstream higher beds appear. Probably the most valuable area for quarrying the St. Louis is just south of the creek and east of the road bridge near the south quarter-corner section 33, Farmington Township. The following section may be seen in the south creek bank at this point:

	Feet
6. Clay, glacial and residual	12
5. Limestone, gray, hard, subcrystalline to granular texture, in somewhat uneven beds, probably one bed when freshly exposed. Included are two 1-inch shale seams	7
4. Limestone, gray, hard, shaly, and possibly unsound	½–1
3. Limestone, gray, fine-grained, subconchoidal fracture, probably one bed when unweathered. The lower surface is somewhat uneven	2½
2. Shale, gray to drab, of different thicknesses to accommodate the uneven lower surface of No. 3	¼
1. Limestone, conglomeratic or brecciated, rudely stratified, both matrix and included fragments hard, gray	5½

Limestone appears below No. 1 of this section near the bridge just mentioned and again in the south creek bank in section 33. It is brownish, magnesian, fairly hard, of granular to subcrystalline texture and lies in massive and usually regular beds, though locally disturbed or somewhat conglomeratic. This member has a thickness of 10 feet. Numbers 3 and 5 of the section given are, as exposed, suitable for any road or concrete purpose, and Nos. 1 and 4 and the underlying magnesian limestone are usable for surfacing stone and probably for the most part as aggregate also. A thickness of about 25 feet of rock is thus available here. These beds apparently underlie some 25 acres of the bench with 10 to 20 feet of overburden.

In a similar bench in NW¼ NE¼, NE¼ NE¼, and SE¼ NE¼ section 5, Farmington Township, an area of about 50 acres is underlain by the limestone at the top of the Ste. Genevieve, with 5 to 25 feet of overburden. Following is the section in and below the open quarry in NW¼ NE¼ section 5:

	Feet
12. Limestone, buff, weathered, rather soft	2
11. Limestone, gray, compact, hard, sound, usually fine-grained, in massive and regular beds, with a few fossils	12
10. Shale, calcareous, gray to drab, fossiliferous	4½
9. Limestone, hard, gray, wavy-bedded	½
8. Not well exposed. Shale or soft sandstone	½
7. Limestone, gray, hard, sound, crystalline, one strong even ledge, with many large nodular masses of pink chert and crystalline calcite in the upper foot	3½
6. Shale, calcareous, with a 3-inch ledge of hard limestone near the top, and a few thinner ledges below	3
5. Limestone, gray, hard, laminated, weathering to thin plates	1
4. Shale, calcareous	¼
3. Limestone, gray, hard, sound, crystalline, in wavy beds, with the top surface deeply ripple-marked	¾
2. Shale, calcareous, with a 3-inch ledge of hard limestone in the middle	½
1. Limestone, gray, hard, sound, crystalline, fossiliferous, in regular and heavy beds with two 1-inch seams of shale. To bottom of exposure in the bed of Indian Creek	7

The beds up to and including No. 7 are referred to the Upper St. Louis and those above to the Ste. Genevieve. The similarity of No. 1 to No. 5 of the preceding section is apparent. The quarry face includes Nos. 11 and 12, though No. 12 is usually removed with the overburden. Numbers 1, 3, 7, 9, and 11 are of good quality for surfacing or aggregate. After No. 11 is quarried, it may prove worth while to strip off Nos. 8, 9, and 10, then to quarry No. 7, then to strip off Nos. 2 to 6 inclusive, and then to quarry No. 1 and such beds below it as are usable. If these lower beds are similar to those below No. 5 of the preceding section, this lower lift might be made to furnish a large quantity of stone.

A crushing and screening plant was operated in 1930 at this point by the Des Moines Valley Stone Co., but in 1931 and 1932 the work has been carried on only at infrequent intervals. The rock is drilled by air drills, blasted down, and loaded by hand on small horse-drawn carts which dump to larger cars through a trap in the quarry floor. These are pulled by cable up an incline across the creek to the north and into the hopper that feeds the primary crusher. The primary crusher is of the gyratory type. Rock is elevated from it to the cylindrical revolving screens, and the oversize is returned to a gyratory secondary crusher and thence again to the elevator and screen. The plant is electrically operated, and its capacity is about 25 tons per hour. A spur track connects it with the Chicago Burlington & Quincy railroad.

The Mississippian beds do not appear on Indian Creek farther upstream than this point.

In 1931 a 1-foot ledge of very hard sandstone of Pennsylvanian age was quarried for riprap in a small way in SW¼ NW¼ section 2, Farmington Township, but this is unavailable at any one point except in very small quantity.

Bonaparte Area. — The Mississippian rocks are abundantly and well exposed in the bluffs bordering the Des Moines River valley and the lower courses of its tributaries, appearing in valleys of Reed and Coates Creeks as much as three miles back from the main stream. The lower part of the bluffs is made up of the Keokuk limestone, which is here available for quarrying in limited quantity at a few points, especially in W½ section 8, and SW¼ section 17, Bonaparte Township. The rock is similar to that east of Bentonsport, which will be described later. The Warsaw and Spergen are not well exposed and may here be somewhat thinner than elsewhere. The most important outcrops are of the St. Louis in the middle bluffs and the Ste. Genevieve higher up.

Van Tuyl [69] has made careful studies of the St. Louis and Ste. Genevieve formations in this locality, especially along Reed Creek. The following is condensed and adapted from his section west of the center of the north line of section 14, Bonaparte Township:

	Feet
7. Limestone, light gray, compact to subcrystalline, some layers very fine-grained; layers 1 inch to 1½ feet thick, separated by thin shaly partings. The upper 12 feet is pure, hard, and sound, the lower part shaly and unsound, grading into the member below	21½
6. Shale, bluish, argillaceous to calcareous	3–6
5. Limestone, light gray, compact, in thin irregular layers with shaly partings	¾
4. Sandstone, bluish, fine-grained, soft, with a thin bed of limestone in the lower part and with pebbles and fragments of limestone and chert	9½
3. Limestone, buff, magnesian, massive, with small scattered sand grains	9
2. Limestone, compact, buff to gray, slightly disturbed but not conglomeratic	9
1. Limestone, brownish, magnesian, mashed and deformed, shaly in the lower part	28

Numbers 1, 2, and 3 are referred by Van Tuyl to the St. Louis and the upper members to the Ste. Genevieve. The upper 12 feet of No. 7 is the only zone of unquestioned quality for aggregate, though parts of the St. Louis limestones are probably suitable. All except Nos. 4 and 6, and possibly the lower parts of Nos. 1 and 7, may be used for road surfacing. At this particular point the bluff rises steeply above the exposure, and very little stone is available by stripping, but to the north, in SE¼ SW¼ SW¼ section 11, bed No. 7 of this section underlies an area of about 5 acres with a maximum overburden of not over 15 feet. At this point the sandstone equivalent to Bed No. 4 has a thickness of about 30 feet, and the limestones beneath it are thus available only by mining. Moderate quantities are available for quarrying farther north in section 11 at other exposures of the Ste. Genevieve.

The following is the succession of the Ste. Genevieve limestones along Slaughter's Branch in NE¼ NE¼ section 22, Bonaparte Township:

	Feet
4. Limestone, hard, sound, gray, compact, fine-grained	3(App.)
3. Not well exposed. Probably shale or shaly limestone	6
2. Limestone, gray, compact, hard, fine-grained. The upper part is in massive and regular beds separated by thin fossiliferous shale partings, but the lower two or three feet is shaly and irregularly bedded	15
1. Shale or sandstone	

At this point rather large quantities of limestone are available with moderate stripping by working along the edge of the bluff east and north of a small abandoned quarry opening.

69 Van Tuyl, F. M., The Stratigraphy of the Mississippian Formations in Iowa: Iowa Geological Survey, Vol. XXX, pp. 254 and 291, 1921-22.

The following section is generally in the bluffs on both sides of Coates Creek in sections 29 and 32, Harrisburg Township:

		Feet
4.	Limestone, light gray, evenly bedded, fine-grained, hard, mostly sound, nonfossiliferous. As a result of post-St. Louis erosion, the upper part of this member seems to be locally missing	11–15
3.	An extremely irregular zone, consisting chiefly of limestone, gray or brown, irregularly and unevenly bedded or locally conglomeratic, with minor amounts of shale or soft shaly limestone, about	8
2.	Shale or shaly limestone, drab	2–5
1.	Limestone, brown, granular, medium hard, sound, rather heavily and somewhat unevenly bedded	10

These beds are all referred to the St. Louis. No. 4 has been quarried in a small way at several points and is still available in rather large areas with 10 or 15 feet maximum depth of stripping. It is suitable for surfacing work, and in the most part, for aggregate. Numbers 1 and 3 may also be used for road surfacing. Favorable locations for quarrying are in NE¼ SW¼ section 29, NW¼ NE¼ section 32, south of center SW¼ section 32, and one-fourth mile south of center section 32.

The three preceding sections are typical of the St. Louis and Ste. Genevieve limestones in the vicinity of Bonaparte, but these locations are by no means the only ones where rock might be obtained. Outcroppings are abundant on both sides of the river, and quarrying for limited quantity is easy at numerous points. At some locations, as in sections 29 and 32, Harrisburg Township, or W½ NW¼ section 23, Bonaparte Township, the Ste. Genevieve is missing (probably as a result of pre-Pennsylvanian erosion), and the St. Louis forms the top of the rock exposure.

Bentonsport Area. — Just east of Bentonsport, the whole thickness of the Keokuk limestone is well exposed in the north bank of the river. The following section is obtained by combining two detailed sections at and east of Bentonsport with Van Tuyl's general section at Bentonsport and vicinity:[70]

		Feet
11.	Limestone, shaly limestone, and shale, interbedded in about equal proportions	8
10.	Limestone, shaly or calcareous shale	5
9.	Limestone, gray, coarse-grained, hard and sound, one bed, with little or no chert, very persistent	3
8.	Shale or shaly limestone	1
7.	A somewhat variable zone, usually consisting principally of massive hard and sound limestones, separated by thin shaly members	10
6.	Limestone, partly sound and partly unsound	5
5.	A zone very similar to that above, but with a greater proportion of hard and sound stone. Chert is usually present in moderate quantity	9
4.	Shale, locally becoming a shaly limestone	5

70 Van Tuyl, F. M., The Stratigraphy of the Mississippian Formations in Iowa: Iowa Geological Survey, Vol. XXX, p. 169, 1921-22.

3. Limestone, hard and sound, cherty	3½
2. Limestone, shaly, and locally, shale	3½
1. Limestone and chert, the latter constituting 25 to 50 percent of the whole. The limestone is hard and usually sound, but the chert shows rather poor resistance to weathering. Many of the lower beds are strongly crinoidal, and the passage into the Burlington limestone beneath is indistinct	16

Numbers 1, 2, and 3, and possibly also 4 and 5, may be referred to the Montrose chert member and the remainder to the Keokuk limestone proper. Though this section is rather generalized, the differences in character of these beds make it impossible to give any more details which can be depended upon throughout the area.

These beds are well exposed for a few miles along the Des Moines and the lower courses of its tributaries (especially Bear Creek) in this vicinity. A few quarries have been opened in the past, and a large part of the stone available by stripping has been removed. No point is known where a quantity sufficient to support a permanent concrete aggregate plant is obtainable by stripping, although mining from the outcrop might prove practicable. The horizon of greatest value for road or concrete work is that represented by Nos. 7 to 9 of the General Section. At a point one-half mile east of the Bentonsport depot this zone has a thickness of 14 feet, 2 inches, of which about 12 feet is stone suitable for aggregate. The bottom of the Keokuk limestone is here about six feet above low water level in Des Moines River.

The Warsaw and Spergen formations are usually present above the Keokuk in these bluffs, and farther back the St. Louis appears in many places. Most of the exposures show the Spergen or Lower St. Louis beds. The following section, obtained by Beyer [71] in quarries which were formerly operated in NW¼ NW¼ section 11, Henry Township, is typical:

	Feet
7. Drift, sand, and gravel	2½–10
6. Blue-gray "Soapstone" shale, with thin limestone layers in lower portion	6
5. Arenaceous limestone, light brown to bluish	2½
4. Sandy blue magnesian limestone, a solid ledge, with some chert near the base	5
3. Limestone irregularly bedded, gray to blue, coarse-grained, fossiliferous	5+
2. "Soapstone," containing chert, to water in creek	1½
1. White limestone, reported to unknown depth	1½

Much of this rock is rather soft for use as aggregate, but all except beds Nos. 2 and 6 probably are satisfactory surfacing material. Here, and at numerous other points in the higher bluffs in this locality, similar stone is available in limited quantity with moderate stripping, or in larger quantity by mining.

71 Beyer, S. W., and Williams, I. A., Geology of Iowa Quarry Products: Iowa Geological Survey, Vol. XVII, p. 451, 1906.

Keosauqua — Mt. Zion Area. — At the mouth of Rock Creek, in NW¼ section 21, Washington Township, the top of the Keokuk limestone lies at river level, and upstream from this point it appears only in a very limited exposure low in the bank near Kilbourne. A number of quarries have been operated in this locality in past years, but none in recent years. The following section, condensed from one taken by Van Tuyl at and near an abandoned quarry at the mouth of Rock Creek,[72] shows the character of the St. Louis and Ste. Genevieve formations:

		Feet
9.	Limestone, gray, fine-grained	7¾
8.	Sandstone, fine-grained, massive, more calcareous and approaching brecciated limestone locally in the upper part	11¾
7.	Limestone, gray, compact, fine-grained, brecciated	5–8
6.	Sandstone, soft, fine-grained, bluish, with some limestone in the lower part	2
5.	Limestone, buff, magnesian, brecciated	8–12
4.	Limestone, buff, magnesian, massive	7–8½
3.	Limestone, compact, gray, with shaly seams	2
2.	Limestone, buff to bluish, mostly magnesian, compact, tough	9
1.	Sandstone, fine-grained, bluish, calcareous. Exposed	5

Numbers 8 and 9 represent the Ste. Genevieve, and the remainder belongs to the St. Louis. All except Nos. 1, 6, and 8 are satisfactory as surfacing material, and a major part of them is suitable for aggregate. At this and other points in the vicinity, moderate quantities are available by stripping and larger quantities by mining.

A number of quarries have been operated just northeast and east of Keosauqua. The face of an old quarry in NW¼ NE¼ section 36, Van Buren Township, shows 11 to 12 feet of hard gray massive limestone; this is underlain by 15 feet of very irregular conglomeratic stone with a wide range in character and containing lenses and pockets of sandstone and green shale. The stone is available by stripping along both sides of the creek here over an area including at least five acres. Only the upper member is suitable for aggregate though both might be used for road surfacing. Similar stone is exposed and may be quarried in moderate quantity in N½ N½ section 31, Van Buren Township (T. 69, R. 9), and again in SW¼ section 31.

Exposures are numerous, and rock has been quarried at intervals on the south side of the river south and southwest of Keosauqua. The outcropping beds include the Ste. Genevieve and the upper part of the St. Louis. At the top is a light gray fine-grained limestone having various thicknesses up to about 12 feet. Below this the exposed strata

[72] Van Tuyl, F. M., The Stratigraphy of the Mississippian Formations in Iowa: Iowa Geological Survey, Vol. XXX, p. 258, 1921-22.

are principally of soft yellowish fine-grained sandstone, which locally contains irregular lenses or beds of limestone with a maximum thickness of a few feet. The total thickness of the sandstone formation is 15 to 25 feet. The principal quarries were in NW¼ NE¼ section 1, SE¼ NW¼ section 1, and SE¼ SE¼ section 2, all of township 68 N., range 10 W. Limited quantities of the upper limestone are available at several points in the locality, and all of this stone is suitable for any road or concrete purpose.

Pittsburgh-Chequest Area. — Mississippian rocks appear along Chequest Creek from its mouth at Pittsburg as far west as section 18, Chequest Township. However, the most easily workable deposits are to the east, in Van Buren Township. Following is Van Tuyl's section [78] near the mouth of Chequest Creek (NE¼ SW¼ section 27, Van Buren Township):

	Feet
6. Limestone, gray, slightly brecciated	7½
5. Sandstone, massive, fine-grained, bluish, weathers yellowish, with a few blocks of compact gray limestone	6–7½
4. Limestone, compact, gray, locally disturbed	1–3½
3. Sandstone, massive, bluish, locally with limestone pebbles	3–7
2. Limestone, fine-grained, gray, rather soft, massive, with occasional small dark-colored rounded chert concretions, locally slightly brecciated; tends to flake off parallel to the face of the bluff and may be unsound	8½
1. Sandstone, fine-grained, bluish, soft, some layers calcareous	2

Number 6 corresponds to the limestone south of Keosauqua, while the lower beds are evidently the equivalents of the underlying sandstone. Number 6 is the only bed of value for road or concrete work, and it is available in this locality only in limited quantity.

Farther west along Chequest Creek the beds of the Upper St. Louis again are hard and durable. There are good exposures and several old quarries in sections 18 and 20, Van Buren Township (T. 69, R. 10). The following section is a composite record of five core drill holes put down in 1927 in SE¼ NW¼ section 20, for the Chequest Quarry Co., the record being furnished by W. G. Osborn of Keosauqua, Consulting Geologist for the company.

	Feet
7. Clay, glacial and residual, with some gravel	5–25
6. Limestone, fine-grained, gray, interbedded with shale	0–3
5. Sandstone, buff, ranging locally to sandy shale	0–9
4. Limestone, light gray, hard, sound, texture granular to subcrystalline, somewhat unevenly bedded but mostly massive	7–19
3. Limestone, gray, hard, fine-grained, subconchoidal fracture	2½–10
2. Limestone, conglomeratic, mostly hard and apparently sound, but locally containing small seams and pockets of green shale, or passing into a	

78 Van Tuyl, F. M. The Stratigraphy of the Mississippian Formations in Iowa, Iowa Geological Survey, Vol. XXX, p. 262, 1921-22.

	rather soft yellow shaly limestone	2½–4
1.	Limestone, gray to buff, granular texture, fairly hard, in regular and very heavy beds; dolomitic, and usually showing a porous texture	22–24

Numbers 5 and 6 represent the Ste. Genevieve and the lower members the St. Louis. In one hole the drill found below No. 1 a thickness of 61 feet of shales and thin limestones, which evidently represent the Warsaw, and 52 feet of cherty limestone with beds of shale, which represent the Keokuk. All but Nos. 5 and 7 of the section given are suitable for surfacing material, and Nos. 3 and 4, and possibly also a part of Nos. 1, 2, and 6, are satisfactory for concrete aggregate. These beds are available by stripping in fairly large areas along both sides of Price Creek. Quarrying has been carried on at this point and also east of center section 20 and in NW¼ SE¼ section 18, at which points also more rock is available. Other possible quarry sites exist along Chequest Creek to the east and west of this locality.

Kilbourne Area. — Near the mouth of Lick Creek the top of the Keokuk limestone is three feet above water. Above it is some 43 feet of Warsaw and Spergen strata, which are overlain by the St. Louis and Ste. Genevieve limestones. The following is Van Tuyl's section of these two latter formations at this point: [74]

		Feet
5.	Slope, strewn with blocks of limestone	5
4.	Limestone, gray, resting on the uneven surface of the bed below	3
3.	Limestone, granular to compact, thin-bedded, much fractured; contact with bed below irregular	6–8½
2.	Limestone, dense, compact, gray, brecciated, resting on the irregular surface of the bed beneath	3½–8½
1.	Limestone, buff, magnesian, massive. Exposed	16½

These beds are for the most part suitable for crushing for any road or concrete work. Limited amounts are available by stripping, or almost any quantity by mining, in E½ E½ section 12, township 69, range 10; W½ section 1, township 69, range 10; and SW¼ and NE¼ section 36, township 70, range 10.

Douds-Selma Area. — To the west the beds of the St. Louis maintain the good quality observed at Kilbourne and also show a somewhat greater thickness. Upstream they lie lower and lower, and at the quarry one mile east of Douds the division between Lower and Upper St. Louis is at the river level. The Mississippian appears naturally above Selma only in the bed of the river. In general, the St. Louis is overlain throughout this area by sandstone and limestone of Ste. Genevieve age,

74 Van Tuyl, F. M., The Stratigraphy of the Mississippian Formations in Iowa: Iowa Geological Survey, Vol. XXX, p. 262, 1921-22.

and that by Pennsylvanian strata. Thus, only small quantities are available at any point by stripping, though exposures are numerous and quarrying on a small scale is easy at several points on both sides of the river. Large quantities are easily obtainable by mining.

The following section, at the quarry of the Douds Stone Co. in section 25, Village Township, is typical of the Mississippian in this area:

		Feet
10.	Limestone, light gray, weathers white, hard and sound, fine-grained, much weathered. Visible at only one point, at the extreme top of the quarry face	1–6
9.	Sandstone, generally soft, but locally well indurated. Mostly drab in color. Included in it are a few thin beds or lenses of gray sandy limestone. Shows a noticeable northward dip	8 (App.)
8.	Limestone, light gray, medium to fine of grain, in fairly regular and heavy beds, hard, tough and sound. This member shows slight undulations and a general dip to the north. Its greatest thickness is to the south	6–10
7.	Principally a drab calcareous shale, which locally includes a thin bed of limestone and one of sandstone in its lower portion. At a few points the shale disappears entirely, being replaced by limestone. The greatest thickness is to the south, so that the lower surface of it is nearly level, though slightly irregular	3–6
6.	Limestone. For the most part it is similar to the stone in No. 8, but locally the thickening of the member below reduces it to almost zero	9 (App.)
5.	Limestone, brecciated. The included fragments are a gray fine-grained hard and sound nonmagnesian limestone, of angular shape and all sizes up to one foot or more. The matrix is for the most part fine-grained gray limestone, much of it slightly darker than the fragments. Thin veins of green clay or soft shale run in all directions through the matrix and locally thicken up so as to become small pockets. In places this member shows undulating shattered beds, whose fragments preserve nearly their original position, but elsewhere it is a massive unstratified breccia. It is estimated that about 90 percent of the stone is suitable for concrete aggregate. At the bottom of this member is a well-defined though slightly undulating line of division	9–16
4.	Limestone, grayish brown, subcrystalline texture, hard, sound and tough, magnesian, in regular and heavy beds. The contact with the member above is somewhat irregular, though plainly marked, and suggests disconformity as a result of contemporaneous erosion. In the lower half of the member are numerous well-rounded chert or flint nodules, commonly six inches or less in diameter, and a few very thin discontinuous bands of chert. The total chert content probably does not exceed 5 percent	12
3.	This consists of a bed of silica sand grains, about 1/50 inch in diameter, in a matrix of light gray fine-grained hard and sound limestone. The silica content is estimated at 30 percent. No definite bedding plane exists between this and the member above. The rock is massive and regularly bedded and in places shows a distinct banded appearance	4½
2.	Limestone, light gray, fairly hard, and may be sound, with two or more very thin continuous or nearly continuous seams of dark colored shale	½
1.	Limestone, gray with a brownish tinge, slightly magnesian, medium-grained, subcrystalline texture, hard, sound, and tough, in regular and heavy beds. To the present bottom of the quarry pit	5½

Numbers 1 to 4 inclusive of this section represent the Lower St. Louis, Nos. 5 to 8 inclusive the Upper St. Louis, and Nos. 9 and 10 the Ste. Genevieve. Excavation in the bottom of the quarry pit shows that below No. 1 lie dark colored calcareous shales or shaly limestones, evidently representing the Spergen or Warsaw. All but Nos. 7 and 9 of this section are or can be used for aggregate or surfacing.

This site was originally worked by stripping, but, as the inferior character of much of the upper stone became apparent, stripping was abandoned. The rock is now mined from several entries leading out from the quarry pit at various levels up to the middle of Bed No. 6, the upper half of No. 6 being left as a roof for the highest entry. The primary crusher is in the quarry pit, and rock is fed to it from a floor at the level of the middle of Bed No. 4. Rock is loaded by hand on small cars, which from the upper entries are pushed to the crusher feeding floor, and from the lower entries are elevated by derrick to that floor. The rock is raised from the primary crusher by bucket belt elevator to the screening and recrushing plant, which is built above the track level. Track level is at the top of Bed No. 8 of the section. Vibrator screens are used for sizing. The plant is operated by electricity, and its capacity is about 40 tons per hour. It has connection with the Rock

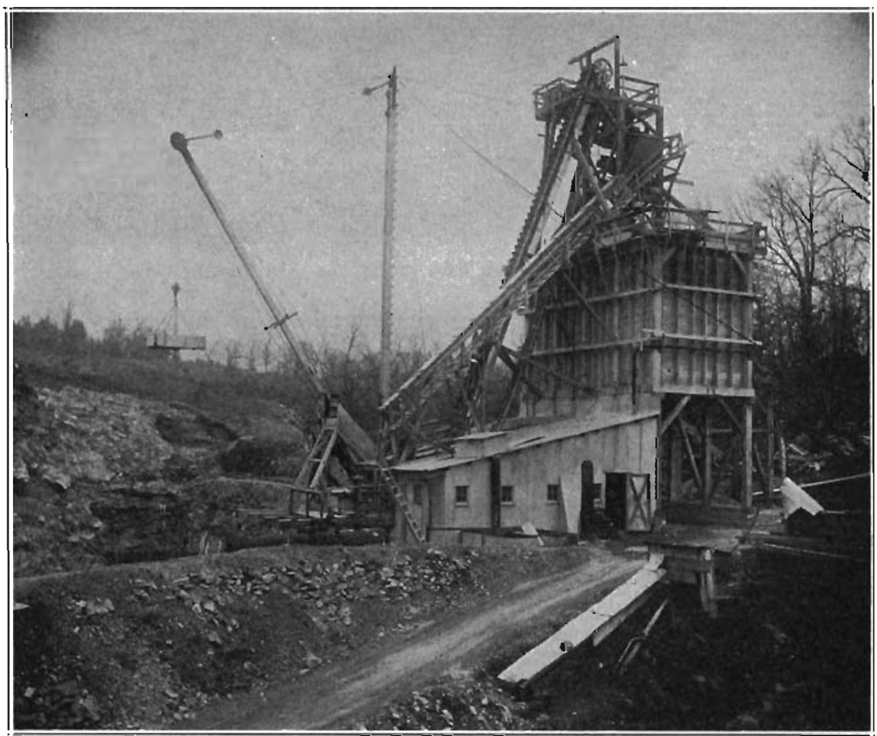


FIG. 12. — Douds Stone Co., at Douds, Iowa. General view of the crushing and screening plant.

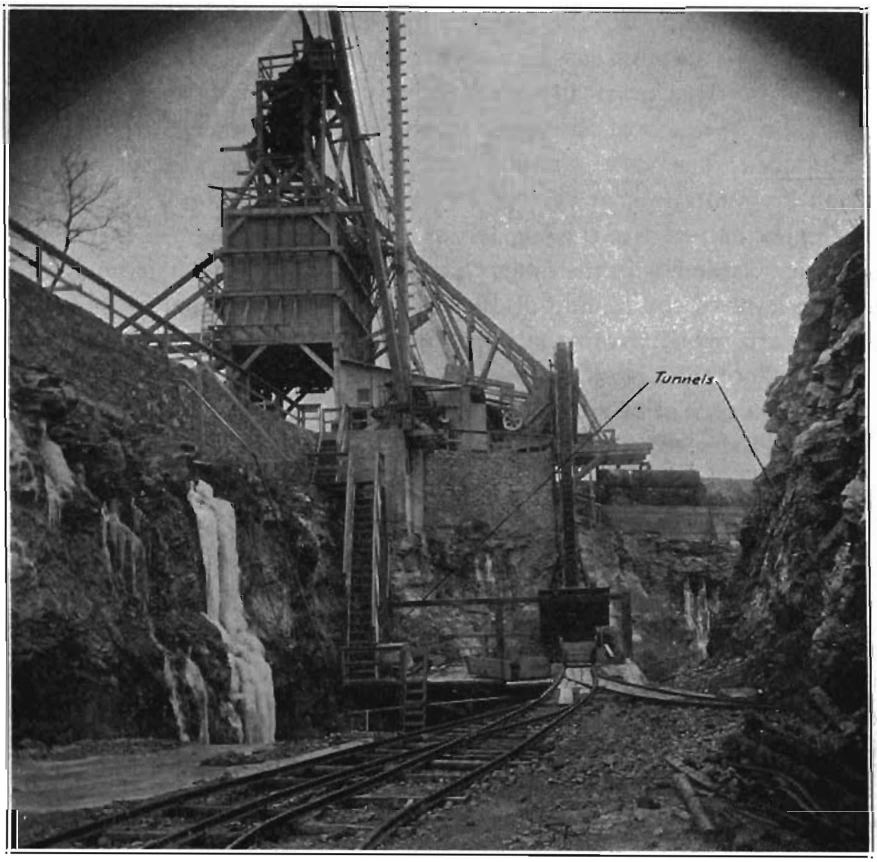


FIG. 13. — Douds Stone Co., Douds, Iowa. View of the quarry pit, showing tunnel openings.

Island Ry. Figures 12 and 13 are general views of the quarry plant and pit. The wall around the top of the quarry pit is high enough to keep out surface water, and the amount of ground water which leaks in is small. The quantity of rock available by mining is obviously very large.

Cedar Creek Area. — A general section for the exposures in the north part of Cedar Township is about as follows:

	FEET
4. Limestone, in beds of various thicknesses up to 8 feet, separated by thinner beds of shale or sandstone. The limestone is light gray in color, usually rather fine-grained, hard, and sound. Thickness is as given, except where reduced by post-Mississippian erosion	10–15
3. This zone consists chiefly of soft sandstone, with which may be irregularly interbedded light-gray hard limestone or drab calcareous shale	15
2. Limestone, fine to coarse texture, locally granular or sandy, gray in color, massive, sound, hard except for local zones or beds of soft granular material	15–20

1. Limestone, drab to brown, magnesian, mostly sound, not very hard, granular to subcrystalline texture. Exposed 10

The nature of these beds suggests the reference of Nos. 1 and 2 to the St. Louis and Nos. 3 and 4 to the Ste. Genevieve. The lower members appear only in the lower slopes along Cedar Creek in sections 1, 2, 3, and 12. The upper members are in the higher slopes and, appearing along many of the small tributary creeks, are the ones most commonly found available. Typical exposures and possible quarry sites are as follows: south of northeast corner section 9, on both sides of a small tributary of Summer Creek; SE¼ NE¼ section 4, south bank of Cedar Creek; south of north quarter-corner section 3, south bank of Cedar Creek; ¼ mile east of center section 3, along a small east-flowing branch; N½ SE¼ SE¼ section 3, south of Cedar Creek; S½ S½ section 2, slopes south of Cedar Creek; and ¼ mile south of center section 13, slopes north of Rock Creek. Other possible quarry sites are available in the same locality. At any of these points, a limited quantity of surfacing material can be quarried with little difficulty, though stripping is in some places rather heavy. A major portion of the limestone is also suitable for concrete aggregate.

Sand and Gravel

Glacial gravels are present in small quantity at numerous points in this county as in the other counties of southern Iowa. However, on account of the easy availability of road or concrete materials in the stream gravels or the limestone beds of the county, no careful survey of upland gravel deposits has been made. The only one known at present is near center SW¼ section 29, Van Buren Township (T. 69, R. 9), which may contain 1,000 cubic yards or more. The position of this gravel suggests that it may be a terrace deposit, but the nature of the material shows its glacial origin.

In the channel of Des Moines River are bars of sand and gravel, some of considerable size. Most of these are located near Keosauqua, where the river has had more opportunity to develop the meanders which are necessary for the formation of bar deposits. Smaller deposits are formed at the mouths of tributary creeks at other points, much of the material having originated from the tributary rather than from the main stream. A survey of the Des Moines River channel shows the following bars of importance:

NE¼ NE¼ sec. 11 and NW¼ NW¼ sec. 12, Van Buren Twp.	Long low bar on south bank shows principally sand

S½ sec. 34, T. 69, R. 10; NE¼ sec. 3, N½ sec. 2, and NW¼ NW¼ sec. 1, T. 68, R. 10	Continuous bar around inside of bend, 50 to 150 feet wide, and 1 foot to 2 feet above low water level, shows principally gravel, which has been prospected in three places and found to be available to the amount of 31,000 cubic yards or more
N. of center sec. 31, T. 69, R. 9, Van Buren Twp.	Bar on south bank prospected and found to contain 50,000 cubic yards of gravel
NW¼ sec. 32, and most of sec. 29, T. 69, R. 9, Van Buren Twp.	Bar on west bank shows gravel in the upstream end and sand below, covers about 15 acres and rises 2 to 3 feet above low water level
SE¼ sec. 20, and NW¼ SW¼ sec. 21, Henry Twp.	10-acre bar on south bank shows fine gravel at upper end, grading into sand below
SW¼ SE¼ sec. 21, Henry Twp.	Bar on south bank, 3 or 4 acres, all sand
SW¼ SW¼ sec. 27, and NW¼ NW¼ sec. 34, Washington Twp.	5-acre bar on east bank, three feet above low water level, all gravel and coarse sand
NE¼ SE¼ SE¼ sec. 34, Washington Twp.	2-acre bar of coarse sand on north bank
Near S. quarter-corner sec. 8, Bonaparte Twp.	1-acre bar of coarse gravel, three feet above low water level, in north bank
NW¼ NW¼ sec. 16, Bonaparte Twp.	Small shallow bar of gravel and broken stone at mouth of creek in north bank
NW¼ SW¼ sec. 15, Bonaparte Twp.	2-acre bar of sand with some veins of gravel, on west bank
NW¼ SE¼ sec. 15, Bonaparte Twp.	Small shallow bar of coarse gravel and broken rock at mouth of Reed Creek
NW¼ NW¼ sec. 26, Farmington Twp.	1-acre bar on west bank at mouth of creek, mostly sand
N. of center NW¼ sec. 35, Farmington Twp.	2-acre bar of coarse gravel on east bank, probably not far down to solid rock
SE¼ SW¼ sec. 35 and NW¼ NE¼ sec. 2, Farmington Twp.	10-acre bar in west bank, nearly all sand, much of which is very fine

NW¼ NW¼ sec. 12, Farmington Twp.	Bar on east bank covers three acres and contains coarse sand.

The material in these bars is usually clean and well-sorted and may ordinarily be used for aggregate or, if coarse enough, for surfacing work.

Many of the small streams of the county, especially those of high gradient, are actively cutting in the drift or the bedrock and carry considerable amounts of sand, gravel, and broken rock fragments, which are deposited at favorable points along their courses. Most of these deposits are small, but along the larger streams, such as Lick Creek, Coates Creek, and others, they are large enough to be worth developing. A deposit of this kind on Lick Creek north of center section 36, Lick Creek Township, has been found to contain about 400 cubic yards of such material, and one on Coates Creek in SW¼ SW¼ section 5, Bonaparte Township, has been found to contain about 3,300 cubic yards. This material is of good quality for road surfacing, but only a little is clean enough or well enough assorted to be of value as aggregate.

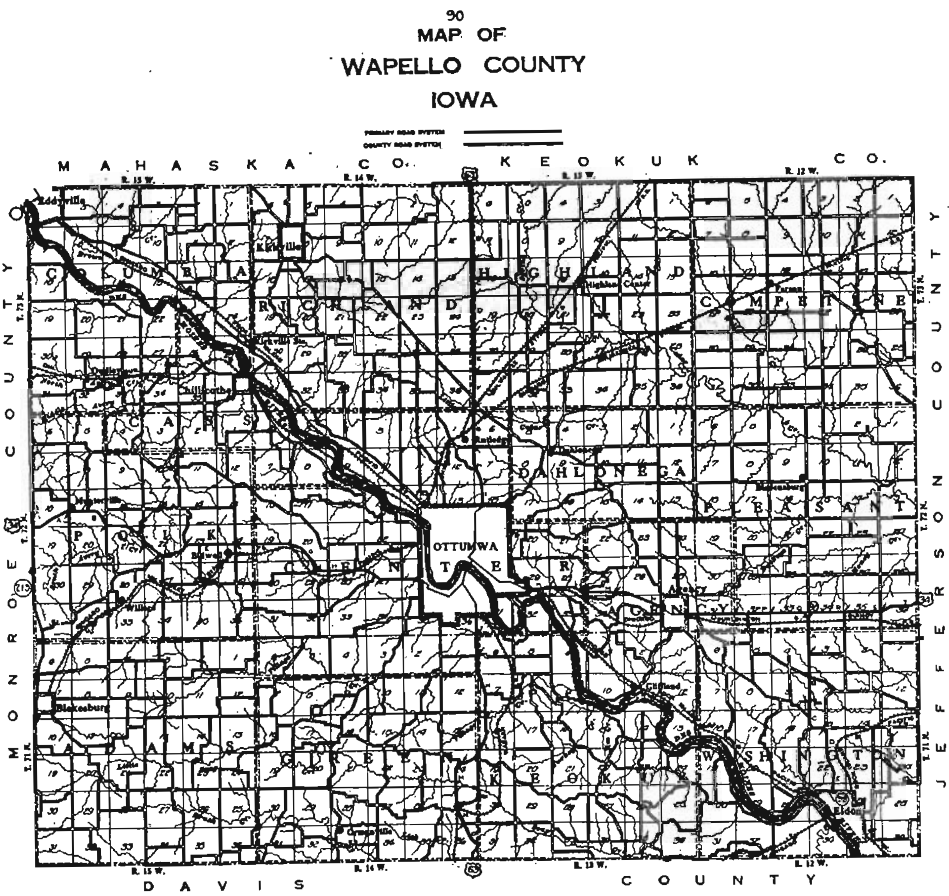
A few terrace deposits of sand or gravel are present in the Des Moines River valley. A terrace at the southeast corner of Farmington has an area of about 10 acres and is underlain by five feet of gravel, with at least 15 feet of coarse sand below. The deposit has been worked in a small way at various times, but the bulk of the material is still there. Development is difficult on account of the presence of permanent improvements on the tract. A terrace area of 50 acres in the NW¼ section 12, Farmington Township, has been prospected and found to be underlain by about 1,100,000 cubic yards of gravel and 200,000 cubic yards of sand, under some 450,000 cubic yards of stripping. This material is suitable for road surfacing work if the oversize is crushed, and most of it may be used with satisfaction in concrete. The prominent terraces in the Keosauqua oxbow area have been investigated but have not been found to contain any amount of available gravel.

Alluvial deposits in the southern and southwestern parts of the county, along Indian Creek and Fox and Little Fox Rivers, consist almost entirely of silt or fine sand.

WAPELLO COUNTY

The Ste. Genevieve formation is exposed at intervals near Des Moines River and underlies the whole of the county. The combined thickness of exposed beds referable to it is about 40 feet. In most of the county it is overlain by strata of the lower (Cherokee) stage of the Des Moines series, which have a thickness in places of 200 feet or more. Upon these strata is a mantle composed of two glacial drift sheets, the Nebraskan below and the Kansan above. The former is definitely exposed in few places, but its presence may be inferred from well records and from outcrops in adjoining counties. The thickness of drift ranges from 0 up to perhaps as much as 200 feet, but at few points is it more than 125 feet. A veneer of post-Kansan loess covers the drift in depths up to about 10 feet, but in the rougher areas near the larger streams it has been for the most part removed by recent erosion. Alluvial deposits are abundant in the valleys of Des Moines River and a few of its tributaries.

IOWA GEOLOGICAL SURVEY. PLATE XXXVI



Limestone

Definite outcrops of the Mississippian strata are confined to the valleys of Des Moines River and the lower courses of its tributaries from Eddyville to Ottumwa, though at many points near Cliffland, and again above and below Eldon, the river bed seems to be on solid limestone that is probably of Mississippian age. All of the exposures may be referred to the Ste. Genevieve formation. The following is adapted from a general section given by Leonard: [75]

	Feet
6. Limestone, gray, hard	1–6
5. Marly shale	2
4. Limestone	½–1
3. Marly shale	3
2. Limestone, light gray, hard, fine-grained, for the most part sound, but with some marly unsound zones, heavy-bedded, fossiliferous	5–11
1. Sandstone, yellowish, fine-grained, mostly soft	6+

Number 1 is too soft to be used for aggregate but locally it is well enough indurated to be crushed and used for surfacing material. Number 2, except for the marly unsound zones, is suitable for any road or concrete purpose. Number 6 likewise is of good quality but in natural exposures is commonly less than two feet thick. Usually where No. 2 is exposed, the beds above are present at or just back of the face, making quarrying by stripping very difficult. On account of the thinness of the ledge, part of which must be left as a roof, mining also is difficult.

At the face of the Lafferty quarry, now abandoned, west of center section 7, Columbia Township, No. 6 is 1 foot thick; Nos. 3 to 5 have a total thickness of 8 feet; and No. 2 is 10 feet thick, about 10 percent of this bed being marly or shaly and unsound. The quarry has now been worked to a point where overburden is more than 10 feet thick, and further extension is thus difficult. Core drillings here in 1920 by the Marquette Cement Co. show No. 2 to be 11 feet thick and No. 1 to be 9½ feet thick or more.

The river bluff in SE¼ section 7, shows beds Nos. 1 to 5 inclusive; above them lies 50 feet or more of Pennsylvanian beds, which are principally soft sandstone. Bed No. 2 is 10 feet thick. Practically nothing is available in the river bluff, though limited quantities are obtainable along small creeks tributary from the west.

A number of exposures and several old quarries are present on Avery Creek between Chillicothe and Dudley. Bed No. 2 of the general

75 Leonard, A. G., Geology of Wapello County: Iowa Geological Survey, Vol. XII, p. 459, 1901.

section is seen in various thicknesses up to 10 feet, commonly with 5 to 15 percent of shaly unsound material. In most cases all of the rock under moderate stripping has been removed. However, an area of 2 or 3 acres is available in SE¼ SE¼ section 26, Cass Township, and an area of 1 or 2 acres in NW¼ NW¼ section 34 might be worked. It is possible that systematic search through sections 27 and 33, Columbia Township, and section 34, Cass Township, would disclose other areas, though it is doubtful if any stone is available with less than 10 feet of overburden. At other exposures on South Avery Creek, in sections 35 and 2, Cass Township, the rock has not been so extensively quarried and is, therefore, more easily obtainable. Number 2 of the general section has a thickness of 6½ feet.

The Ste. Genevieve is exposed in the east part of Columbia Township in the beds or lower banks of some of the small creeks tributary to Des Moines River from the north. Only small quantities are available under less than 10 feet of overburden.

Similar beds outcrop and have been quarried in a small way in SW¼ section 9, and SE¼ section 8, Cass Township, but the exposures now show overburden increasing rather abruptly from a minimum of about nine feet.

Quarrying has been carried on in the bluff south of Bear Creek in SW¼ section 23, Center Township (T. 72, R. 14). The workings are now abandoned, and the ledges are entirely obscured by slumping. It appears that only small quantities are still available. Other quarries were formerly worked on Harrow's Branch in Ottumwa (SW¼ sec. 13, T. 72, R. 14), but these are filled up by wash of the overlying materials, and it is obvious that little or nothing further can be obtained at reasonable cost.

A low benchlike area south of Sugar Creek near northwest corner section 33, township 72, range 13, shows the upper five feet of Bed No. 2 of the general section with about six feet of overburden. If this member has its full normal thickness of 10 feet, which, judging from exposures in the creek bed, is believed to be the case, it is available for quarrying over an extensive area.

Much of the bed of Des Moines River at Ottumwa lies on solid limestone, which at intervals has been quarried in a small way in times of low water. The thickness of the bed is unknown, but its quality is probably good. A similar situation exists in the river bed below Eldon.

Most of the limestones of Pennsylvanian age are thin, the greatest known thickness being about four feet for the black limestone above the coal near Laddsdale. None of these limestones is known to be available anywhere in this county.

Sandstone

In the vicinity of Cliffland large quantities of sandstone of Pennsylvanian age are available. However, the sandstone is too soft to be of value for crushing and too fine-grained to be broken down and used as sand, unless possibly in the finer part of an asphaltic aggregate.

Mine Shale

For many years coal has been mined in Wapello County. Most of the large-scale mining has been in three localities, near Kirkville, near and north of Ottumwa, and west of Eldon. In addition, a mine has been worked at Willard.

The largest mines at Kirkville were located in NE¼ section 18, and in NW¼ section 16, Richland Township.

Near Ottumwa, mines were located at Keb (sec. 34, Richland Twp.), and in SE¼ SW¼ section 1, center section 2, and SW¼ SE¼ section 11, all of Center Township.

Mines at Laddsdale were located in the south part of sections 31 and 32, Washington Township.

Road surfacing material is available at any of these locations though definite information as to quantity and quality is lacking.

The dump at the old Willard mine in NW¼ NW¼ section 33, Polk Township, contains about 20,000 cubic yards of material, most of which, however, is poorly burned.

Sand and Gravel

Deposits of sand or gravel within the body of the glacial till are not definitely known to exist within the county, but it is likely that a careful survey would disclose supplies of that type. Certain sand and gravel deposits are reported as occurring between the glacial drift and the underlying Des Moines shales, and the following is quoted from Leonard's description of them: [76]

". . . In the NW¼ of the NW¼ of section 6, Cass Township, along a tributary of South Avery Creek — the black shales are overlain by a very ferruginous gravel and coarse, cross-bedded sand. In places the iron is so

76 Leonard, A. G., Geology of Wapello County: Iowa Geological Survey, Vol. XII, p. 474, 1901.

abundant as to form a cementing material for the constituent particles and a firm conglomerate or coarse sandstone is formed. — On North Avery Creek, in the SW¼ of section 26, the ferruginous gravel is again exposed at the base of the drift, which here has a thickness of six to fifteen feet. Still another locality where this deposit occurs is on the Des Moines River just above Eldon. The gravel and sand here have a thickness of ten feet; they rest on the shales of the Coal Measures and are overlain by fifty feet of drift. — The age of these gravels may be either Aftonian or Kansan. Their presence at the base of the Kansan Drift, from which they are not separated by any dividing line, makes it seem quite probable that they belong with that drift sheet, though this could not be determined with certainty."

Alluvial sand and gravel deposits in this county may be divided into two classes: those in the present bottomlands of the river but not in the channel, and those within the present channel of the stream. Terrace or second-bottom deposits are not known to be composed of sand or gravel anywhere within the county.

To the first class of alluvial deposits belong several pits, mostly near Ottumwa and Eddyville, very few of which are at present being commercially worked. The Eddyville Sand and Gravel Co. built a plant in the NE¼ section 7, Columbia Township, some few years past, but on account of financial difficulties the plant was shut down. The stripping at their deposit was about four feet, and the material below was of good quality and rather well graded, with 25 percent retained on the No. 4 screen.

The Ottumwa Sand Co. pump sand and whatever gravel is available from a bottomland area adjoining the river channel near center section 25, Center Township. The deposit shows 2 to 5 feet of overburden and 10 feet of clean sand to water level, with slightly coarser materials below. The sand and gravel is pumped from a barge through a pipe line to their plant on the shore. The plant consists of revolving screens, screw washers for the gravel, and a modified cone type of classifier for the sand. Large storage space is provided by pumping the sand, after it has been separated from the gravel, to the classifiers, which are arranged in tandem on a high trestle and discharge directly on the ground. The plant has railroad connection, and the cars of sand are loaded by crane from the stockpile or direct by chute from the classifiers, while gravel cars are loaded direct from small elevated bins at the plant. Figure 14 shows the pump barge and Figure 15 the arrangement of screening plant and sand classifiers and storage. The plant is

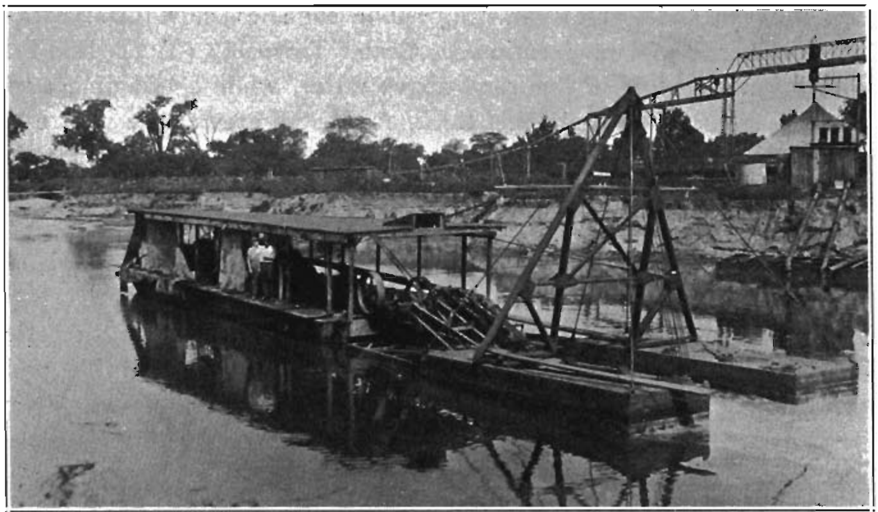


FIG. 14. — Ottumwa Sand Co., Ottumwa. View of Pump Barge.

electrically operated, and its capacity is estimated at 100 tons per hour, about three fourths being sand. Though shale and coal sometimes cause trouble, the material produced is ordinarily of good quality for concrete and, when coarse enough, for road surfacing as well.

A deposit of some 70 acres near the west end of the Vine Street bridge at Ottumwa shows five feet of clay overburden to water, then three to five feet of fine sand, followed by an average thickness of nine

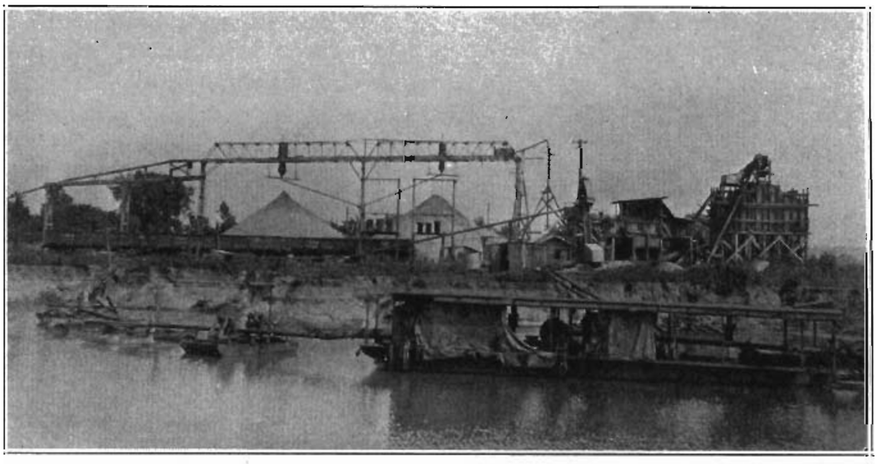


FIG. 15. — Ottumwa Sand Co., Ottumwa. General view of plant, showing sand classifiers and storage piles.

feet of gravel and coarse sand. A limestone ledge lies below this. Another deposit west of center section 31, Center Township (T. 72, R. 13), shows some 10 feet of fine sand above water, while a bed of gravel below is reported to be 12 feet thick. A 20-acre area at the west end of the dam near northeast corner section 23, Center Township, is underlain by sand and fine gravel down to the Ste. Genevieve limestone, which is found a few feet below water level.

From the foregoing descriptions it will be seen that the bottomland material consists chiefly of sand with a coarser sand or gravel below water level in some instances. It seems quite probable that a systematic examination of the bottomlands between Ottumwa and Eddyville, and to a lesser extent between Ottumwa and Eldon, would reveal other deposits accessible to transportation and of value equal to that of those mentioned. Stripping will be of differing thicknesses but easy of excavation and therefore inexpensively removed.

To the second class of alluvial deposits belong the sand and gravel bars found in the channel of Des Moines River and to a much smaller extent in the courses of some of its tributaries. Bars appear commonly in the Des Moines from Eddyville to Chillicothe. From Chillicothe to Ottumwa they may be present, but they are covered by back water from the Ottumwa dam. Below Ottumwa a few bars, some of large size, occur at irregular intervals. Brief descriptions of the more important deposits of this type follow:

SW¼ NW¼ sec. 6, T. 73, R. 15	Bar of coarse sand and fine gravel on west bank covers one acre
NE¼ SE¼ sec. 7, T. 73, R. 15	3-acre bar on west bank, 3 to 5 feet above low water, all fine gravel and coarse sand
NW¼ NW¼ sec. 17, T. 73, R. 15	3-acre bar on east bank prospected and found to contain some 50,000 cubic yards of gravel, much of it very coarse, and most of it below water
S. of center sec. 16, T. 73, R. 15	5-acre bar on south bank, mostly sand but with one acre of gravel at the upstream end
NW¼ NW¼ sec. 31, T. 73, R. 14	Small gravel bar on north bank at highway bridge
NE¼ SE¼ sec. 9, T. 71, R. 13	2-acre bar on east bank, shows gravel at upstream end, and the remainder sand

SW¼ SE¼ sec. 10, T. 71, R. 13	5-acre bar on north bank, nearly all fine sand
NW¼ SW¼ sec. 27, T. 71, R. 12	About three acres of gravel in large bar on southwest bank, material has an average of 75 percent passing the No. 4 screen
Near center NE¼ sec. 34, T. 71, R. 12	Bar on west bank below the mouth of Soap Creek shows two acres of gravel at upper end, with silt and sand near lower end, only six feet to bedrock.

The material in these bars is quite similar except for grading. Most of it is clean and composed of sound, hard particles, with much broken limestone in the larger sizes, and it is ordinarily suitable for any road or concrete purpose. The most common detriment to its use in concrete aggregate is the presence of shale or coal pebbles, in some cases constituting several percent of the whole.

Some of the smaller streams of high gradient are actively cutting in the drift or even in the consolidated rocks and therefore are carrying limited quantities of sand, gravel, and broken stone, which are deposited at favorable points in their channels. Such material supplies are small in size but are widespread in extent; most of them are easily available and thus of value for small local improvement projects.

WARREN COUNTY

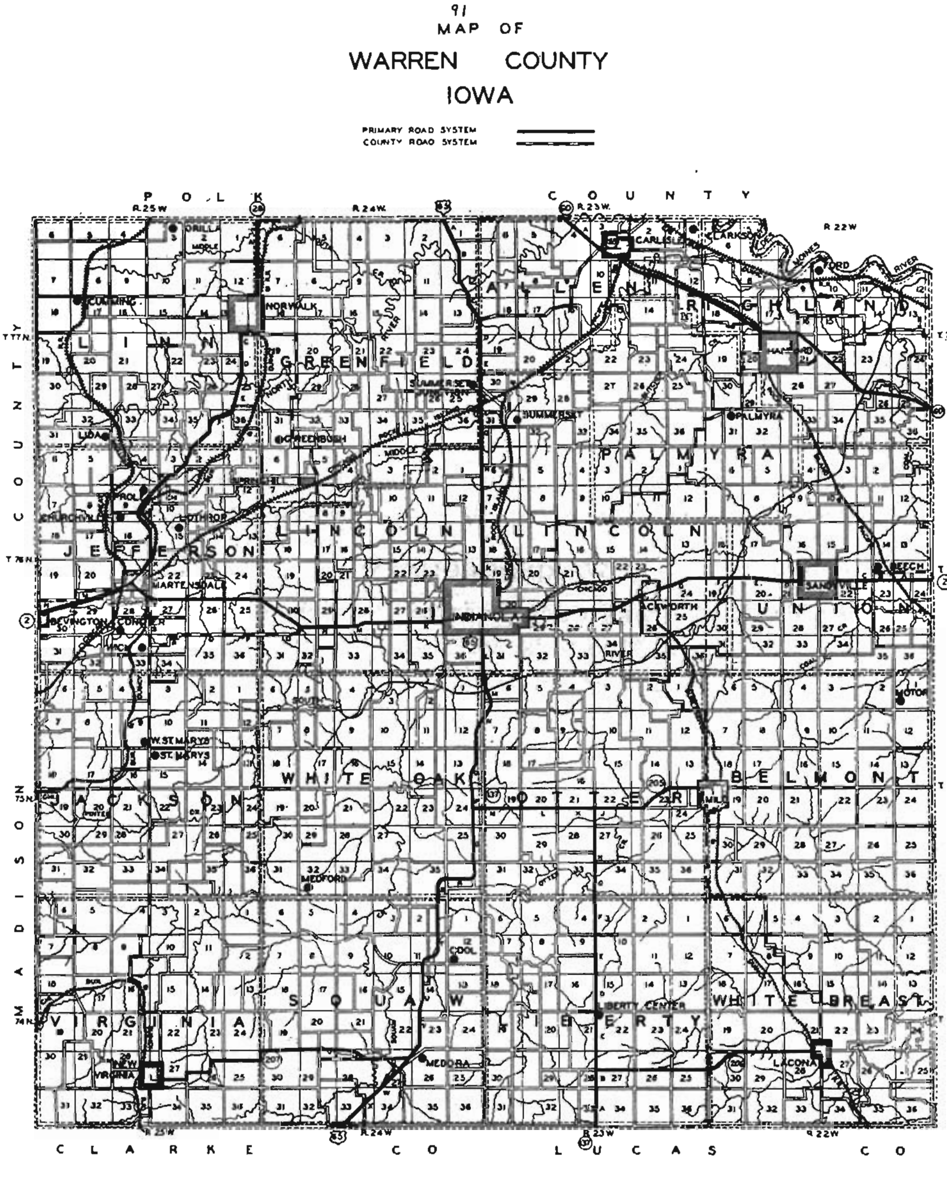
The bedrock of Warren county is of Pennsylvanian age; it was found in a drilling at Milo to be 350 feet thick and is probably much thicker in the western part. Upon this are found the Nebraskan and Kansan drift sheets, the former appearing in only a few of the deeper valleys. Loess mantles the drift in thickness up to about 10 feet, but in the rougher areas it has been largely removed by recent erosion. Alluvial deposits are extensive along the larger streams. In the case of the Des Moines these consist of silt, sand, and gravel. while on other streams they are almost entirely silt or fine sand. The total thickness of unconsolidated deposits is commonly less than 150 feet.

Limestone

The Pennsylvanian strata show a number of limestone ledges, of which none is known to be more than three feet thick. Only very small quantities, insufficient to justify the installation of a crushing plant, are available at any one point.

Surface limestones being thus unavailable, the possibility of mining from a vertical shaft may be worth considering. In this connection it is of interest to note that a drilling three miles south of Hartford reached 38 feet of limestone beginning at 330 feet, while one at Milo reached 17 feet of limestone beginning at 351 feet.

IOWA GEOLOGICAL SURVEY. PLATE XXXVII



Sandstone

Large bodies of sandstone are present at various points, some of them having thicknesses as much as 60 feet. However, the thick sandstones, so far as known, are entirely too soft to be of value for crushing and too fine-grained to be broken down and used as sand, unless possibly in some bituminous mixtures. Many of the thin sandstones are well indurated, but they are unavailable in sufficient quantity to justify the installation of even a temporary crushing plant. The best-known sandstone deposits are near Ford, Lacona, and southwest of Indianola.

Mine Shale

Coal mining has been carried on in all parts of the county for many years. The operations have all been on a small scale, largely as a result of unsatisfactory transportation facilities, and only meager quantities of possible road surfacing material have accumulated in the refuse dumps. Most of the mining has been in the northern and eastern parts of the county. One large mine has recently been opened, a stripping pit in NW¼ SW¼ section 30, Lincoln Township (T. 77, R. 23), but it is believed that the nature of the operation here will result in such a small proportion of coal in the waste banks that there is little or no possibility of combustion of the material in them.

Sand and Gravel

About fifteen sand and gravel prospects within the body of the glacial drift have been investigated by the State Highway Commission, but nothing worth opening was discovered. These prospects were all in the southern and southwestern parts of the county, in the territory adjacent to the Jefferson Highway. A careful detailed search might possibly bring to light workable deposits of this type, as has been the case in the nearby counties of Madison, Union, Clarke, and Mahaska.

Brief descriptions of the more important bar deposits on the south side of Des Moines River where it forms the northern border of this county are given below:

North of NW¼ NW¼ sec. 5, Richland Twp.	3-acre bar of gravel, coarse at the upper end and medium coarse at the lower end, extensively worked in 1932 and 1933; near south quarter-corner section 5, bar of coarse sand; north of southeast corner section 5, bar of coarse sand

NE¼ NW¼ sec. 10, Richland Twp.	Large bar rising five feet above water and showing gravel and coarse sand at the upper end, and sand farther down
NW¼ NE¼ sec. 11, Richland Twp.	5-acre bar showing gravel at upper end.

The material in these bars is for the most part clean and sound and of good quality for road or concrete work.

As is the case in the adjoining counties of Polk and Marion, the Des Moines River bottomlands here are underlain by large quantities of sand and gravel. Definite information on any such deposits in this county is lacking, but it is believed that the material may be found with only a few feet to 10 feet of overburden and that much of it may be suitable for any road or concrete work. On the other large streams of the county, the lower as well as the upper alluvium consists of silt and fine sand.

Many of the small short creeks which are actively cutting in the drift or bedrock carry sand and gravel, which is accumulated at various points in their channels. All deposits of this type in this county are very small, and the larger streams are observed to carry only silt or fine sand.

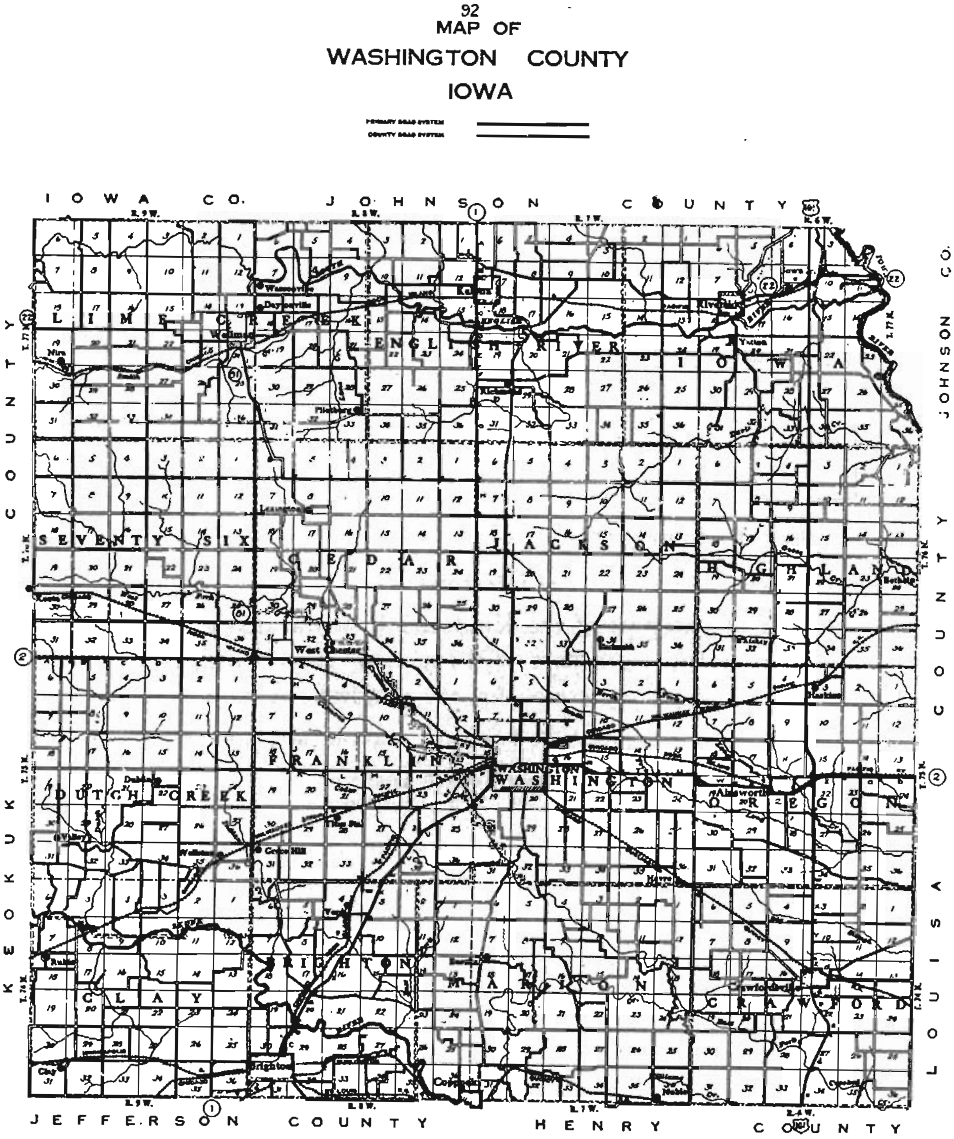
WASHINGTON COUNTY

Practically all of the bedrock of this county is of Mississippian age; the Kinderhook occupies the northern and northeastern parts, the Burlington the central part, and the St. Louis and Ste. Genevieve the southern one third. On account of the scarcity and obscurity of outcrops, the boundaries between the areas of the different formations can not be accurately drawn. A few small outliers of Pennsylvanian beds overlie the Mississippian, but these have no importance in connection with this report.

Both Nebraskan and Kansan drift sheets are represented in the mantle rock, the former appearing at a few places in the deeper valleys. Aftonian deposits are recognized in the bluffs along Iowa River and perhaps at other points. A mantle of loess lies upon the drift; generally it is only a few feet thick, and in the rough areas near the larger streams it has been mostly removed by recent erosion. Alluvial deposits are not extensive and consist almost entirely of silt and fine sand.

The total thickness of unconsolidated deposits in most of the county is commonly less than 100 feet. However, well records have shown the presence of a preglacial channel from two to four miles in width, extending diagonally from the northwest corner to the southeast corner (see Figure 16), in which the bedrock is overlain by 100 to 350 feet of loose materials. Obviously, in this area it is useless to look for rock exposures.

IOWA GEOLOGICAL SURVEY. PLATE XXXVIII



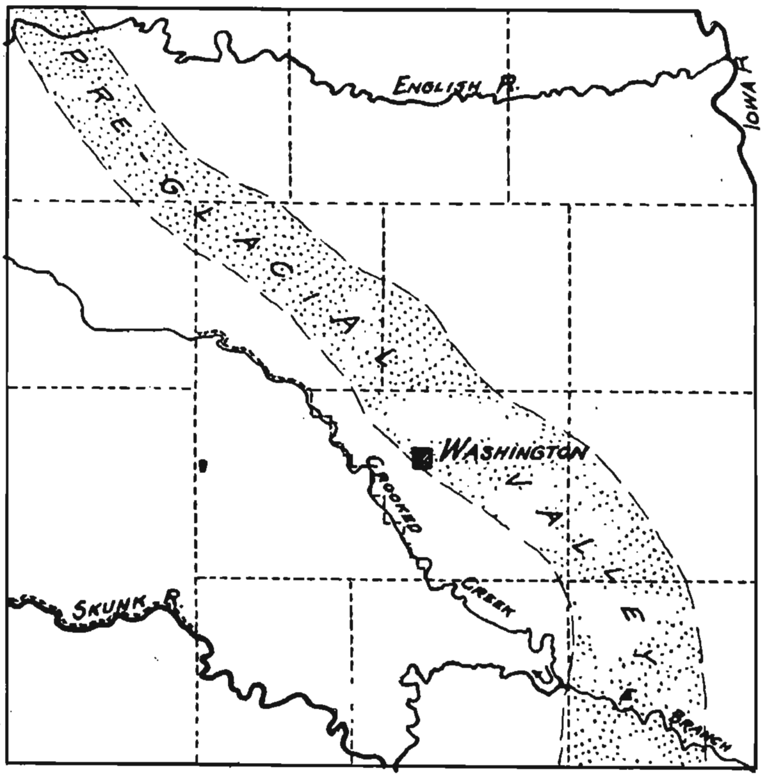


FIG. 16. — Map of Washington County showing present drainage and pre-glacial valley (after Bain).

Limestone

A number of outcrops of the Kinderhook strata, many of them obscured, occur in the north part of the county. Bain [77] has worked out the following general succession for the Kinderhook here:

	Feet
3. Wassonville limestone, soft, buff, magnesian, heavy-bedded, with several bands of white chert	30
2. English River gritstone, a soft, fine-grained sandstone	18
1. Maple Mill shale, argillaceous and for the most part soft	12

The Wassonville limestone is too soft for crushing for aggregate, but may be used for surfacing on roads which carry a light or moderate traffic. The other two divisions are of no value for road or concrete work.

On account of the thickness of the Wassonville member, it is available for quarrying in limited quantity, though not with light stripping, at almost all the points of its exposure. Following are listed possible

[77] Bain, H. F., Geology of Washington County: Iowa Geological Survey, Vol. V, p. 134, 1895.

quarry sites: SW¼ SW¼ section 18, township 77, range 6, old quarries, 20 feet deep; NW¼ SW¼ section 32, township 77, range 6, 15 to 20 feet of stone in south bank of Davis Creek; N½ NW¼ NE¼ section 6, Highland Township, stone 20 feet high in the east bank of Davis Creek; SE¼ SW¼ section 17, township 77, range 7, 5 to 10 feet of stone in upper bluff south of English River; SE¼ NE¼ section 20, township 77, range 7, small old quarry; NE¼ NE¼ section 24, township 77, range 8, about 10 feet of stone adjoining small old quarry; SW¼ NE¼ section 16, township 77, range 8, 16 feet of stone in old railroad quarry; NW¼ SE¼ section 8, township 77, range 8, south bank of English River at Maple Mill, 16 feet of stone; SW¼ section 6, township 77, range 8, old quarry, 30 feet of stone; and E½ SE¼ section 12, township 77, range 9, recent quarry workings, 15 feet of stone. Other locations are reported to be farther west along English River. At any of these points minimum stripping is 10 or 15 feet, but moderate areas are workable without exceeding a depth of 20 feet.

The Burlington formation is obscurely exposed at a few points in the northern and eastern parts of the county. It consists principally of coarse-grained medium-hard crinoidal limestone with a few thin bands of chert. Examination of these sites shows that in every case overburden is of prohibitive thickness. Mining from the outcrop is a possibility, but in general the exposure is so limited in extent, and beds are so thin and so low with regard to the ground water table, that even the mining operation might prove difficult. At most places only a few feet of stone can be seen. The best-known localities of outcrop are as follows: NE¼ NE¼ section 13, township 77, range 9; SW¼ SW¼ section 17, township 77, range 8; SE¼ SW¼ section 31, township 77, range 6; south of center section 20, Highland Township; NE¼ SE¼ section 17, Oregon Township; through section 33 and in SW¼ NW¼ section 34, Highland Township, on Whisky Run; and in SW¼ NW¼ section 22, and east of center NE¼ section 21, Highland Township.

More extensive outcroppings of the Burlington limestone are found near Crooked Creek east and north of Westchester. Two or three long-abandoned quarries are located in NE¼ SW¼ section 2, township 75, range 8. These have been worked back to a point where overburden is 10 to 15 feet thick, and only 8 feet of limestone is now exposed. However, both Bain [78] and Van Tuyl [79] have published sections observed at

78 Bain, H. F., Geology of Washington County: Iowa Geological Survey, Vol. V, p. 127, 1895.

79 Van Tuyl, F. M., The Stratigraphy of the Mississippian Formations in Iowa: Iowa Geological Survey, Vol. XXX, p. 142, 1921-22.

this point, and these show 19 to 20 feet of coarse-grained gray crinoidal limestone, with a few layers of brown or gray finer-grained limestone, a few small lenses of chert, and at least one shaly parting a few inches thick. With such a thickness of stone available, even this heavy overburden might be profitably moved.

Good exposures of the Burlington limestone occur in W½ W½ section 20, Cedar Township, and more limited exposures are present in E½ section 19, and NE¼ section 29, Cedar Township. This rock is available in fairly large quantity and has been quarried at different times in SW¼ SW¼ and SW¼ NW¼ section 20. The section obtained in SW¼ SW¼, the site of the most recent operations, is as follows:

		Feet
10.	Loam and glacial clay	2+
9.	Limestone, brown, soft, much weathered, with much clay and chert	3
8.	Limestone, similar to the above but less weathered and cleaner	1
7.	Limestone, brown to buff, coarse-grained, heavy-bedded	3¾
6.	Shale, green	½
5.	Limestone, coarse-grained, light gray to brown, hard, crinoidal	4
4.	Chert, white	½
3.	Limestone, similar to No. 5	3½
2.	Limestone, buff to yellow, crystalline, coarse-grained	¾
1.	Limestone, brown, fairly hard, crystalline, coarse-grained	3½

Here also is found some 20 feet of limestone. The stone is suitable for surfacing work but rather soft for aggregate, except possibly in concrete where medium high strength is satisfactory.

Exposures of the St. Louis limestone are present in the territory south of Washington as far as Coppock and Brighton and near Skunk River west of Brighton, as follows:

An exposure of 22 feet of limestone is located immediately northwest of the junction of Cedar and Crooked Creeks, in SW¼ NE¼ section 31, township 75, range 7. This stone is not uniform in quality but on the average is suitable for road surfacing. It is available on an area of two acres with 2 to 20 feet of overburden. The rock is evidently Upper St. Louis, as at Verdi. An exposure in the same horizon in NE¼ NE¼ section 31, shows, in descending order, seven feet of hard brecciated and folded limestones, in beds of various thicknesses, and nine feet of sandy, poorly indurated massive marl.

A number of outcroppings of the Lower St. Louis are present in sections 5, 21, 31, and 33, all of Marion Township. However, these show interbedded shale and limestone, the former predominating and the latter almost entirely unavailable for quarrying.

Scattered exposures of St. Louis strata are visible in the bluffs south of Skunk River from Coppock west to the county line. In the vicinity of Brighton these are overlain by the Ste. Genevieve beds. The most representative sections are north of Brighton. The following section is combined from the records of test holes made near the old quarries in SE¼ NE¼ section 30, Brighton Township:

	Feet
5. Thin-bedded limestone, sandstone, and shale, in roughly equivalent proportions	4
4. Limestone, gray, medium-grained, grading into a hard calcareous sandstone	2¾–3¼
3. Sandstone, yellowish, soft, locally with some shale	6–9
2. Limestone, gray, fine-grained, hard, sound, massive, in regular but slightly flexed beds	8½–9½
1. Sandstone, calcareous, fine-grained, soft	2+

Numbers 2 and 4 are commonly suitable for road or concrete work. However, so extensive have been quarrying operations here, even in recent years, that most of the stone available by stripping has been removed. Limited quantities are still available farther north, in NE¼ NE¼ section 30.

The following section is combined from the records of test holes put down near a limestone exposure in NW¼ SW¼ section 28, Brighton Township:

	Feet
4. Limestone, hard, gray, fine-grained, with calcite nodules and some sandy zones	½–2
3. Sandstone, soft, gray, locally with some shale	1½–7½
2. Limestone, hard, sound, gray, fine-grained, with numerous small nodules of calcite and pyrite; includes a 3-inch sandstone bed, and locally a 1-inch shale seam near the top	6–7
1. Sandstone, soft, gray	1+

The beds of this section are given the same numbers as their equivalents in the section preceding. According to Van Tuyl, who has published sections for this locality,[80] Nos. 3, 4, and 5 represent the Ste. Genevieve and Nos. 1 and 2 the Upper St. Louis. At the location last mentioned the limestone (No. 2) is available by stripping to the extent of 9,000 cubic yards. The quantity might be increased by mining, which, however, with such a thin ledge, might prove difficult and dangerous.

Exposures of the Upper St. Louis, and in some places the Ste. Genevieve beds, occur at other points in sections 28, 29, 30, and 19, Brighton Township. However, weathering has obscured them, and old quarrying operations have taken out much stone, so that at no point is limestone as easily available as in NW¼ SW¼ section 28. The Lower St. Louis is present in the lower part of the bluffs and is exposed at a few

80 Van Tuyl, F. M., The Stratigraphy of the Mississippian Formations in Iowa: Iowa Geological Survey, Vol. XXX, pp. 272-273, 1921-22.

points. Here also it consists of shale with subordinate amounts of limestone.

Van Tuyl [81] has published the following section, obtained near Verdi (NE¼ sec. 9, Brighton Twp.):

	Feet
6. Drift, reddish, with decayed granite boulders	4½–11
5. Sandstone, coarse-grained, yellowish, soft	6½
4. Limestone, compact, gray, finely brecciated	⅓
3. Limestone, ash-gray, fine-grained, rather soft, brecciated; thin-bedded and laminated above; locally little disturbed and heavy-bedded below	9½
2. Sandstone, gray, fine-grained, soft, incoherent, shaly; thickens and thins owing to mashing down of limestone above	1–2½
1. Sandstone, massive, fine-grained, soft, gray, weathering yellowish; with mashed irregular lentils of compact gray limestone. Exposed	7

All but Nos. 5 and 6 of these beds are referred to the Upper St. Louis. More obscure exposures of similar strata are present in sections 9, 15, 16, and 17, Brighton Township, and a few others near Grace Hill, but at no point is any large quantity of stone easily available for quarrying.

A number of outcroppings west of Brighton and south of Skunk River, show only the Lower St. Louis beds, which are predominantly shale and offer nothing of value for quarrying.

A few scattered exposures in the northwest part of Dutch Creek Township indicate the presence of the Burlington limestone but show almost nothing available for quarrying.

Sand and Gravel

Little is known of the glacial gravels in Washington County. Nevertheless, they have been observed and reported at a few points, and it is believed that careful search would reveal other supplies, none, perhaps, of large size but sufficient for at least a part of the local needs. The following locations are known:

NW¼ sec. 18, Marion Twp.	In a road ditch one fourth mile south of school
SE¼ SW¼ sec. 33, T. 76, R. 8	High bank on south side of creek shows sand and gravel, with till both above and below
Near SE corner sec. 36, Iowa Twp. (T. 76, R. 6)	An exposure of 20 feet of sand and gravel, mostly fine, overlain by 10 to 50 feet of till.

The Iowa River bottomlands in Johnson and Louisa Counties are underlain by large deposits of sand and fine gravel, which may also be

81 Van Tuyl, F. M., The Stratigraphy of the Mississippian Formations in Iowa: Iowa Geological Survey, Vol. XXX, p. 272, 1921-22.

found in those bottomland areas that lie along the east side of Iowa Township of this county. In general, the river is close to the west bluffs here, and such bottomland areas are small. The following are brief descriptions of those bars which appear on the west bank of the river in Iowa Township:

NE corner sec. 3	1-acre bar of fine gravel and coarse sand
NW¼ SW¼ sec. 2	2-acre sand bar with a thin layer of gravel at the surface
NW¼ SE¼ sec. 2	1-acre high sand bar
SE¼ NE¼ sec. 11	2-acre sand bar
SE¼ NE¼ NE¼ sec. 14	4-acre bar, principally coarse sand, with some gravel at the upper end
SE¼ NW¼ SW¼ sec. 24	2-acre bar, principally coarse sand
E of SE corner, sec. 36	3-acre bar of coarse sand.

Alluvial deposits along English and Skunk Rivers consist almost entirely of very fine sand and silt. In the case of the latter stream, bars are sometimes formed at the mouths of those tributary streams that have cut into the Mississippian limestones. Such bars contain an ill-assorted mixture of sand, gravel, boulders, and broken rock, some of which is usable for road surfacing work by crushing.

Any of the small creeks of high gradient that have cut into a considerable thickness of glacial till or Mississippian limestone have along their courses numerous small bars of sand, gravel, or broken stone. Such bars are individually of no importance, but together they constitute a source of material for local road improvements that is worthy of consideration.

WAYNE COUNTY

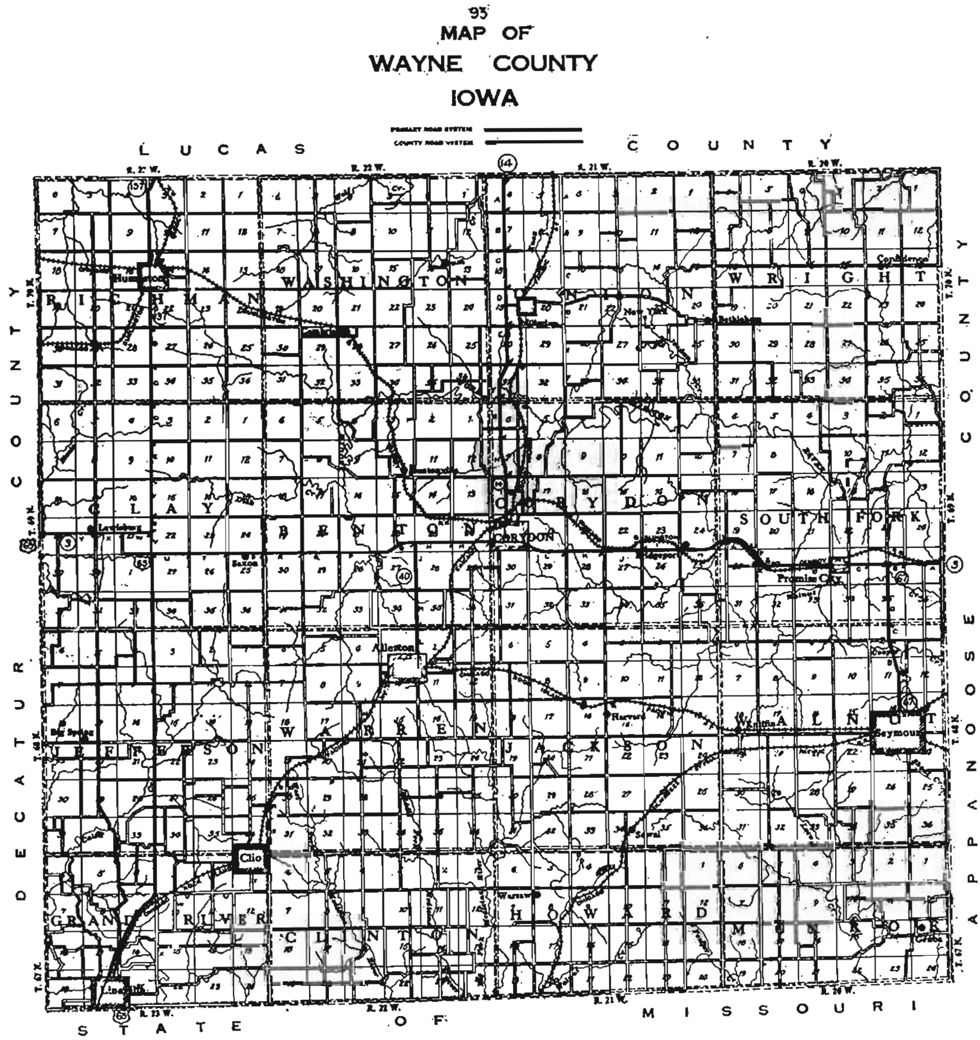
Beds of the Des Moines series underlie the whole county but appear only in the northeast and southeast corners of Wright Township and the northeast corner of South Fork Township. Both Nebraskan and Kansan drifts are recognized above the consolidated rocks, the total thickness of the two reaching locally as much as 400 feet. Loess veneers the drift over most of the county to a depth of a few feet. Alluvial deposits are extensive on a few of the larger streams but consist almost entirely of silt or fine sand.

Limestone

Limited exposures in section 1, Wright Township, show only one bed of limestone, which is 1½ feet thick and thus unavailable for quarrying.

A number of outcroppings, most of them obscure, in the S½ section 36, and extending into the southeast corner of section 35, Wright Township, and the NW¼ section 1, South Fork Township, show limestone which in places is as much as 15 feet thick, and which is underlain by shale. The section obtained in SW¼ SE¼ section 36 is given below:

IOWA GEOLOGICAL SURVEY. PLATE XXXIX



		FEET
3.	Limestone, gray, hard, fine- to medium-grained, subcrystalline, sparingly fossiliferous, massive	3–4
2.	Limestone, as above, but somewhat brecciated with numerous irregular partings of shale. A 2- or 3-foot zone of rather soft shaly limestone near the middle appears to be quite persistent	12
1.	Shale, gray, argillaceous	10+

Numbers 2 and 3 are suitable for surfacing work and in large part for aggregate as well. They are available along the bluff in considerable quantity.

An old quarry in NE¼ SW¼ section 36 may be extended to the north. The stone is not well exposed but appears to be at least eight feet thick and to be similar to No. 2 of the section given.

Similar beds appear in a small area northeast of the bridge in NW¼ SE¼ section 36, where they might be quarried by stripping. Four feet of gray hard fine-grained thin-bedded limestone may be seen east of center NW¼ section 1, in the bluff west of the South Fork of Chariton River. It is underlain by nine feet of more massive and brecciated limestone. Above the exposure the hill rises steeply, and only a small quantity is available, except by mining.

Some nine feet of similar stone can be made out in the bank of a new channel of South Fork, in SE¼ NW¼ section 1. This may be available over an area of about one half acre with 10 to 15 feet of overburden.

The Mississippian limestones are far below the surface in Wayne County (748 feet in a drilling at Corydon), and mining of them from a vertical shaft would thus prove rather costly.

Mine Shale

Coal mining has been and still is carried on at various points in the county, principally near Seymour and Harvard and in the eastern part of Wright Township. Only at Seymour have the operations been on such scale as to furnish any important amounts of surfacing material from the refuse dumps. Large dumps exist in SW¼ NE¼ section 13, and again in SW¼ NE¼ section 24, both of Walnut Township. Each of these has furnished many thousand cubic yards of surfacing material and is able to furnish a fairly large additional quantity.

Sand and Gravel

Although the drainage of Wayne County is complete, the streams are all small. Relatively few of the slopes are steep, and consequently there are not many exposures of the till, with its included masses of gravel or sand. Small pockets, none worthy of development, have been seen near the southwest corner of Jefferson Township; in section 32, Clay Township; in section 4, Benton Township; and in Warren Township, southeast of the town of Allerton.

Many of the streams within the county have excavated their valleys largely in the glacial till, and the sand and gravel from the till appears in bars along their courses. However, since glacial time none of the streams has been sufficiently energetic to carry coarse sand or gravel far enough so that any considerable quantity is accumulated in one place. Bars are few and where present consist principally of fine sand and silt.

CHAPTER IV

DEVELOPMENT OF MATERIAL DEPOSITS

PROSPECTING METHODS

The first step in the development of a material deposit is the determination of the quality and amount of material which may be obtained from it. This is of the greatest importance; upon it depends not only the decision as to whether or not the development will be made, but also the choice as to type of equipment used, arrangement of that equipment, and the whole operating program. Conservative and sound practice in this state dictates that as much as 10 percent of the total cost of development may properly be spent on prospecting.

Factors Governing the Value of Material Deposits

Before any detailed prospecting work is done, a certain amount of preliminary investigation is necessary in order to determine which deposit, if any, shows promise of being worthy of detailed examination looking forward to development. In making such a determination the most important factors are as follows: quality and amount of material present in the deposit; overburden on that material, which must be removed, or supported while the material is excavated from beneath; accessibility to transportation; and probable market which can be served from the deposit in question.

Quality and Amount of Material. — The accurate determination of this factor must wait until detailed prospecting is done; however, some kind of approximate estimate is necessary as a first step in making the decision as to whether or not any more detailed investigation is warranted.

To produce concrete aggregate economically, the deposit worked should show a fair degree of uniformity, so that frequent changes in operating procedure will not be necessary to meet variations in the material. Though such changes can be made in the modern well-equipped plant, they add noticeably to the production cost and should be avoided if possible. On the other hand, a deposit desirable in other respects but deficient in this may be considered for development, and the operating schedule may be designed for the differences which may be expected. If a deposit is to be utilized only for surfacing work, less uniformity is required as experience has shown that a satisfactory road surface can be made with widely diverse materials.

The grading of the material in a deposit is not often that which is desired in the finished product; however, equipment that is available and in common use is adequate to correct the grading at reasonable cost for either fine or coarse aggregate or for surfacing material. If such correction involves wasting a part of the material, it of course increases the cost.

In many deposits impurities are not present in sufficient amount to prevent use of the material for surfacing work without any special provision for removing the undesirable substances. However, if it is intended to produce concrete aggregate, constant watch must be kept for those impurities which experience has shown are not removable or even reducible in amount to the prevailing specification limits at reasonable cost. Watch must also be kept for any other foreign substances not mentioned in specifications but nevertheless possibly harmful. The most troublesome of these impurities in southern Iowa are soft stone and iron oxide in gravel, or soft stone, unsound stone, shale, and chert in crushed stone. They give difficulty because their specific gravity and many other of their physical properties are not much different from those of stone of good quality. Ordinary low-cost methods, such as screening and washing, are inadequate to remove them; the only alternative is the rather expensive one of hand picking. Such undesirable substances as silt, organic matter, coal, and sticks are removed with very little difficulty by washing or screening. Shale in gravel offers more of an obstacle, but in southern Iowa it is not commonly present in any important amount.

The size of deposit which can be profitably developed differs widely, depending upon such factors as capital cost of the development and margin of price obtainable over production expense. If capital cost is high, either the volume of material produced — and sold — must be large, or the margin of profit on a smaller quantity must be good in order to liquidate that cost. If capital cost is low, or if the plant and equipment are of a portable type that can be cheaply moved and used elsewhere, a smaller quantity of material or a smaller margin of profit will be sufficient. In general, experience in Iowa has shown that a portable plant for making surfacing gravel may be profitably moved in for quantities as low as 1,000 cubic yards. The plant for making surfacing stone requires more machinery and is seldom set up for less than 2,000 cubic yards. Portable or semiportable plants for the production of concrete aggregate, either gravel or crushed stone, have operated profitably under favorable conditions on as little as 25,000 cubic yards of material. Larger plants, permanently located and with rail shipment facilities, are seldom built for less than 500,000 cubic yards of material.

Overburden. — The accurate determination of overburden must likewise await detailed prospecting, but a general approximation of its amount and character is usually a part of the preliminary estimates. The amount of overburden which can be removed per unit of material obtained depends entirely on the cost of removal and the margin of profit that may reasonably be expected in production. General practice in the state of Iowa does not allow the removal of more than one-half cubic yard of overburden per cubic yard of material for permanent plants, or more than one cubic yard per cubic yard of material for temporary plants. However, a few cases are known where, on account of favorable location and good quality of material in a deposit, as much as $1\frac{1}{2}$ or 2 yards per yard of usable material have been profitably removed.

In some rock deposits where overburden is light, the upper part of the rock is much weathered and roughened, while the same formation where more deeply buried shows a more even and solid upper surface. Thus the removal of a moderately heavy overburden in the latter situation may prove no more expensive than a very light one under the former conditions.

The cost of removing the overburden depends on its nature; thus loam or soft clay, unless very wet, may be handled more cheaply than muck, mud, shale, or rock.

In cases where the overburden on a rock deposit is heavy, it may prove advisable to leave this overburden in place and mine out the rock by tunneling, leaving a part of the rock as pillars and roof. This method of operation will be described in more detail in the following section. It may be said here that where overburden is heavy the tunneling plan is practicable and no more expensive. Mining of deeply buried road or concrete materials from a vertical shaft is another but more expensive alternative, which will receive further mention in the following section.

Accessibility to Transportation. — To be capable of profitable development a deposit must be accessible to transportation. Until a few years ago this required proximity to a railroad. Now, however, with the wide-spread improvement in highways during the past few years, together with a corresponding decrease in highway transportation costs, the availability of rail transportation is not so important, and many plants that are intended to serve a local market are not equipped for rail shipments. For hauls of about 20 miles or more, rail transportation is still cheaper, and if it is desired that a deposit reach both the local and the more distant markets, the plant should be equipped for both highway and rail shipments. All points in the state are accessible from some public highway, but those that are close to a main artery of traffic or to a well-improved highway connecting with main arteries of traffic can obtain the cheapest highway transportation. If large quantities of material are to be shipped by rail, locations close to the junction of two or more railroad systems are desirable as being within easy reach of the larger territory.

Transportation by water is cheaper than that by either rail or highway, but it is unavailable to most of the material deposits in southern Iowa. Certain supplies in the channels of Mississippi and Missouri Rivers in this area are available for water haulage. It must be remembered that even though water transportation is available for a material supply, it may not be available to all of the markets which that supply is intended to reach.

Available Markets. — Market is a rather indefinite thing and often very difficult to estimate accurately. Yet an analysis of this factor is important if the material development venture is to prove successful. Too many plants in Iowa and adjoining states have been built without due consideration for this item, with the consequent result of financial failure and loss of capital by owners or stockholders.

To discuss this subject comprehensively is beyond the scope of this study and beyond the knowledge of the writer. It may be said briefly that market depends upon such factors as classes of trade which may be supplied, competition from other plants for these classes of trade, duration of such trade, possibility of developing new lines, and many other factors of similar nature. In general, the best markets are found near centers of population or near main arteries of travel.

Many small deposits are developed by means of temporary or portable plants, with a view toward serving only one class of trade in the immediate locality or even to serve some definite improvement project. These smaller markets are much easier to define and evaluate correctly than are the larger ones, which are to be reached by the permanent plants.

Preliminary Material Surveys

The preliminary survey constitutes an essential part of prospecting work. It can be handled most efficiently by one man. This man must know enough about the origin and occurrence of road or concrete materials to enable him to estimate the probable size and nature of the deposits from their surface outcrops. He must also be familiar enough with the uses to which the materials are to be put so that he can make the decision as to which deposits warrant further investigation. It is furthermore desirable that he be familiar enough with the general materials situation to enable him to consider the deposits that he sees in true proportion to their worth. All these qualifications are necessary in order that his judgment on the questions which confront him may be correct, for much depends upon his decisions and his recommendations for further work.

After a territory for examination has been selected, the first step in the preliminary survey is to study the available literature on the geology of that territory. In Iowa, the most fruitful and most easily available source of such information is in the publications of the Iowa Geological Survey. In many localities there are amateur or professional geologists who are especially familiar with local conditions and who can give valuable information, which is unobtainable in any other way.

After a study of the geology, the next step is to inquire of any persons who may be well informed as to points where material deposits may be found. Such persons may be local engineers or other professional men, county or township or city officials, or any private individuals who may have information.

The next step is a careful visual examination of the most promising territory. Such an examination may often be made best on foot by following the larger valleys and examining any other localities where erosion is active and subsurface formations are thus more likely to be exposed. After making such an examination and noting points which show promise of having available material, it may sometimes be advisable to make a more careful visual examination of those points. It is usually good practice to take one or more representative samples of the material, if they are easily obtainable, in order to check the visual judgment on it.

Detailed Prospecting

Organization of Party. — The Chief of a prospecting party need not be a man of technical training, especially not if the preliminary material survey has been well done. He should know something about the occurrence of materials and the uses to which they are put, so that he can locate his test holes properly, put them down to the right depth, and know when he has put down enough of them. This knowledge is best gained from experience in investigating material deposits. He should have the organizing ability to enable him to use his men to best advantage and to keep them satisfied on the work. He should know enough about engineering drafting so that he can draw up a complete and understandable report on his findings. He should, above all, be industrious and painstaking in his work.

If a prospecting party is permanently organized it is convenient to have some man on it to whom the Chief can delegate his authority in his absence. Such a man should be able to conduct the work of the party for periods of time ranging from a few hours to a day or two.

The number of assistants on a prospecting party differs with the kind of work to be done and the size of the deposit that is being investigated. For work on small deposits which may show only a few thousand cubic yards of available material, or even none at all, one or two assistants may be sufficient. In the prospecting of large deposits, as many as ten assistants, or even more, may be profitably employed. In general, it may be said that assistance on prospecting work is inexpensive help, and that the Chief should use as many men as he can keep busy. For this purpose common labor is usually employed, though for operation of the equipment used in prospecting under water, experience in that work is a valuable asset.

Determination of Overburden. — A sufficient number of stripping holes should be put down so that a good idea will be obtained, not only of the thickness and character of the overburden, but also of the variations in that thickness and character. As the prospecting of any particular deposit progresses, the results of test holes will indicate how far apart stripping holes should be. Often only such determinations of overburden are necessary as are made in putting down test holes for quantity and quality of the underlying material; such is the case where the overburden shows no greater or more numerous differences in character than does the material, as with most gravel deposits. On the other hand, many rock deposits show uniform and dependable strata but have an extremely irregular upper surface, the result of erosion and weathering; in these cases one or two determinations of thickness and character may be sufficient for the whole deposit, while stripping holes must be not more than 30 or 40 feet apart.

Overburden ordinarily consists of clay or of some form of soft or inferior rock, such as shale. If the clay is not too hard, the ordinary soil auger or post hole auger is satisfactory for penetrating it. If a post hole auger is used, the 4-inch, 6-inch, or 8-inch size is most desirable. When auger holes are put down through a glacial drift clay overlying rock, the auger may be stopped by a boulder in the clay or by a large loose fragment of the rock at some distance above the solid ledge, thus giving an erroneous measurement of the thickness of overburden. Consequently, where stripping holes on rock must be carried to any depth, it is usually more desirable to put down a pit large enough so that a man can work in it and examine the bottom and sides closely; such a pit may be round and about four feet in diameter, or about four feet square, or rectangular in shape, about 2½ feet by 5 feet, or any other shape that is convenient. It is usually unnecessary to slope the sides of the pit; if they do not stand up alone, cribbing is more satisfactory.

Determination of Thickness of Material. — As with overburden, the number of holes into the material should be sufficient to give a good idea of the variations in thickness and character in the deposit. The practical consideration of cost of putting down test holes or pits, also the amount that is available to spend on prospecting must also be kept in mind. On deposits of glacial gravel, many of which show wide differences within short distances, it is desirable to have holes not more than 50 feet apart. Alluvial and terrace gravels are ordinarily much more uniform, and test holes in them may safely be 100 feet, or in large deposits 200 to 300 feet apart. Certain types of rock, such as sandstone, conglomerate, or conglomeratic limestone, show wide range in character, horizontally as well as vertically, and test holes through such deposits, if they can be put down at reasonable cost, should be not more than 200 feet apart. Most limestones, however, are very uniform and dependable within the limits of any single deposit, and one or two test holes may be sufficient for areas up to five or even ten acres. Sections of rock faces which show the succession of the strata may often be substituted for test holes through the deposit.

Test holes should be carried wherever possible to the bottom of the deposit or to the bottom of material that is likely to be worked. In case some of the holes cannot be put down the whole depth, enough should be put down so that a satisfactory number will reach the bottom of the deposit.

Holes in gravel deposits up to about 15 or 20 feet in depth may often be put down satisfactorily and most cheaply with the 6-inch or 8-inch post hole auger operated by hand. The handles of most such augers are made of a standard size of pipe, so that extensions may easily be added as the hole is deepened. A disadvantage in the use of the auger for the deeper holes is that material caves from the sides of the hole and falls to the bottom, where it is mixed and brought up with bottom material; thus accurate sampling becomes impossible. If a deposit is intended to be utilized for surfacing material only, accurate sampling is not so essential, and the auger may be used as deeply as it will work. Instances are known where holes have been put down with an ordinary post hole auger to depths as great as 55 feet. When gravel is coarse or contains numerous pebbles larger than 2 or 3 inches, it becomes impossible to use a post hole auger in it to any depth; in such case, either a 12-inch or 18-inch well auger or some other type of power-driven auger must be employed, or a pit must be dug.

Dug pits are commonly used in gravel, where accurate sampling of deep holes is necessary, or where the material is too coarse or too hard and firm to be penetrated by an auger. The previous section, on Determination of Overburden, mentions convenient sizes and shapes for such pits. A man can throw material out of a pit 8 or 10 feet deep; when the pit becomes deeper, two or more men are required, one to dig the material, and one or more to hoist it to the surface in a bucket. For refilling a pit an ordinary slip scraper is useful. If material which is being dug through shows a tendency to cave, it may be necessary to crib the pit. Such cribbing must be made strong enough to withstand the pressure from the sides; it should also fit tightly in the hole or the hole should be backfilled outside it to prevent impact against it of masses of material which might otherwise become loosened and fall against it. Cribbing may be framed from timber or may consist of sections of steel or concrete pipe of large diameter.

Gravel under water will not stand in vertical or nearly vertical walls; consequently, if prospect holes are to be carried below water, some kind of casing outfit must be used. If the gravel pebbles do not exceed about two inches in size, the most convenient plan is to use an ordinary sand bucket or slush bucket (a length of tube with some kind of check valve in the bottom) inside a 4-inch, 5-inch, or 6-inch casing. The sand bucket is agitated up and down in the bottom of the hole and the current thus created in the water washes the sand and gravel up into the tube, where it is held by the check valve. As the sand and gravel is taken out, the casing is sunk. The sinking and later removal of the casing is much easier when a flush-joint casing is used.

For coarser gravel under water some kind of grab bucket, operating inside a larger casing, must be used. Various types of these buckets are in use; Figure 17 illustrates one of the orange-peel type used by the

FIG. 17. — Orange-peel bucket, used with 12-inch casing.

State Highway Commission inside a 12-inch casing. With any kind of casing outfit it is usually advisable to open the hole down to the water line by some other means, as both casing and sand or grab bucket work much better in wet material than in dry.

Test pits may also be put down in solid rock by drilling and blasting. This is often rather expensive, but the expense is in many cases justifiable. Time and money will be saved if a power drill, driven by air from a portable compressor, is used for the drilling preparatory to blasting. Core drilling may be slightly cheaper than blasting down of test pits but has the disadvantage that the core obtained seldom gives sufficient stone for a complete set of physical tests. The size of core drill commonly used is from 1 inch to 2 inches, though cores as large as 5 or 6 inches have been taken. Churn drilling in rock is usually cheaper than core drilling but has the disadvantage that only a few physical tests can be made on the cuttings, which constitute the only sample obtained; the speed and ease of drilling and the experience and judgment of the driller are the only means for estimating the quality of the stone. However, as mentioned previously, cleaning off one or two open natural faces somewhere around the edge of the deposit is often the only test into the rock that is necessary. From these faces, the succession and attitude of the strata may be observed and satisfactory test samples obtained.

Sampling. — When auger holes are put down in gravel, the material taken from them is commonly piled in a ring around the mouth of the hole, where it is convenient for sampling. If more than one kind of material is encountered, it is usually advisable to take separate samples of each kind rather than to attempt to include them all into one composite sample. It is obvious that all samples should be accurately identified as to location of test hole and depth in test hole from which they were obtained. Samples of 25 to 60 pounds of pit-run gravel are adequate for a complete series of tests, the larger sample being taken from the coarser material.

Gravel samples from dug pits may be taken from material piled at the surface, as described for auger holes, or they may be taken directly from the sides of the pit. The latter method is preferred, as being more accurate. Samples from casing holes must of course be taken at the ground surface.

Samples of ledge rock for physical tests should each contain at least 60 or 75 pounds of material. If the samples are taken from a naturally exposed face, the weathered stone at the surface must be rejected and only fresh stone included. Composite samples including more than one kind of rock should never be taken, as the presence of two or more types has a pronounced effect on the result of the abrasion test; it has been found that when cubes of hard stone and cubes of soft stone are rattled together in this test, the hard cubes wear unduly on the soft ones, giving a higher percentage of wear than would be the case if either kind were tested separately.

Much of the soft or inferior rock associated with Iowa limestones occurs in thin beds that break easily into thin chips or flakes. In the preparation of a stone sample for the abrasion test, these thin chips or flakes are automatically rejected ($1\frac{1}{4}$-inch cubes being required), and it is thus useless to include such material in the sample. The better plan is to include in the report on the deposit a section showing the thickness and succession of strata, both those that are represented by samples and those that are not.

When core drill holes are put down in stone, the best plan is to send to the laboratory for test the entire core, accurately identified.

Reports. — The exact form of a report on investigation of a material deposit will of course depend upon the purposes for which the material is to be used and the properties of the material that are most important in evaluating it for those purposes. Some kind of report should always be made and kept as a matter of permanent record. The report should show the logs of all test holes, results of field tests if any are made, and identification of all samples taken for laboratory test, and should be accompanied by a sketch or map showing the locations where holes were put down. The map is of utmost importance and should be drawn in sufficient detail so that from it the deposit may readily be located by persons who have not seen it before.

In this connection it may be advisable to say a word about reports on locations that are prospected, but where no material is found available. At first thought it may seem useless to make any report on such locations; however, experience has shown that when prospecting work is continued over a period of years, there is probability that the same territory will be gone over a second or even a third time, in which case a complete record of previous work is valuable.

PRODUCING PLANT PRACTICE

On this subject a great volume of literature is available, both in permanently bound books and in the current publications for the trade. Space will not be given here for a bibliography on the subject, but such a bibliography can be obtained from any of the technical publishing houses.[82] The writer's experience does not qualify him to discuss this subject exhaustively, and he will give here only such a brief

82 E.g.: McGraw-Hill Book Co., 370 Seventh Ave., New York City; Tradepress Publishing Corporation, 542 South Dearborn St., Chicago, Ill.

resumé as will be necessary to aid the reader in evaluating the various properties of road and concrete materials and the various features of the deposits in which these materials occur.

Rock Production Practice at Permanent Plants

Quarrying. — Removal of overburden from a rock deposit is in most plants done with the steam, gasoline, or electric shovel. This is necessitated by the fact that most of the overburden is glacial or residual clay, much of which is very difficult to dig by hand methods. Where a part of the overburden consists of soft or otherwise inferior stone, the common practice is to cut with the shovel first to the top of the inferior stone, then to blast the stone and take it out in a second cut of the shovel; it is often advisable to handle such stone thus separately so that it can be piled up by itself and perhaps be later put to some use. The upper surface of many rock deposits is very irregular, owing to weathering and erosion; if a clean stone free from impurities is required, a certain amount of hand work with pick and shovel may be necessary after the power shovel has finished. In some cases, where overburden is but a very few feet thick, it may be inadvisable to use a machine at all for excavating it, since under such circumstances hand methods of digging and loading are no more expensive. If overburden is of a light and friable nature it may be excavated by scrapers of various types, or by a clam-shell or orange-peel bucket on a crane, or by a drag-line bucket.

When overburden is to be moved only a short distance it can be cast by the shovel or whatever other digging equipment is used, thus saving any transportation cost. However, in most quarries, especially those which are permanently located, overburden must be moved some distance. This is done by means of wagons, trucks, tractor-trailers, or narrow-gauge or standard-guage railroad cars. If the overburden includes masses of weathered or broken rock, the heavier equipment, such as large trucks, trailers, or railroad cars, is almost essential.

Experience in Iowa and other states has shown that when overburden becomes excessively heavy or difficult to remove, it is often cheaper to leave it on and take out the rock by mining. Under this system tunnels are driven back from the outcrop, the upper part of the rock being left in place as a roof and supported at intervals by pillars of rock that is also left in place. The roof should consist of several feet of hard, strong rock, and pillars must be spaced closely enough and be large enough so that the roof will have adequate support. Such a method of quarrying has the disadvantages of higher drilling costs and in many cases of higher blasting and loading costs. The advantages are independence from weather conditions, saving of stripping cost, and sometimes the better quality of stone obtained. The pillars and roof constitute a large part of the stone in the deposit, but, after tunnels are driven as far back as desired, the pillars may be saved by backing out and allowing the roof to fall. It has been observed in this and adjoining states that the finished product from such a mine can be sold at about the same price as that from many of the open quarries.

Mining from a vertical shaft is an operation very similar to that just described, but it has the further disadvantages of added capital cost of sinking a shaft and added operating cost of hoisting from the mine to the surface of the ground. This plan has been tried out in a few instances but was not in operation in Iowa in 1933. The advisability of working deeply buried rock deposits by mining from a vertical shaft may be considered in localities where road materials are scarce at the surface and expensive to ship in.

After a rock deposit is stripped, the next step is to drill it for blasting. For this purpose operators use either the ordinary churn drill (such as is commonly used in well work) or the smaller hammer drill operated by compressed air. If holes are to be drilled to a depth of more than 15 or 20 feet, the churn drill is almost a necessity. It makes a hole about five inches in diameter, large enough for the placing of heavy charges of explosive. The air drill makes a hole 1 inch to 2 inches in diameter. The explosive charge in it is necessarily smaller, and air drill holes must be placed closer together than churn drill holes. Where the rock drilled is massive and tends to break out in large unwieldy pieces, better fragmentation results from placing the explosive in the smaller holes set closer together. The air drill is commonly used on the smaller and shallower rock deposits on account of its greater mobility; the churn drill is used in the larger and deeper quarries on account of slightly lower operating costs per cubic foot of hole. In mines the air drill must necessarily be used.

One of the various kinds of dynamite is commonly used as an explosive in rock quarrying. Less often, black powder may be employed. A new type of explosive, employing liquid oxygen and carbon, has recently come on the market and offers some advantages to operators of the larger quarries. The drill holes may be loaded to a part or all of their capacity or may or may not be loaded more heavily in the lower part depending upon the nature of the rock, degree of breakage required, placement desired for the broken rock, and many other factors. The whole subject of choice of explosives and manner of spacing and loading drill holes is a rather complicated problem, the correct solution of which depends upon a careful analysis of local conditions by someone educated and experienced in the use of explosives.

A part of the blasted rock is often in masses too large to be handled, either by hand or by power shovel. These masses are broken by secondary blasting with small charges of explosive, placed either in small shallow drill holes or on a flat surface of the rock and capped with mud.

The almost universal practice in the larger and more permanent quarries is to load the rock with a power shovel after blasting. The shovel is the cheapest method for any but very small quantities of rock,

Fig. 18. — Dubuque Stone Products Co., Dubuque. View of quarry face and loading and hauling equipment.

where conditions do not prevent its use. However, if the rock is mined and tunnels are not high enough to allow head room for a shovel, hand loading may be necessary. Likewise, if seams or pockets of inferior or undesirable stone are present in the quarry, hand loading may be necessary in order to separate the good stone from the bad. In Iowa, hand loading has been satisfactorily and profitably employed in quarries producing up to 300 cubic yards per day.

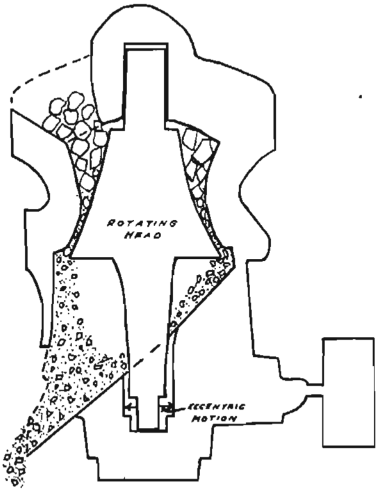


FIG. 19. — Side view of a gyratory crusher showing principle of operation.

The rock may be loaded on wagons, trucks, or narrow-gauge or standard-gauge railroad cars for transportation to the crushing plant. The type of transportation equipment used depends almost entirely upon local conditions and the personal preference of the operator. Figure 18 illustrates loading and hauling methods in the quarry of the Dubuque Stone Products Co., Dubuque, one of the larger quarries in the state.

Crushing. — In order to complete the reduction in size from the large masses blasted out of the quarry face to the fragments of size desired in the finished product, two or more stages of the crushing process are necessary. The initial breakage is commonly known as primary crushing and that which follows as secondary crushing. Three types of crushers are in common use in Iowa rock plants, namely: the gyratory or cone crusher, the jaw crusher, and the hammer mill. Figure 19 illustrates the essential principle of operation of the gyratory crusher, figure 20 the jaw crusher, and figure 21 the hammer mill.

Any of these types of crushers is manufactured in various sizes to fit the amount and size of the output required.

Primary crushing may be done by means of any of the three crusher types mentioned. The jaw crusher has the advantage of being able to handle large masses of rock, thus minimizing the amount of secondary blasting necessary. The gyratory crusher also will handle fairly large masses of rock and has a large output of crushed material per unit of power employed. The hammer mill revolves at high speed and is well adapted to the reduction of large quantities of rock in fragments of medium size. It has also been found to have the effect of pulverizing much of the weaker and softer stone, allowing it to escape with the dust and retaining more of the hard and durable stone in the sizes desired for aggregate or surfacing material.

Following the primary crushing, the stone is ordinarily conveyed to a secondary crusher, a scalping screen being sometimes interposed between the two. A scalping screen is one having openings as large as the maximum size of fragment allowable in the finished products; material that passes through these openings is sent on to the sizing

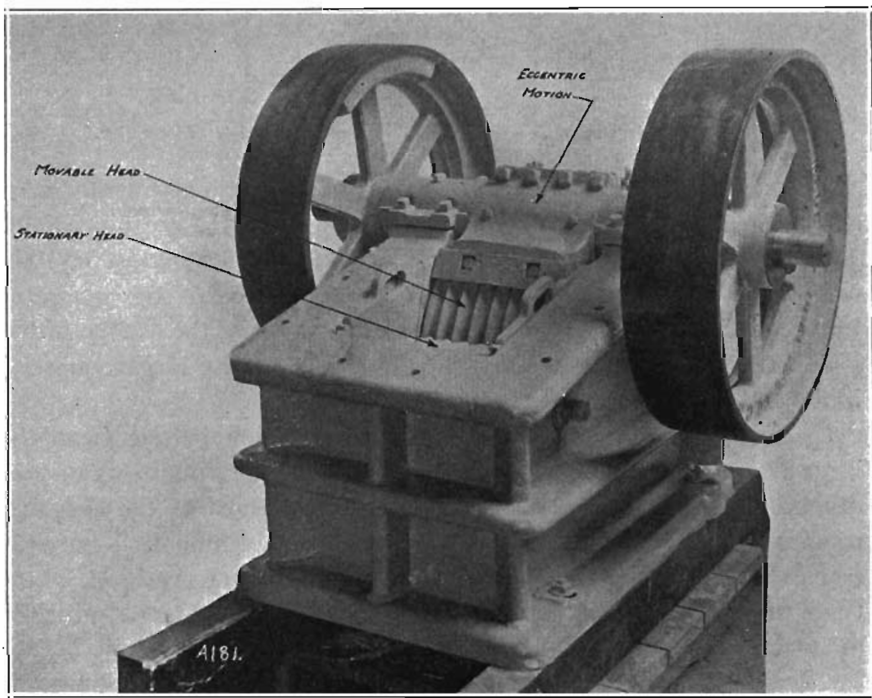


Fig. 20. — View of jaw crusher. Courtesy Iowa Manufacturing Co., Cedar Rapids.

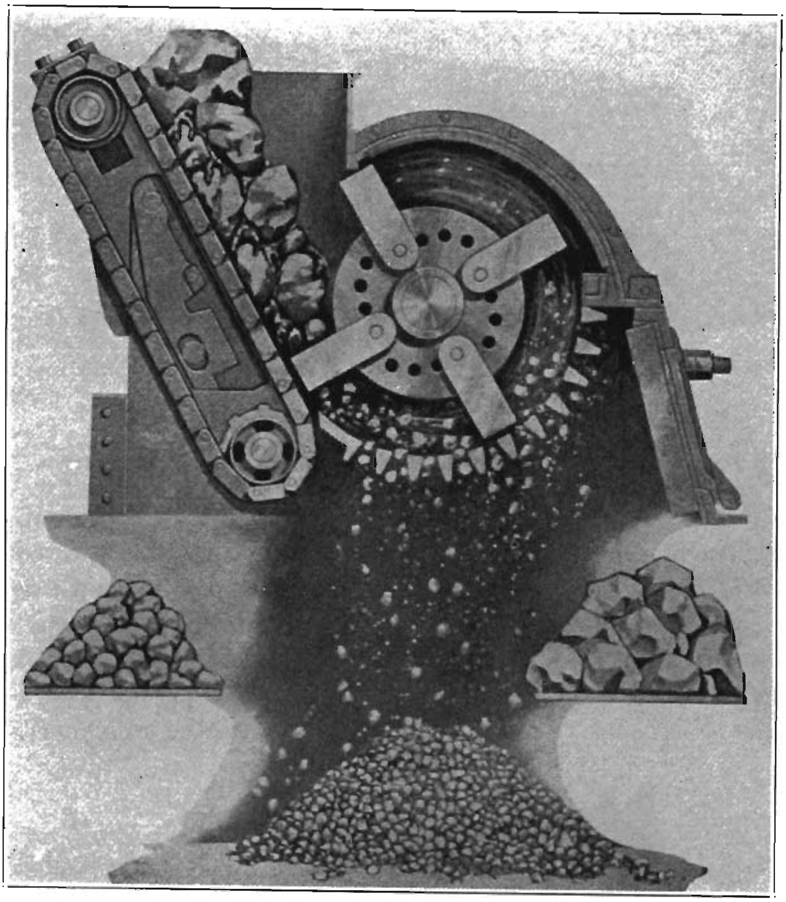


FIG. 21. — Principle of operation of hammer mill. Courtesy Dixie Machinery Manufacturing Co.

screens without further crushing, while that retained is returned to the secondary crusher. The secondary crusher or crushers may be of any of the types mentioned, though it has been observed that the gyratory, cone, or hammer type is in more common use in this state than is the jaw type. Material from the first secondary crusher is conveyed to the sizing screens. Some provision for collecting any rock that may not have been crushed below the maximum allowable size is ordinarily used on these screens; this rock is returned for further crushing either in the first or in an additional secondary crusher.

Screening. — When stripping and loading in a rock quarry is carefully done, the material which reaches the screening plant is ordinarily free from dirt; consequently, no washing is necessary and the rock may

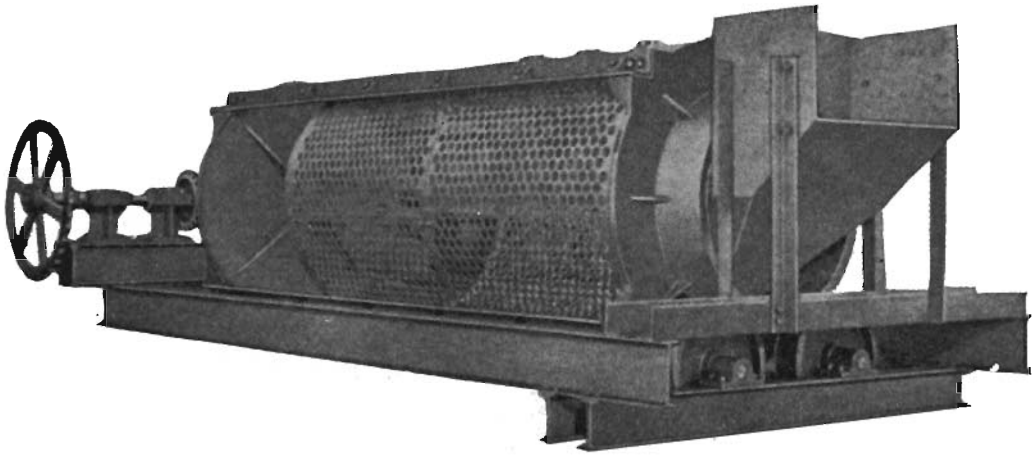


Fig. 22. — Revolving screen. Courtesy Iowa Manufacturing Co., Cedar Rapids.

be screened dry. Screens now used in Iowa are almost entirely of two types. The first, known as the revolving screen, is cylindrical or conical in shape and is illustrated in figure 22. The second, known as the vibrator screen, is illustrated in figure 23. Revolving screens turn slowly, usually not more than 10 times per minute. On the other hand, a vibrator screen may complete 1,000 or more vibrations per minute. Details concerning vibration, such as speed, amplitude, manner, and

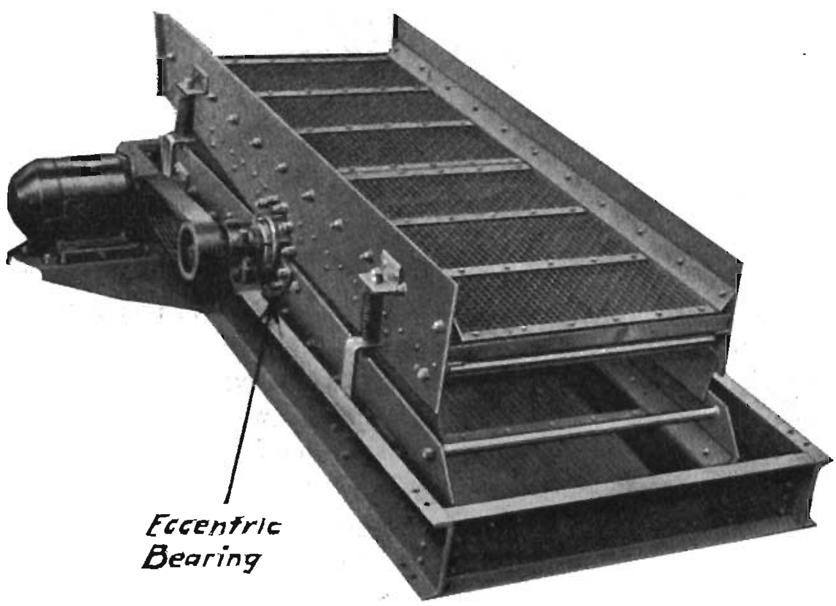


Fig. 23. — Double-deck vibrator screen. Courtesy Rock Products Magazine.

actuating cause, differ according to the design of individual screens. Vibrator screens require less power to operate and offer greater screening capacity per unit of space occupied. Screening of the larger rock fragments does not usually require the violent agitation necessary with the small particles, so that many plants use a combination of both types of screen, the revolving type for the larger sizes, and the vibrator type for the smaller sizes.

During rainy weather the rock in open quarries becomes damp so that the dust from blasting and crushing sticks to it and is very difficult to dislodge by ordinary screening methods. For this reason the washing of the material on the screens and the screening of it wet instead of dry has been tried by a few operators. Wet screening appears to cost very little more than dry screening. It offers the advantages of a more uniformly clean product and of greater independence from varying moisture conditions, but it has the disadvantage of being difficult to operate in freezing weather. Very little information or experience on the washing of stone has been gained in this state to date, but the trend of rock screening practice in other states indicates that the plan is gaining in favor.

Sand and Gravel Production Practice at Permanent Plants

Excavating. — As with a rock quarry, the first step in the excavation of a gravel deposit is the removal of overburden. For this purpose the same equipment as is used for stripping a rock deposit may be employed. Overburden on gravel deposits is in many cases only a few feet thick and is composed of soft easily dug materials such as soil or silt, so that the lighter types of excavating equipment are more commonly used. Since the upper surface of the gravel is in most deposits quite level, and since it is easy to dig down far enough into the gravel to remove any pockets of clay which may lie at the top of it, hand work on the overburden is very seldom done. Transportation methods on overburden are the same as those in use with a rock deposit.

Since neither the upper part of a gravel deposit nor its overburden has any supporting power as a roof, it has not been found practicable to mine out gravel, either by tunneling or from a vertical shaft.

In only a very few instances is gravel sufficiently cemented together by clay or iron oxide to necessitate any blasting before it is dug. In cases where blasting is found to be advisable, the common practice is to use small horizontal auger holes drilled a few feet back into the bank from the pit face.

Gravel is commonly excavated by power shovel, clam-shell or orange-peel bucket, drag-line bucket, scrapers, pump, or less commonly by hand. In dry pits (where the gravel lies above the natural water level) the equipment most used in the larger deposits is the clam-shell

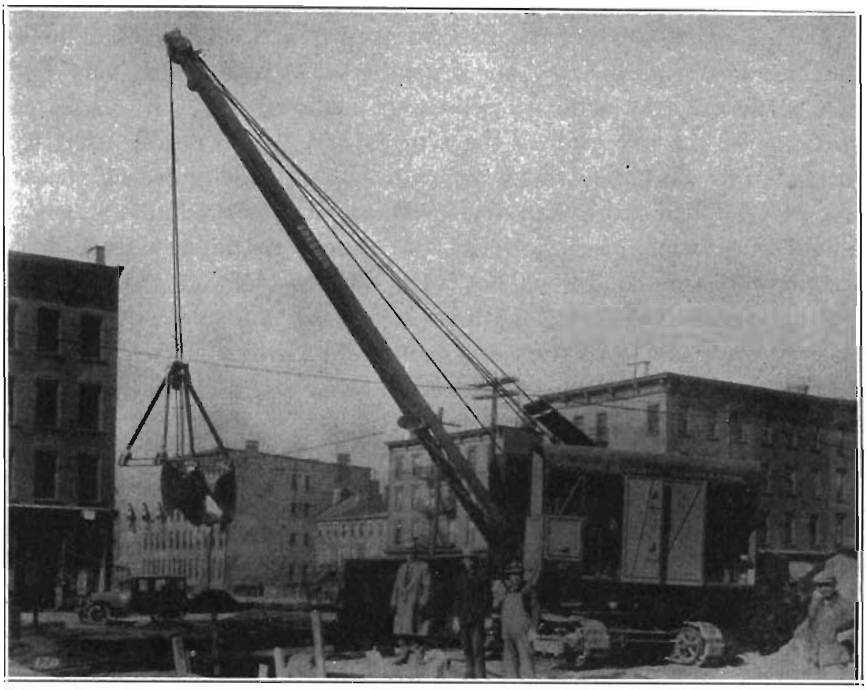


FIG. 24. — Crane equipped with clamshell bucket. Courtesy Speeder Machinery Corporation, Cedar Rapids.

bucket machine or the drag-line bucket machine, and in the smaller deposits some type of scraper. Figure 24 illustrates a clam-shell machine, and Figure 25 a drag-line machine. Figure 26 illustrates a type of scraper in common use in gravel deposits, especially those from which surfacing material is taken. In wet pits (where part or all of the gravel lies below the natural water level) the most common excavating equipment is the drag-line bucket or the pump. Where the plant can be located close to the deposit being worked, and the deposit has small areal extent, an inexpensive excavating method is to use a drag-line bucket that is operated from a cableway instead of being mounted on a machine. Figure 27, a view of the operation at a gravel plant at Har-

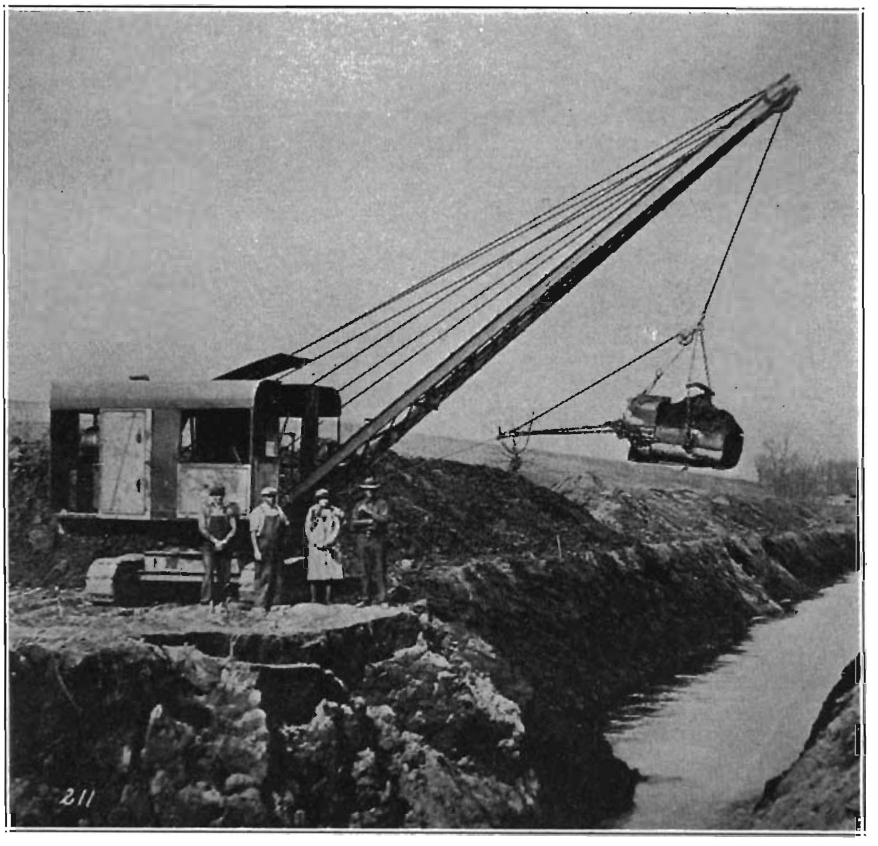


Fig. 25. — Crane equipped with dragline bucket. Courtesy Speeder Machinery Corporation, Cedar Rapids.

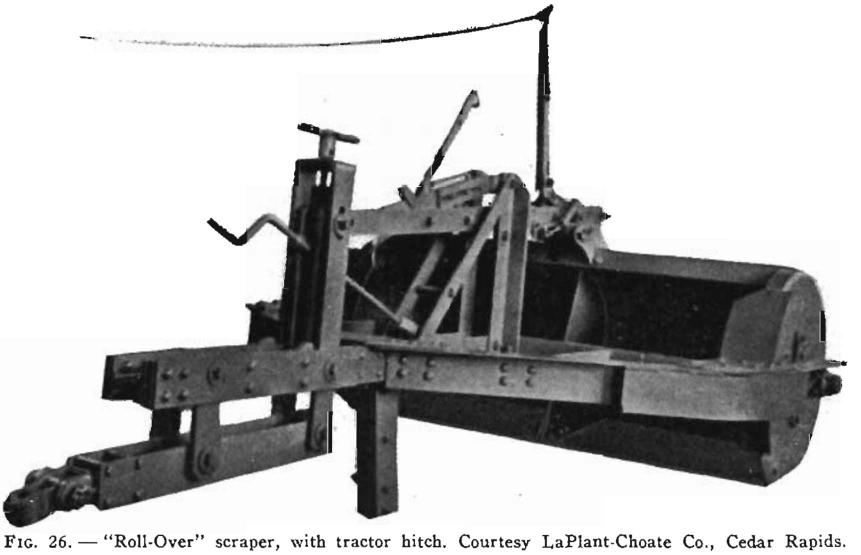


Fig. 26. — "Roll-Over" scraper, with tractor hitch. Courtesy LaPlant-Choate Co., Cedar Rapids.

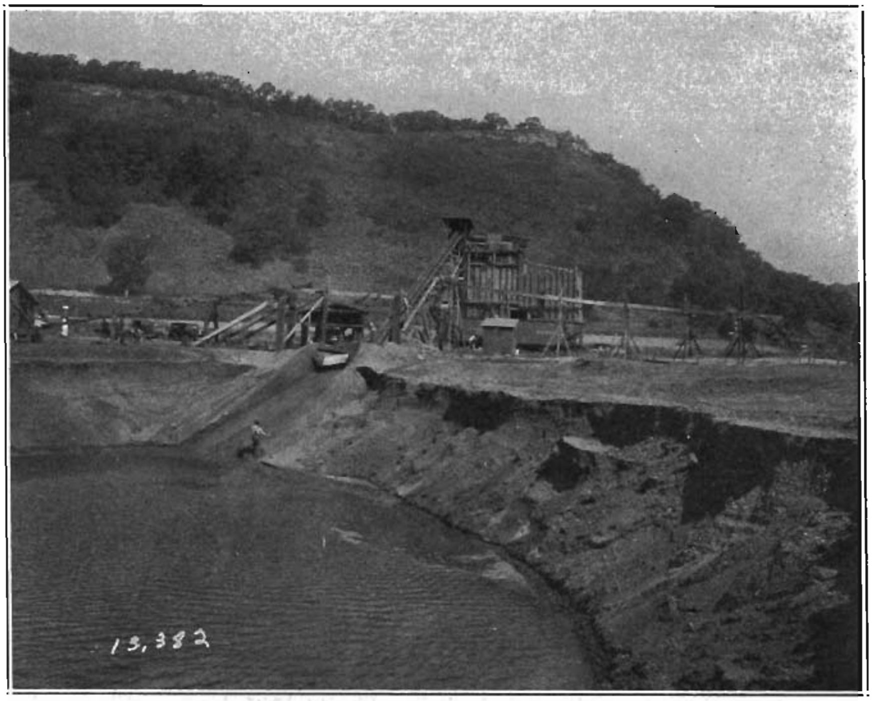


FIG. 27 — Northeast Iowa Sand and Gravel Co., Harpers Ferry. General view of the plant showing excavation by cableway dragline.

pers Ferry, Iowa, shows this method. It may be said that the gravel deposit here has a thickness of about 15 feet above water and 5 to 30 feet below water. Figure 28 shows a typical pump set-up with pipeline connecting to the plant and, in this case, with suction head raised. The centrifugal type of pump is nearly always used, and the diameter of the discharge pipe ordinarily differs at the different plants from 4 to 12 inches. Experience has shown that where pumping can be satisfactorily used, it is the cheapest known method for excavating gravel.

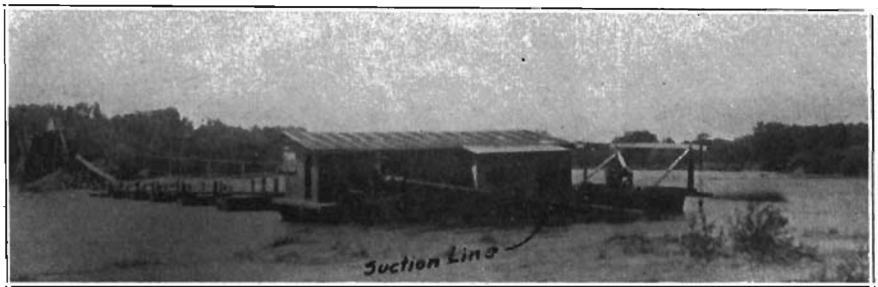


FIG. 28. — Pump boat with suction head raised. Courtesy Lyman-Richey Sand and Gravel Co., Omaha.

When the pump is used, the means of transportation to the plant is the pipe line. If the cableway drag-line bucket is used, transportation is on the cableway. For other types of excavating equipment the means of transportation may be wagons, trucks, trailers, railroad cars on narrow-gauge or standard-gauge track, or belt conveyors. Figure 29

FIG. 29. — Bellevue Sand and Gravel Co., Bellevue. View of the Belt Conveyor System.

illustrates a typical belt conveyor for gravel. Where the transportation machinery leaves the gravel at the bottom of the plant, some means of elevation to the top is necessary, such as a bucket, belt elevator or conveyor belt elevator, as the almost universal practice is to start the washing and screening process at the top of the plant.

Washing and Screening. — Since the two operations of washing and screening usually take place together, they are so discussed here. Washing is seldom necessary on road surfacing material, though it may be done to facilitate the screening process. On aggregates, washing is almost universally practiced, either to remove silt, shale, coal, or other impurities, or to aid in the separation of the various sizes desired in the finished product.

When material comes to the plant in a dry or moist condition, a large quantity of additional water is necessary for washing and screening. An idea of the large amount of water necessary may be obtained from the statement that the pumps which furnish water for washing and screening in one of the larger plants of the state are rated to deliver 4,000 gallons per minute. When material is excavated from under water by pumping, only 15 to 20 percent (by volume) of that which passes through the discharge pipe is solid matter, and the additional quantity of water needed for screening and washing may be small or none.

If oversize material is present in the gravel, it is usually screened out first (the process known as "scalping") and taken to a crusher for reduction. The scalping process is usually done before any water is added, as damp or even sticky materials can usually be passed without difficulty through openings the size of the largest pebble or fragment allowable in the finished product. Scalping and crushing may be done at the top of the main plant, or, since crushing machinery is heavy, it may be done in a small preliminary plant on the ground, allowing no oversize material to reach the top of the main plant. A revolving or a vibrator screen may be used for scalping.

When the scalping process is completed before the gravel reaches the main plant, the first succeeding step is the addition of water. The gravel and water then passes to the sizing screens, at some plants going first through a scrubber of some kind (often a cylinder or drum in which the material rolls around, its agitation being aided by chains or paddles of some kind inside the drum). The type and arrangement of sizing screens differs widely according to the results desired and the nature of the material. However, it may be said that both revolving and vibrator screens are in common use, the vibrator being often more favored for the smaller sizes of pebble or grain.

Size classification of sand is usually accomplished by the action of water currents in conjunction with the washing process. Though differing widely in design, nearly all sand classifiers make use of a strong current of water passing through the sand and washing out with it the silt, fine sand, or particles of shale, coal, or other light weight and deleterious substances that may be present. The overflow carries the undesirable materials out over the top to waste while the washed material is drawn off at the bottom or side and goes to the storage bins or piles. Figure 30 illustrates the principle of the cone classifier and Figure 31 the principle of the drag classifier, two types in common use in Iowa. Sands that are too coarse may be corrected by screening out the larger grains.

For many gravels the agitation with water on the screens and perhaps also in the scrubber is sufficient to break up the undesirable mate-

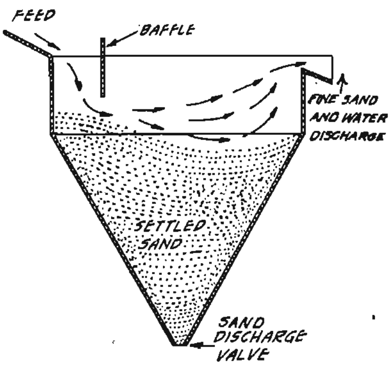


FIG. 30. — Sketch showing principle of operation of cone classifier. Courtesy Rock Products Magazine.

rials present, so that the water may readily wash them away. However, some gravels require additional treatment. This may take the form of hand picking on tables or belts, or of passage through some type of washer. One washer consists of a screw auger in an inclined trough. Gravel is fed into the lower end, where it meets a strong rising current of water which carries out many of the light and undesirable pebbles. The screw forces the gravel up the slope of the trough against the current of additional water admitted from beneath, and the cleaned

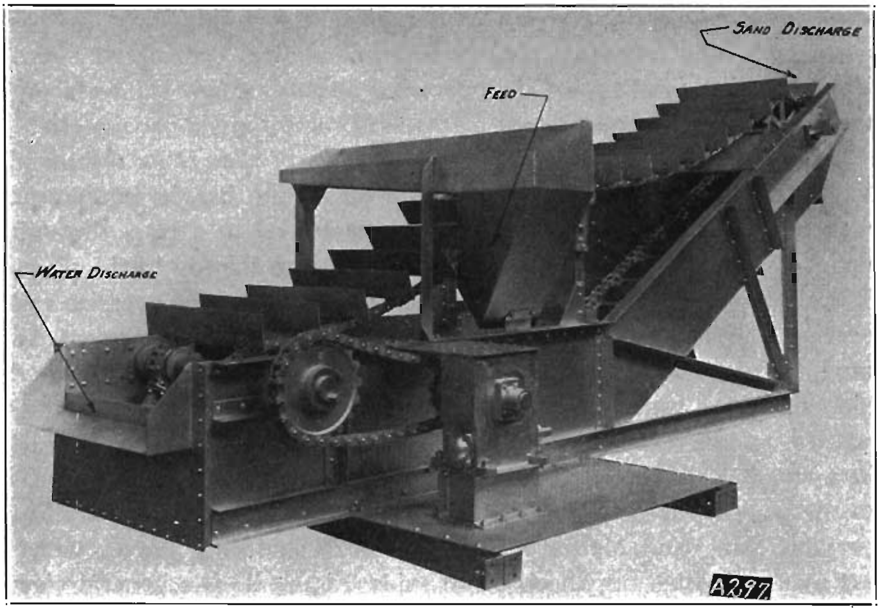


FIG. 31. — Drag type sand classifier. Courtesy Iowa Manufacturing Co., Cedar Rapids.

gravel passes out at the upper end, while the water and unwanted materials overflow at the lower end. Another type of washer employs a rapidly revolving drum into which the material is introduced, the centrifugal force agitating it violently against the circumference of the drum, resulting in the disintegration of soft or inferior material.

After the washing and screening of gravel or sand is completed, the material may be conveyed or chuted direct to railroad cars or trucks, which haul it to the destination where it will be used, or it may pass to storage bins or piles for later shipment. Storage bins are ordinarily built underneath the screening and washing plant. Storage piles may be located underneath or beside the plant or may be at some little distance from the plant. Material may be taken to the pile by chutes or belt conveyors or may be chuted on the ground or on trucks or railroad cars, whence it is picked up and piled by a clam-shell bucket machine or by some other piling or loading device.

Figure 32 is a general view of the plant of L. G. Everist, Inc., at Hawarden, Iowa, one of the larger and newer gravel plants in the state.

Portable Plant Practice

The portable plants are used mostly for the production of road surfacing material, whether it be gravel or rock, as surfacing material rarely requires washing nor does it require as careful sizing as does aggregate. The necessary plant equipment is thus considerably less. The type of equipment and the operating methods employed are about the same as in those permanent plants which work in similar materials.

Excavation at portable gravel plants is nearly always by means of scrapers, though, if the material is difficult to dig, heavier equipment may be necessary. The scraper carries the gravel to a trap, through which it falls to a conveyor belt which takes it to the top of the plant. The plant ordinarily consists of a screen for removing the oversize and perhaps another screen for removing excess sand if any is present, all mounted on a steel frame above the 10- to 25-cubic yard steel or wood bin. The bin is usually set high enough so that trucks can pass underneath it and be loaded by gravity. Oversize material usually is crushed in a small portable crusher and returned on the main conveyor belt to the plant. It is now possible to purchase completely self-contained portable plants suitable for the production of surfacing gravel, which are mounted either on wheels or on skids. Figure 33 is a general view of a portable plant used for the production of surfacing gravel.

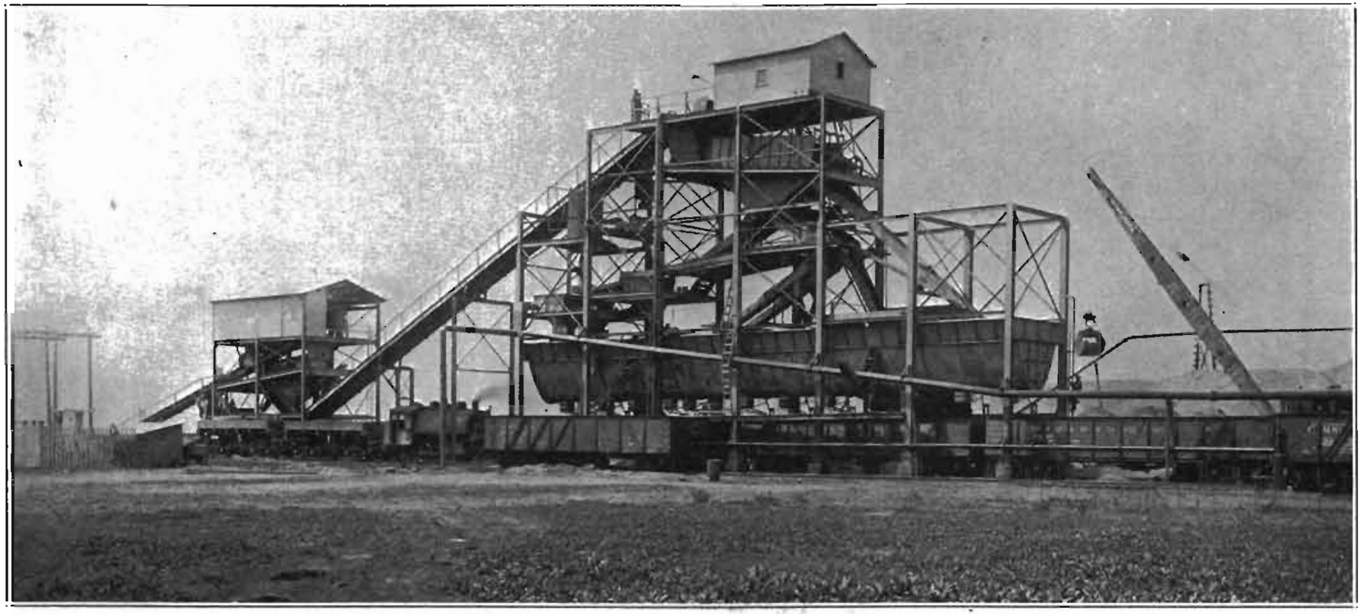


Fig. 32. — Gravel screening and washing plant at Hawarden. Courtesy L. G. Everist, Inc.

FIG. 33. — Portable surfacing gravel plant. Courtesy Iowa Manufacturing Co., Cedar Rapids.

FIG. 34. — Portable surfacing stone plant.

Portable rock plants are very similar to the more permanently located plants except that screening and crushing machinery is mounted on skids or wheels, and cumbersome storage equipment is kept to a minimum. Figure 34 is a general view of a portable plant used for the production of road surfacing stone.

Portable or semi-portable plants are occasionally used for the production of aggregate, whether it be gravel, sand, or crushed stone. The machinery necessary for such a plant is usually more than is required to produce surfacing material, and special effort must be made to keep all heavy or cumbersome equipment at a practicable minimum.

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