IOWA
GEOLOGICAL SURVEY

VOLUME XXXVI

Annual Reports, 1930, 1931, 1932, and 1933

with

Accompanying Papers

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Published by
THE STATE OF IOWA
Des Moines
1935

Geological Survey Organization

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PRINTED IN THE UNITED STATES OF AMERICA
THE TORCH PRESS, CEDAR RAPIDS, IA.

CONTENTS

THIRTY-NINTH, FORTIETH, FORTY-FIRST, AND FORTY-SECOND ANNUAL REPORTS OF THE STATE GEOLOGIST

IOWA GEOLOGICAL SURVEY
IOWA CITY, DECEMBER 31, 1933.

To Governor Clyde L. Herring and Members of the Geological Board:

GENTLEMEN:

Four papers are herewith submitted to the Board with the recommendation that they be published as Volume XXXVI — the Thirty-ninth, Fortieth, Forty-first, and Forty-second Reports of the Iowa Geological Survey. The titles and authors of the papers are as follows:

The Road and Concrete Materials of Southern Iowa, by L. W. Wood.

Deep Wells Drilled in Iowa in 1928-1932, by W. H. Norton.

Additional Deep Wells, by James H. Lees.

Mineral Production in Iowa in 1930, 1931, and 1932, by James H. Lees.

Respectfully submitted,

GEORGE F. KAY,
State Geologist.

THE ROAD AND CONCRETE MATERIALS OF SOUTHERN IOWA

by

L. W. WOOD

TABLE OF CONTENTS

TABLES

LIST OF ILLUSTRATIONS

THE ROAD AND CONCRETE MATERIALS OF SOUTHERN IOWA

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 1½-inch screen, 20 to 90 percent to pass a ¾-inch screen, and 5 to 50 percent to pass a ⅜-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 $1\frac{1}{2}$ 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.

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

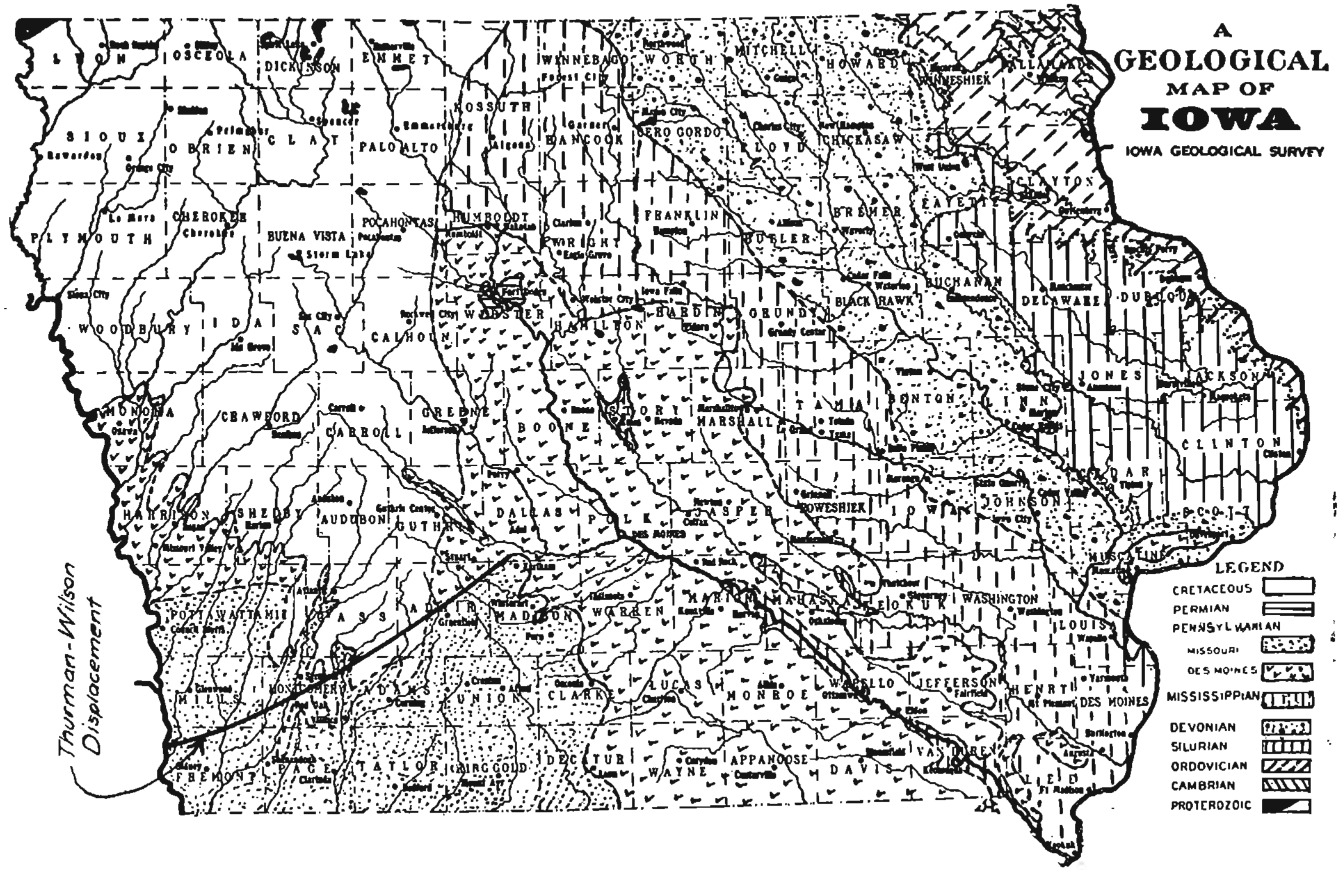
GEOLOGY OF THE ROAD AND CONCRETE MATERIALS OF SOUTHERN IOWA

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.

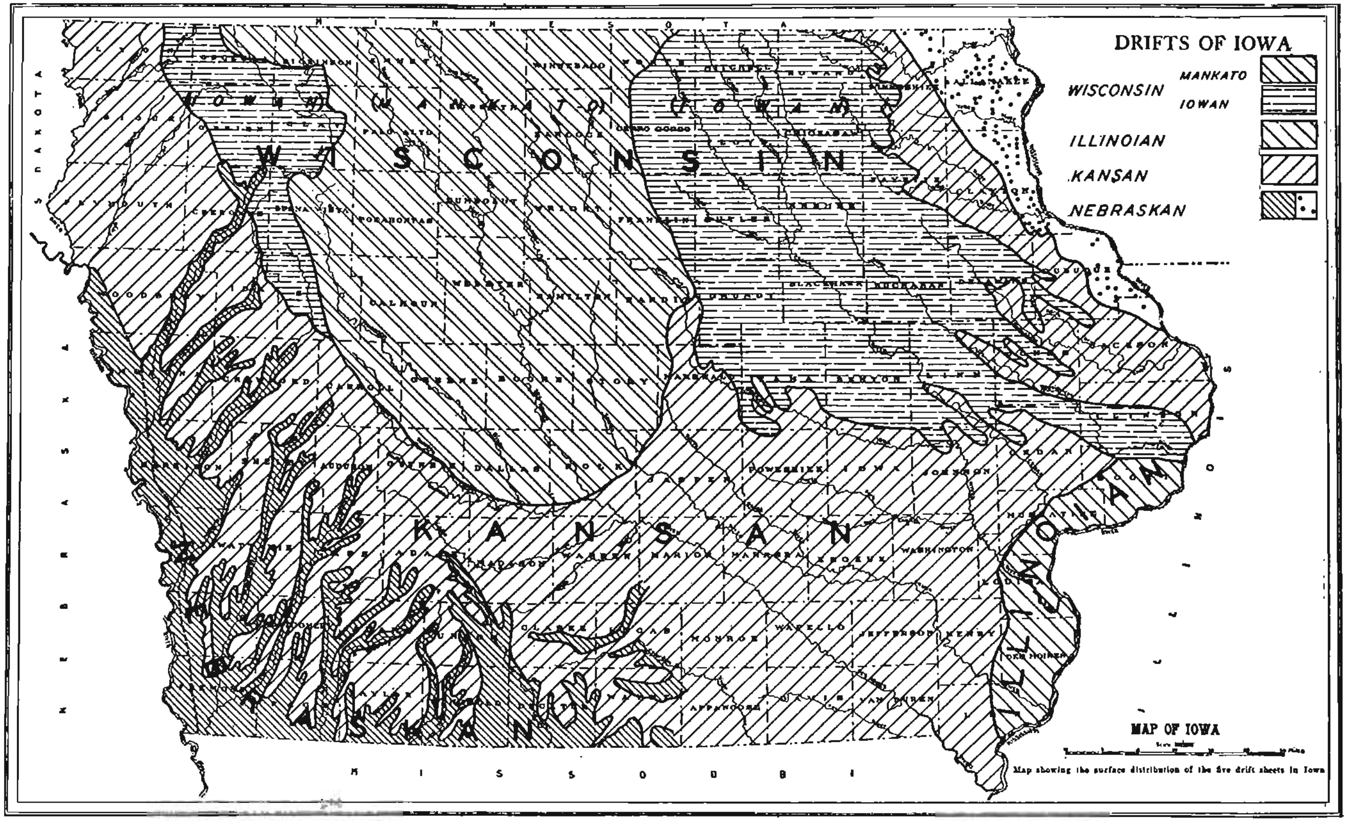
A general section for the rocks of Iowa is given in the Table between pages 316 and 317. Plate I shows the areas of outcrops of the various rock systems, with the exception of the Pleistocene.[2] It will be noted from this plate that the oldest Paleozoic rocks appear in the extreme northeast corner of 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.



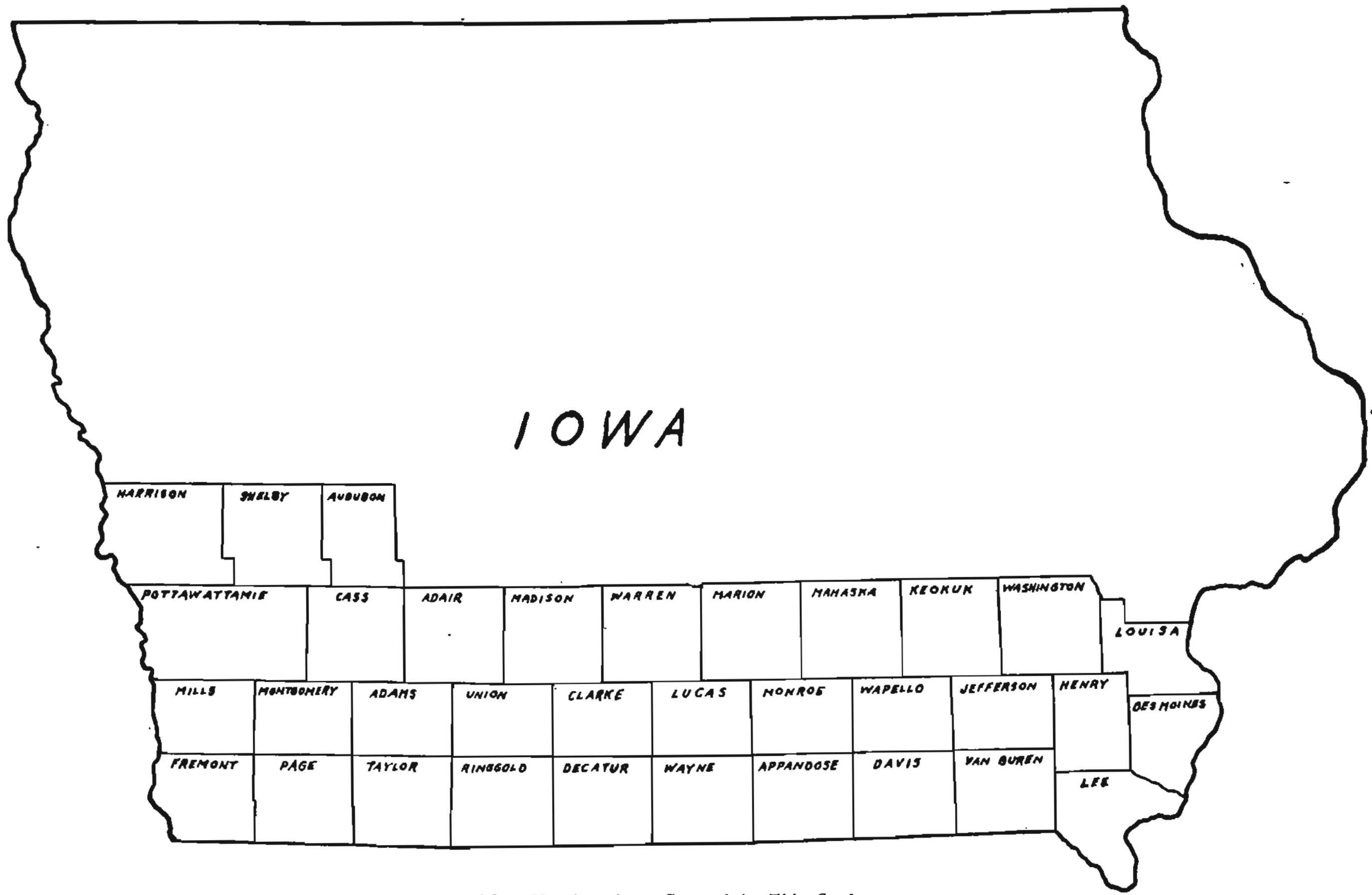
GEOLOGICAL MAP

PLATE I



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

MAP OF AREA COVERED



Map Showing Area Covered in This Study

Geological Distribution of Road Materials

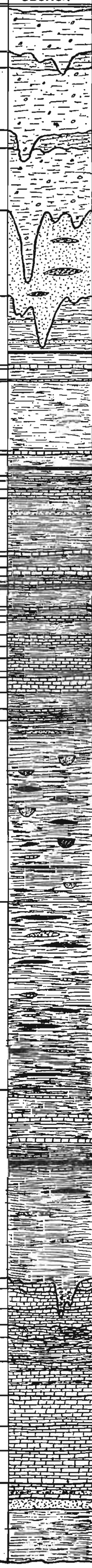
General Statement. — The gravels of Iowa are of glacial, fluvioglacial, and interglacial origin. Of the four glaciers which invaded Iowa, not all carried the same proportions of sand and gravel. In southern Iowa the Nebraskan, Kansan, and Illinoian ice sheets deposited relatively small amounts, while 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	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	1	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
		Douglas	Oread	10	Limestone
			Lawrence	7	Shale
			Stanton		Limestone
		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.

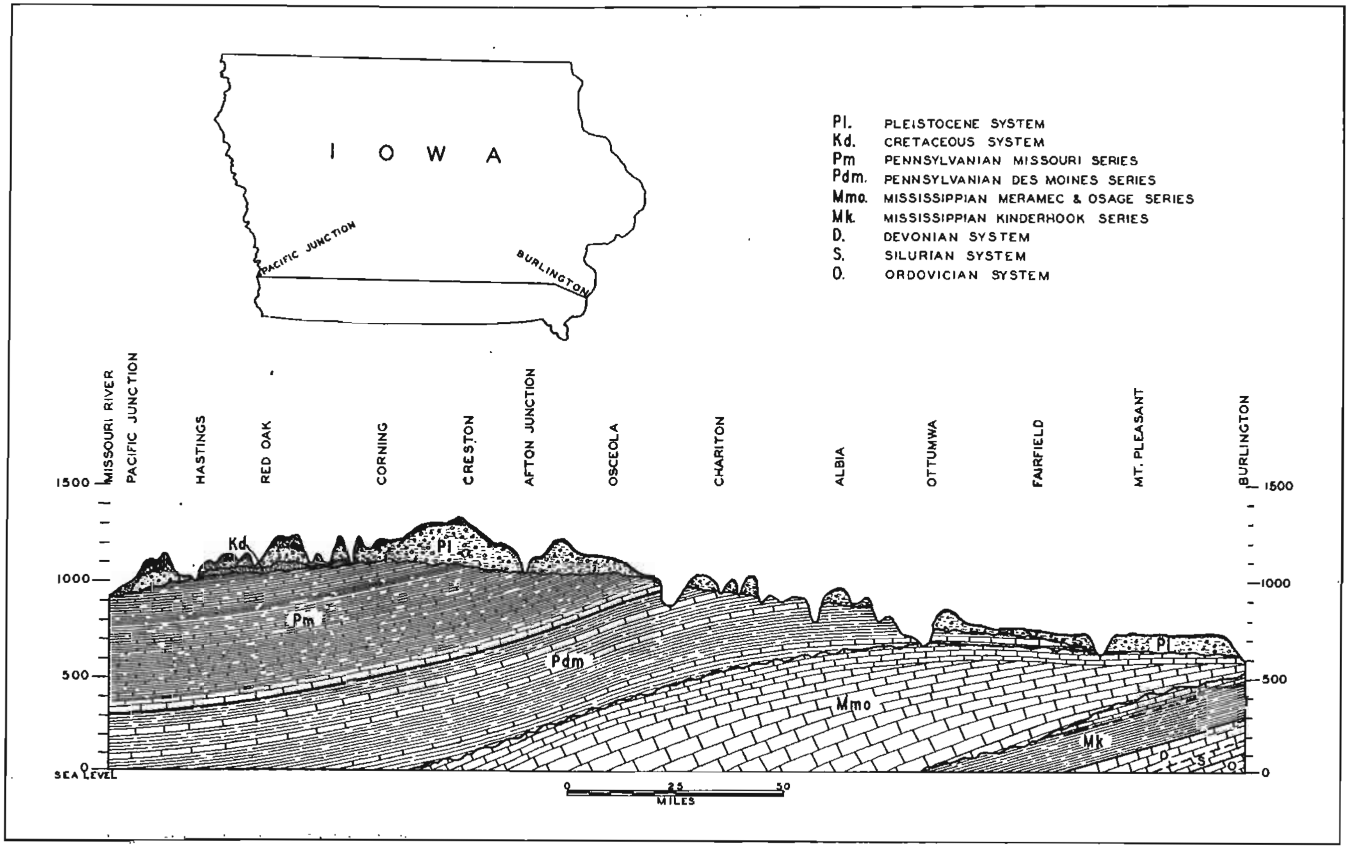
Structure of Southern Iowa

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 (SW$\frac{1}{4}$ 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.

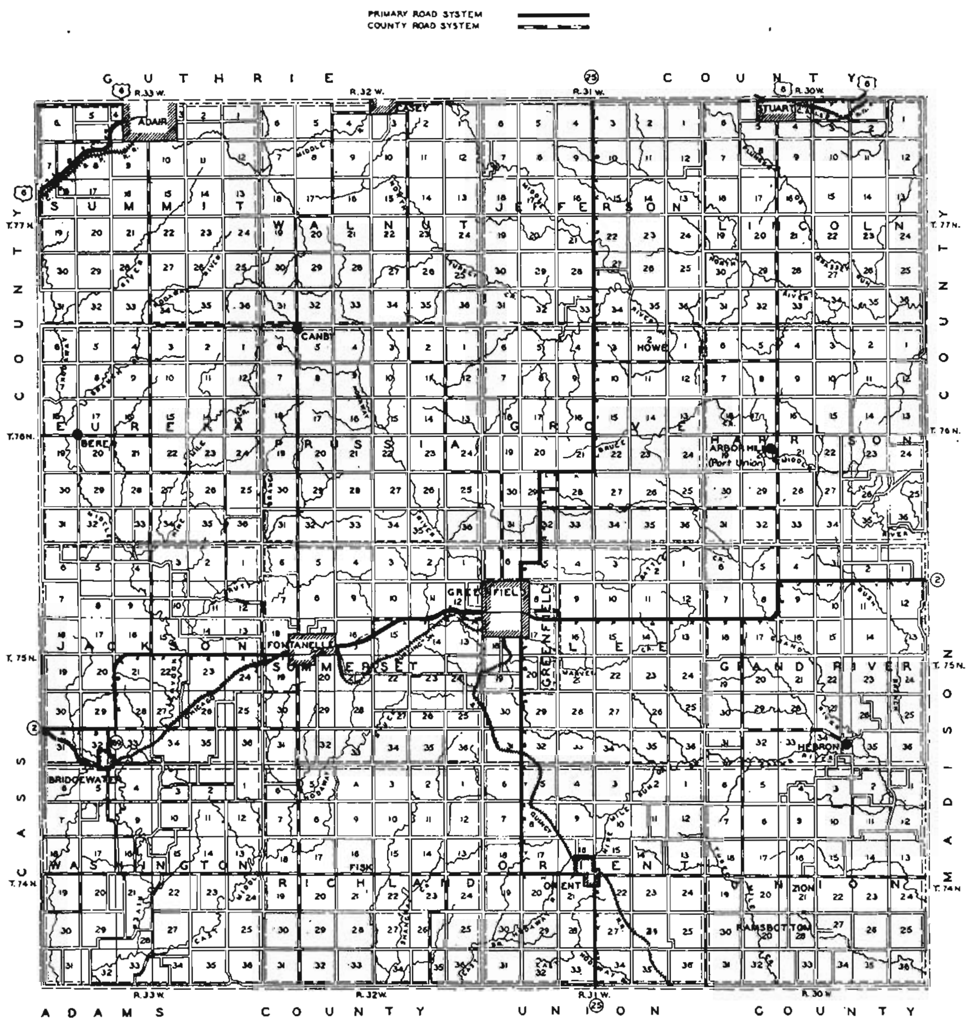
Gow [1] and Beyer [2] have published sections at the Perry quarry in the

[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

MAP OF
ADAIR COUNTY
IOWA



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 [3] 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,

[3] 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.

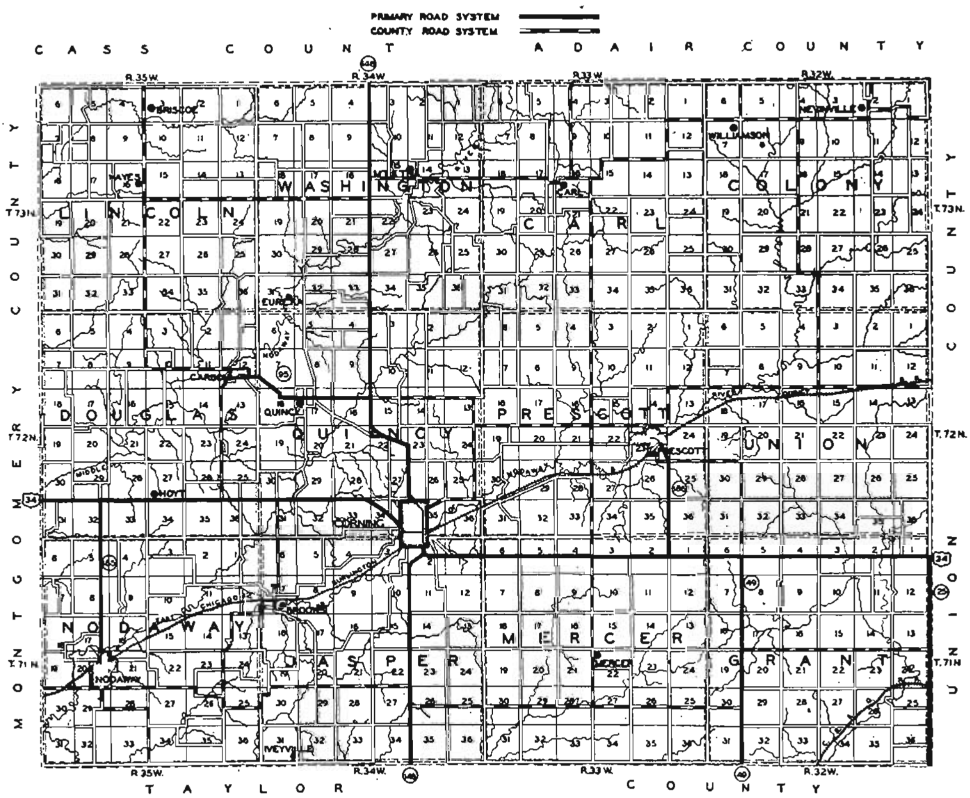
ered by this study. Scattered exposures of the limestones and shales of the upper portion of the Missouri series of the Pennsylvanian system are found near Corning and Brooks. Cretaceous sandstones appear at a few points in the west part of the county but are not known to be coarse-grained there or to 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

MAP OF
ADAMS COUNTY
IOWA



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

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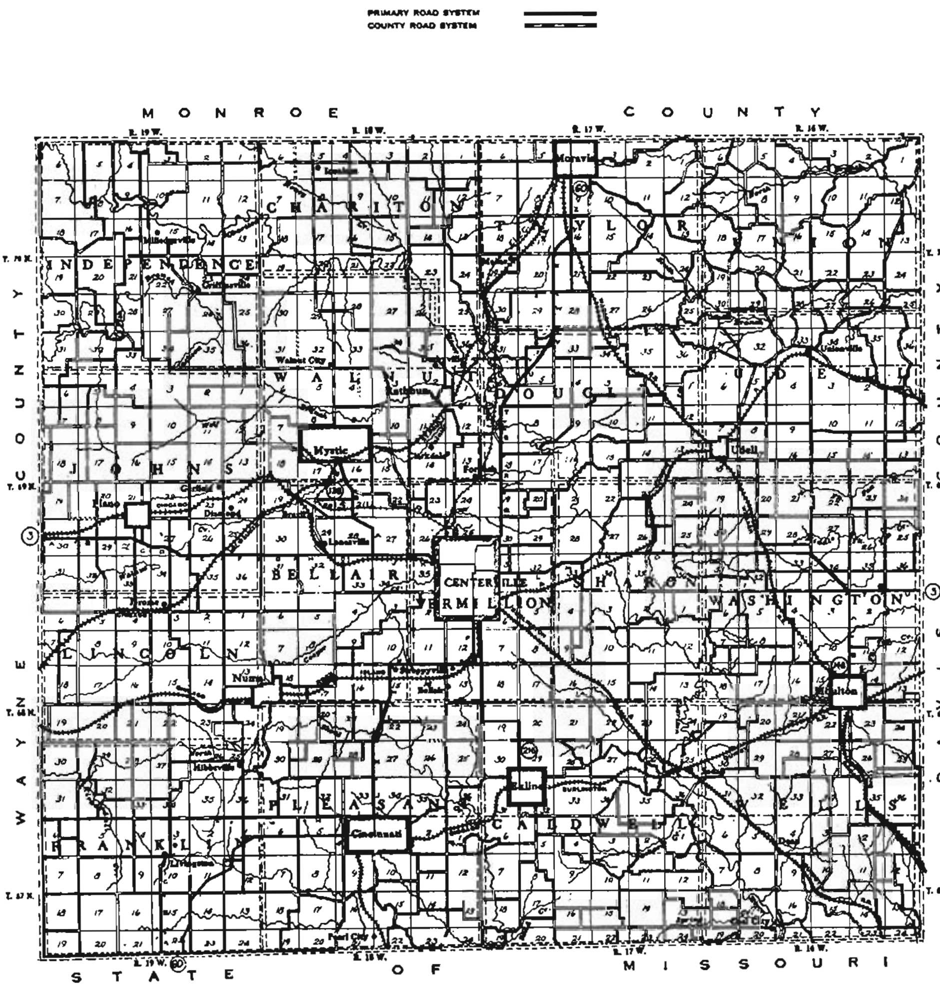
MAP OF
APPANOOSE COUNTY
IOWA



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

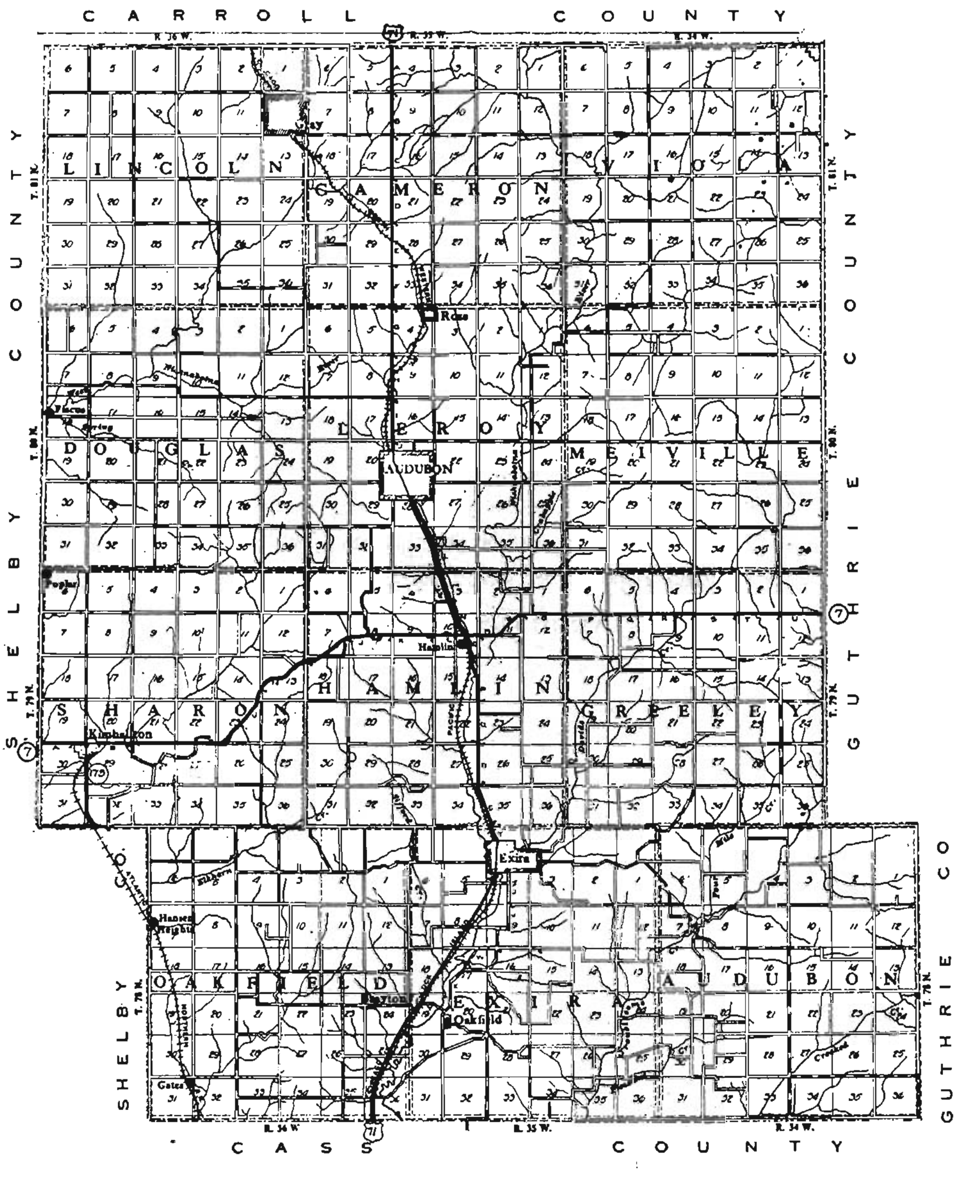
With regard to the presence and availabiliy of road materials Audubon is one of the more barren counties in the state. No exposures of the indurated rocks are known, though it is possible that sandstones of the Dakota stage of the Cretaceous appear at a few points in the east part of the county. The 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

PRIMARY ROAD SYSTEM
COUNTY ROAD SYSTEM



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.

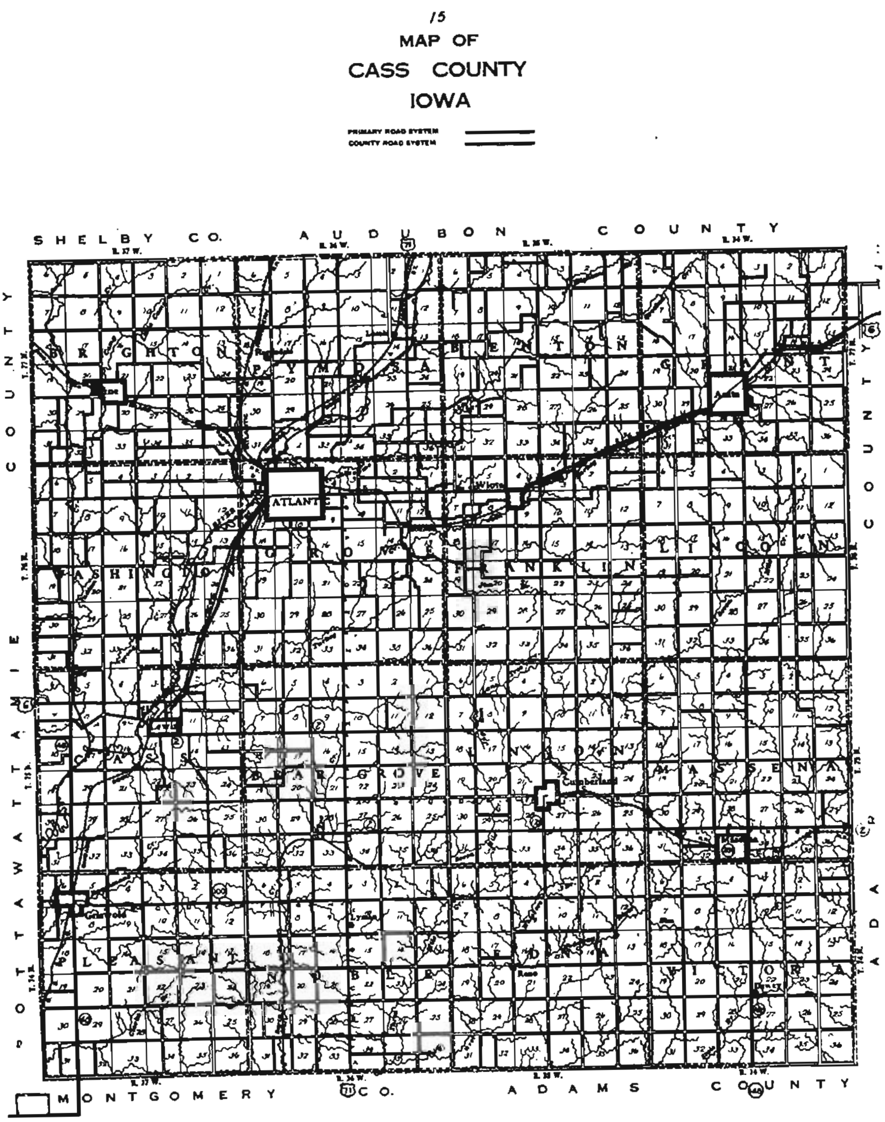
CASS COUNTY

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:

NE¼SW¼ sec. 7, Noble Twp., 2,000 cu. yds. available.
NE¼SE¼ sec. 2, Grant Twp., 600 cu. yds. available.
NE¼NE¼ sec. 29, Union Twp., 800 cu. yds. available.
NW¼SE¼ 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 (NE¼ NE¼ 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

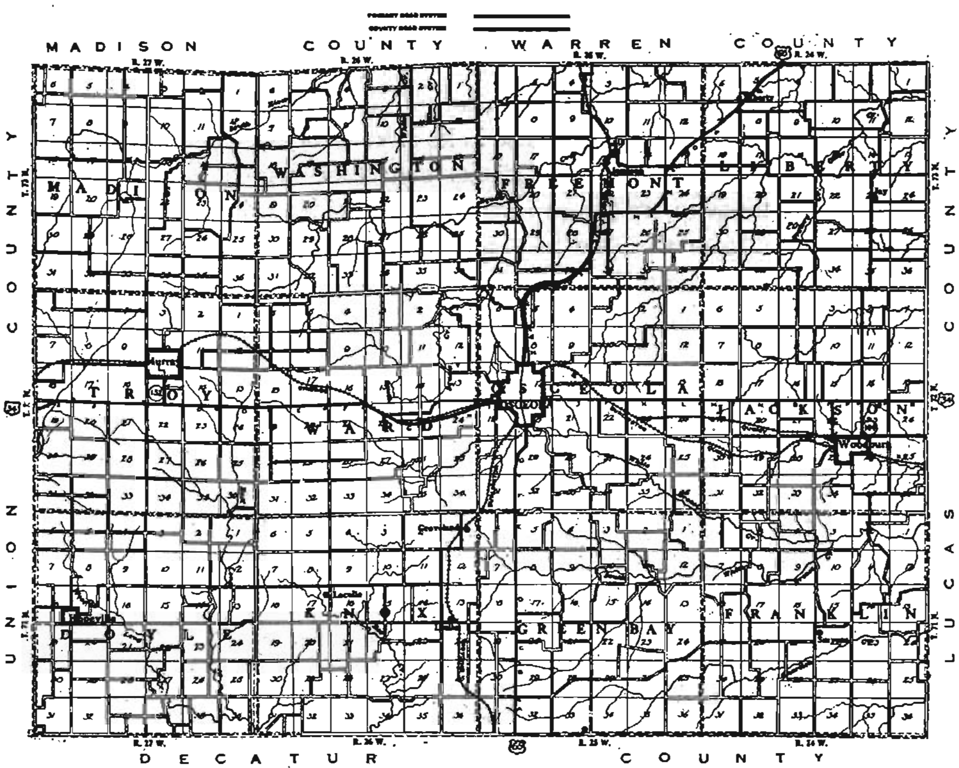
Strata of the Des Moines series form the country rock in the northeastern one-third of the county but are exposed only at very rare intervals and even there to an extremely limited extent. In the remainder of the county the uppermost consolidated rock is referred to the Missouri series. Exposures are 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

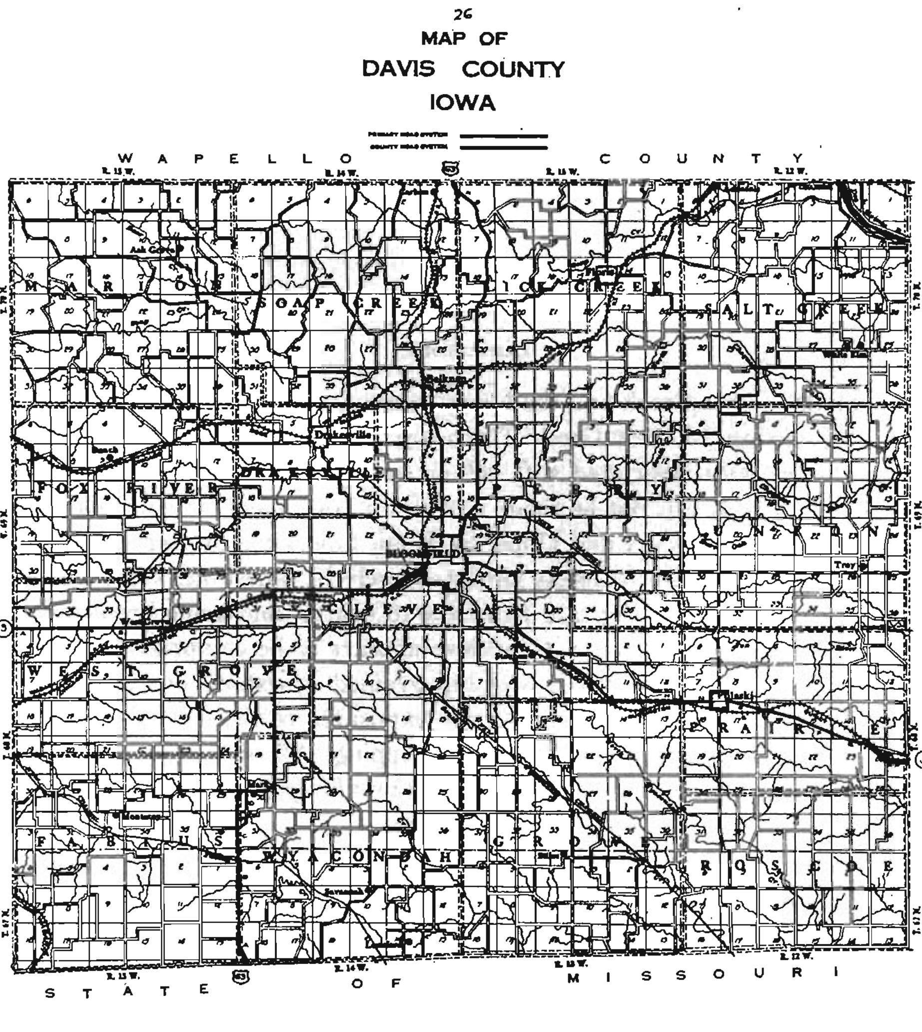
A comprehensive survey of all known gravel and sand prospects within the glacial deposits of the county has been made. While it is realized that such a survey can never be complete — that with the passage of time additional possibilities will always continue to be discovered — it is nevertheless believed 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 N½ 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 NW$\frac{1}{4}$ SE$\frac{1}{4}$ section 2, and one in NW$\frac{1}{4}$ NW$\frac{1}{4}$ 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.

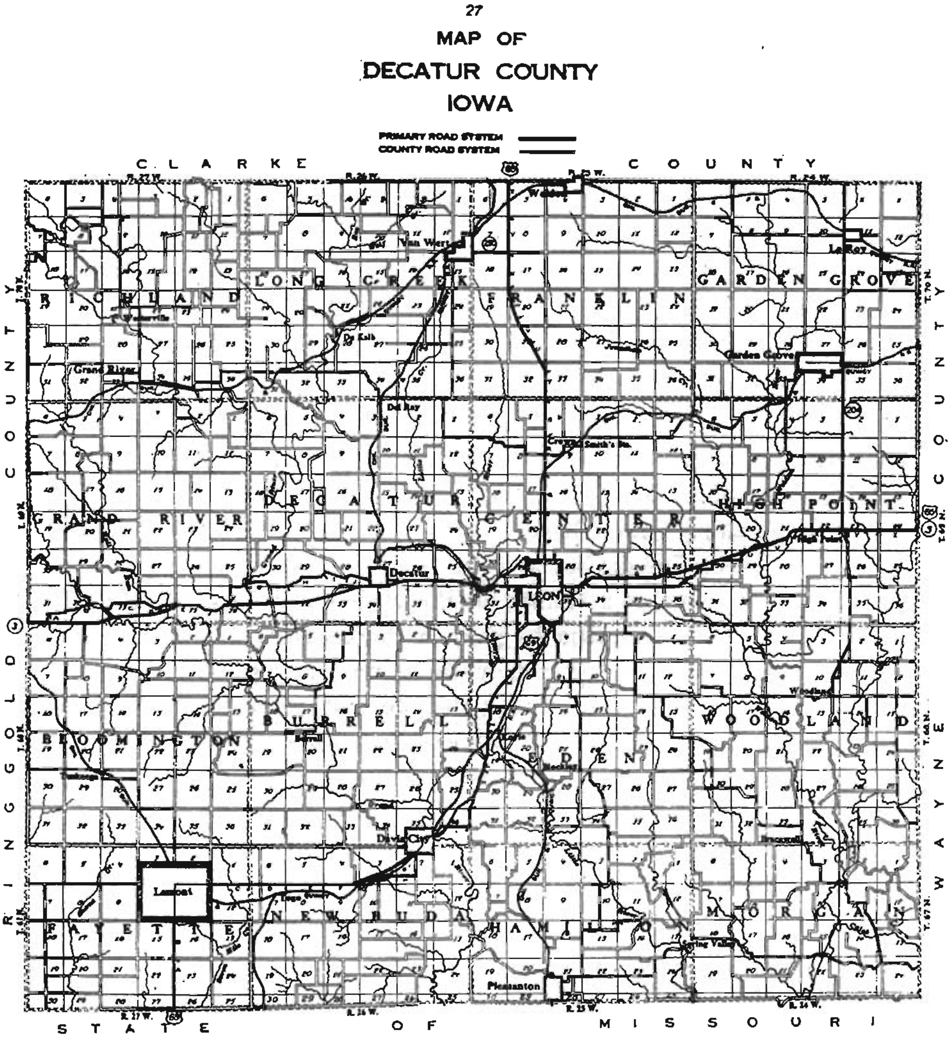
Limestone

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

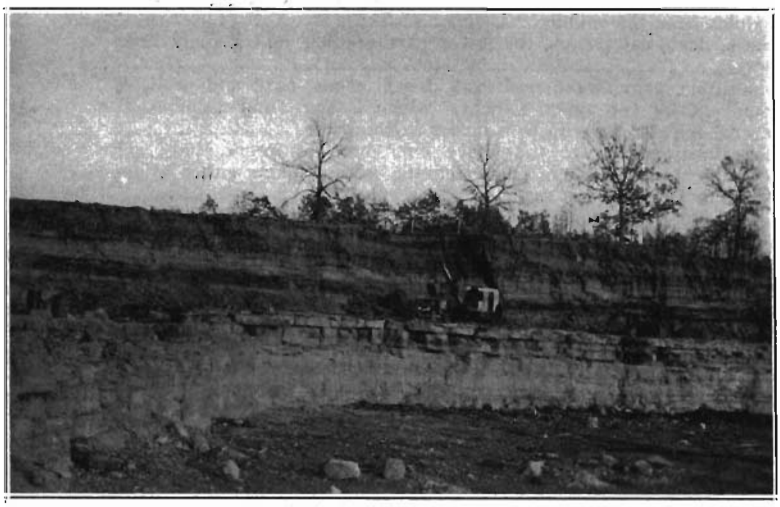


FIG. 1. — Sargent quarry in section 32, Decatur Township, Decatur County.

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.

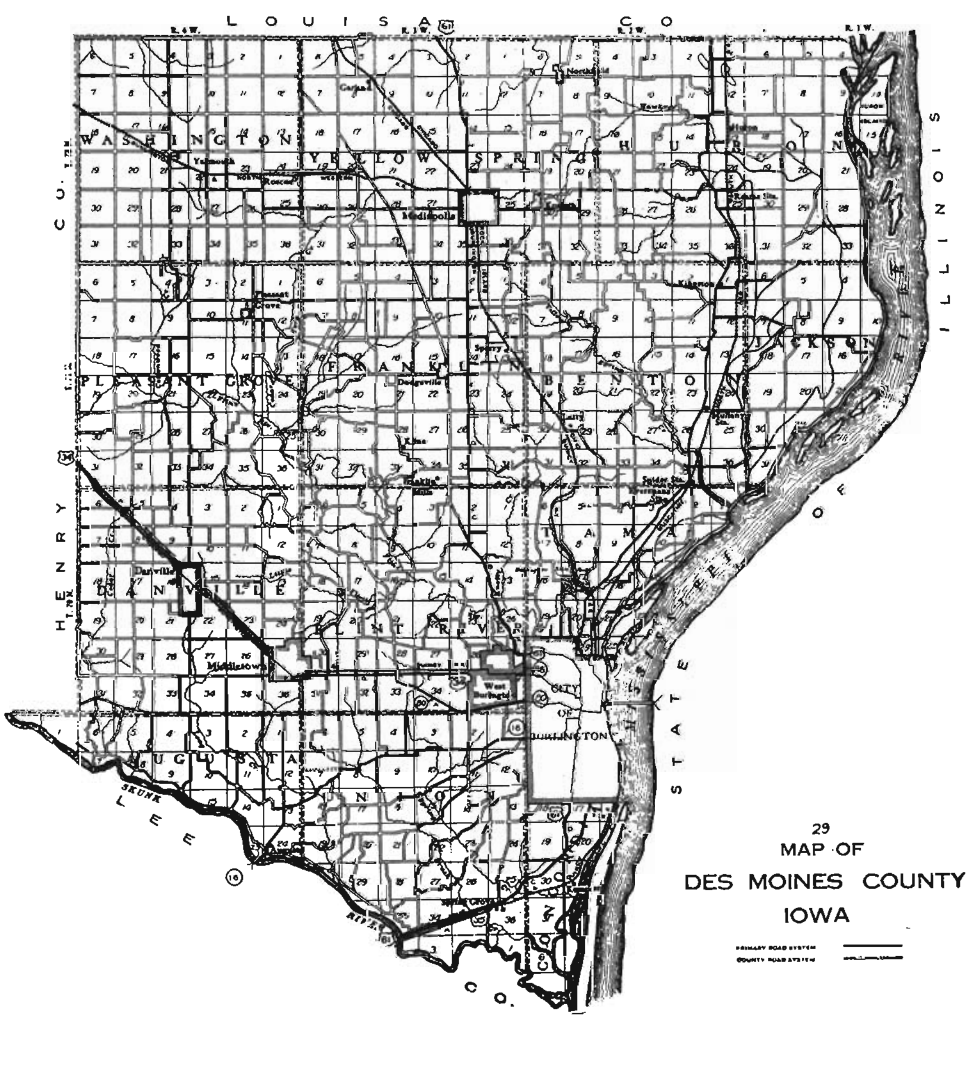
Besides the above, some twenty other gravel prospects have been investigated but not found to be worth opening. A careful visual survey of the bluffs bordering the valley of Grand River throughout its course in the county, and of Elk Creek from its mouth to section 34, Grand River Township, has disclosed 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



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.

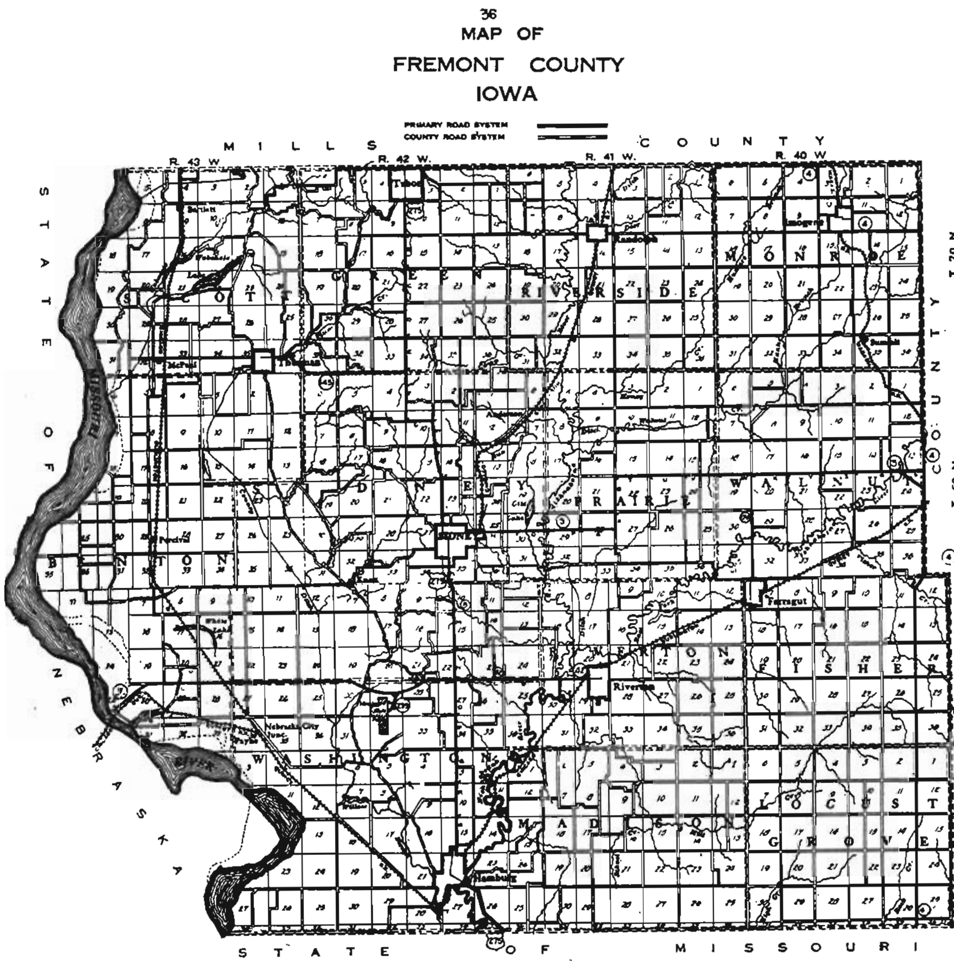
Higher and better-developed terraces are known in the south part of

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.

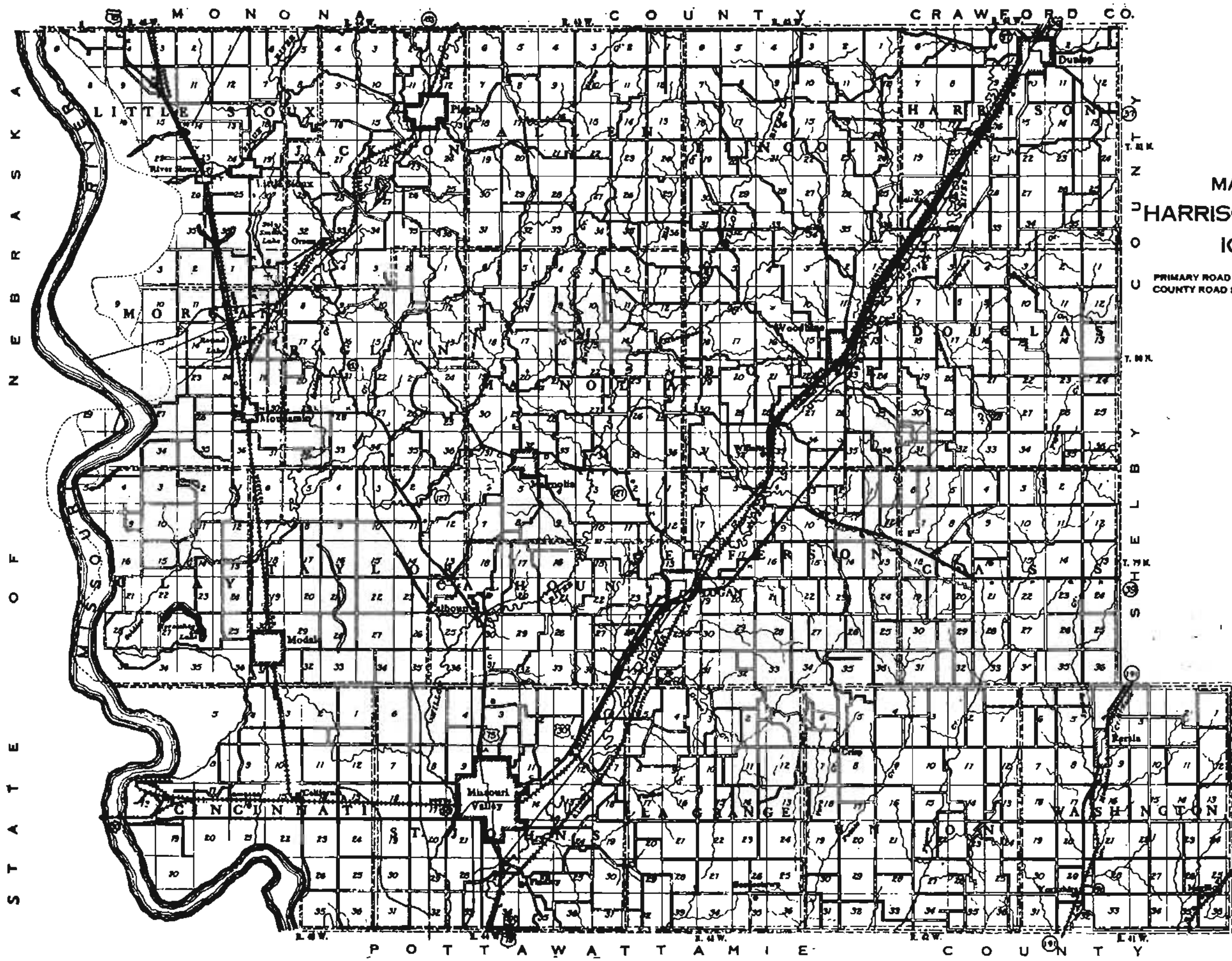
The valleys of both branches of Nishnabotna River are underlain by beds of sand and gravel, which, however, are usually so thin or so deeply buried as to be not workable under present conditions. A recent investigation of well data in these valleys, made with a view toward obtaining more definite information 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.



43
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.

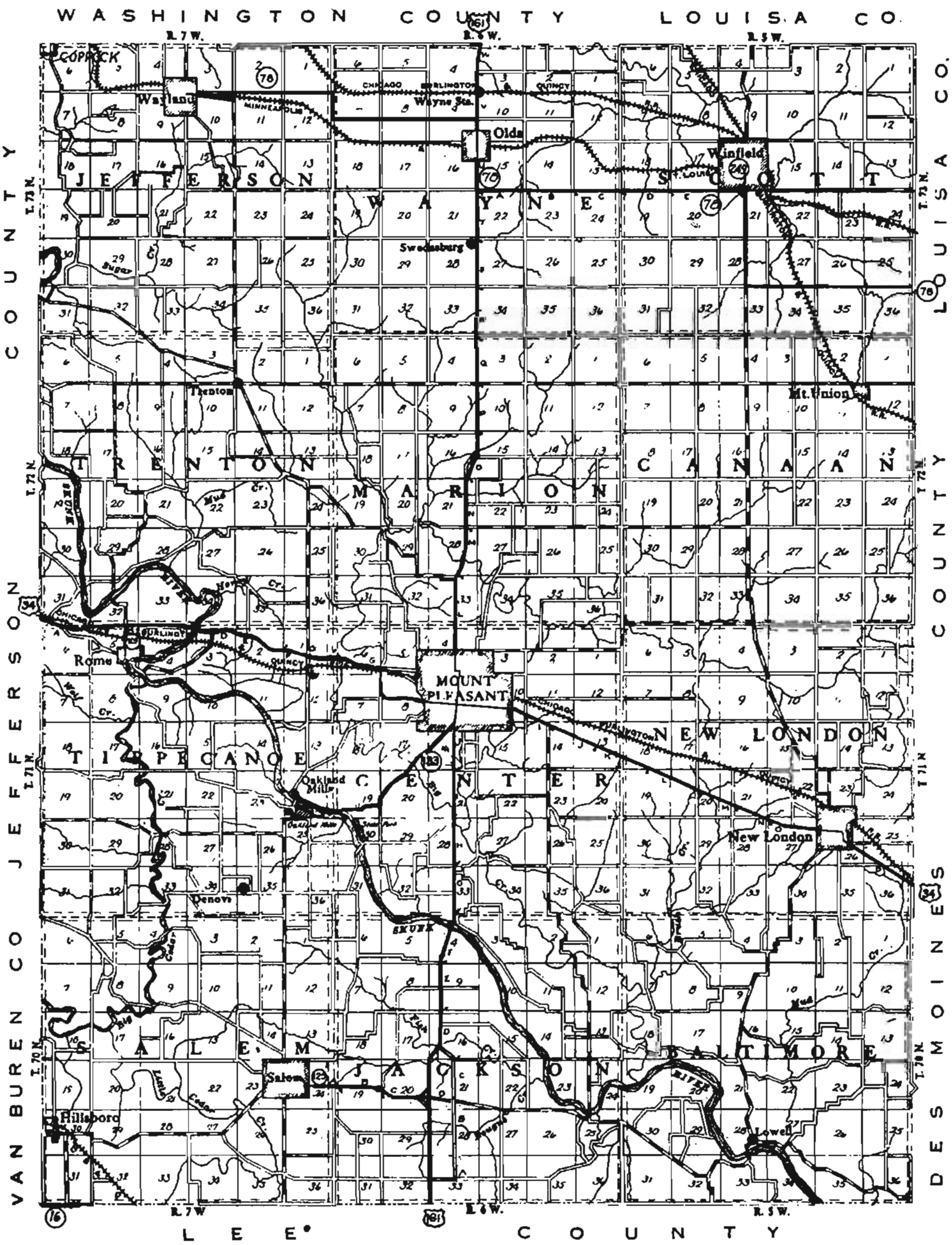
It appears from available information that Nebraskan and Aftonian glacial deposits lie next above the bedrock throughout most of the county. However, surface exposures definitely referable to those stages are difficult to find, and it may be that they are only a few feet thick. The Kansan drift sheet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

44

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.

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.

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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

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[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

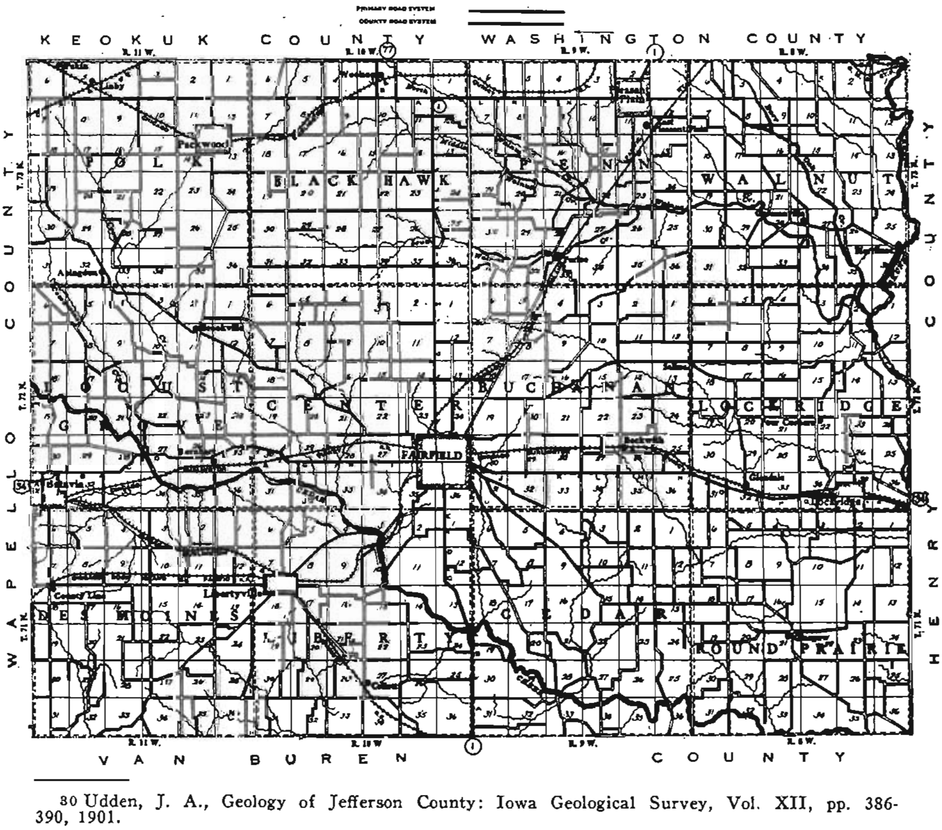
Creek in Walnut and the eastern part of Penn Townships, near Rocky Branch all along the south line of Walnut Township, near Skunk River and the lower course of its tributaries in eastern Walnut and Lockridge Townships, near Cedar Creek through Round Prairie and eastern Cedar Townships, and in scattered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

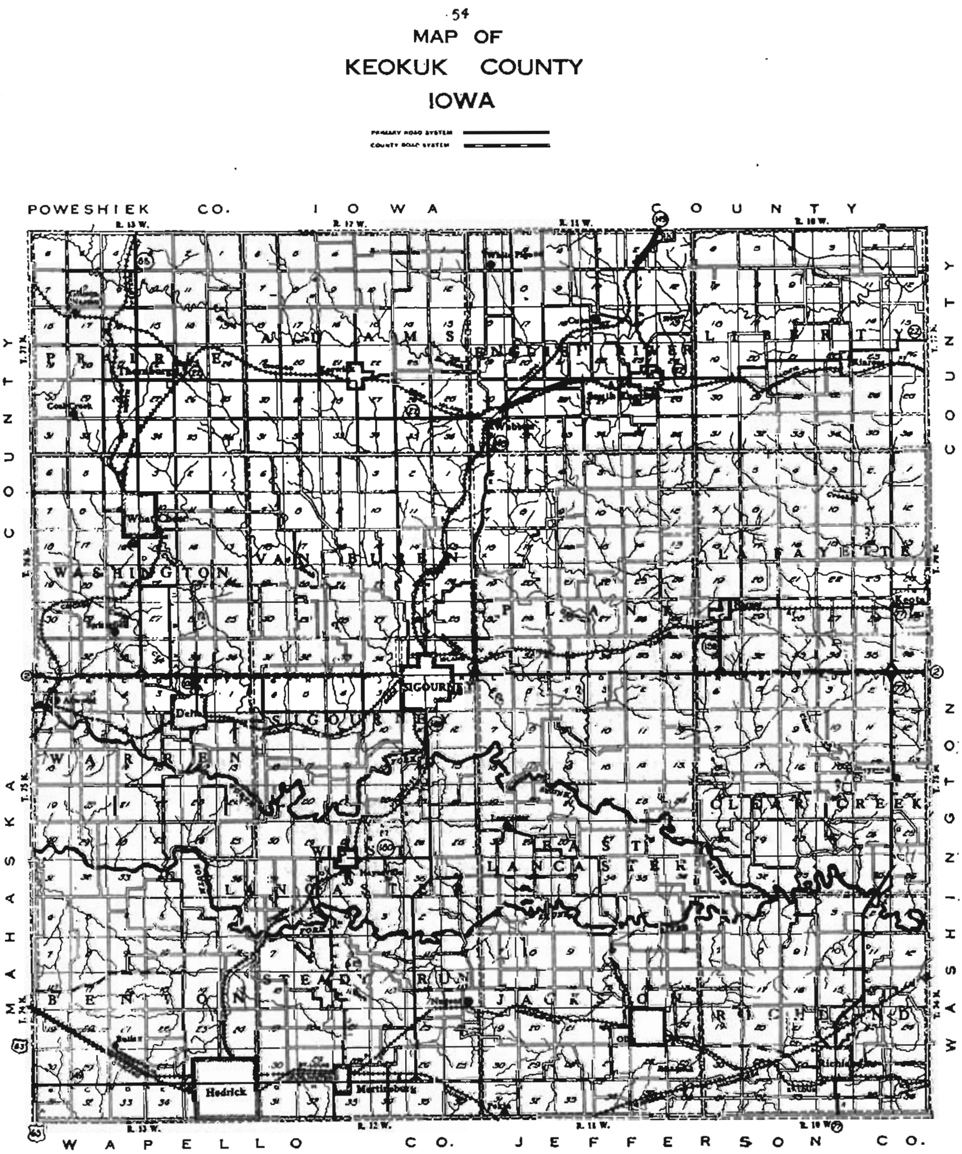
KEOKUK COUNTY

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

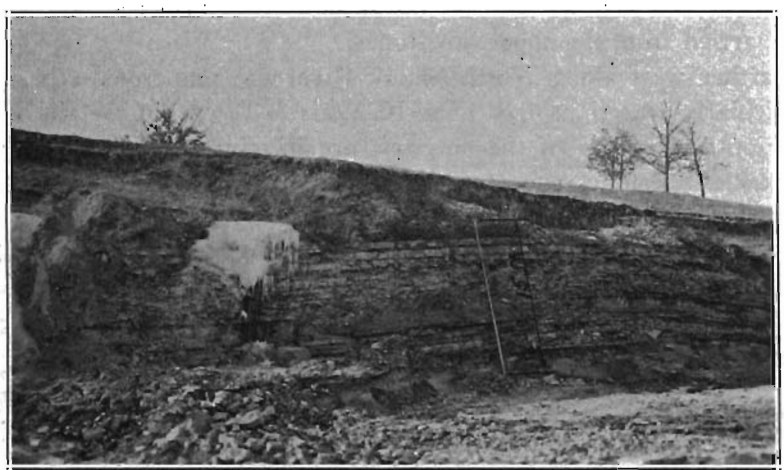


FIG. 2. — Ste. Genevieve limestone in County Quarry in section 13, Van Buren Township, Keokuk County. This shows the characteristic thin bedding and variable dips.

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

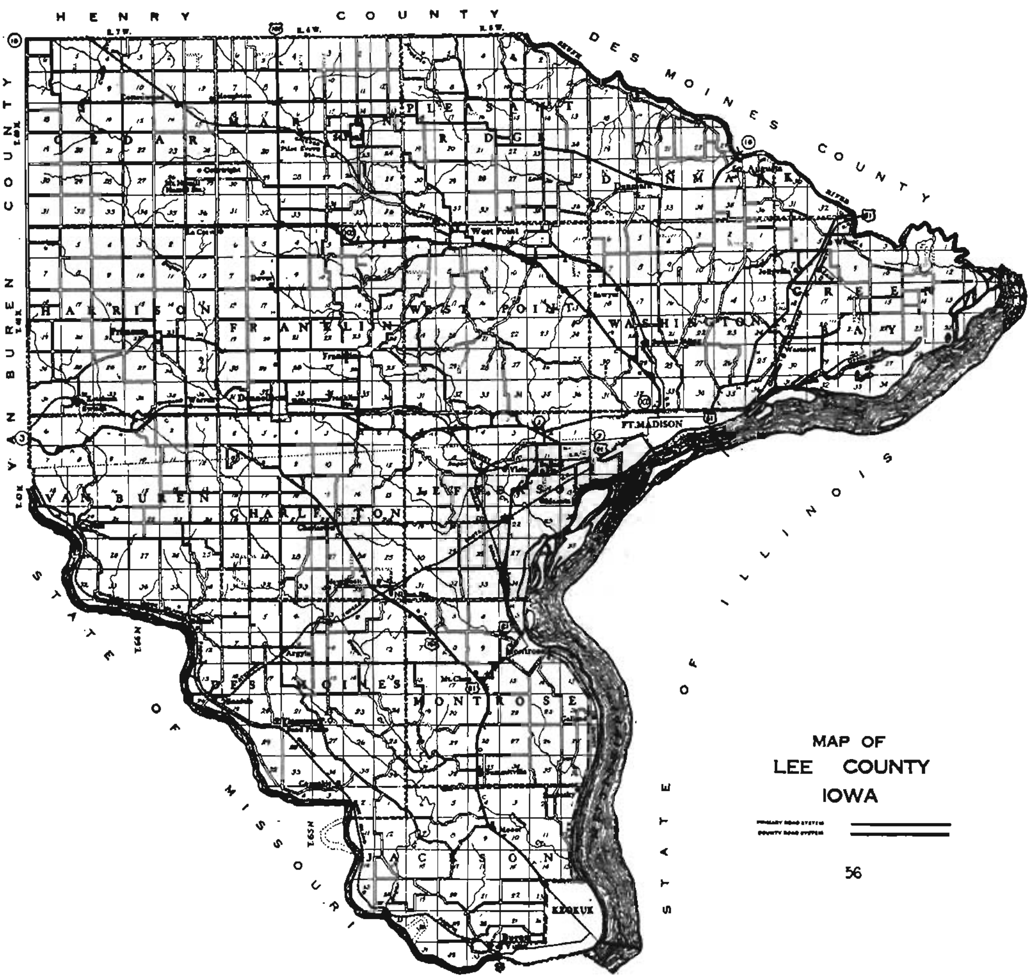
Except for the Kinderhook formation, the whole Mississippian section for southeastern Iowa is visible in Lee County. The Burlington appears in the lower slopes near Wever and Augusta and north and northwest of Denmark. The Keokuk may be seen in the higher slopes in the same locality and it forms the 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

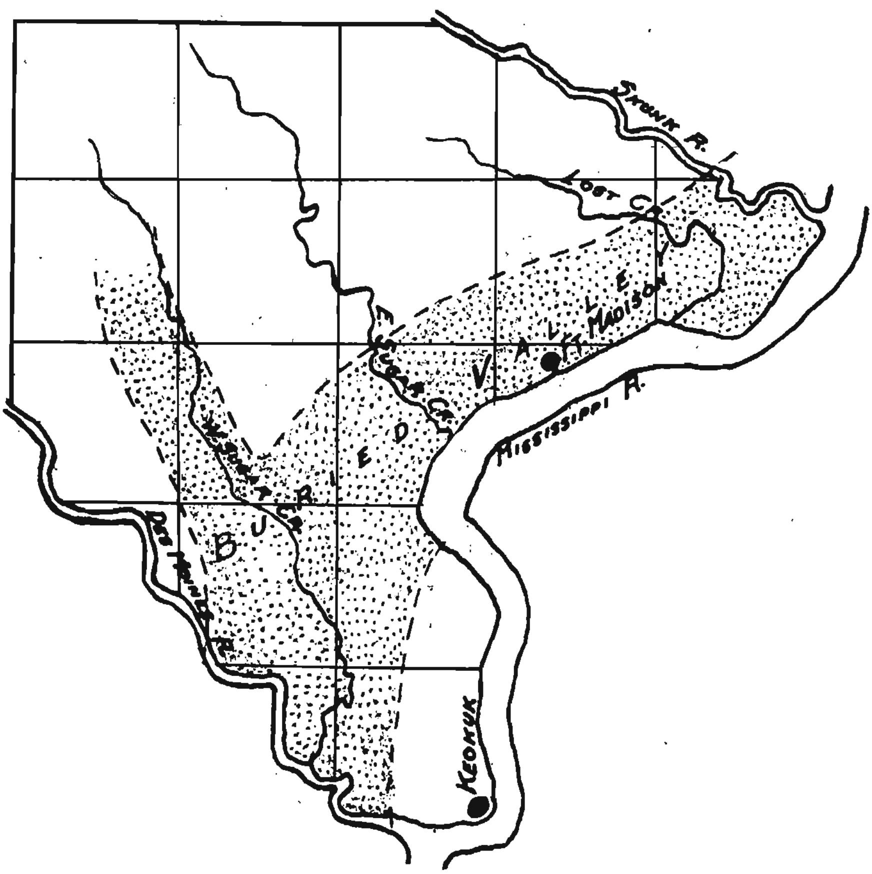


Fig. 3. — Map of Lee County showing buried valley (after Gordon).

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 (SE¼ SE¼ sec. 25, T. 65, R. 5) and again in NW¼ section 32, and SW¼ 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.

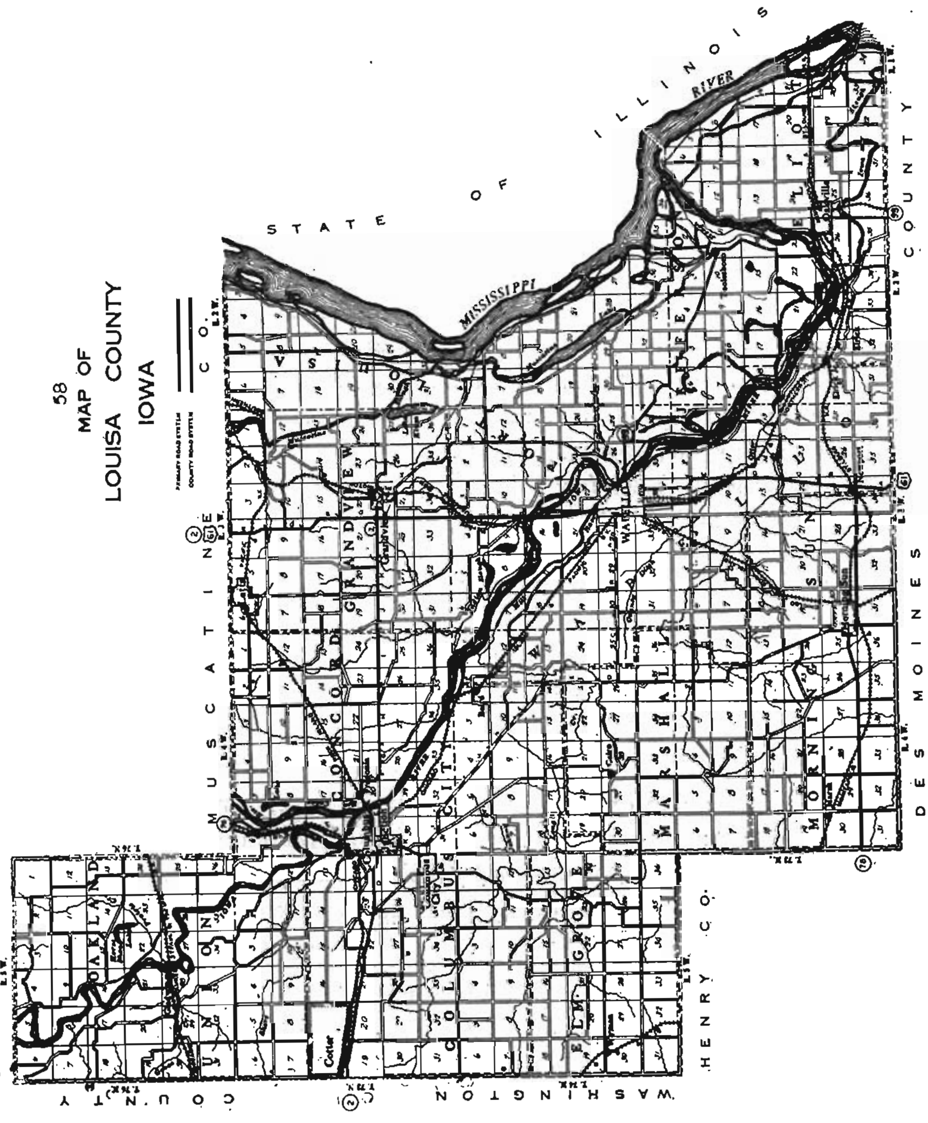
Along the larger streams, and particularly in the extensive lowland areas bordering Iowa and Mississippi Rivers, the loess, and at many points the Illinoian or even the Kansan, is largely eroded away, and the remnants are covered by the alluvium. This alluvium is of post-Illinoian or even Recent age 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.

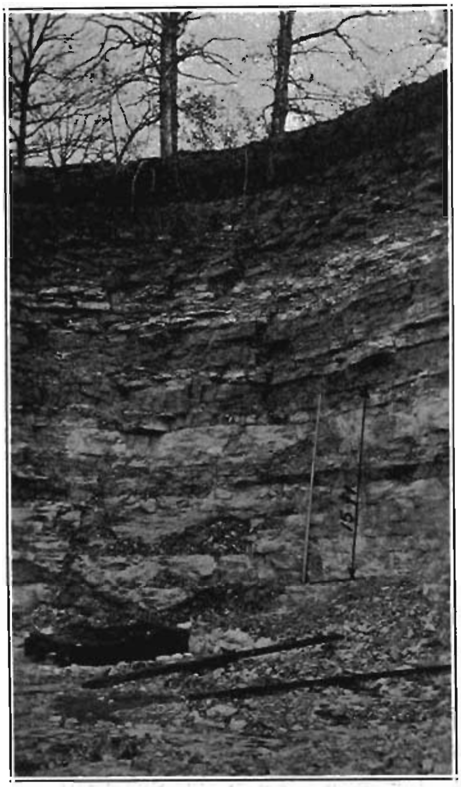


FIG. 4. — Quarry face two miles east of Morning Sun.

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.

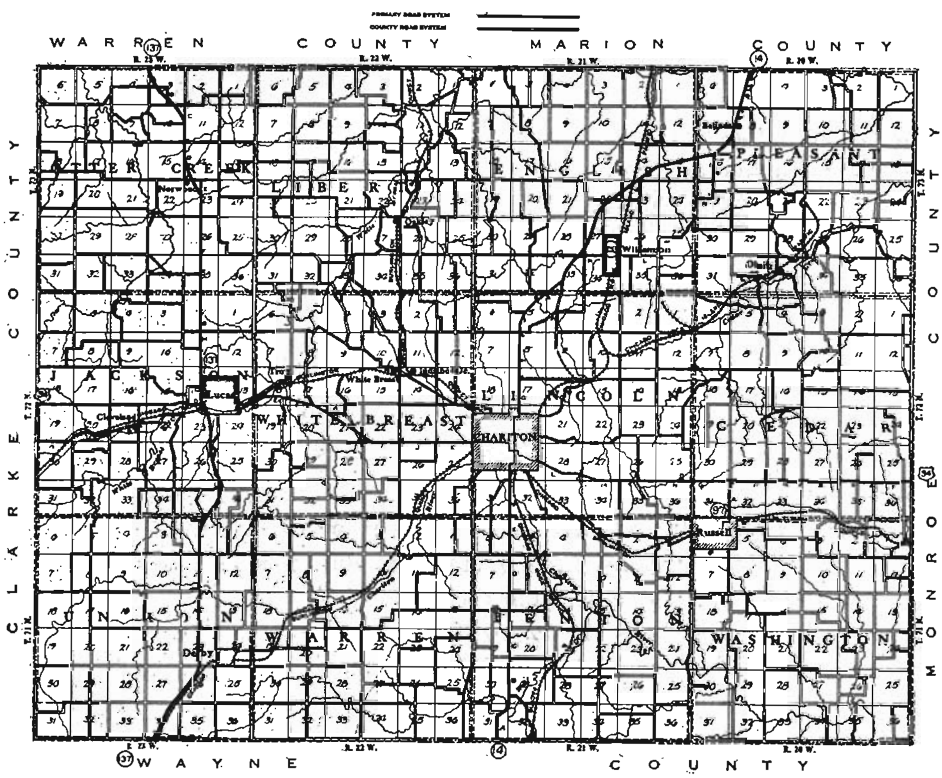
Deposits along the Smaller Streams. — Many of the smaller creeks and intermittent streams, having cut deep into the glacial drift, or even at places into the underlying rock, have collected important quantities of sand, pebbles, and broken rock to form bars along their courses. Most of these bars are 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

59
MAP OF
LUCAS COUNTY
IOWA



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.

[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.

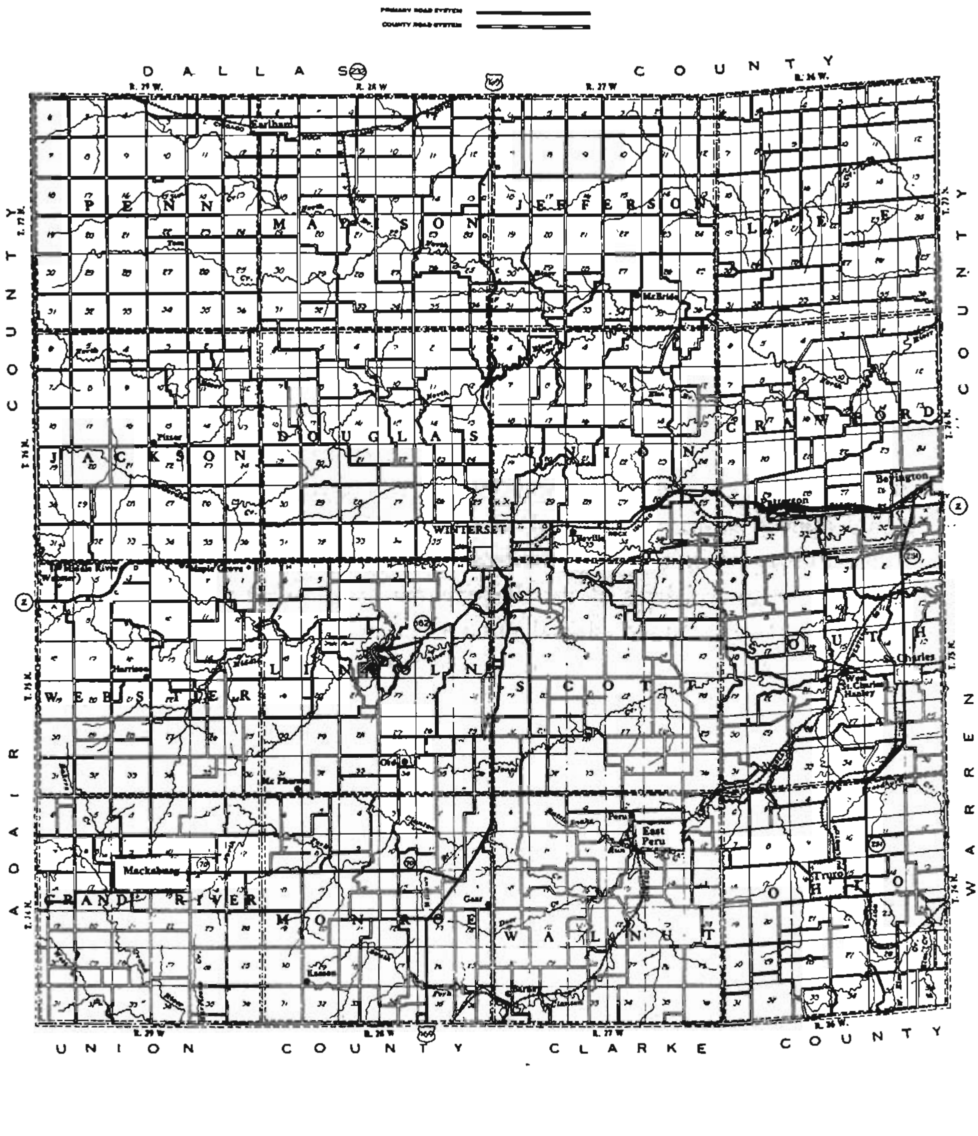
In a few cases, where an outcrop of soft or moderately hard sandstone has been exposed to the weather for many years, the broken fragments appear similar to gravel, and interested parties have reported such outcrops as indications of a gravel bed.

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

61

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 W½ section 17, Lincoln Township, and it is found above the Winterset along the small creeks in W½ section 22, W½ 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. SW¼ NW¼ 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 SW¼ 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 SW¼ SW¼ section 8, N½ SW¼ section 16, E½ W¼ section 17, and N½ SW¼ section 17, Lincoln Township, and in SE¼ NW¼ section 23, SW¼ SW¼ section 10, S½ SE¼ section 9, NW¼ NE¼ section 8, and SW¼ SE¼ 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 N½ section 25, Douglas Township, dipping beneath the creek in NW¼ section 25. Quarrying on a small scale was carried on during the 1931 season near center NE¼ 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

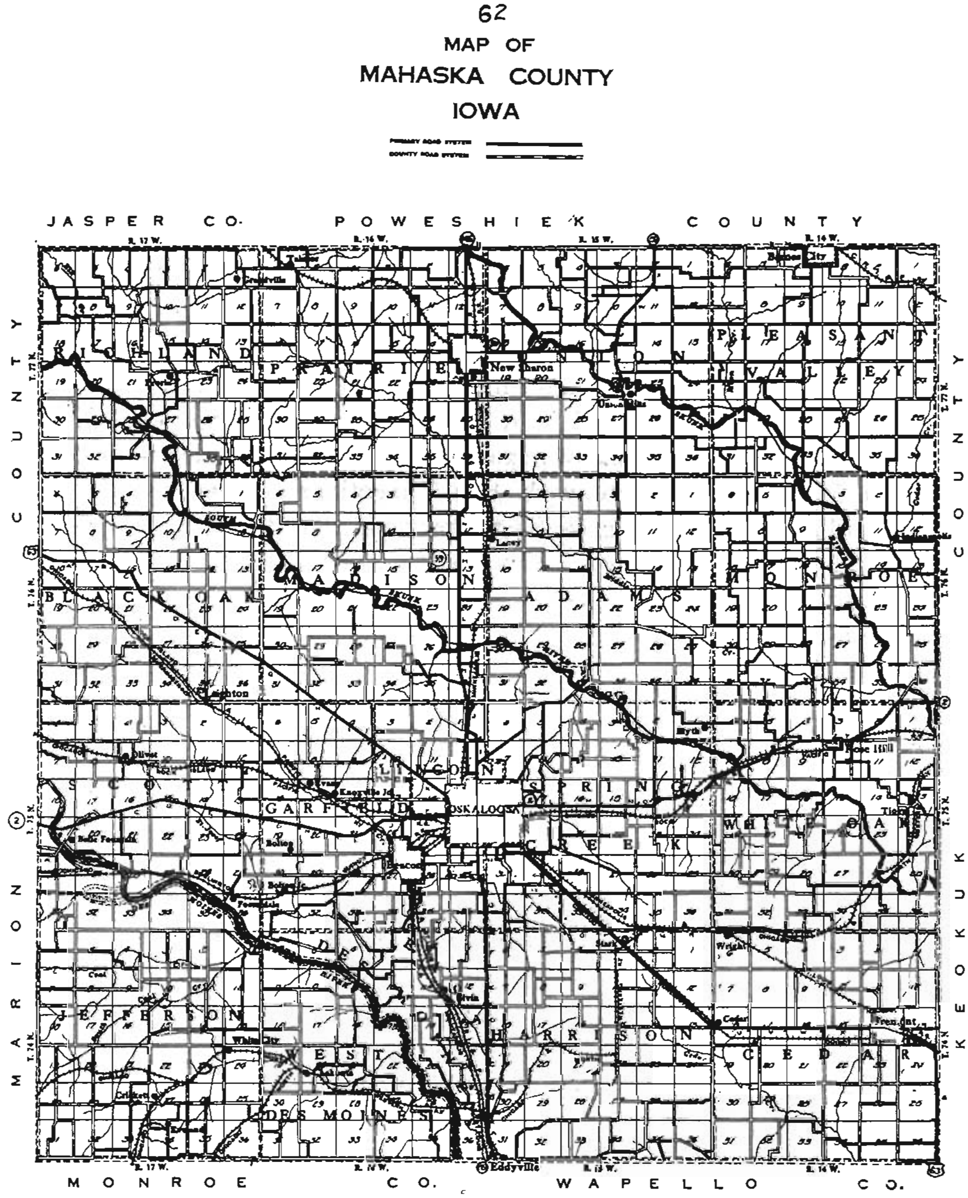
The entire county is underlain by the St. Louis and Ste. Genevieve limestones, which, however, appear at the surface only in narrow belts along Des Moines, South Skunk, and North Skunk Rivers and the immediate lower courses of a few of their tributaries. Elsewhere the country rock is of Pennsylvanian (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

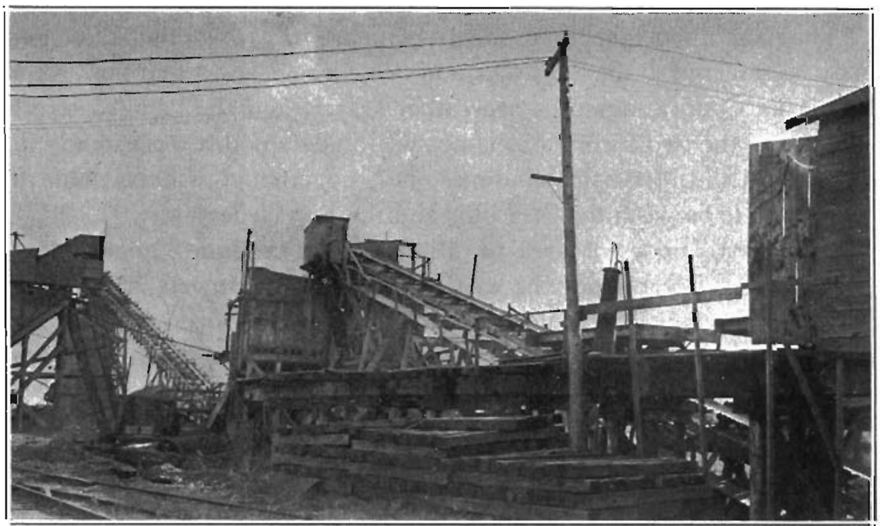


FIG. 6. — Concrete Materials Corporation, Eddyville. General view of the screening and washing plant.

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.

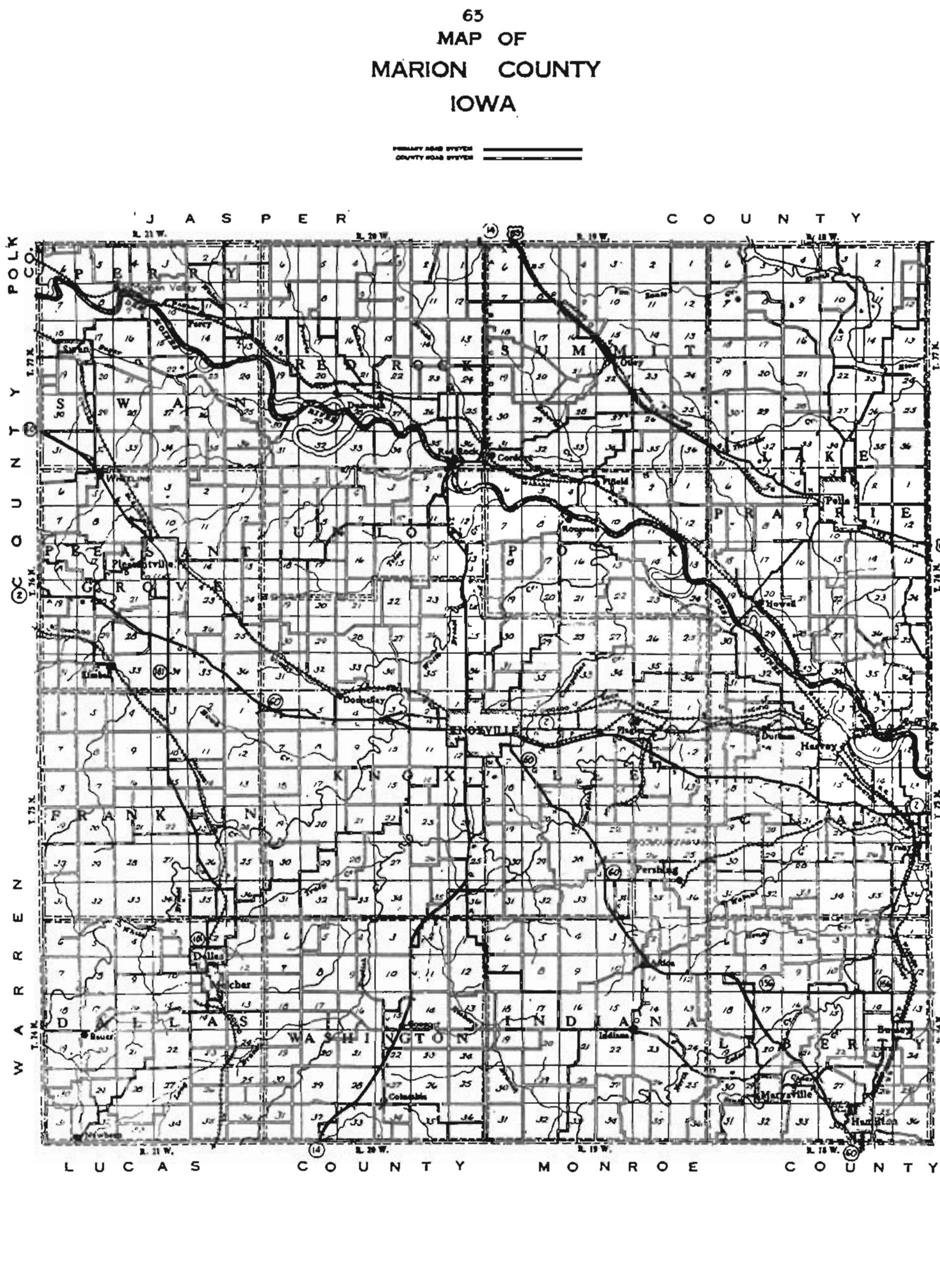
Limestone

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



	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

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

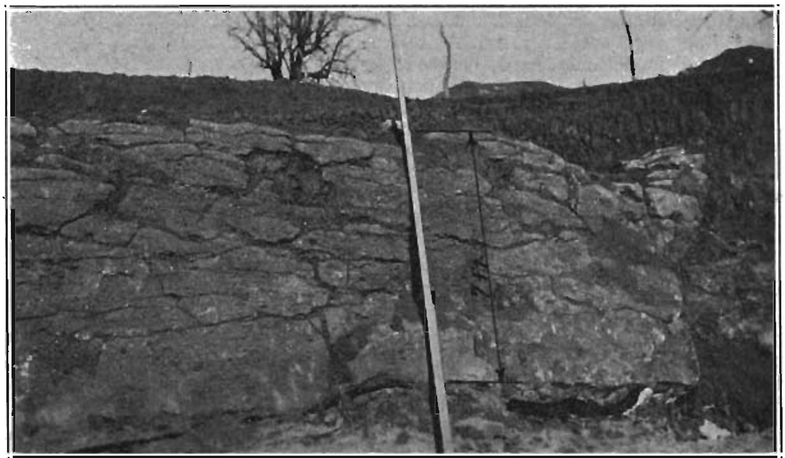


FIG. 8. — Detail of part of quarry face shown in figure 7 showing weathering of upper part of conglomerate and unconformity with shale and coal below.

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

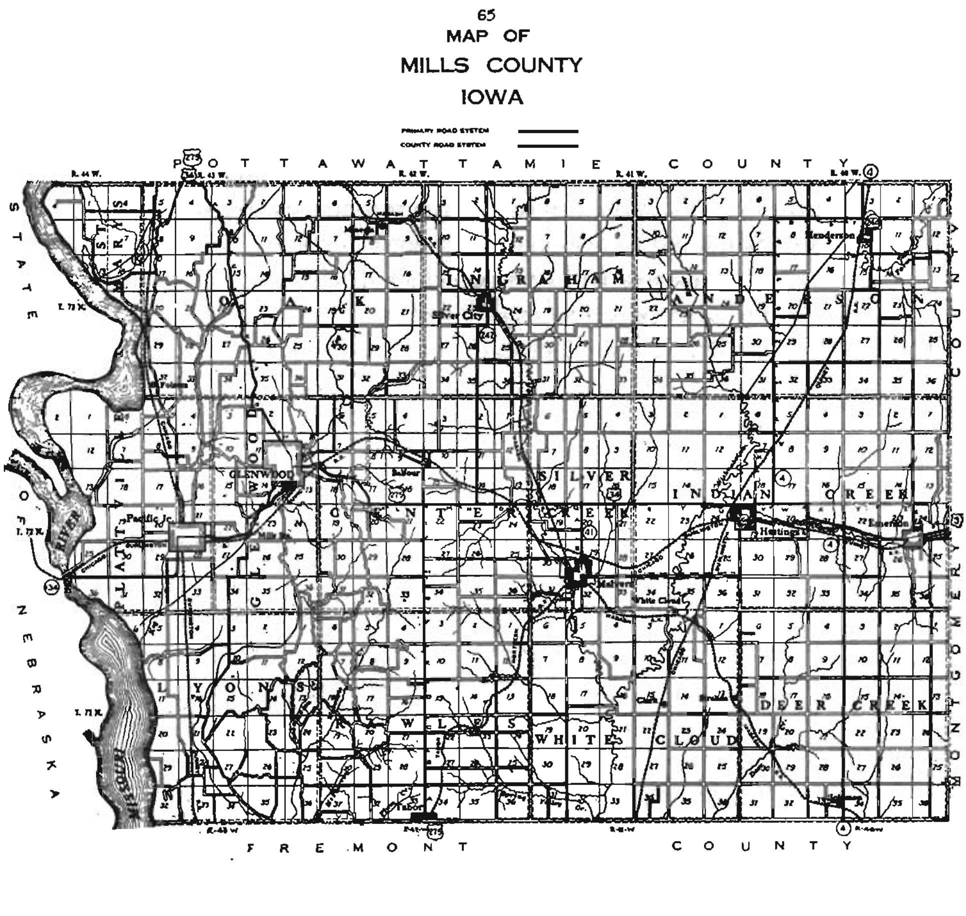
The material in all these bars is very similar, usually clean, hard, and sound, and suitable for any road or concrete purposes. Occasional streaks of silt, or thin beds containing sticks, shale, or coal, are objectionable features.

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	¾
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 ($S\frac{1}{2}$ $NE\frac{1}{4}$ 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 $SE\frac{1}{4}$ $SW\frac{1}{4}$ 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 $SE\frac{1}{4}$ $NE\frac{1}{4}$ 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-

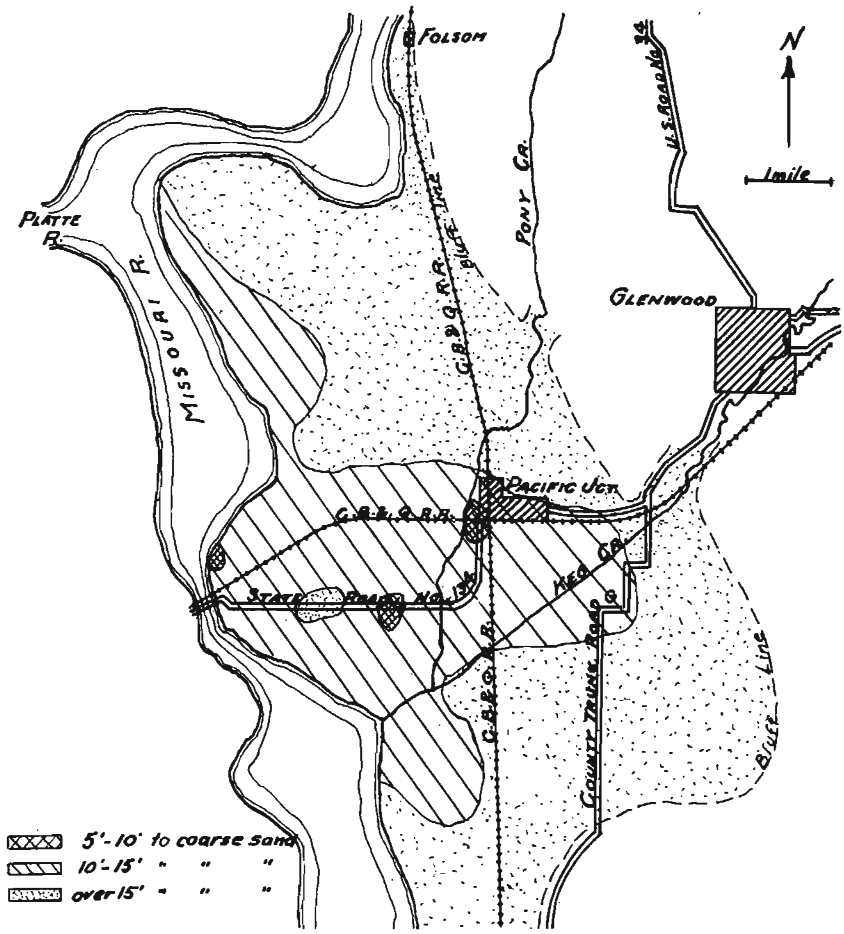


FIG. 9. — Map of the western part of Mills County showing the depth to coarse sand in Missouri bottomlands.

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:

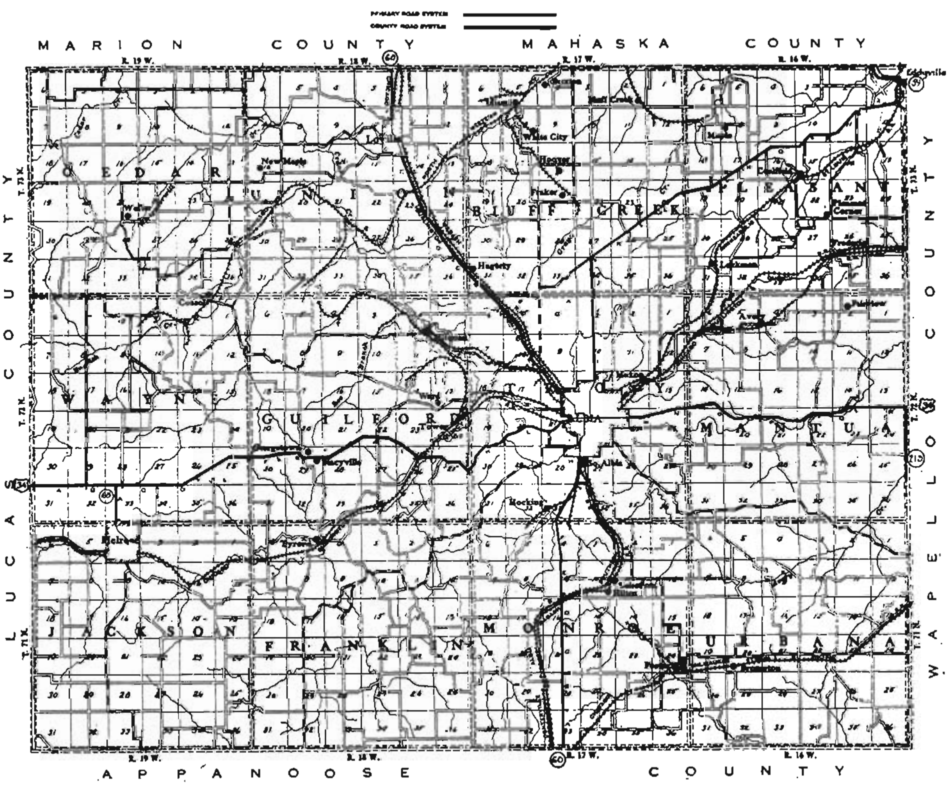
	Feet
7. Drift and surface wash	5
6. Shale, arenaceous, with calcareous cement	7
5. Limestone, compact, brittle, containing pyrite balls	3
4. Limestone, oölitic, evenly bedded, with broken shell fragments	3½
3. Marl, fossiliferous	½
2. Limestone, compact, lithographic, softer below	4
1. Sandstone, in 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

68
MAP OF
MONROE COUNTY
IOWA



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:	
SE$\frac{1}{4}$ NE$\frac{1}{4}$ sec. 23	Quantity 16,000 cu. yd. in 1926
SW$\frac{1}{4}$ NW$\frac{1}{4}$ sec. 23	Quantity 21,000 cu. yd. in 1926
Wayne Township:	
NE$\frac{1}{4}$ SW$\frac{1}{4}$ sec. 3	Quantity 82,000 cu. yd. in 1926
Guilford Township:	
Center sec. 2	
SE$\frac{1}{4}$ SE$\frac{1}{4}$ sec. 3	
NE$\frac{1}{4}$ SW$\frac{1}{4}$ sec. 11	
Troy Township:	
NW$\frac{1}{4}$ SW$\frac{1}{4}$ sec. 33	Quantity 20,000 cu. yd. in 1932
Mantua Township:	
NE$\frac{1}{4}$ SE$\frac{1}{4}$ sec. 3	
SW$\frac{1}{4}$ NW$\frac{1}{4}$ sec. 11.	Quantity 7,000 cu. yd. in 1926
NW$\frac{1}{4}$ NW$\frac{1}{4}$ sec. 13	Material very poorly burned
West of center sec. 16	
Center NE$\frac{1}{4}$ sec. 23	Quantity 25,000 cu. yd. in 1931
NW$\frac{1}{4}$ SW$\frac{1}{4}$ sec. 23	
Monroe Township:	
NE$\frac{1}{4}$ NE$\frac{1}{4}$ sec. 4	Quantity 25,000 cu. yd. in 1932
NW$\frac{1}{4}$ NE$\frac{1}{4}$ sec. 5	Quantity 100,000 cu. yd. in 1932
NW$\frac{1}{4}$ NW$\frac{1}{4}$ sec. 9	Quantity 80,000 cu. yd. in 1932
SW$\frac{1}{4}$ SW$\frac{1}{4}$ sec. 10	Quantity 32,000 cu. yd. in 1926
SE$\frac{1}{4}$ SW$\frac{1}{4}$ sec. 24	

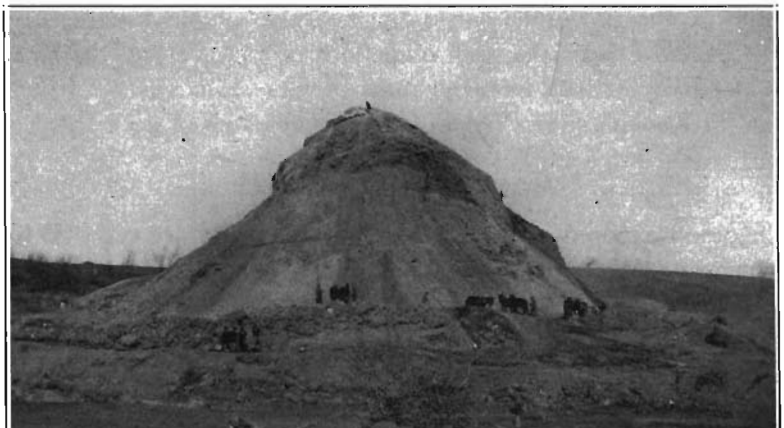


FIG. 10. — Coal mine dump near Albia.

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

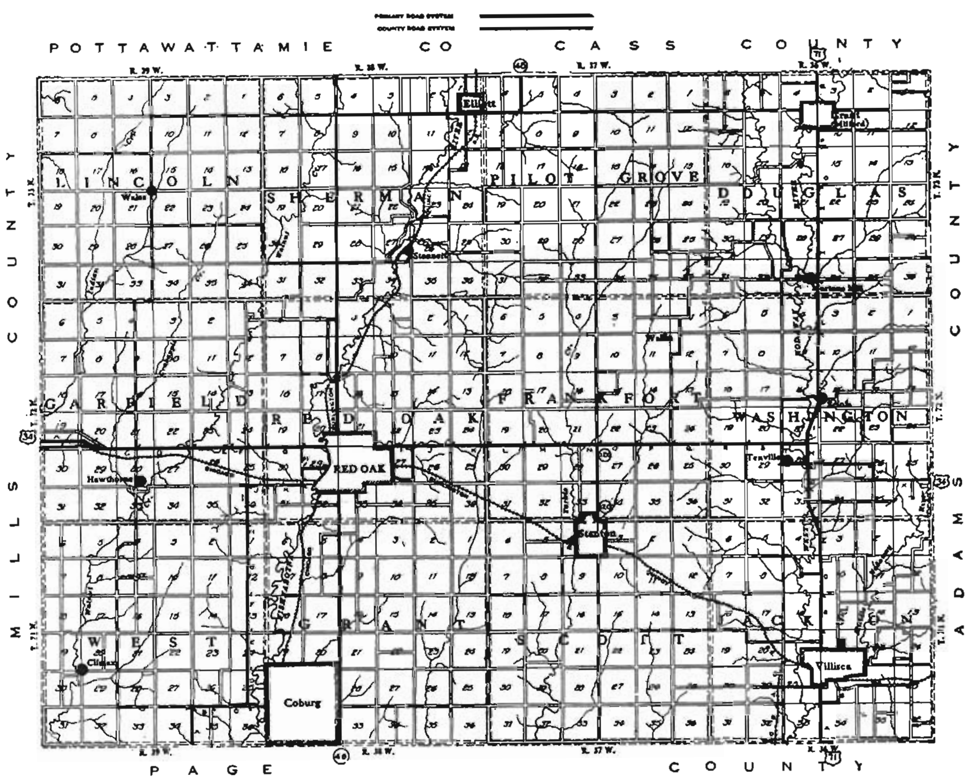
The oldest exposed rocks of Montgomery county are referred to the Shawnee and Wabaunsee stages of the Missouri series and consist principally of shale, with comparatively thin limestones and one or two thin coal seams. Outcrops are scarce and very limited in extent except near Stennett. In the higher 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

69
MAP OF
MONTGOMERY COUNTY
IOWA



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

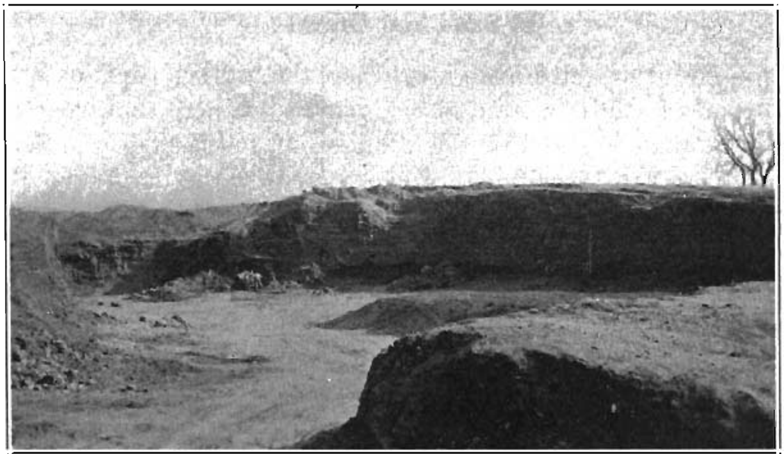


FIG. 11. — Cretaceous gravel in the State pit south of Red Oak.

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.

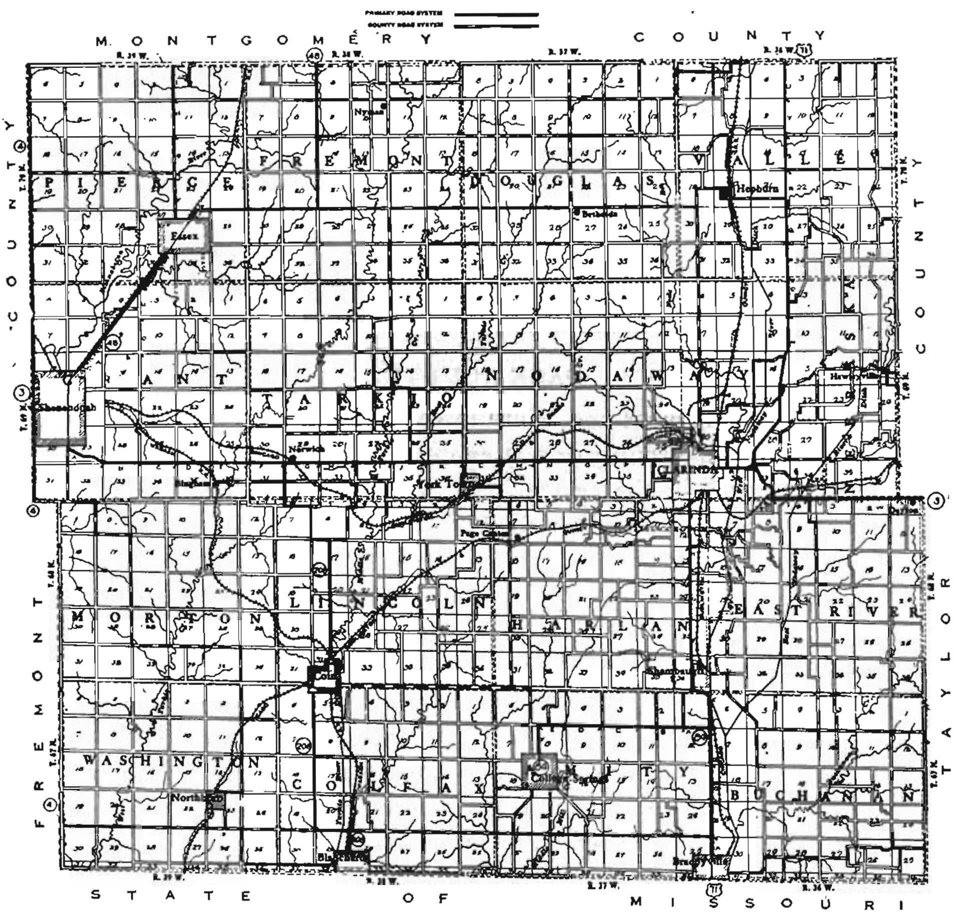
Limestone

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

73
MAP OF
PAGE COUNTY
IOWA



67 Smith, Geo. L., Carboniferous Section of Southwestern Iowa: Iowa Geological Survey, Vol. XIX, pp. 634-635, 1908.

7.	Limestone, soft, earthy	⅔
6.	Shale parting	½
5.	Limestone, dark bluish gray, hard, sound, fine-grained	1⅓
4.	Shale	7–12
3.	Limestone, shaly, soft	1½
2.	Shale	3½
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

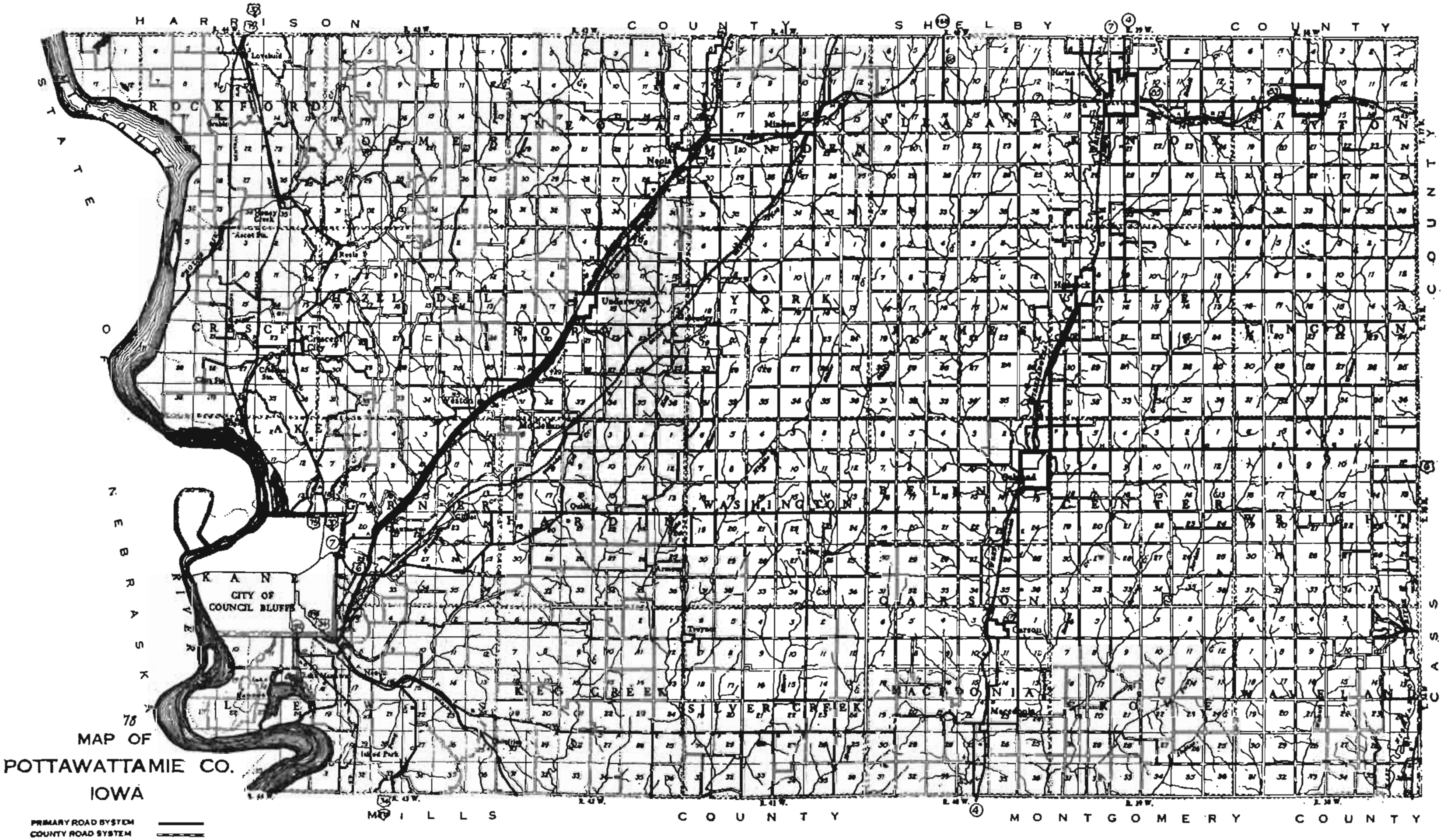

HARRISON COUNTY
SHELBY COUNTY
CASS COUNTY
MILLS COUNTY
MONTGOMERY COUNTY
STATE OF NEBRASKA
MISSOURI RIVER
ROCKFORD
BOOMER
NEOLA
MINDEN
PLEASANT
KNOX
LAYTON
HAZEL DELL
CRESCENT
NORWALK
YORK
VALLEY
LINCOLN
LAKE
GARNER
HARDIN
WASHINGTON
BELKNAP
CENTER
WRIGHT
KANE
CITY OF COUNCIL BLUFFS
CARSON
KEG CREEK
SILVER CREEK
MACEDONIA
GROVE
WAVELAND
Underwood
Neola
Minden
Loveland
Honey Creek
Crescent City
Weston
Treynor
Carson
Macedonia
Hancock
Oakland
MAP OF
POTTAWATTAMIE CO.
IOWA
PRIMARY ROAD SYSTEM
COUNTY ROAD SYSTEM

PLATE XXX

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.

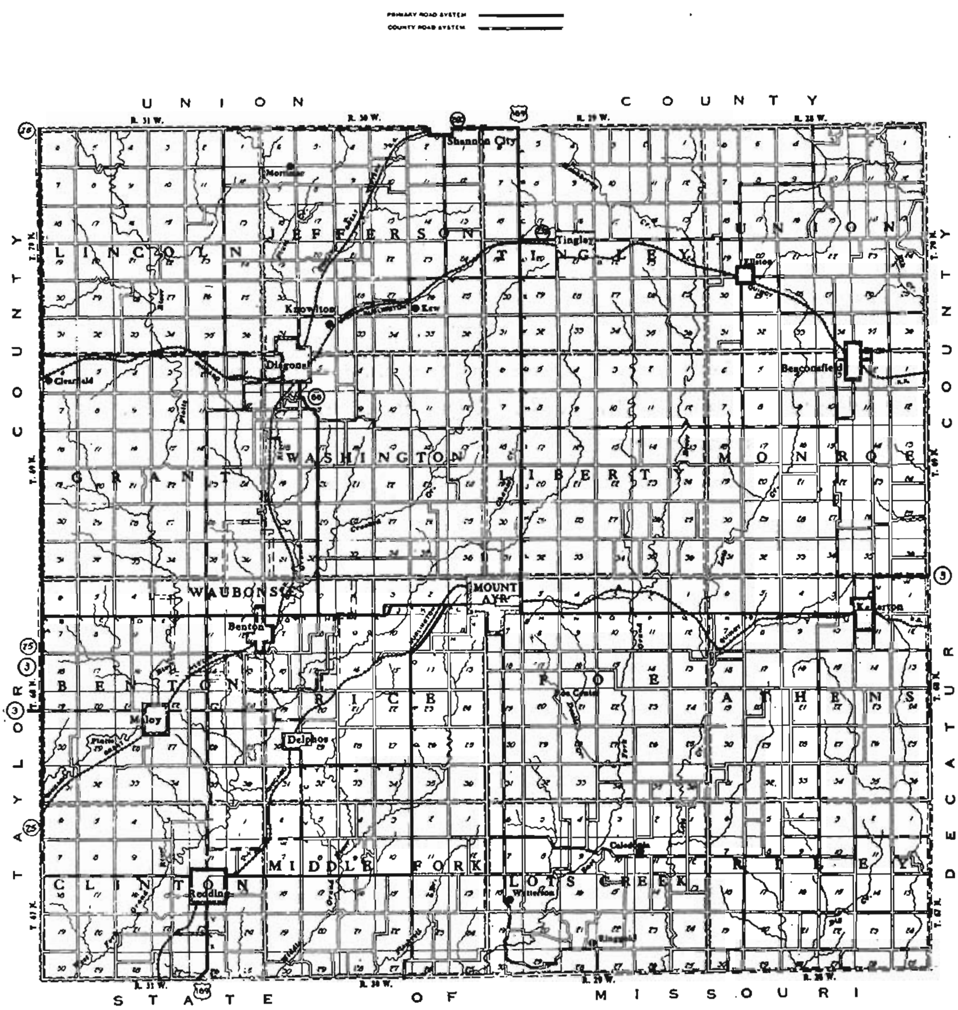
Limestone

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

80

MAP OF
RINGGOLD COUNTY
IOWA



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

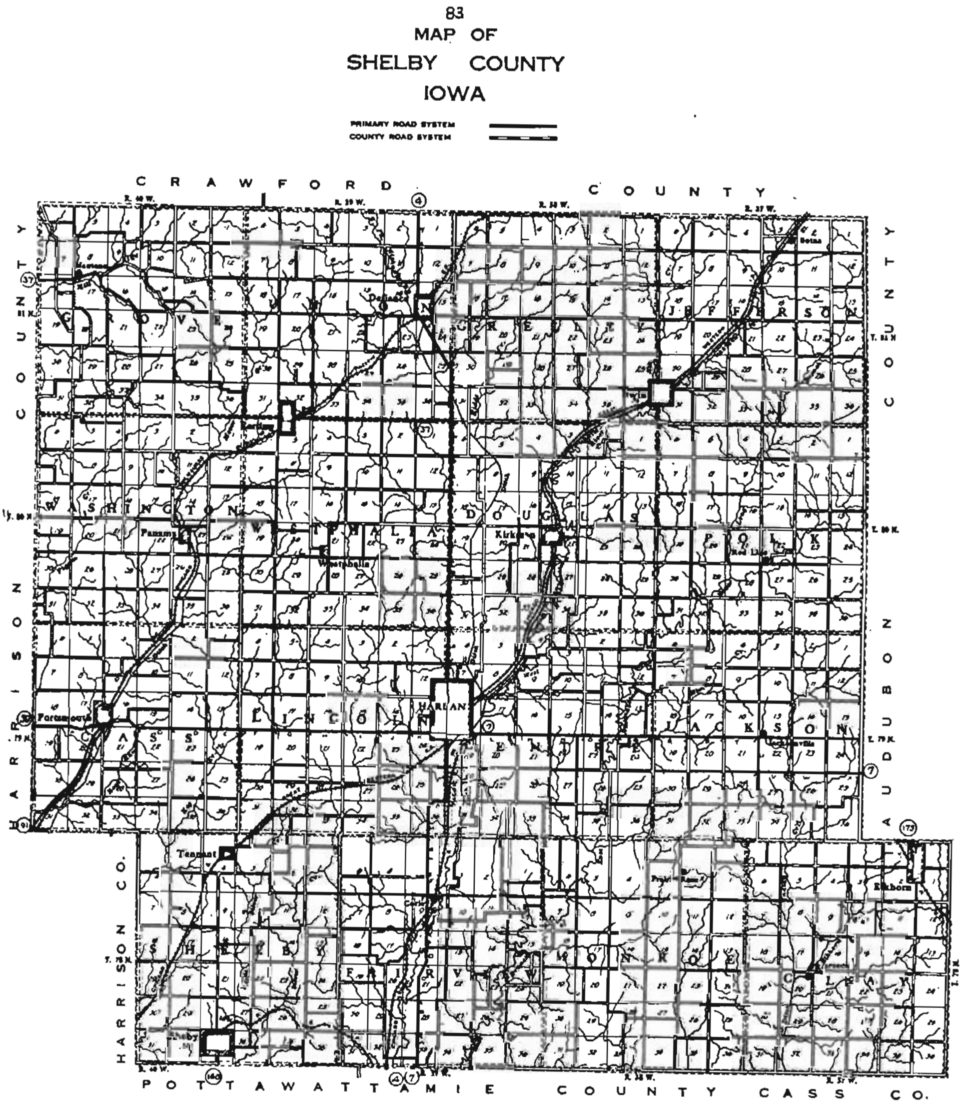
Careful surveys of the glacial gravels made by the State Highway Commission in the years 1926, 1927, and 1928 and covering some fifty locations have revealed very little available gravel. The largest deposits found are as follows: NE¼ SE¼ section 9, Washington Township, 1,600 cubic yards; NE¼ NE¼ section 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

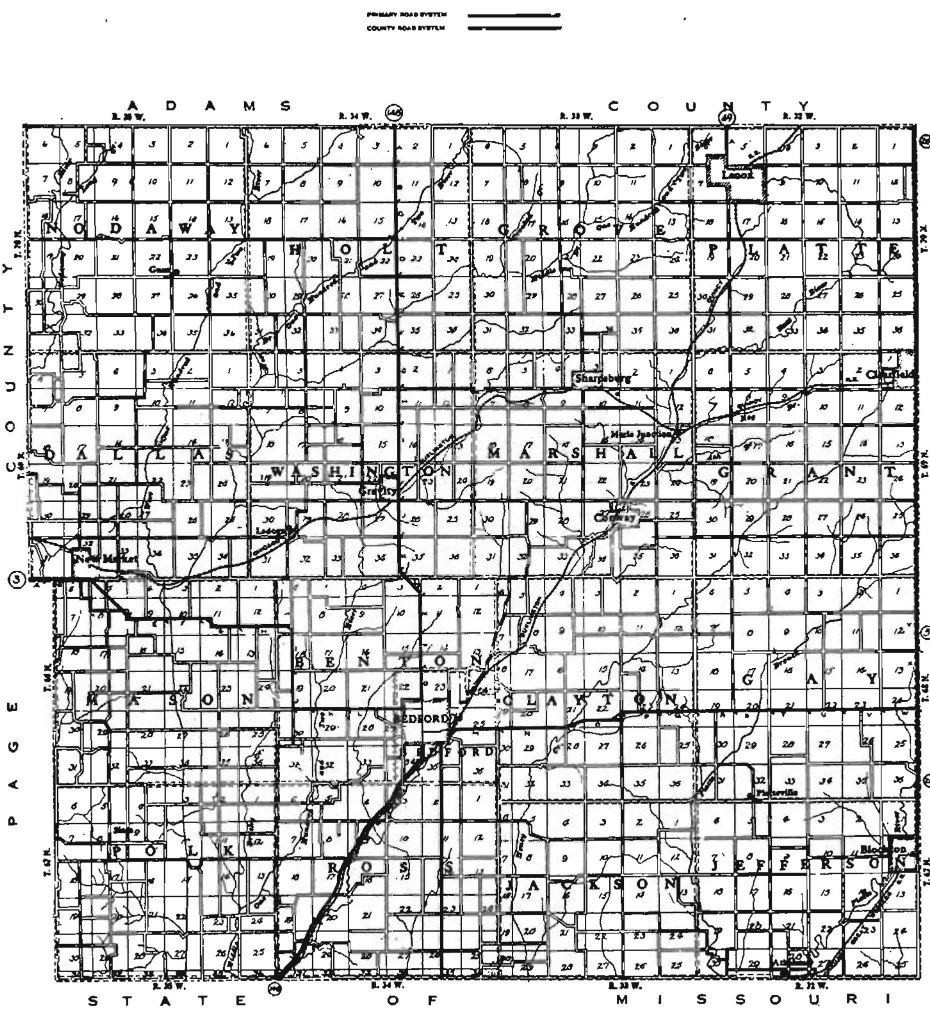
The few obscure exposures of bedrock at Bedford and in the southwest part of Nodaway Township evidently represent the Shawnee stage of the Missouri series, which probably underlies the whole county. Nebraskan and Kansan drift sheets are present, forming most of the surface exposures, the former in the 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

87
MAP OF
TAYLOR COUNTY
IOWA



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

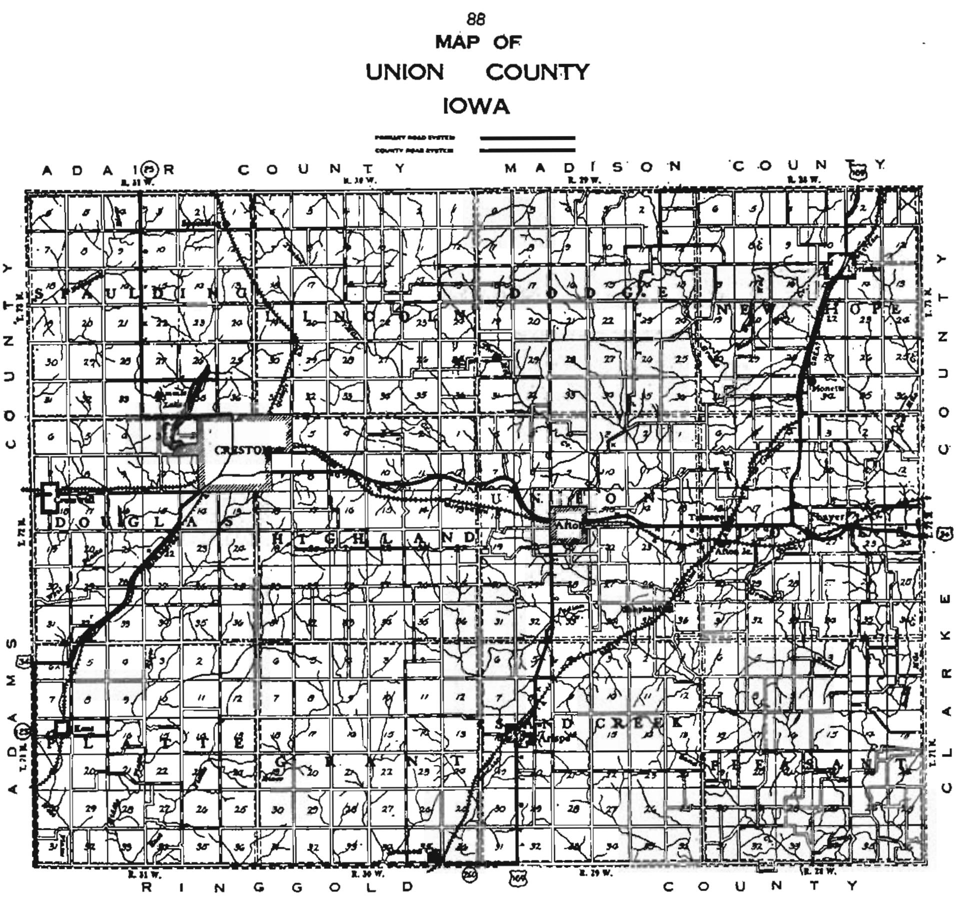
Sand and gravel pockets within the glacial drift are numerous, a survey recently completed by the State Highway Commission revealing about 85 prospects of this class. However, these are invariably small, most of them not being worth opening. The largest found are as follows: N½ SW¼ section 28, Clayton 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



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 E$\frac{1}{2}$ NE$\frac{1}{4}$ section 19, Jones Township, and in the Twelve Mile Creek bottomlands near center NW$\frac{1}{4}$ 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.

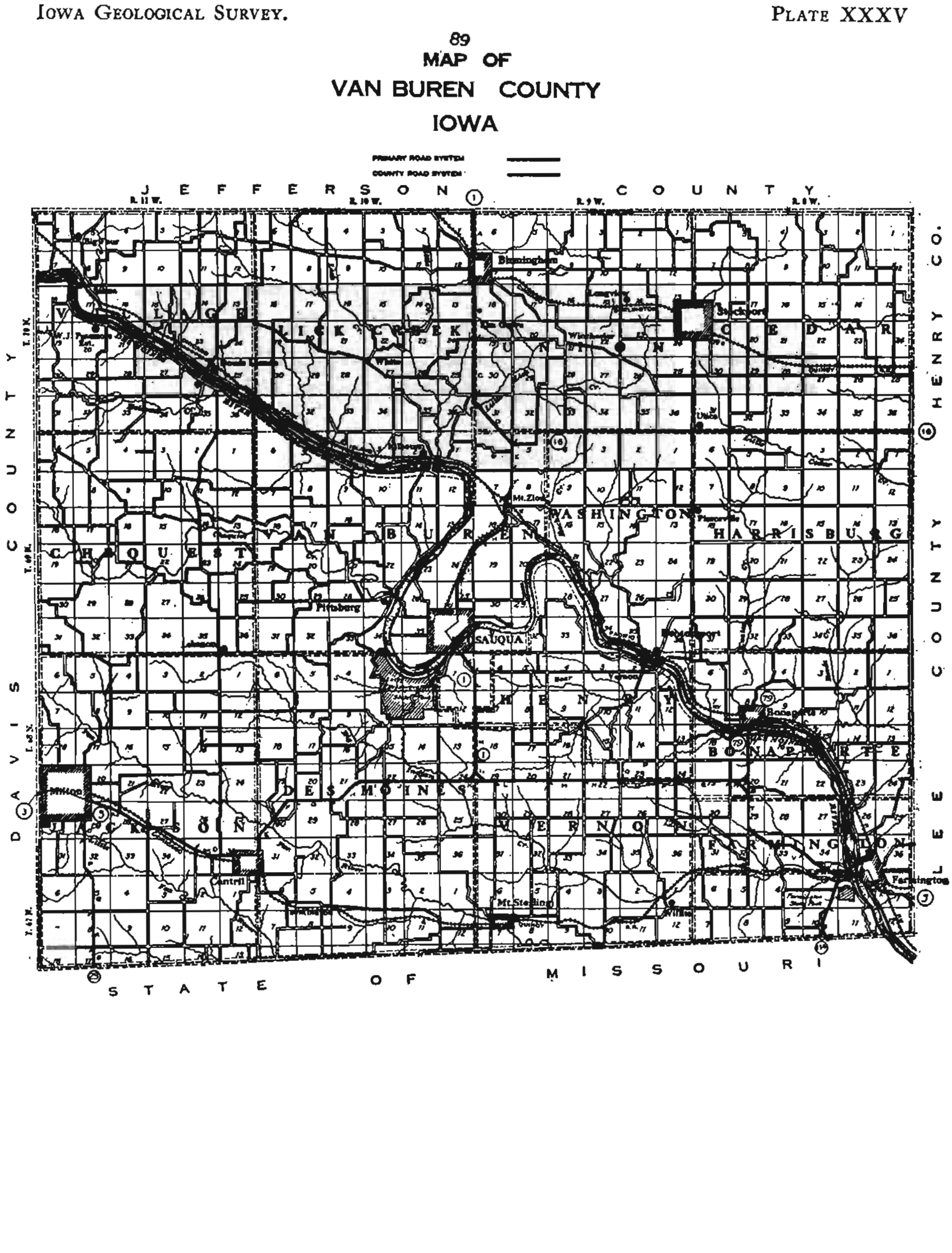
The Des Moines series underlies the upland areas throughout the remainder of the county and is known to be exposed in every township except Jackson. Though the Des Moines covers such a large part of the county, it is in most places thin and consists almost entirely of shales. Sandstone and limestone 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



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	$\frac{1}{2}$–1
3.	Limestone, gray, fine-grained, subconchoidal fracture, probably one bed when unweathered. The lower surface is somewhat uneven	$2\frac{1}{2}$
2.	Shale, gray to drab, of different thicknesses to accommodate the uneven lower surface of No. 3	$\frac{1}{4}$
1.	Limestone, conglomeratic or brecciated, rudely stratified, both matrix and included fragments hard, gray	$5\frac{1}{2}$

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 NW$\frac{1}{4}$ NE$\frac{1}{4}$, NE$\frac{1}{4}$ NE$\frac{1}{4}$, and SE$\frac{1}{4}$ NE$\frac{1}{4}$ 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 NW$\frac{1}{4}$ NE$\frac{1}{4}$ 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	$4\frac{1}{2}$
9.	Limestone, hard, gray, wavy-bedded	$\frac{1}{2}$
8.	Not well exposed. Shale or soft sandstone	$\frac{1}{2}$
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	$3\frac{1}{2}$
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	$\frac{1}{4}$
3.	Limestone, gray, hard, sound, crystalline, in wavy beds, with the top surface deeply ripple-marked	$\frac{3}{4}$
2.	Shale, calcareous, with a 3-inch ledge of hard limestone in the middle	$\frac{1}{2}$
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	16¼

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

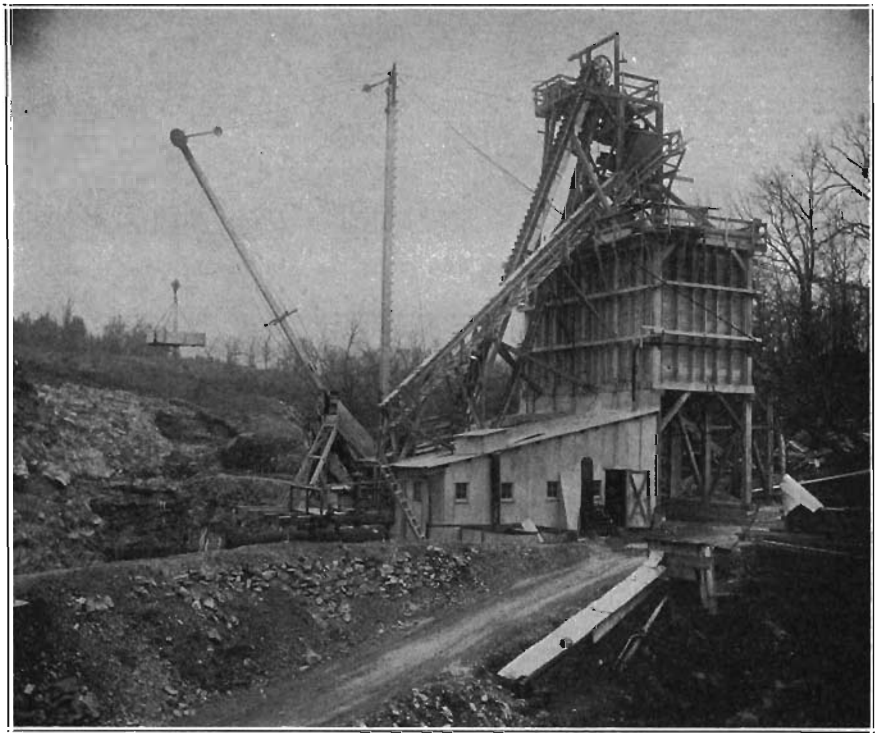


FIG. 12. — Douds Stone Co., at Douds, Iowa. General view of the crushing and screening plant.

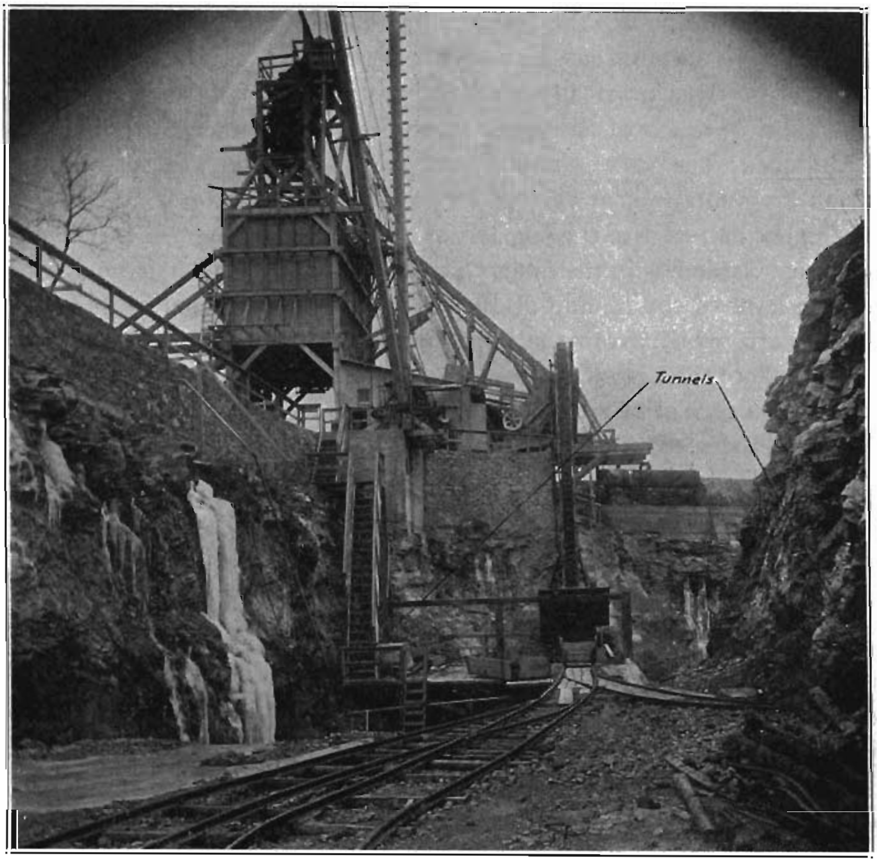


Fig. 13. — Douds Stone Co., Douds, Iowa. View of the quarry pit, showing tunnel openings.

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.

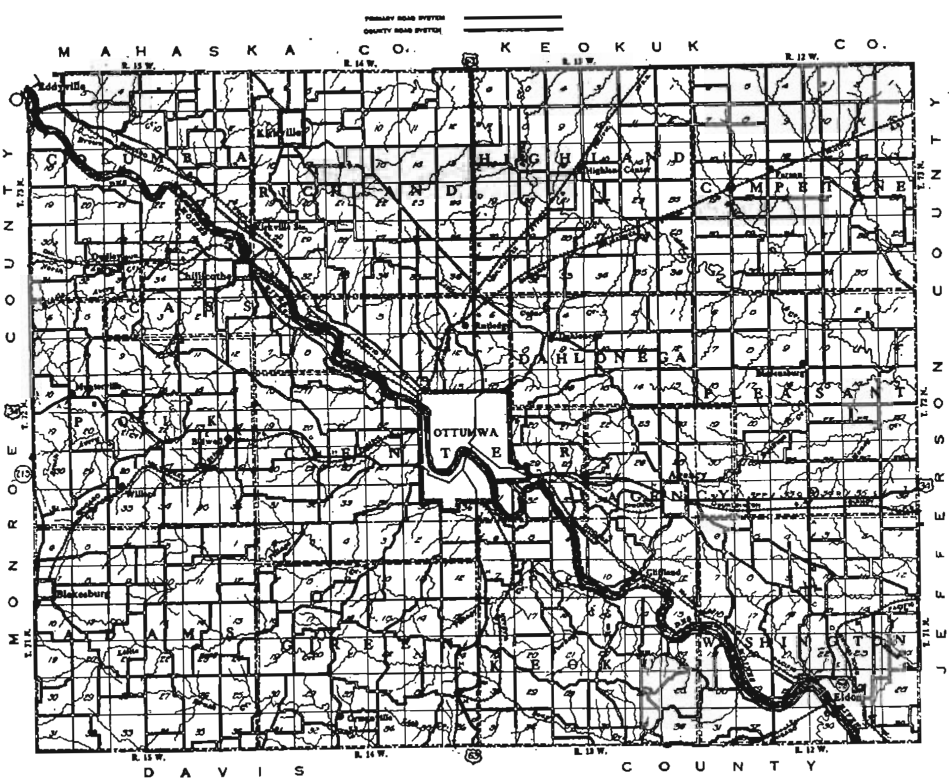
Alluvial deposits in the southern and southwestern parts of the county, along Indian Creek and Fox and Little Fox Rivers, consist almost entirely of silt or fine sand.

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

90
MAP OF
WAPELLO COUNTY
IOWA



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

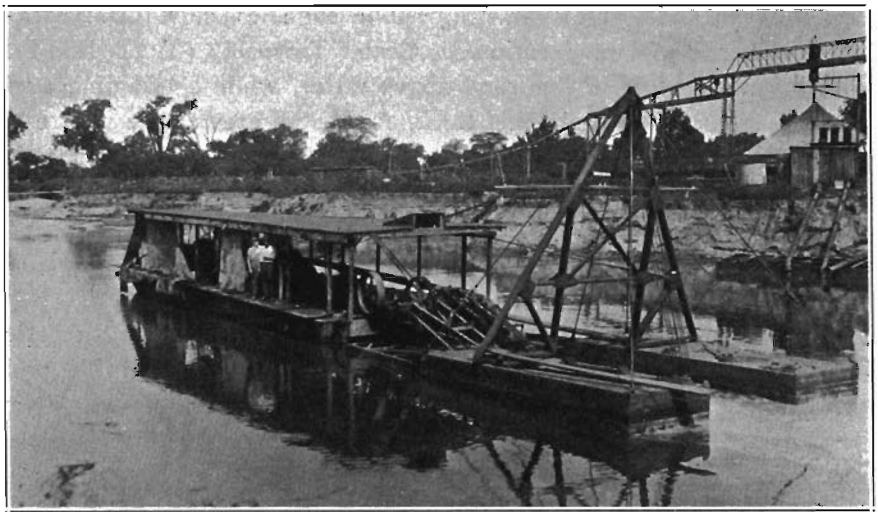


FIG. 14. — Ottumwa Sand Co., Ottumwa. View of Pump Barge.

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

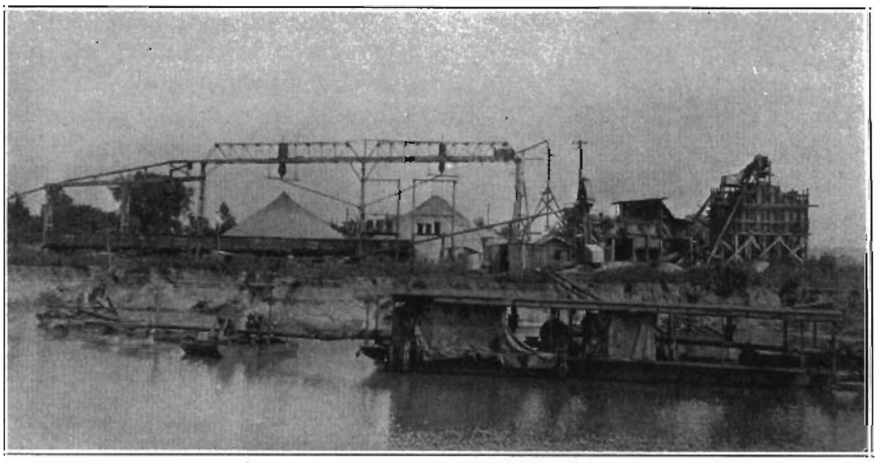


FIG. 15. — Ottumwa Sand Co., Ottumwa. General view of plant, showing sand classifiers and storage piles.

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

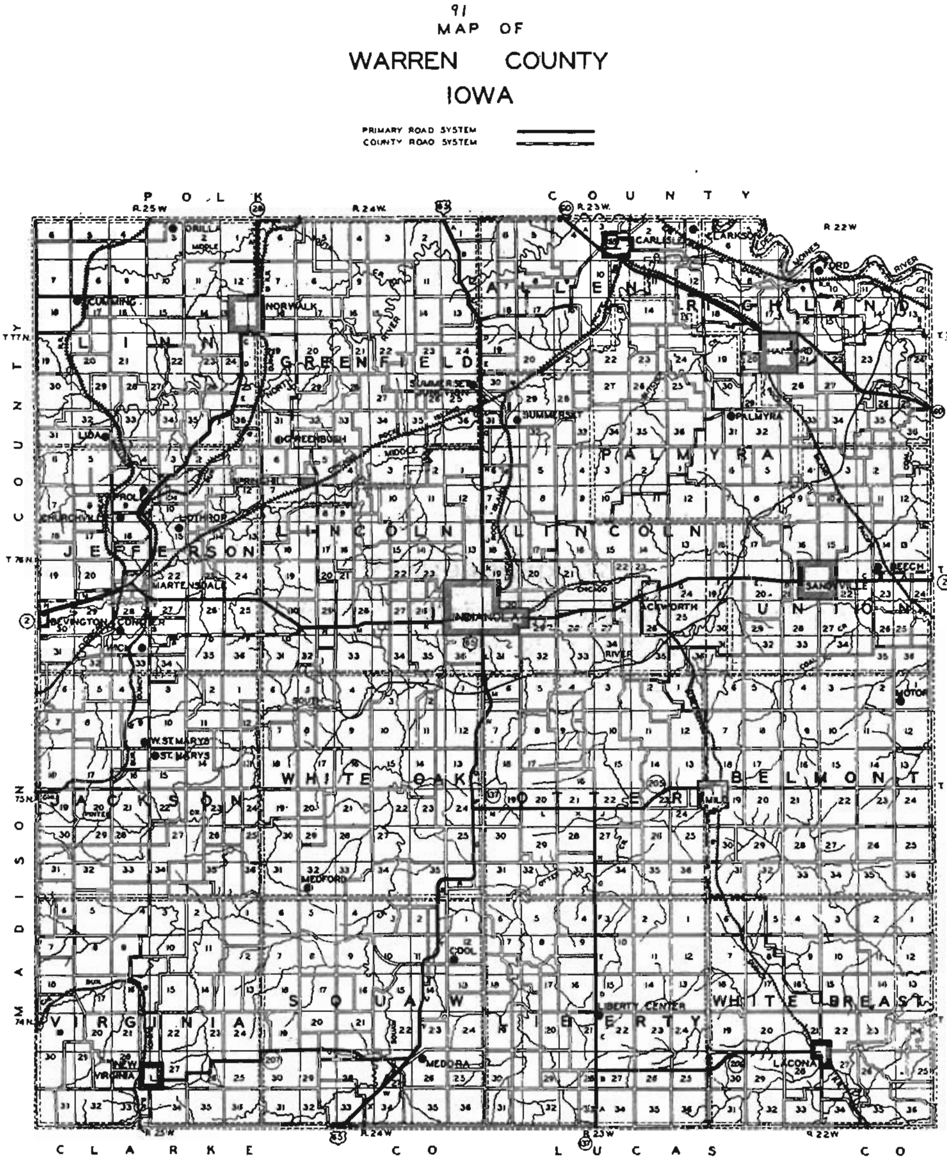
The bedrock of Warren county is of Pennsylvanian age; it was found in a drilling at Milo to be 350 feet thick and is probably much thicker in the western part. Upon this are found the Nebraskan and Kansan drift sheets, the former appearing in only a few of the deeper valleys. Loess mantles the drift 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.

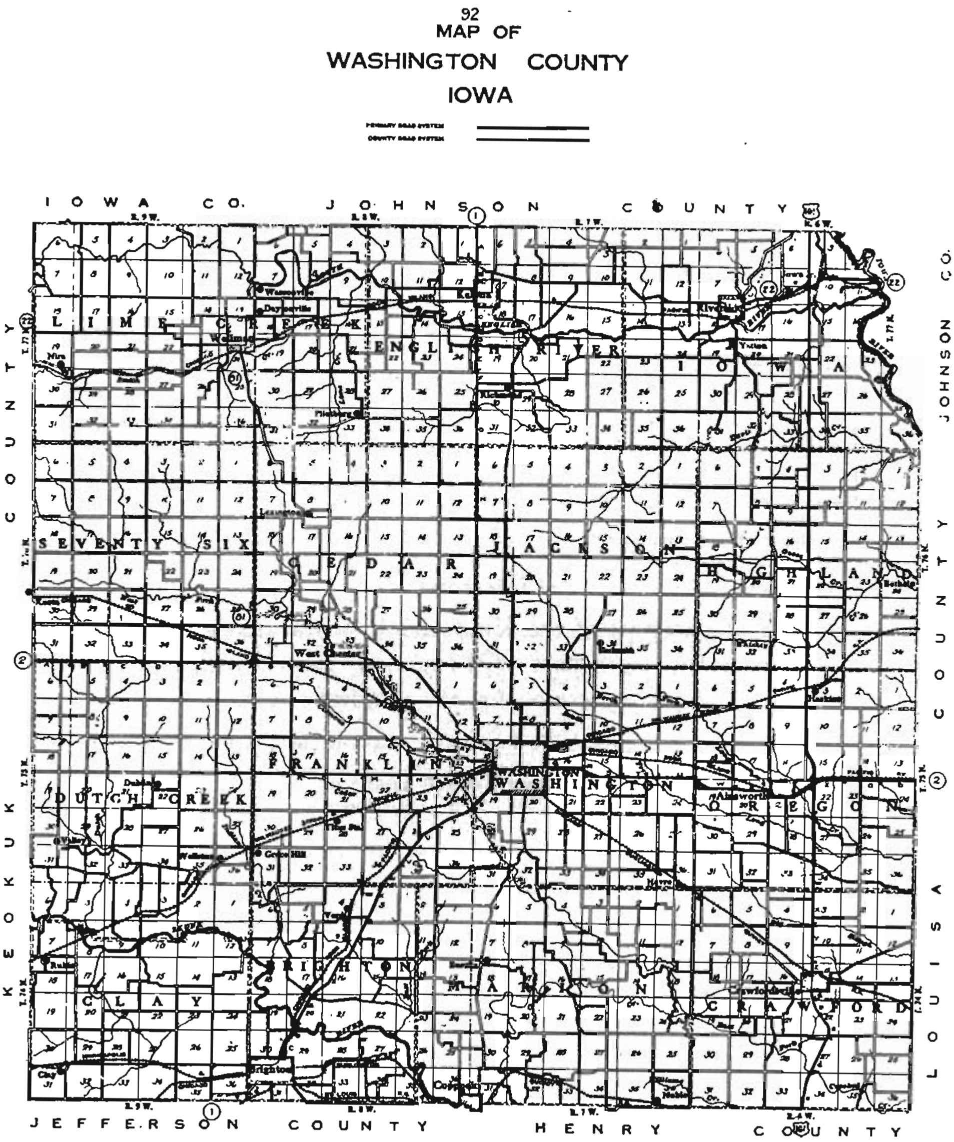
WASHINGTON COUNTY

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



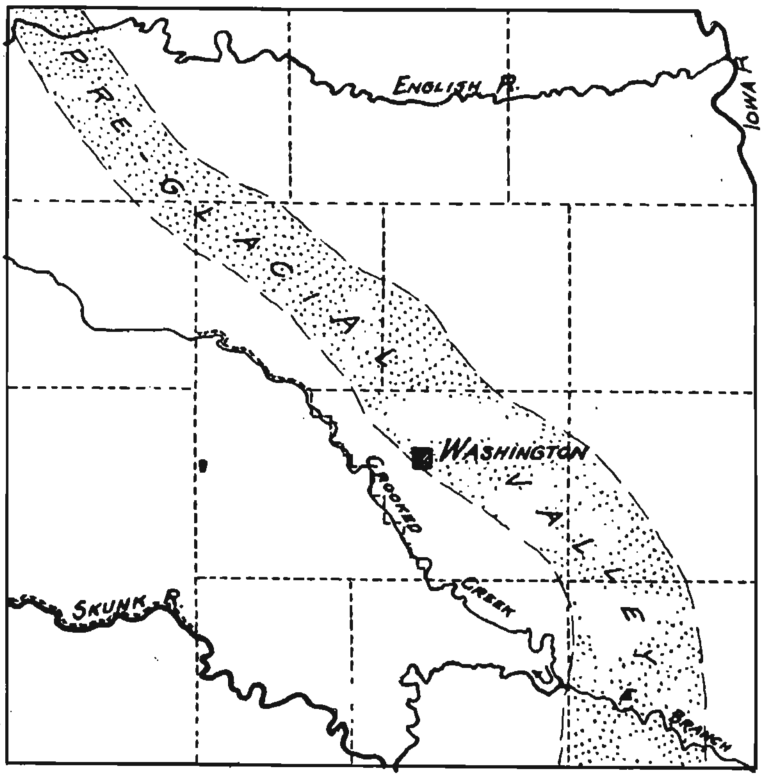


FIG. 16. — Map of Washington County showing present drainage and pre-glacial valley (after Bain).

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

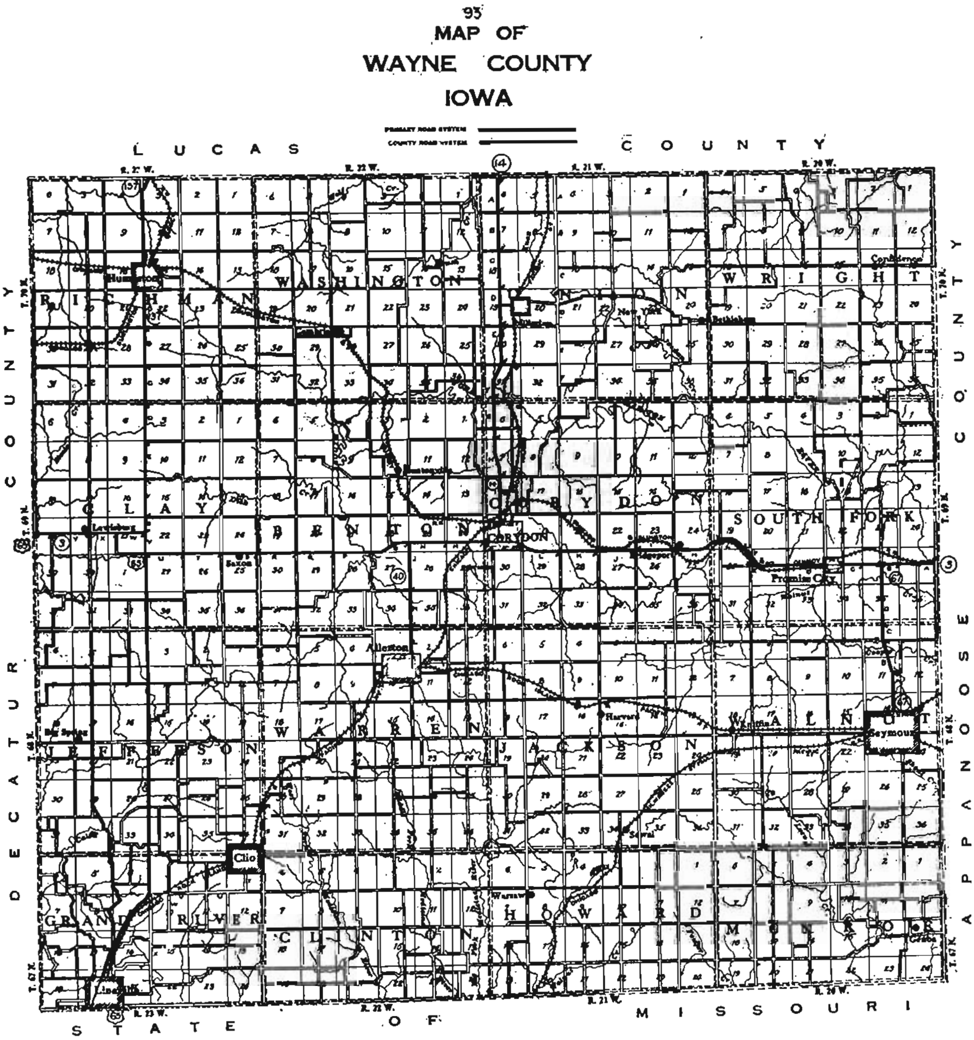
Beds of the Des Moines series underlie the whole county but appear only in the northeast and southeast corners of Wright Township and the northeast corner of South Fork Township. Both Nebraskan and Kansan drifts are recognized above the consolidated rocks, the total thickness of the two reaching locally 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 (1¼-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.

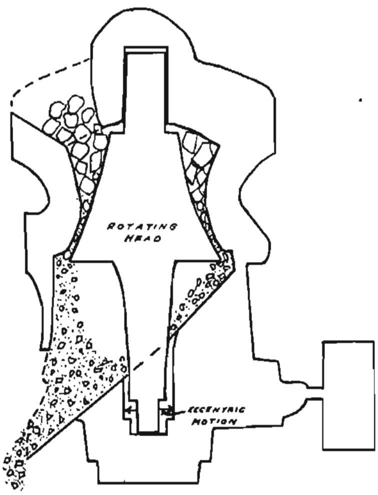


FIG. 19. — Side view of a gyratory crusher showing principle of operation.

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

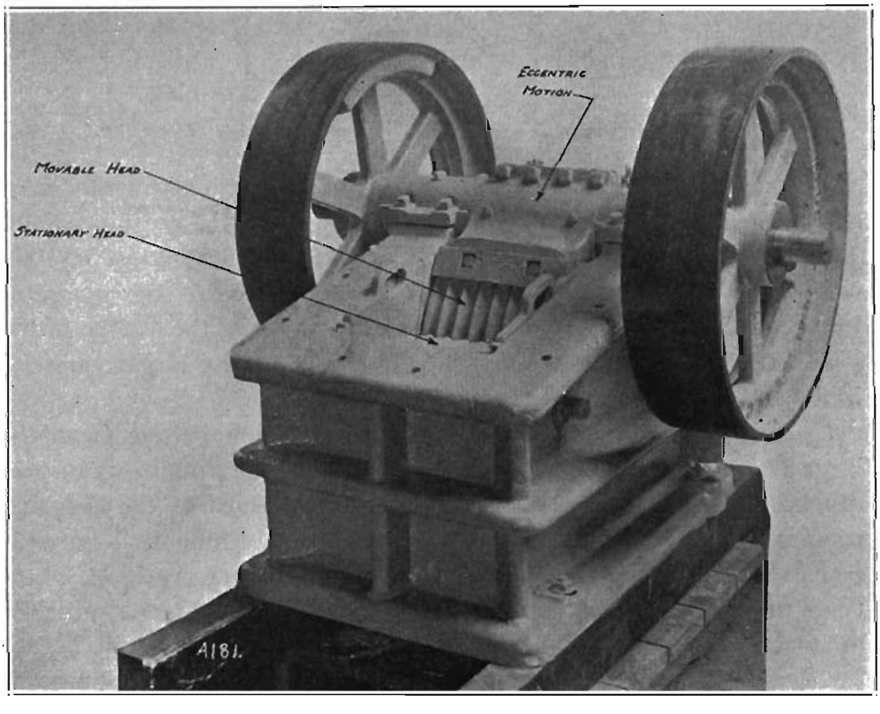


FIG. 20. — View of jaw crusher. Courtesy Iowa Manufacturing Co., Cedar Rapids.

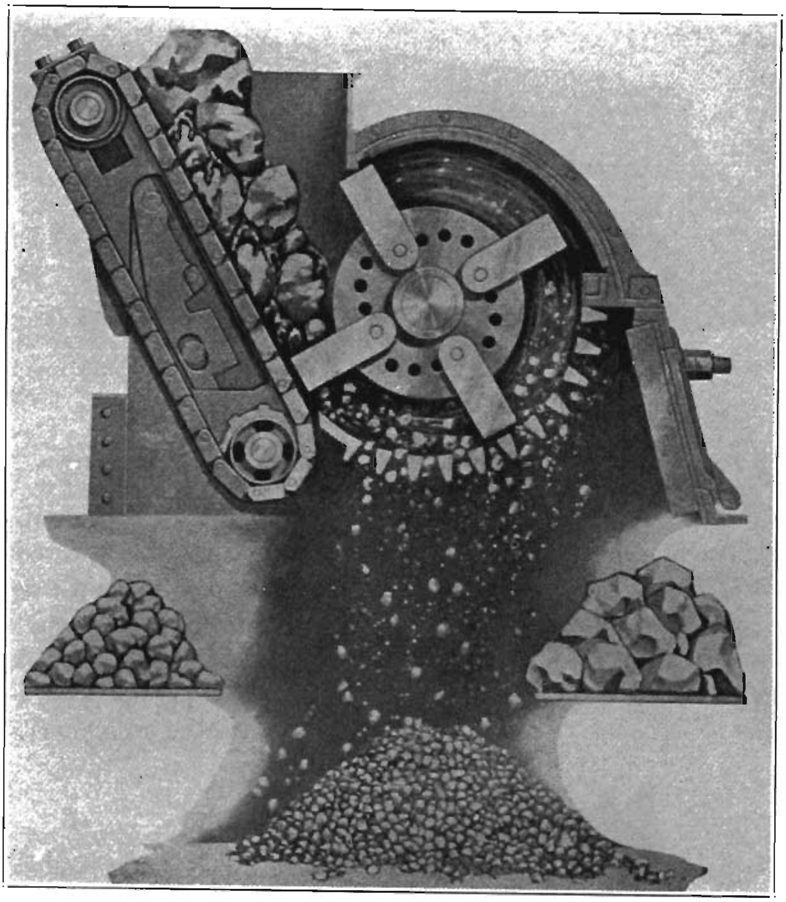


FIG. 21. — Principle of operation of hammer mill. Courtesy Dixie Machinery Manufacturing Co.

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

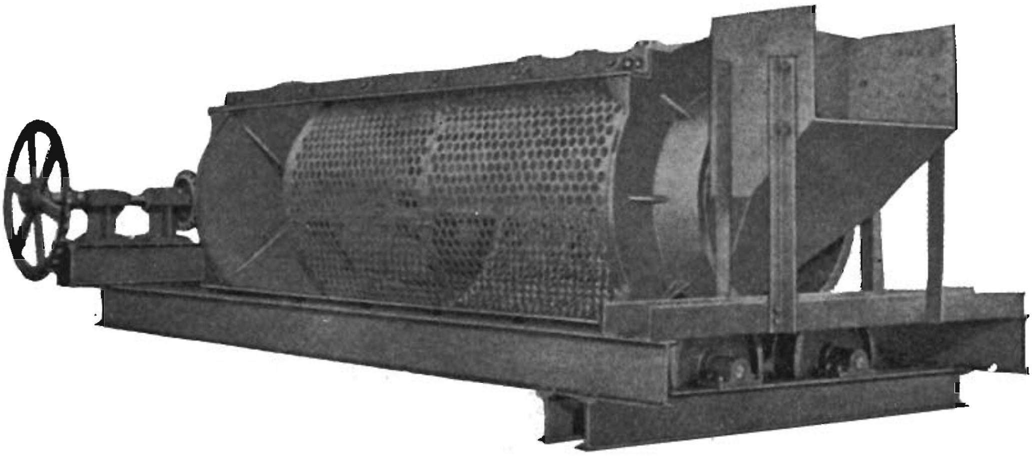


Fig. 22. — Revolving screen. Courtesy Iowa Manufacturing Co., Cedar Rapids.

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

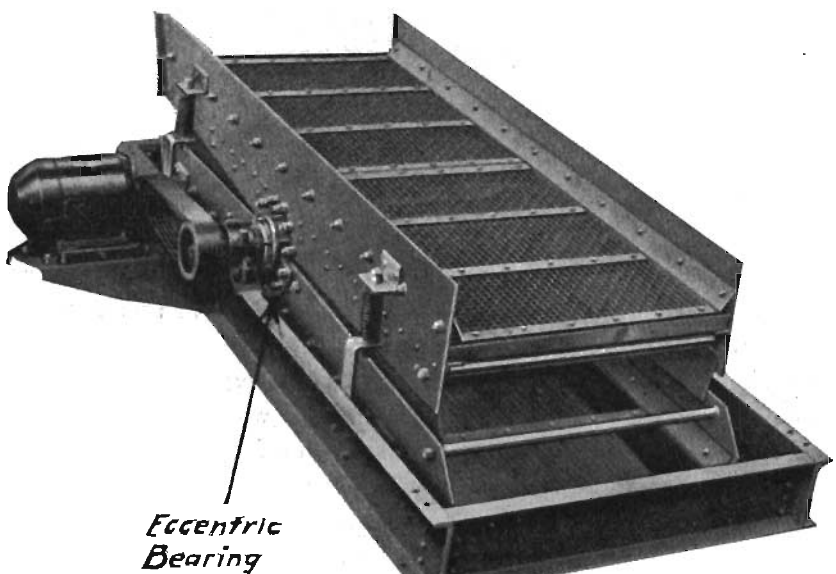


Fig. 23. — Double-deck vibrator screen. Courtesy Rock Products Magazine.

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

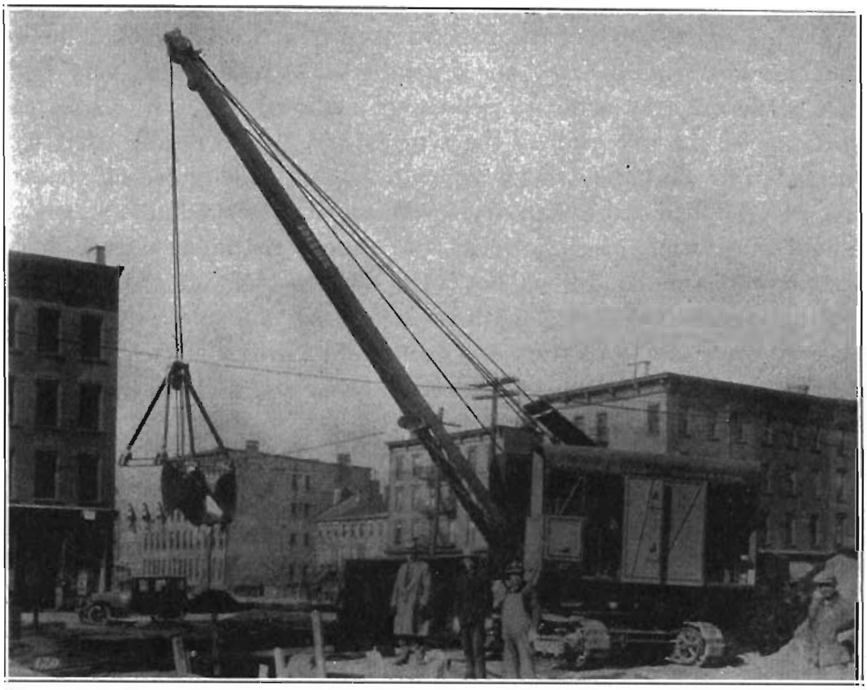


FIG. 24. — Crane equipped with clamshell bucket. Courtesy Speeder Machinery Corporation, Cedar Rapids.

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-

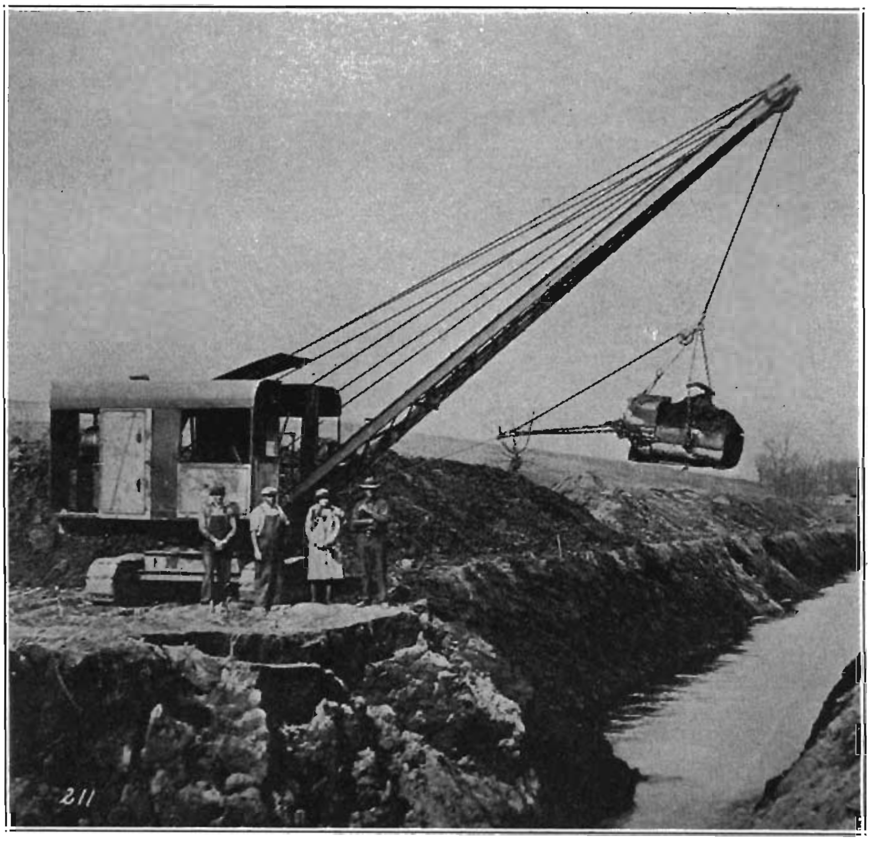


FIG. 25. — Crane equipped with dragline bucket. Courtesy Speeder Machinery Corporation, Cedar Rapids.

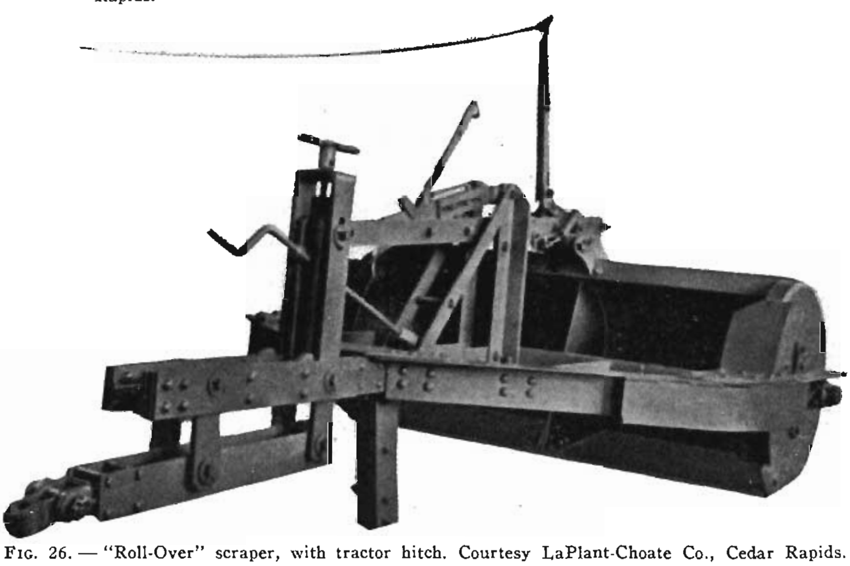


FIG. 26. — "Roll-Over" scraper, with tractor hitch. Courtesy LaPlant-Choate Co., Cedar Rapids.

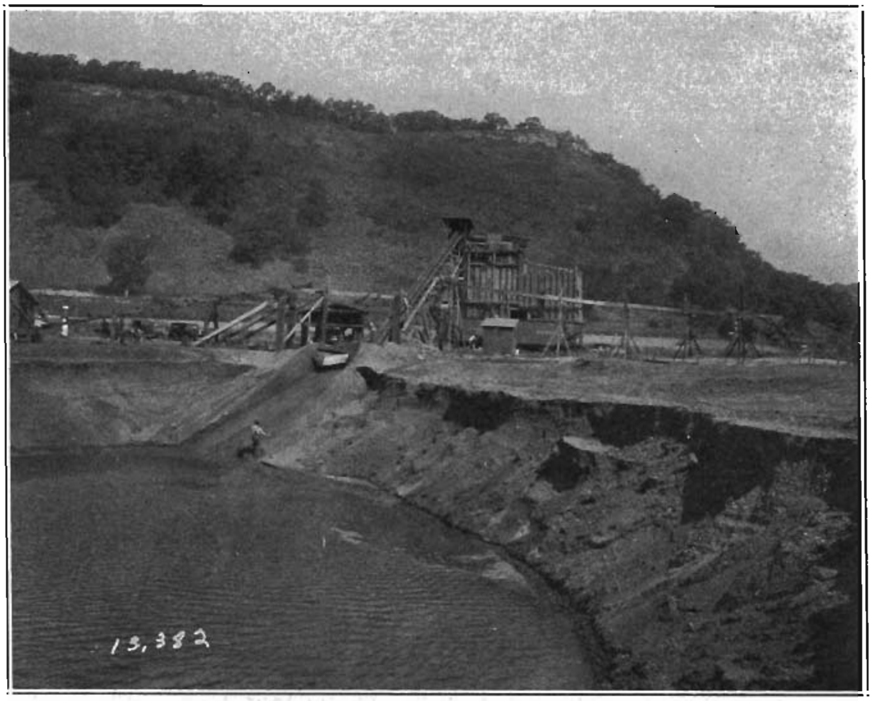


FIG. 27 — Northeast Iowa Sand and Gravel Co., Harpers Ferry. General view of the plant showing excavation by cableway dragline.

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.

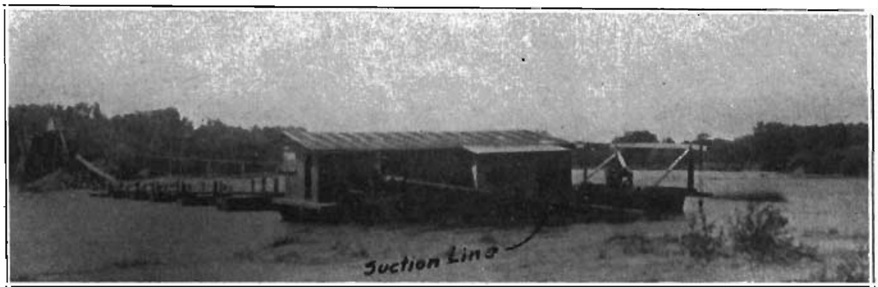


FIG. 28. — Pump boat with suction head raised. Courtesy Lyman-Richey Sand and Gravel Co., Omaha.

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-

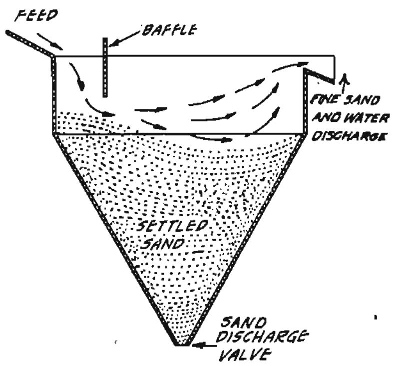


FIG. 30. — Sketch showing principle of operation of cone classifier. Courtesy Rock Products Magazine.

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

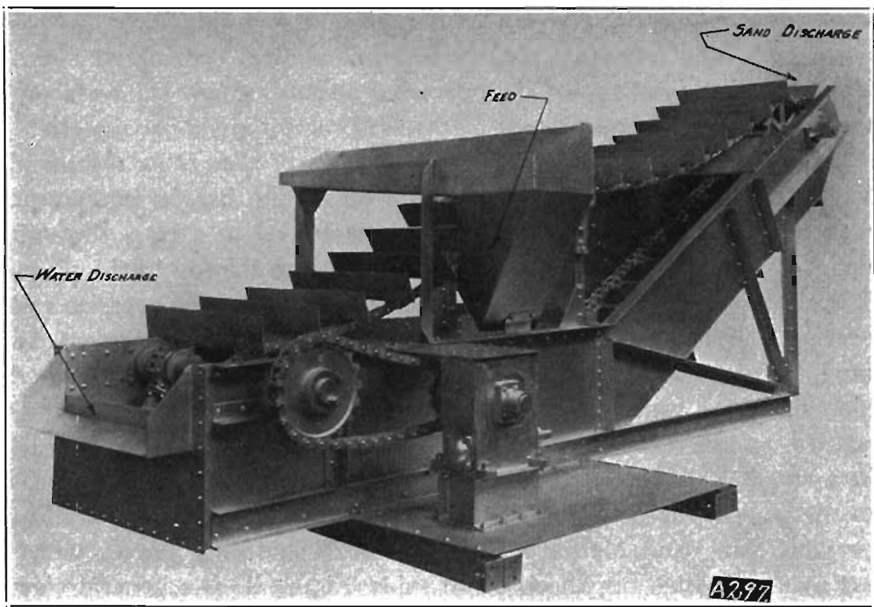


FIG. 31. — Drag type sand classifier. Courtesy Iowa Manufacturing Co., Cedar Rapids.

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.

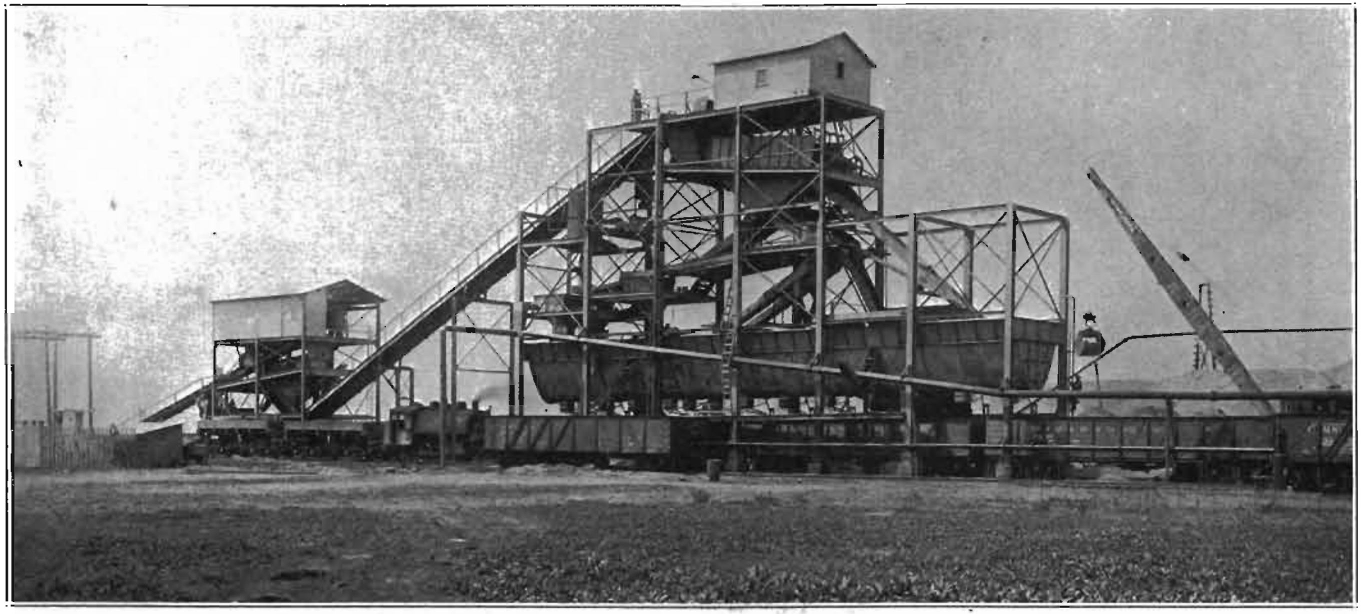


FIG. 32. — Gravel screening and washing plant at Hawarden. Courtesy L. G. Everist, Inc.

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.

INDEX

DEEP WELLS DRILLED IN IOWA 1928-1932

by

W. H. NORTON

CONTENTS

DEEP WELLS DRILLED IN IOWA 1928-1932

INTRODUCTION

The general geologic section for Iowa on which the following notes are based is given in tabular form facing page 316. This table is identical with that which appeared in vol. XXXIII, Deep Wells, except for certain recent revisions of the Pleistocene section by G. F. Kay and others, and of the Cambrian section by A. C. Trowbridge and others.

This report sets forth the data of Iowa deep wells that have come to the author's hands since the completion of his report of 1928. The significance of these data is discussed in the notes on the several well sections. The Bellevue well confirms the existence and character of the unnamed formation lying immediately below the Saint Peter sandstone, which was disclosed in the Maquoketa, DeWitt, and Preston wells. The Shellsburg well fixes the position, hitherto in some doubt, of the Independence fossiliferous shales, and it exhibits the Hoing sandstone in some force. The Vinton well adds considerably to the maximum known thickness of the Wapsipinicon Devonian and exhibits a nondolomitic Galena limestone. The New London and Fulton, Illinois, wells penetrate the Cambrian to unusual depths and deserve the attention of all students of its deeper formations. The New Sharon well brings up the problem of the high mineralization of certain waters and that of the origin of solution channels in deep-lying limestone terranes. Wells at Harper and West Point shed additional light on the underground geology of southeastern Iowa, and the well at Sac City shows the changes undergone by the Paleozoic formations in their extension westward across the state. The wells of this report confirm for their localities the substantial accuracy of the author's contour map of the top of the Saint Peter sandstone.[1] Exception must be made of the Sac City well, which moves the contour of 200 feet below sea level from south of the town to the north of it. This contour map, which has formed a part of the author's last three reports on Iowa deep wells, is here omitted. Nor has it been thought necessary to include cross sections, since many of these, illustrating the subsurface geology of almost

[1] Deep Wells of Iowa, Iowa Geol. Survey, Vol. XXXIII, Pl. 1.

the entire state, have already been published in the author's papers, and one especially, the Baraboo-Des Moines section, has repeatedly been reprinted by the Survey.[2]

The assistance of well drilling and engineering companies in supplying well logs, cuttings, and various other data is gratefully acknowledged. In the well logs published, the author is responsible for the assignment to geological formations.

Bellevue, Jackson County

In 1930 two deep wells were completed in Bellevue by C. W. Varner of Dubuque. The first, completed in February, was drilled for the United States Bureau of Fisheries. It is located near the bank of Mississippi River about 100 feet south of the small stream (Mill Creek) which enters the river just south of the town. The depth is 1,040 feet; the diameters are 12 inches to 19 feet, 8 inches thence to the bottom. The well is cased to 19 feet. The main supply enters the well below the Jordan sandstone, from 800 feet to the bottom. The static level was not measured. When casing was extended 10 feet above the surface, the well had a natural flow of 300 gallons per minute; when casing was extended 32 feet above the surface, water rose to the top with a flow not measured. The flow has been maintained for more than two years since completion of the well. The elevation of the curb is stated by the driller to be about 30 feet below that of the city well. The second well, completed in June, was drilled for the town of Bellevue. It is 1,186 feet deep, and its diameters are 16 inches to 100 feet, 10 inches to 517 feet, and 8 inches thence to the bottom. The principal supply was found below the Jordan horizon. As in the Fisheries well, the sandstones of the basal formation of the Saint Peter group either were dry or yielded a comparatively small amount. The natural flow was 260 gallons per minute. In the two years since completion the well has "lost flow." The well is cased as follows: 16-inch pipe to 43 feet; 10-inch pipe from surface to 100 feet, the space about it being filled with cement; 8-inch pipe from 474 to 517 feet, to case out caving shale in the basal formation of the Saint Peter group. The well is located on the terrace of Mississippi River with a probable elevation of about 617 feet. A fine set of samples, taken every five feet, was received at this office from Bellevue, but unfortunately it is uncertain to which of the two wells it belongs, or whether both wells may not

2 Artesian Wells of Iowa: Iowa Geol. Survey, Vol. VI, Fig. 35.

General Section of Iowa Strata

Group	System	Series	Formation	Character
CENOZOIC	Quaternary, patches of Tertiary	Pleistocene or Glacial	(Recent)	Soil, geest, alluvium
			Eldoran: Wisconsin	Boulder clay
			Eldoran: Peorian	Loess, forest bed, sand, gravel
			Eldoran: Iowan	Boulder clay
			Centralian: Sangamon	Gumbotil, soils, forest bed, sand, gravel
			Centralian: Illinoian	Boulder clay
			Ottumwan: Yarmouth	Gumbotil, peat, soil, sand, gravel
			Ottumwan: Kansan	Boulder clay, gravel
			Grandian: Aftonian	Gumbotil, peat, soil, gravel
			Grandian: Nebraskan	Boulder clay, gravel
MESOZOIC	Cretaceous	Upper Cretaceous	Colorado	Shale, limestone
			Dakota	Sandstone
PALEOZOIC	Permian	Fort Dodge		Gypsum, shale
	Pennsylvanian	Missouri	Wabaunsee Shawnee Douglas Lansing Kansas City	Limestones, shales, coal
		Des Moines	Pleasanton Henrietta Cherokee	Shales, coals, sandstones, limestones
	Mississippian	Iowa Series: Meramec	Ste. Genevieve (Pella) St. Louis Spergen Warsaw	Limestones, marls, sandstones
		Iowa Series: Osage	Keokuk Burlington	Limestones
		Iowa Series: Kinderhook		Shale, limestones
	Devonian	Upper Devonian	Lime Creek — State Quarry	Shale, limestones
			Cedar Valley	Limestone, shale
			Wapsipinicon: Davenport	Limestone
			Wapsipinicon: Independence	Shale
			Wapsipinicon: Otis	Limestone
	Silurian	Cayugan?	Salina ? nowhere exposed	Limestone, gypsum
		Niagaran	Gower Hopkinton	Dolomites
		Alexandrian	Waucoma	Limestone
	Ordovician	Cincinnatian	Maquoketa	Shale, dolomite
		Mohawkian	Galena	Dolomite
			Decorah	Shale, limestone
			Platteville	Limestone, shale
		Canadian	Glenwood	Shale
			St. Peter	Sandstone
			Prairie du Chien: Shakopee	Dolomite
			Prairie du Chien: New Richmond	Sandstone
			Prairie du Chien: Oneota	Dolomite
PALEOZOIC	Cambrian	Saint Croixan	Trempealeau: Jordan	Sandstone
			Trempealeau: Lodi	Siltstone, sandstone, limestone, shale
			Trempealeau: St. Lawrence	Dolomite
			Franconia	Glauconitic sandstone, shale, limestone
			Dresbach: Galesville	Sandstone
			Dresbach: Eau Claire	Shale, sandstone
			Dresbach: Mt. Simon	Sandstone
	Cambrian (?)	Red Clastic Beds		Sandstone, shale, conglomerate
PROTEROZOIC	Algonkian	Huronian	Sioux	Quartzite
ARCHEOZOIC	Laurentian?		Nowhere exposed	Granite, schist

be represented. The samples below 1,040 feet clearly belong to the city well, and it is the opinion of the contractor that his foremen may have shipped all the samples from this well. The altitudes in the following record of strata are based on the assumption that this was the case.

Record of Strata	Depth in Feet
No Sample	0–5
Ordovician:	
Galena-Platteville (325 feet thick; top 612 feet above sea level) —	
Dolomite, yellow, blue-gray, and brownish, cherty at 130-150, 180-190, and at 210; 26 samples	5–235
Limestone, light gray, rapid effervescence in cold dilute HCl; 3 samples	235–250
Limestone, gray and brownish, some flakes of brown inflammable shale; 2 samples	250–260
Shale, blue and green, calcareous	260–265
Limestone, gray and brownish, rapid effervescence, in sand; 4 samples	265–285
Limestone, brownish, in large chips, highly argillaceous	285–290
Limestone, gray and light gray; 7 samples	290–325
Limestone, brown	325–330
Glenwood (5 feet thick) —	
Shale, blue-green, finely laminated, noncalcareous	330-335
Saint Peter sandstone (60 feet thick; top 282 feet above sea level) —	
Sandstone, white, grains well rounded and frosted, up to 1 mm. in diameter	335-340
Sandstone, white, finer than above; 4 samples	340–365
Sandstone, grains as above, yellow and buff in mass; 6 samples	365–395
Formation unamed (285 feet thick; top 222 feet above sea level) —	
Sandstone, dark red, hard, noncalcareous, grains of clear quartz of Saint Peter facies, interstitial filling red and ochreous, in chips; sandstone, light red and buff, in chips; chert, white; dolomite, light gray; some chips composed of dolomite, chert and quartz sand with chert as matrix; much loose quartz sand up to 2.5 mm. diameter, reddish buff in mass; a chip, dark, siliceous, with bright red band 1 mm. wide; blackish siliceous chips finely quartzose; chips of dark, highly pyritic sandstone	395–400
Sandstone, buff in mass, some grains show bright red stains and ochreous red interstitial cement, fine to medium, larger grains well rounded	400–405
Sandstone, darker buff, as above	405–410
Sandstone, medium dark red, secondary enlargement of grains; some bright yellow shale, noncalcareous, minutely quartzose; a fragment of shale, drab, feebly calcareous, fossiliferous	410–415
Sandstone, reddish buff	415–420
Sandstone, buff, some crystalline enlargements	420–425
Sandstone, light brownish buff; 2 samples	425–435
Sandstone, light chocolate-brown, with considerable argillaceous material	435–440
Sandstone, dark reddish brown, in friable concreted masses owing to argillaceous material; washed grains of clear quartz remain somewhat stained; 6 samples	440-470
Sandstone, brownish buff, secondary enlargements	470–475
Sandstone, brown and reddish brown, somewhat concreted; 6 samples	475–510
Sandstone, light pinkish buff, grains mostly clear and colorless, mass color due to some grains stained ocher yellow and chips with noncalcareous ochreous cement; 4 samples	510–530
Sandstone, reddish brown; 2 samples	530–540
Sandstone, bright ocher yellow, grains of clear quartz stained, color remains after washing and only partly removed by boiling in HCl; secondary enlargements	540–545
Sandstone, dark reddish brown	545–550
Sandstone, terra cotta pink	550–555
Sandstone, reddish brown	555–560

Sandstone, bright ocher yellow, reddish at 575; 3 samples	560–580
Sandstone, ocher yellow, some chips of light gray dolomite up to 0.75 cm.; 2 samples	580–590
Dolomite in chips as above, some with irregular pitted or vesicular surfaces; shale, dark brown, hard, noncalcareous; shale, red and green interlaminated; much quartz sand; buff in mass	590–595
Dolomite, gray and blue-gray, in large chips; sand reddish buff in masses, a little red and green interlaminated shale in large fragments; 3 samples	595–610
Chert, white and gray, in chips and irregularly surfaced pebbles, one being 1.2 cm. diameter; chips and slightly rounded pebbles of white sandstone; a little dolomite; much quartz sand; chips of red shale; all concreted by red clay into masses friable with difficulty	610–615
Shale, light green, dark blue-green, and red, in chips; sand and clay, brick red; large chips of red and light green-gray sandstone intermingled, red sandstone with matrix of brick red clay; green-gray sandstone of fine irregular grains in argillaceo-siliceous matrix	615–620
Shale, red-brown; sandstone fine to medium grains, brightly stained red; some light gray dolomite; some grains of cryptocrystalline silica; some green shale	620–625
Chert with crystalline silica in irregular masses; dolomite, gray, vesicular, sporadically arenaceous, in large chips; shale, red and green; red sandstone and shale interlaminated; all concreted by red powder of shale into hard masses; 2 samples	625–635
Concreted reddish brown masses of powdered red shale containing sand stained red; gray arenaceous dolomite in large chips; shale in chips	635–640
Concreted dark reddish brown masses of powdered shale, inclosing chips of green shale; red arenaceous shale; chert, pinkish, some arenaceous with fine rounded grains, and red stained sand	640–645
Shale, bright venetian red, in chips and in concreted powder inclosing chips of pink sandstone; and pink chert, with inclosed particles of bright red shale and sporadic grains of quartz sand	645–650
Concreted dark reddish brown masses of powdered red shale inclosing sand; chips of white chert with irregular surfaces stained red; sandstone, whitish, argillaceous matrix; a little gray dolomite; chips of red shale; 2 samples	650–660
Concreted red brown masses of powdered red shale inclosing chips of hard dark red shale; light green shale; quartz sand stained; chips of sandstone, whitish, fine, hard, with considerable cryptocrystalline silica; a large chip of highly arenaceous light green shale with fine to medium rounded grains	660–665
Shale, dark iron red; shale, green; chert, white and gray; stained sand, not so much concreted as above; 3 samples	665–680
Prairie du Chien: Oneota (30 feet thick; top 63 feet below sea level) —	
Chert, light yellow-gray, slightly arenaceous, grains minute; some chips of red and green shale from cave	680–685
Chert, as above, stained yellow, some chips sparingly arenaceous with rounded medium-sized grains of sand; some smooth spherical grains of siliceous oölite	685–690
Sandstone, ocher yellow, rounded grains; much white chert; oölite as above; a fragment of chert with a rough and decayed surface partly covered with drusy pyrite	690–695
Same, less chert	695–700
Chert, white, in fine chips, some arenaceous; and quartz sand stained ocher-yellow	700–705
Chert, highly arenaceous, white; sandstone, fine, with cherty matrix; loose grains of ocher-yellow sand	705–710
Cambrian:	
Trempealeau: Jordan (?) (35 feet thick; top 93 feet below sea level) —	
Sandstone, fine, white, in chips and loose grains stained yellow	710–715
Sandstone, light buff in mass from grains stained ocher-yellow, in loose grains, some concreted masses with whitish argillaceous powder at 725; 3 samples	715–730

Dolomite, gray, in fine chips, some minutely arenaceous; chips of white noncalcareous sandstone; most of sample loose yellow sand	730–735
Sandstone, very light gray, grains minute, dolomitic cement; a little dolomite; 2 samples	735–745
Trempealeau: Lodi and St. Lawrence (115 feet thick; top 128 feet below sea level) —	
Dolomite, gray, sporadically arenaceous; much quartz sand; 5 samples	745–780
Dolomite, as above, buff in mass, sporadically arenaceous	780–785
Dolomite, light gray with quartz sand; 3 samples	785–800
Dolomite, very light gray, finely quartzose, slightly glauconitic; 4 samples	800–820
Dolomite, dark gray and buff, minutely quartzose, glauconitic; 3 samples	820–840
Dolomite, brown, minutely quartzose; rather large amount of glauconite in minute grains in residue	840–845
Dolomite, pink in mass; 2 samples	845–855
Dolomite, gray, glauconitic, minutely quartzose, red brown in mass from powder of red shale; some dark gray dolomitic sandstone highly glauconitic	855–860
Franconia (85 feet thick; top 243 feet below sea level) —	
Sandstone, red from argillaceous content, of minute grains; dolomite, gray, glauconitic	860–865
Sandstone, pink, minute grains, dolomitic, glauconitic, argillaceous, in concreted masses friable with difficulty; 2 samples	865–875
Sandstone, light greenish gray, dolomitic, argillaceous, glauconitic, in lumps as above; 2 samples	875–885
Sandstone, grains minute, green-gray, brighter and darker than above from larger amount of glauconite, argillaceous, dolomitic; 11 samples	885-930
Shale, highly siliceous with minute quartzose grains, greenish gray, some translucent cryptocrystalline silica, dolomitic, sparingly glauconitic	930–935
Shale, venetian red, in concreted masses, inclosing some flakes of green dolomitic slightly quartzose shale; dolomite, hard, red, argillaceous, cherty, minutely arenaceous; dolomite, gray, minutely arenaceous, glauconitic	935–940
Dolomite, gray, arenaceous with rounded grains, glauconitic	940–945
Dresbach: Galesville (140 feet thick; top 328 feet below sea level) —	
Sandstone, light grayish buff in mass, well rounded grains of colorless quartz up to 1 mm. diameter; 21 samples	945–1050
Sandstone, clear quartz sand, finer than above; 7 samples	1050–1085
Dresbach: Eau Claire (penetrated 55 feet; top 468 feet below sea level) —	
Sandstone, buff, very fine, glauconitic	1085–1090
Sandstone, as above, fine	1090–1095
Sandstone, fine to medium, grains well rounded, frosted, some stained with ferric oxide, giving light yellow color to mass; glauconitic; 9 samples	1095–1140
Unknown, no samples	1140–1186

Notes. — At Bellevue the high bluffs fronting the Mississippi comprise a bold escarpment of massive Niagaran limestone crowning a long slope, the outcrop of the weak Maquoketa shale. The Galena dolomite outcrops a few feet above water level at points along the river terrace. The well sections, therefore, probably measure the full thickness of the Galena-Platteville at this locality. The upper dolomitized portion is much thicker than the limestones and shales on which it rests, as is the case usually in Jackson and Dubuque Counties, both in outcrops and deep wells.

The Glenwood shale, though unmistakeably present, is thin, a condition common in this area.

The drill at Bellevue disclosed beneath the normal Saint Peter sandstone the same unnamed formation, assigned to the Saint Peter group, which the writer has described from the wells at Holstein, Maquoketa, DeWitt, and Preston. The significance of these deposits has been discussed at length.[3] In brief they mark one of the major unconformities of the geologic history of the Upper Mississippi valley, a long erosion interval after the deposit of the Prairie du Chien dolomites, during which these marine limestones and the beds beneath were uplifted to form land and were deeply weathered to red residual soils. An uplift brought about the deep dissection of this ancient land and the rapid stripping of its soils with their deposition in valleys and basins under conditions which forbade the reduction of their iron content. A later depression brought in the transgressing sea, reworking in part, at least, these ferruginous deposits and later laying down the sands of the Saint Peter as seen in its normal outcrops and deep well sections.

As Trowbridge[4] has pointed out, the outcrops of the Saint Peter in Iowa show valley fills of ferruginous sands, as at Pictured Rocks, McGregor, which include residual cherts at Church, Allamakee County. A well sunk at Pictured Rocks would supply stained sands indistinguishable in their colors from those of the Bellevue well at the same horizon. However, the basal formation of the Saint Peter group as disclosed by deep wells is far thicker than that seen in any natural outcrop. It includes shales, conglomerates, and dolomitic beds, the last mentioned affording a resemblance to the basal beds of the Saint Peter in Missouri that are named the Everton by Dake.

The varicolored sandstone at Bellevue resembling that at Pictured Rocks in its bright colors of buff, ocher-yellow, venetian red, and brown is 85 feet thick. At top, however, this formation shows a bed not recognized at McGregor — a thin layer of debris containing chert, dolomite (probably from pebbles), red banded shale, and reddish buff sand coarser than that below it or above. The color of this varicolored sandstone is due to ferruginous stain coating the grains and in no case is there enough ochreous or argillaceous material in the cuttings to form hard concreted masses. At 580 feet dolomite appears and at 590 feet it gives place to dark brown and green shales. Dolomite recurs at

[3] Norton, W. H., Deep Wells of Iowa: Iowa Geol. Survey, Vol. XXXIII, pp. 37-42.

[4] Trowbridge, Arthur C., Prairie du Chien-St. Peter Unconformity in Iowa: Proc. Iowa Acad. Science, Vol. XXIV, pp. 177-182.

595 feet. Sand is present in these samples in large amount and is as individual in color as is that of the overlying beds. To what extent it is native is not determined. The character of the underlying strata forbids reference of the dolomite to the Prairie du Chien. From 610 to 680 feet the samples comprise red shales, green shales passing into greenish argillaceous sandstones, much chert, interlaminated red sandstone and shale, red sandstone, varicolored red and greenish gray sandstone, and a few chips of sandy dolomite. The chert is in many cases arenaceous, and chips are found inclosing particles of bright red shale. In these samples the cuttings are concreted by dark reddish clay into masses that are friable with difficulty. The entire 70 feet of this bed resembles the cherty conglomerate found at the same horizon at DeWitt. From 680 to 710 feet the samples consist of stained sands with considerable amounts of chert. Siliceous oölite is found as at DeWitt and is characteristic of the Oneota dolomite. The amount of quartz sand, however, the arenaceous character of the chert, and the surfaces of some of the chert fragments raise the question whether these beds do not belong with those immediately above them. At 710 feet the drill entered a white sandstone 35 feet thick, not of normal Jordan facies, which possibly also should be referred to the basal formation of the Saint Peter. The St. Lawrence dolomite clearly was reached at 745 feet. Below 800 feet it is minutely quartzose and more or less glauconitic. The Franconia is entirely typical, and the Galesville is clearly defined, at least in its upper contact. The Galesville is given about the same thickness as at Fulton by assigning the fine glauconitic sandstone at 1,085 feet to the top of the Eau Claire.

It is noteworthy that the wells in eastern Iowa that disclose this basal formation of the Saint Peter group are all located in an elliptical area in Jackson and Clinton Counties whose longer diameter, north and south, is only about 30 miles. A southward extension of this axis strikes the wells at Moline and East Moline, in Illinois, in which the same formation was found.

Dayton, Webster County, City Well of 1931

The first deep well at Dayton was drilled in 1895. The depth is 688 feet. The well foots in the Kinderhook limestone.

The well of 1931, drilled by the Thorpe Bros. Well Co., is 1,240 feet in depth, and its diameters are from 18 to 8 inches. Water was first encountered at 138 feet in glacial sand, the yield being 25 gallons per minute. Water was found also from 860 to 900 feet and the main supply at 1,235 feet. The yield is 175 gallons per minute under a draw-down of 103 feet. The static level is 62 feet below the surface. The well is cased with 13-inch pipe to 323 feet, with 10-inch pipe from 312 to 505 feet, and with 8-inch pipe from 770 to 966 feet.

Driller's Log	Depth in Feet
Pleistocene and Recent (144 feet thick; top 1089 feet above sea level) —	
Soil	0–5
Clay	5–75
Gravel	75–77
Clay	77–138
Fine sand	138–144
Pennsylvanian, Des Moines series (241 feet thick; top 945 feet above sea level) —	
Dark shale	144–258
Coal	258–260
Shale and thin streaks of rock	260–385
Mississippian, undifferentiated (304 feet thick; top 704 feet above sea level) —	
Rock and shale alternating	385–410
Rock and thin streaks of shale	410–444
Lime rock	444–689
Mississippian, Kinderhook shale (58 feet thick; top 400 feet above sea level) —	
Light green shale, very soft	689–717
Lime rock	717–735
Gray shale	735–747
Devonian and Silurian (penetrated 493 feet; top 342 feet above sea level) —	
Lime rock	747–1240

Notes. — The terrane "shale and streaks of rock" from 260 to 365 feet, is placed with the Des Moines, since the cuttings of the well of 1895 clearly show the shale to be of Coal Measures facies.

In the author's report of 1912 [5] the geologic section of the well of 1895 was drawn with its base (401 feet above sea level) 50 feet above the top of the Devonian, the Kinderhook shale not having been encountered. The allowance thus made for the Kinderhook shale proves sufficient within 8 feet. This shale must lie immediately below the base of the well of 1895. Throughout this area the Kinderhook shale is thin compared with that of its southeastern extension, and it contains more or less intercalated limestones. Its thickness at Dayton, 58 feet, may be compared with that at Gowrie, 50 feet; Fort Dodge (Beaver Products Co. Well No. 3), 50 feet; and Ogden, 80 feet. The drill probably would have struck the Maquoketa shale within a few feet of the bottom of the well.

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[5] Iowa Geol. Survey, Vol. XXI, Plate XVI.

Fulton, Illinois, City Well No. 3, 1931

Through the courtesy of Mr. F. T. Thwaites of the Wisconsin Geological Survey we are able to present here the geologic section of this well, the latest drilled in the Clinton-Lyons-Fulton artesian field and the one best sampled. The elevations above sea level are added to Mr. Thwaites' determinations. The static level is 15 feet above the surface, and the natural flow at surface is 200 gallons per minute.

Record of Strata	Depth in Feet
Pleistocene (190 feet thick; top 590 feet above sea level) —	
No samples	0–100
Clay, gray-blue, dolomitic	100–110
Gravel, pebbles chert; sand, coarse, gray, dolomitic; 3 samples	110–130
Sand, coarse, yellowish gray, dolomitic, glacial (?)	130–140
Same as above except finer; 2 samples	140–160
Clay, rusty brown, dolomitic	160–170
Sand, fine, rusty brown, very dolomitic	170–180
Sand, fine, gray, dolomitic, glacial	180–190
Ordovician:	
Maquoketa shale (152 feet thick; top 400 feet above sea level) —	
Dolomite, light bluish gray	190–200
Shale, blue-gray, dolomitic; 9 samples	200–290
Dolomite, dark blue-gray, shaly; 5 samples	290–342
Galena-Black River (348 feet thick; top 248 feet above sea level) —	
Dolomite, light gray, 23 samples	342–570
Dolomite, gray and brown, pyritic	570–580
Dolomite, brownish gray and bluish gray	580–590
Dolomite, gray, blue spots	590–600
Dolomite, light gray	600–610
Same, some blue spots	610–620
Dolomite, gray	620–630
Dolomite, light gray	630–640
Dolomite, gray, blue spots; 2 samples	640–660
Dolomite, light gray, some white, very sandy	660–672
Shale, gray and brown, calcareous	672–682
Sandstone, coarse, gray, pyritic, dolomitic; shale, greenish gray	682–690
Saint Peter (70 feet thick; top 100 feet below sea level) —	
Sandstone, fine to medium, light gray, dolomitic	690–700
Same, lighter color, 2 samples	700–720
Sandstone, medium, white; 2 samples	720–740
Shale, greenish gray; much sand; some soft white chert (?)	740–750
Same, but some white dolomite, very soft; sand not in shale, which is hard and caves	750–760
Prairie du Chien (370 feet thick; top 170 feet below sea level) —	
Dolomite, light gray; chert, white; shale cavings	760–770
Dolomite, light gray; 3 samples	770–800
Sandstone, medium, light gray, very dolomitic	800–810
Dolomite, light gray; 2 samples	810–830
Dolomite, light pink	830–840
Dolomite, light gray; 4 samples	840–880
Dolomite, light gray; chert, white; 2 samples	880–900
Dolomite, light gray; 3 samples	900–930
Dolomite, light gray; chert, white; 2 samples	930–950
Dolomite, light gray; 2 samples	950–970
Dolomite, light gray; chert, white	970–980
Same, mostly chert; 6 samples	980–1040
Same, some yellowish brown chert	1040–1050
Dolomite, light gray	1050–1060

Dolomite, gray; some white chert	1060–1070
Same, more chert, some yellowish brown	1070–1080
Dolomite, gray; some white chert	1080–1090
Dolomite, light gray; 2 samples	1090–1110
Sandstone, fine, light gray, very dolomitic	1110–1120
Dolomite, light gray; chert, white	1120–1130
Cambrian:	
Trempealeau: Jordan sandstone (10 feet thick; top 540 feet below sea level) —	
Sandstone, medium to coarse, light gray, very dolomitic	1130–1140
Trempealeau: Lodi and St. Lawrence (170 feet thick; top 550 feet below sea level) —	
Dolomite, light gray; some sand; 3 samples	1140–1170
Dolomite, light gray and light pink	1170–1180
Same, with pyrite, and some dark gray; 2 samples	1180–1200
Dolomite, light gray and light pink, pyritic; 2 samples	1200–1220
Dolomite, light gray and light pink	1220–1230
Same (a few grains of glauconite); 2 samples	1230–1250
Dolomite, pink and gray; some glauconite; 6 samples	1250–1310
Franconia (90 feet thick; top 720 feet below sea level) —	
Dolomite, gray and pink, very sandy, very glauconitic; 2 samples	1310–1330
Sandstone, very fine, greenish gray, dolomitic, glauconitic; 3 samples	1330–1360
Sandstone, fine, greenish gray, dolomitic, glauconitic; 1 inch chunk of gray chert in part oölitic	1360–1370
Same; 2 samples	1370–1390
Sandstone, exceedingly fine, pink and greenish gray, very dolomitic, glauconitic	1390–1400
Franconia: Ironton (40 feet thick; top 810 feet below sea level) —	
Sandstone, fine to medium, light gray, dolomitic, a few glauconite grains; 3 samples	1400–1430
Sandstone, medium to coarse, light gray, dolomitic	1430–1440
Dresbach: Galesville sand stone (90 feet thick; top 850 feet below sea level) —	
Sandstone, medium, white; 2 samples	1440–1460
Same, dolomitic; 2 samples	1460–1480
Sandstone, medium, white; 5 samples	1480–1530
Dresbach: Eau Claire (180 feet thick; top 940 feet below sea level) —	
Sandstone, fine, light gray, dolomitic; 2 samples	1530–1550
Same, glauconitic	1550–1560
Sandstone, fine, pink, glauconitic, slightly dolomitic	1560–1570
Sandstone, medium, light gray, some glauconite, dolomitic; 3 samples	1570–1600
Sandstone, medium, pink, dolomitic	1600–1610
Sandstone, fine to medium, gray, very dolomitic, hard; 2 samples	1610–1630
Sandstone, fine, light pinkish gray, dolomitic, glauconitic; some shale, dark gray	1630–1640
Same, finer, less shale; 4 samples	1640–1680
Sandstone, fine, red, dolomitic	1680–1690
Sandstone, very fine, gray, dolomitic, glauconitic; 2 samples	1690–1710
Dresbach: Mount Simon (penetrated 233 feet, top 1120 feet below sea level) —	
Sandstone, meduim to fine, white, slightly dolomitic; 2 samples	1710–1730
Sandstone, medium to fine, light pink, dolomitic	1730–1740
Sandstone, medium to fine, white, dolomitic; 2 samples	1740–1760
Like above, more dolomitic, hard; 3 samples	1760–1790
Sandstone, medium to fine, white, dolomitic; 2 samples	1790–1810
Sandstone, medium to coarse, white; 14 samples	1810–1943

Harper, Keokuk County

In 1931 the Sewell Well Co. of St. Louis completed a well one mile southwest of Harper for the Continental Construction Co. The depth of the well is 1,530 feet. The diameters, top and bottom, are 20 and

$6\frac{1}{4}$ inches. The elevation of the curb is stated to be approximately that of Harper, 796 feet above sea level. Water was found at the base of the drift at 50 feet; in the Keokuk limestone at 150 feet; in soft dolomitic limestones, probably Silurian, at 730 feet, sulphurous; in Galena-Platteville dolomite at 1,165 feet; in the Saint Peter at 1,303 feet; and in the New Richmond sandstone, the main flow at 1,500 to 1,530 feet.

The head of the Galena-Platteville aquifer was 130 feet below curb. At 1,335 feet, at the bottom of the Saint Peter sandstone, the head had dropped to 182 feet below curb. The head rose to 119 feet below curb on the completion of the well under the pressure of the main flow from the New Richmond.

Casing was placed as follows: 47 feet of 16-inch casing to 47 feet; 153 feet of 12-inch casing to 153 feet; 317 feet of 10-inch casing; 1,002 feet of 8-inch casing. A 6-inch liner from 1,260 to 1,368 feet prevents caving from the Saint Peter sandstone and also prevents lateral escape of water from the New Richmond, whose static head is 63 feet higher than that of water from the Saint Peter.

The well tests 200 gallons per minute.

Record of Strata	Depth in Feet
Pleistocene (55 feet thick; top 796 feet above sea level) —	
Drift	0–55
Pennsylvanian (93 feet thick; top 741 feet above sea level) —	
Shale, mainly blue	55–148
Shale, olive-drab, hard, laminated, in chips and concreted masses, somewhat calcareous	74–100
Mississippian:	
Keokuk (62 feet thick; top 648 feet above sea level) —	
Limestone, very light gray, highly crinoidal, soft, in chips, rapid effervescence in cold dilute HCl; a little chert	148–155
Limestone, whitish and light buff, soft, rapid effervescence; much whitish chert	155–160
Limestone, light yellow-gray, granular, moderately rapid effervescence; much whitish chert; 3 samples	160–180
Limestone, as above; limestone, buff, slow effervescence, siliceous; much chert	180–185
Limestone, light gray, rapid effervescence; much chert	185–190
Limestone, light gray and buff; some chert	190–195
Limestone, as above, very cherty	195–200
Chert, whitish; limestone, yellow, crystalline-granular, moderately rapid effervescence; 2 samples	200–210
Burlington and Kinderhook (100 feet thick; top 586 feet above sea level) —	
Limestone, whitish, soft, in large chips, earthy, highly argillaceous; 3 samples	210–225
Limestone, gray and dark gray, fine-grained, argillaceous, rapid effervescence; 3 samples	225–240
Limestone as above, moderately rapid effervescence; 2 samples	240–250
Limestone, gray, finely crystalline, pyritic; 2 samples	250–260
Limestone, yellow-gray, calcilutite, fossiliferous at 275; rapid effervescence; 5 samples	260–285

Limestone, gray and brownish gray, finely crystalline-granular, in large flakes, rapid effervescence; 2 samples	285–295
Limestone, light yellow-gray, calcilutite; and darker gray, finely granular; rapid effervescence; fossiliferous at 300; 3 samples	295–310
Kinderhook shale (352 feet thick, top 486 feet above sea level) —	
Shale, blue, plastic, calcareous; 3 samples	310–370
No samples	370–475
Limestone, gray and blue-gray, argillaceous, earthy, in large flakes, rapid effervescence; 3 samples	475–495
Shale, blue-gray, some olive-drab chips; calcareous, plastic	495–520
Shale, as above	520–540
Shale, as above	540–560
Shale, as above	560–580
(Limestone, light yellow-gray and whitish, rapid effervescence, considerable white chert cuttings, clean of shale. Not listed in log and apparently misplaced, 565-575)	
Shale, blue-gray, calcareous, plastic	580–600
Shale as above, with some inclosed chips of drab and olive-drab shale; 3 samples	600–662
Devonian and Silurian (111 feet thick; top 134 feet above sea level) —	
Limestone, gray, earthy, argillaceous, in large chips, rapid effervescence; some gray chert; 2 samples	662-675
Limestone, grayish buff, finely-crystalline, rapid effervescence, argillaceous, in rather large chips	675–685
Limestone, medium dark gray, finely crystalline-granular, moderately rapid effervescence; some drusy quartz; white chert; 3 samples	685–715
Limestone, medium dark gray, finely crystalline-granular, moderately rapid effervescence	715–725
Limestone, dolomitic, gray, rather slow effervescence, finely crystalline-granular, casts of fenestella in large chips	730–735
Limestone, dolomitic, brownish drab, rather slow effervescence, cherty, fenestella casts	740–745
Limestone, dolomitic, brown, finely crystalline-granular	745–750
Limestone, dolomitic, gray, some chert	755–765
Dolomite, yellow-gray, cryptocrystalline	765–773
Ordovician:	
Maquoketa shale (227 feet thick; top 23 feet above sea level) —	
Shale, greenish gray, calcareous, plastic, some hard chips feebly calcareous; 2 samples	773–795
No samples	795–835
Shale, bluish drab, calcareous, plastic	835–875
Shale as above	875–885
No samples	885–938
Dolomite, drab, argillaceous, crystalline-granular; much shale in chips; 2 samples	938–950
Shale, drab, calcareous, plastic, some chips olive-drab	955–975
"Brown shale," no samples	975–1000
Galena-Platteville (285 feet thick, top 204 feet below sea level) —	
Dolomite, dark brown; white calcite; a few chips of brown shale, some inflammable; 2 samples	1000–1020
Limestone, gray, earthy, rapid effervescence; a few flakes of brown inflammable shale; 2 samples	1020–1040
Limestone, light yellow-gray, rapid effervescence	1040–1050
No samples	1050–1060
Limestone as at 1,040; 4 samples	1060–1100
Limestone, light buff, moderately rapid effervescence, some light gray, rapid effervescence; chert; 2 samples	1100–1120
Limestone, light buff, crystalline-granular, moderately rapid effervescence, in sand; much white chert; 2 samples	1120–1140
Limestone, light buff and light gray, moderately rapid effervescence; cherty	1140–1150
Limestone, as above, some of rather slow effervescence	1150–1165
Dolomite, light buff and yellow-gray, in crystalline sand; 4 samples	1165–1195

Dolomite as above; limestone light gray; highly cherty; 2 samples	1195–1215
Limestone, gray, rapid effervescence; some chert	1215–1225
Limestone, light gray, fossiliferous; much brown inflammable shale; 2 samples	1225–1245
Limestone, light gray, rapid effervescence; 2 samples	1245–1265
Limestone, medium dark gray, rapid effervescence; 2 samples	1265–1285
Glenwood formation (18 feet thick, top 489 feet below sea level) —	
Sandstone, fine to medium, Saint Peter facies; much brown inflammable shale	1285–1290
Sandstone, as above, gray in mass	1290–1300
Sandstone, as above, white, largest grains about 1 mm. diameter, speckled with small splinters of dark greenish shale, feebly calcareous	1300–1310
"Green shale, cavey"	1300–1303
Saint Peter sandstone (32 feet thick; top 507 feet below sea level) —	
Sandstone, etc. as at 1300	1310–1325
Sandstone, as above; sample largely flakes of dark greenish shale as above; considerable amounts of pyrite	1320–1330
Sandstone, as above, with much dark greenish shale; chert, white and gray, oölitic	1330–1335
Prairie du Chien: Shakopee dolomite (145 feet thick; top 539 feet below sea level) —	
Dolomite; considerable chert, some oölitic; much shale as above, in large flakes; with some quartz sand as above	1335–1340
Dolomite, light buff; siliceous oölite	1340–1350
Dolomite, light buff, cherty	1350–1360
Dolomite, gray	1360–1370
Dolomite, light buff, considerable light greenish shale; pyrite; 2 samples	1370–1390
No sample	1390–1400
Dolomite, buff, much white chert	1400–1410
Dolomite, buff, highly arenaceous, imbedded grains; 2 samples	1410–1430
Dolomite, light brown, cherty	1430–1440
Dolomite, yellow-gray and buff; 3 samples	1440–1470
Dolomite, dark brown, cherty	1470–1480
Prairie du Chien: New Richmond sandstone (penetrated, 50 feet; top 684 feet below sea level) —	
Sandstone, dolomitic, light yellow-gray, grains rounded, frosted, up to 1.3 mm. diameter; some chert and siliceous oölite; 3 samples	1480–1510
Sandstone, light yellow-gray in mass from rust, fine	1510–1520
Sandstone, as above, but coarser, largest grains 0.5-0.7 mm. diameter	1520–1530

Notes. — The assignment of the beds from 55 to 144 feet is based on the log and its confirmation, so far as it goes, by a single sample. Some corroboration is afforded by the coarse ill-rounded quartz sand found in all cuttings below the shale as far down as 310 feet, where the second casing was bedded. This foreign material would readily be supplied by the basal sand of a Pennsylvanian outlier, even though the seam were too thin to find mention in the log. Such material has been known to find its way down behind a casing. No such thickness of shale occurs at this horizon in the Mississippian, and a Pennsylvanian outlier at Harper has been mapped by Bain in his report on the Geology of Keokuk County.[6]

The cherty limestones, largely magnesian, from 155 to 210 feet are rather clearly the westward extension of the Montrose cherts of the

6 Iowa Geol. Survey, Vol. IV.

Keokuk, and the limestone at 148 feet, although crinoidal, may belong to the same formation. Underlying the Montrose cherts are homogenous limestones, 100 feet thick, which may belong to a single terrane. They show neither the distinctive crinoidal layers expected in the Burlington, nor the intercalated sandstones looked for in the Kinderhook limestones. No Kinderhook oölite was noted. In the absence of fossils the two formations, to one or both of which the beds belong, can not be discriminated.

The Kinderhook shale clearly begins at 310 feet and has a thickness of at least 165 feet, and probably of 352 feet. This maximum is considerably greater than at Morning Sun, Brighton, and New London, where it measures about 280 feet; it is not much in excess of that assigned at Winfield and Donnellson, about 325 feet, and slightly less than at Mount Pleasant, 368 feet. The correlation with the Washington section is close. At Washington the Kinderhook shale has been partly cut away by the erosion of a preglacial channel, but the base of the formation shows a normal dip from Washington to Harper of eight or nine feet to the mile. The correlation with the section at Sigourney, however, is by no means so close. The top of the formation shows a normal dip, but the base is 68 feet higher at Sigourney than at Harper, or if some argillaceous limestones and shales be included with the Kinderhook, it is still 16 feet higher.

The Devonian-Silurian thickness is about the same as at Washington, but much less than at Sigourney, where it measures 317 feet, or with every allowance at least 265 feet. The discrepancy seems due to unconformities: the erosion of the Devonian at Harper, or of the Maquoketa at Sigourney, or both.

The Maquoketa maintains its normal thickness, but thins abruptly southward. The inflammable brown shale found in several well sections near its base probably lies within the "Brown shale" of the log, from 975 to 1,000 feet, and caving supplies the inflammable shale found in cuttings of the upper beds of the Galena.

The Galena-Platteville maintains its usual thickness, exhibiting the not uncommon alternation of limestones, magnesian limestones, and dolomites, with considerable chert. The brown inflammable shale found in the first cuttings of the Saint Peter sandstone is interpreted as cave from the base of the Platteville. The Glenwood and the Saint Peter have the same general relations as at New London (page 332).

The chert of the first cuttings in the Prairie du Chien may come from residual materials and thus represent an unconformity. The beds assigned to the New Richmond show nothing lithologically distinctive, but their position, only 145 feet below the Saint Peter, forbids their assignment to the Jordan, which lies much deeper in this area.

Driller's log, by George L. Smith

	Depth in Feet
Drift	0–55
Blue shale	55–148
Shelly lime	148–152
Gray lime, white flint	152–265
Blue shale	265–277
Gray lime	277–284
Gray shale	284–291
Gray lime	291–302
Blue shale	302–370
Brown shale	370–473
Gray lime	473–494
Brown shale	494–662
Brown lime	662–725
Gray and brown lime, soft	725–737
Brown lime, hard	737–755
Gray lime	755–773
Green shale, cavy	773–810
Blue shale	810–938
Gray lime	938–955
Gray shale	955–965
Brown shale	965–1002
Brown lime	1002–1018
Gray and brown lime	1018–1080
Brown lime	1080–1160
Brown lime, few white specks from top	1160–1170
White sand	1170–1185
Brown lime	1185–1285
Brown lime and white sand	1285–1290
White sand	1290–1300
Green shale, cavy	1300–1303
White sand	1303–1324
Broken sand and shale	1324–1335
Shale and broken lime	1335–1339
Brown lime	1339–1376
Gray lime	1376–1410
Brown sandy lime	1410–1480
Gray lime	1480–1495
Brown lime and white sand	1495–1500
White sand	1500–1530

Keosauqua, Van Buren County

In 1932 a well was drilled for the water supply of Keosauqua by C. W. Varner of Dubuque. The depth is 335 feet. Casing was set as follows: 10-inch to 22 feet, 8-inch from surface to 105 feet, perforated between 25 and 45 feet. A 72-hours' test showed a yield of 116 gallons per minute, the full capacity of the pump, with a draw-down of 24 feet. The static level is 6 feet below the surface. For the above data and for the following log the Survey is indebted to Mr. W. G. Osborn of Keosauqua, who is also responsible for the assignments to Mississippian formations.

Log of City Well No. 1, Keosauqua

	Depth in Feet
Pleistocene (20 feet thick, top 579 feet above sea level):	
Clay, yellow	0–17
Sand and gravel; water	17–20
Mississippian (penetrated 315 feet):	
Limestone, gray above, buff, magnesian below; water. St. Louis	20–50
Limestone and shale, interbedded, gray. Warsaw	50–101
Limestone, buff; water. Keokuk	101–110
Limestone, light gray. Keokuk	110–175
Limestone, buff, magnesian, water. Keokuk	175–185
Limestone, light gray and gray, with chert. Keokuk	185–198
Limestone, white; some water between 240 and 250 feet. Burlington	198–288
Limestone, gray and brown; water at top at contact. Kinderhook	288–292
Limestone, gray, and sandstone, with siliceous inclusions. Kinderhook	292–325
Limestone, as above, with gray shale; water. Kinderhook	325–335

New London, City Well No. 2, 1930

New London's city well No. 1, which is 1,450 feet deep, was drilled in 1916, and is described in volume XXXIII of the Iowa Geological Survey. A second well was drilled in 1930 by Thorpe Bros. Well Co. of Des Moines. The depth is 2,785 feet. On completion the well tested 250-300 gallons per minute on a 48-hour run with a draw-down of but 6 feet. The static level is 185 feet below the curb, 45 feet below the original static level of well No. 1, which tapped the Prairie du Chien aquifers.

"While the water is quite hard, it is not nearly as bad as that of our old well," writes Mr. J. O. Bell, manager of the City Water and Light Department. The water of well No. 1 showed a total hardness of 1,189 parts per million. In this area, then, drilling can continue for 1,000 feet in the Cambrian without striking brine pools and with the prospect of finding better water than that of the Ordovician aquifers.

The well is cased with 252 feet of 10-inch casing, and 1,450 feet of 8-inch casing, making the well impervious to a depth of 1,700 feet. A 6-inch casing was also inserted from 2,300 to 2,500 feet to prevent the caving of certain beds of the Galesville and Eau Claire.

Record of Strata

Gaps in this record are filled when possible from the record of City Well No. 1. Norton, W. H., Deep Wells of Iowa: Iowa Geol. Survey, Vol. XXXIII, pp. 281-283.

	Depth in Feet
No samples or record	0–157
Mississippian:	
Limestone, cream-colored, rapid effervescence in cold dilute HCl; chert, white	157

Sandstone, buff, clayey, somewhat calcareous, sand grains irregular	172
Limestone, as at 157	182
Chert, white; cream-colored limestone	220
Chert, white; some limestone, light buff	230
Limestone, light gray in mass	235
Chert, white; limestone, buff, highly siliceous	248
Limestone, cream-colored, cherty	260
Sandstone, blue-gray, grains minute, angular, calciferous, argillaceous	275
Sandstone, as above	285
Limestone, dark gray, siliceous, argillaceous, residue of minute quartz grains, slow effervescence; limestone, whitish, rapid effervescence	295
Sandstone, blue-gray, grains minute, irregular, calciferous, argillaceous	305
Kinderhook shale (280 feet thick, top 440 feet above sea level) —	
Shale, blue, calcareous; samples at 315, 325, 465, and	470
Devonian (135 feet thick; top 160 feet above sea level) —	
Limestone, blue-gray, highly argillaceous, fine siliceous residue	605
Limestone, brownish buff, rapid effervescence, finely saccharoidal	625
Limestone, brownish buff and gray, rapid effervescence, fossiliferous with fragments of brachiopod shells	640
"Limestone, blue-gray, earthy, fossiliferous, soft; some large chips"	646–651
"Limestone, yellow-gray, effervescence rapid, in fine chips"	651–663
"Limestone, brown, effervescence rapid, earthy, in chips"	663–667
"Limestone, blue-gray, effervescence rapid; pyrite; a little chert"	667-670
Limestone, blue-gray, rapid effervescence	670
Limestone, as above, fossiliferous with fragments of brachiopods	685
Limestone, yellow-gray, rapid effervescence, earthy, fossiliferous with brachiopod fragments	705
Silurian (78 feet thick; top 25 feet above sea level) —	
Limestone, gray, rapid effervescence, in sand, considerable quantity of gypsum and crystals of selenite	740
"Limestone, yellow-gray, effervescence rapid, fossiliferous, in fine chips"	720-730
"Limestone, whitish, rapid effervescence, in flaky chips"	730–740
Gypsum, cream-colored in mass, some limestone of rapid effervescence, all in fine sand	750
Limestone, dark gray, rapid effervescence, much gypsum, in chips and sand	760
Gypsum, gray and white, some limestone	770
Limestone, brown, rapid effervescence; much gypsum in white chips, some slate-colored and blue shale	775
"Limestone, brown and buff, effervescence rapid, in sand; gypsum in white soft masses and chips; 3 samples"	760-796
"Limestone, brown, effervescence rapid, some slow; white chips of crystalline quartz, nongranular, a few cleavage faces noted (altered from anhydrite?)"	796–806
"Limestone, blue-gray, effervescence rapid, some quartz; shale in powder"	806–818
Ordovician:	
Maquoketa shale; Hoing? (34 feet thick; top 53 feet below sea level) —	
"Shale, blue, plastic, calcareous"	818–830
"Shale, blue, in chips; limestone, rapid effervescence; some fine quartz sand in well-rounded grains"	820
Dolomite, gray, rather slow effervescence, arenaceous, grains fine; sandstone, fine, larger grains well-rounded, dolomitic cement; some shale	835
Dolomite, etc. as above	845
"Limestone, blue-gray, highly arenaceous, or sandstone, calciferous"	843–850
"Sandstone, gray, calciferous, larger grains well-rounded, up to 0.6 mm. diameter, in chips and sand"	850–852
Galena-Platteville (282 feet thick; top 87 feet below sea level) —	
"No samples"	852–860
"Dolomite, blue-gray and light buff, cryptocrystalline, in sand"	860–870
Dolomite, buff in mass	875
Dolomite, buff and yellow-gray; 13 samples	915–1090
Limestone, gray, rapid effervescence	1100

Limestone, as above; a little brown shale, inflammable, in small chips	1110
Limestone, light buff, moderately rapid effervescence; limestone, gray, rapid effervescence	1130
"Limestone, light buff, in fine sand, effervescence rather rapid; two samples"	1113–1134
Glenwood formation (46 feet thick; top 369 feet below sea level) —	
"Sandstone, white, grains well-rounded, some secondary enlargements, larger grains 0.5 mm. diameter"	1134–1170
Sandstone, as above	1140–1150
Sandstone, light yellow, very fine, dolomitic	1160
"Shale, green, unctuous, noncalcareous, pyritic"	1170–1180
Shale, as above	1170
Saint Peter sandstone (40 feet thick; top 415 feet below sea level) —	
Sandstone, fine	1185
No samples	1185–1220
Prairie du Chien (562 feet thick; top 455 feet below sea level) —	
Dolomite, gray, light gray and light buff, considerable amount of cave shale and some sand, cherty in places; 19 samples	1220–1470
"Sandstone, clean, white, grains well-rounded and frosted, many larger grains of 1 mm. diameter, some secondary enlargements"	1485
No samples	1470–1515
Dolomite, gray, considerable white chert	1515
Dolomite, yellow-gray, arenaceous, grains fine, rounded, some with secondary enlargements; some warped plates very thin (about 1 mm. thickness) of fine shaly material, brown, highly inflammable, but no chips of brown shale	1520
Dolomite, gray, cherty, much drab cave shale, one fragment, 11 mm. diameter, 5 mm. thick, brown, nonlaminated, inflammable shale; a very few small chips of same	1545
Dolomite, gray, cherty	1560
Dolomite, very light gray, macrocrystalline; some cave shale, including a few chips of brown inflammable shale as above; 4 samples	1590–1615
Dolomite, as above, cherty; some chips of brown inflammable shale at 1,665 and 1,680; dark cave shale in all samples; 7 samples	1630–1695
Dolomite, dark gray in mass, cherty	710
Dolomite, buff-gray in mass, cherty	1726
Dolomite, light yellow-gray in mass, cherty; 3 samples	1745–1760
Dolomite, gray, cherty	1770–1780
Cambrian:	
Trempealeau: Jordan sandstone (128 feet thick; top 1,017 feet below sea level) —	
Sandstone, fine, white, many secondary enlargements, dolomitic cement or matrix	1782
Sandstone, as above, grains up to 0.7 mm. diameter, larger grains smooth and frosted, some grains imbedded in cryptocrystalline siliceous matrix	1800
Dolomite, gray in mass, highly arenaceous, grains fine	1805
Sandstone, dolomitic, fine	1825
Sandstone, buff in mass, grains fine, larger grains well-rounded and frosted, dolomitic	1835
Sandstone, very fine, dolomitic, imbedded grains, some secondary enlargements	1840
Sandstone, gray-buff in mass, fine, grains largely broken, larger grains well-rounded and frosted, dolomitic cement; 3 samples	1860–1890
Trempealeau: Lodi and St. Lawrence (180 feet thick; top 1,145 feet below sea level) —	
Dolomite, gray-buff in mass, highly arenaceous, grains as above	1910
Dolomite, gray, in large chips	1935
Dolomite, gray, vesicular, cavities lined with dolomite crystals, nests of iridescent pyrite	1940
Dolomite, gray; 4 samples	1950–1975
Dolomite, gray, vesicular, cavities lined with crystals of dolomite	1985
Dolomite, gray	1990
Dolomite, light buff in mass	2000–2015

Dolomite, gray, slightly arenaceous	2035
Dolomite, light yellow-gray and light buff in mass; 6 samples	2045–2080
Franconia (260 feet thick; top 1,325 feet below sea level) —	
Dolomite, blue-gray, highly arenaceous with minute or microscopic angular grains of quartz, chips speckled with glauconite	2090
Dolomite, medium dark gray, arenaceous and glauconitic as above	2100
Dolomite, medium dark gray, highly arenaceous with minute grains; concreted mass of light blue-green shale, highly dolomitic and minutely arenaceous	2110–2115
Dolomite, highly arenaceous, as above, glauconitic, argillaceous; 5 samples	2125–2175
Shale, light blue-green, minutely arenaceous, glauconitic, dolomitic, in concreted masses	2180
Dolomite, dark gray, minutely arenaceous, glauconitic; 3 samples	2195-2210
Shale as at 2180	
Dolomite, buff, vesicular with cavities lined with dolomite crystals; sample misplaced (?) labelled	2225
Shale, green, minutely arenaceous, dolomitic, glauconitic	2235
Dolomite, gray, highly arenaceous with minute grains, glauconitic	2245
Shale, blue-gray, minutely arenaceous, glauconitic, somewhat dolomitic in concreted masses; some flakes of hard, olive-green shale	2255
Shale, in dark drab chips, noncalcareous, in blue-gray concreted masses; sandstone, buff and light gray, of minute angular particles, sparingly glauconitic, feebly dolomitic, in chips	2265
Sandstone and shale as at 2265	2270
Sandstone, of minute particles, glauconitic, dolomitic; shale, dark olive-green, noncalcareous, in splintery chips	2280
Dolomite, gray, highly arenaceous as above, glauconitic, in chips; much shale, dark blue-green, noncalcareous, in hard chips	2285
Sandstone, gray and pinkish, grains minute, angular, speckled with grains of glauconite, dolomitic	
Sandstone, grains as above, highly glauconitic, dolomitic cement	2300
Sandstone, gray and pinkish, grains as above speckled with glauconite	2310
Shale, drab, in concreted masses	2315
Second sample, as at 2310	2315
Sandstone, as at 2310. From 2265 all the above samples are blue-greenish, drab in mass from shale in powder and chips, and the sandstone is in small chips	2320
Sandstone, pink, buff and gray, color in mass buff, grains minute, of clear quartz, angular or subangular, an occasional fine grain rounded	2325
Sandstone as above, but green-gray with powder and chips of shale, glauconitic, dolomitic cement	2340
Dresbach: Galesville sandstone (70 feet thick; top 1,585 feet below sea level) —	
Sandstone, in sand and chips, cuttings buff from rust, grains fine to 1.0 mm. diameter, for the most part poorly rounded, pinkish grains not uncommon, dolomitic cement, glauconitic; shale nearly absent	2350
Sandstone, in sand, buff in mass, fine and up to 1.5 mm. diameter, grains rough surfaced, some pinkish; glauconitic	2360
Sandstone, brown-gray, grains as above; lumps of bright green glauconitic sandy clay	2365
Sandstone, 2d sample, iron red, with red clay, grains up to 1.4 mm. diameter, in sand, glauconitic; some chips of fine glauconitic sandstone	2365
Sandstone, light brownish gray, fine, with some larger grains 1 mm. diameter, many pinkish, in sand, glauconitic	2370
Sandstone, gray, fine to medium, grains as above, glauconitic; 3 samples	2380–2395
Sandstone, green-gray in mass, fine to medium, some of the larger grains well-rounded, grains commonly colorless, glauconitic	2400
Dresbach: Eau Claire (235 feet thick; top 1,655 feet below sea level) —	
Sandstone, pink, in chips, cuttings red-brown from red shale and splinters of green shale coated red, grains minute, uncolored, noncalcareous, glauconitic	2420
Sandstone, as above, but without red shale, in chips; one fragment of	

white dolomite mottled with glauconite and arenaceous with minute grains of clear quartz	2425
Sandstone, as above, noncalcareous, light buff, glauconitic; much slate-colored hard shale; 3 samples	2430, 2435, 2460
Sandstone, gray, dolomitic, glauconitic; with much shale as above	2470
Sandstone, gray, dolomitic; dolomite highly arenaceous; both glauconitic and both in grains of quartz sand minute; much red-brown and drab shale in large flakes, finely laminated	2500
Shale, greenish drab, noncalcareous, hard, splintery, finely laminated; some red-brown shale	2515
Sandstone, gray and pinkish, grains minute, dolomitic, highly glauconitic, all cuttings coated with red clay; red and drab shale; two fragments of dark gray dolomite, one 2 cm. thick between bedding planes; highly arenaceous with minute angular grains and highly glauconitic	2550
Sandstone, pinkish in sand, buff in mass, grains very fine, poorly rounded, glauconitic; on boiling in HCl, color removed from grains	2555
Sandstone, light buff, in chips and sand, noncalcareous, grains very fine, slightly glauconitic; 5 samples	2575–2610
Sandstone, buff, dolomitic, glauconitic, grains minute; 2 samples	2637–2645
Sandstone, native color light gray, grains very fine, ill-rounded, in chips and sand	2652
Dresbach: Mount Simon (penetrated 30 feet; top 1,890 feet below sea level) —	
Sandstone, light buff in mass, fine with some grains reaching 1.6 mm. diameter; many chips of sandstone as at 2652; very little shale	2655
Sandstone, gray in mass, many grains from 1 to 2 mm. diameter, larger grains well-rounded and frosted, in sand; chips of pink nondolomitic sandstone of very fine grain; chips of dark drab sandstone, fine- to medium-grained, slightly dolomitic	2660
Sandstone, light gray in mass, clean, fine to medium, with some rounded grains of 1 mm. diameter	2675
Sandstone, red and pink, fine- to medium-grained, grains of colorless quartz, but many rusted, only larger grains well-rounded	2680
Sandstone, reddish brown, clean, coarser than above, larger grains 1 mm. diameter; color removable on boiling in HCl; chips of sandstone of minute grains and some dolomite	2685
Sandstone, reddish brown in mass, grains as at	2685, 2690–2695
Sandstone, light buff in mass, fine grains poorly rounded	2730
Sandstone, reddish brown in mass, larger grains rounded 1.0 and 1.5 mm. diameter	2735
No sample "practically same as last sample only got much whiter, finer and soft"	2735–2785

Notes. — There is some difficulty in correlating the beds above the Kinderhook shale with those of natural sections of this area. The sandstone overlying the Kinderhook shale is evidently identical with that occupying the same stratigraphic place in the Prospect Hill section at Burlington [7] although the latter measures 22½ feet thick, while the samples at New London appear to represent a bed 40 feet in thickness. At Mount Pleasant this sandstone has a thickness of 52 feet, but is argillaceous at top and includes some shale.

The Kinderhook shale should possibly include the argillaceous limestone here placed as the upper beds of the Devonian, which would give it a thickness of 310 feet. This measure is exceeded at Mount Pleasant

7 Van Tuyl, F. M., Iowa Geol. Survey, Vol. XXX, p. 54.

and Donnellson. The brown inflammable shale found in this formation at Keokuk, Mount Pleasant, and Brighton is not represented in the few samples of the shale at New London.

Considering the notable deposits of gypsum in the Silurian of Mount Pleasant and its occurrence at the same horizon at Fairfield, Brighton, Pella, and Des Moines, the gypsum in the cuttings at New London from 750 to 796 feet was to be expected. The absence of evidence of gypsum at Burlington may well be due to lack of data. At Harper the Silurian can not be discriminated, and to the south, at Donnellson and Keokuk, the Silurian apparently has feathered out.

The beds from 818 to 852 feet are referable either to the Maquoketa shale of the Ordovician or to the Hoing sandstone commonly assigned to the Silurian. In their arenaceous content the beds in question are quite like those referred to the base of the Silurian at Washington, Sigourney, Des Moines, Stuart, Centerville, Shellsburg, and Greenfield. At Ogden, 70 feet of chert, with quartz sand and a very little dolomite, overlies the shale assigned to the Maquoketa. The Hoing formation in its type localities in western Illinois is described as spotty and discontinuous in distributon and lenticular in its deposits, with a thickness ranging from 5 to more than 30 feet. It is supposed to lie unconformably on the Maquoketa, occupying hollows in the erosion surface developed on the shale during the erosion interval preceding the deposition of the Niagaran limestone. The Hoing is thus supposed to consist of land deposits reworked by the transgressing Niagaran sea. There are instances, however, among the deep well sections of Iowa where similar arenaceous deposits occur more intimately related to Maquoketa shales. At Mount Pleasant fine quartz sandstone appears 22 feet below the top and 15 feet above the bottom of the shale. At Iowa City cuttings of arenaceous shale, dolomite, and lumps of decayed chert mark a bed 12 feet thick, which lies 63 feet above the base and 118 feet below the top of the Maquoketa. At Charles City, where the Maquoketa is 90 feet thick, the basal stratum of the formation is a fine sandstone associated in the cuttings with an argillaceous dolomite, and the summit beds also are sandy. At Fort Dodge, city well No. 8, the base of the Maquoketa includes chert and sandy beds.

The Glenwood and the Saint Peter, as at Harper, are more intimately connected than is common in deep well sections in Iowa. Taken in connection with examples where the Glenwood consists of shale only, where the shale is sandy, and where it is entirely wanting, we have several variations on a single theme. The Glenwood is a transitional formation between the Saint Peter and the Galena-Platteville; the three formations belong to a continuous cycle of sedimentation unbroken by emergence and erosion. Close as are the normal relations of the Glenwood shale with the Platteville limestone and the Decorah shale, they may be even closer with the Saint Peter sandstone, as at New London and Harper.

The epoch during which the sands of the Saint Peter were laid down closed under conditions of rapid change, which often permitted the calcareous silts of the Platteville to be laid directly on the Saint Peter sandstone. In certain areas under a slower subsidence, however, or other differing conditions, the coarser clastics of the Saint Peter were succeeded by the fine sea muds now known as the Glenwood shale. Continuously deepening waters and retreating shores gave rise to the limy silts of the Platteville, while a little later a slight oscillation produced the shales of the Decorah. Not infrequently, however, after the deposition of the shales of the Glenwood, an oscillation led to the recurrence of the conditions favorable for the deposition of sandstone, still of Saint Peter facies. Again, as shown in several well sections of north-central and western Iowa, conditions long favored the deposition of a heavy shale which may include the Glenwood, Platteville, and Decorah formations, so far as our data show.

On such varying natural sequences it is difficult to impose any cast-iron classification. It seems fairly clear, however, that, apart from the evidence of fossils, and with only such proofs as deep wells supply, the Saint Peter is linked closely through the Glenwood with the Middle Ordovician Galena-Platteville. On the other hand, it is in many places separated from the Lower Ordovician Prairie du Chien by residual deposits of the same significance as the unconformities observed in the Wisconsin outcrops.

The Prairie du Chien, here given a thickness of 562 feet, shows an evident thickening southward from its measures of 380 feet at Washington, 460 feet at Grinnell, and 440 feet at Bettendorf. About the same thickness, 565 feet, is seen at Burlington, and at Mount Pleasant, where it is 527 feet; and it is out of the question to suppose that at New London the Trempealeau dolomite is included mistakenly with the Prairie du Chien. Continuing its thickening toward the south, the formation has a thickness of 760 feet at Keokuk. The New Richmond sandstone is not in evidence. The brown inflammable shale found in samples from 1,545 to 1,680 feet is interpreted as cave material from the usual horizon near the base of the Platteville. It is not represented in Prairie du Chien cuttings from well No. 1.

The Jordan sandstone reaches an exceptional thickness of 128 feet and is dolomitic throughout. Both the St. Lawrence and the Franconia (Saint Lawrence dolomite and shales of earlier reports) run true to form and need no comment. The Galesville is far from typical and is distinguished with some uncertainty from the sandstones of microscopic grain and the shales of the formations between which it lies. The distinction is based chiefly on the presence of decidedly coarser sand and the fact that shale is practically absent. Like them, however, it is here glauconitic. The transition to the Eau Claire is marked by hard, usually noncalcareous, sandstones of microscopic grain and hard splintery shales. The Mount Simon is rather sharply set off by softer nonglauconitic sandstones of coarser grain and by the general absence of shale.

The New London section, well attested with authentic sample cuttings, penetrates the Cambrian to the very unusual depth of 1,003 feet, 203 feet deeper than that of the Crapo Park well at Burlington. It thus becomes of exceptional value in the interpretation of the Cambrian of Iowa.

New Sharon, Mahaska County

In 1930 a deep well was completed for the town of New Sharon by the Thorpe Bros. Well Co. of Des Moines. The well is 2,139 feet deep, footing in the St. Lawrence dolomite. Special interest attaches to this well on account of the prolonged efforts to obtain a potable water in an area where the mineralization of the waters of the higher strata is excessive.

The first test of the well was made on reaching the Shakopee dolomite. The well had been now cased to the top of the Saint Peter sandstone and the static level stood at 108 feet below the curb. The well yielded 90 gallons per minute with a draw-down of 25 feet, and 150 gallons per minute with a draw-down of 40 feet. Analysis (No. 2, table p. 340) shows the quality of the water. The similarity of the water to that of Mississippian well waters of the region suggested the possibility that the upper waters had not been cased out successfully.

Drilling was resumed and the well carried to its full depth. The Saint Peter was cased out, leaving only the large flows entering the well from the Prairie du Chien and the Jordan sandstone. The head was now found to be at 149 feet below the curb. Pumping 200 gallons per minute showed a draw-down of but a foot and pumping 300 gallons per minute a draw-down of but 6 feet. The water, however, continued to be highly mineralized (analysis No. 3).

To test the quantity and quality of the water from the Jordan sandstone a 4-inch pipe was now set, joining the bottom of the pipe which cased out the Saint Peter and extending to the bottom of the well. This pipe was perforated for 40 feet from the bottom to let in the water of the Jordan aquifer, and a rubber packer was placed at the top of that formation. The static level now rose to 112 feet, about its level at the first test. The yield at this level was evidently insufficient. It was suspected that the leakage of upper waters was responsible both for the head and for the high mineralization which still remained.

A 6-inch pipe was now placed, reaching from the curb to the top of the 6-inch pipe already in the well in order to effectively exclude all but the water of the Jordan. The head now fell to 149 feet within the pipe, while it remained at 114 feet outside it. There was a heavy draw-down when pumping 159 gallons per minute. The lowered head seemed to imply that the influx of upper waters had been greatly lessened, if not entirely prevented. An analysis (No. 4) showed a marked improvement but by no means the good quality to be expected. As the yield of the Jordan sandstone was relatively small, and as there was no reason to suppose that the quality of the Prairie du Chien waters was inferior, the 4-inch casing shutting these waters out was now pulled. The head then stood at 155 feet. A pumping test of 66 hours showed a capacity of 280 gallons per minute with a draw-down of but 5 feet. The analysis of the water (No. 5) showed a marked reduction in total solids and in each deleterious ingredient, but the water remained one of the most heavily sulphated of Iowa deep wells and more highly mineralized than any in use as a town supply. The table includes some of the most highly mineralized deep well waters for comparison.

Evidently either the quality of the Cambro-Ordovician waters was truly represented in the last analysis, or the utmost efforts of experienced and skilled drillers had not been able to prevent entirely the influx of upper waters. In either case it remained only for the town to decide whether the water could be safely used. It was pointed out that, though the water was very bad as a boiler water, this fact might be disregarded in a nonindustrial town. Hendrixson has said, in summing up the effects of such waters on health: "Apparently waters containing more than 2,000 parts of mineral matter are unpalatable, and this amount may be taken as the maximum amount allowable in a water supply for city use and particularly for drinking. An organically pure water with 2,200 parts may be considered usable if no better can be obtained." This limit is set by Hendrixson largely because of unpalatability; for he also states regarding water containing only this maximum amount of 2,000 parts per million: "So far as is known no serious effects on the health of the people can be traced to the use of such waters." [8]

More specifically it was pointed out that any possible injury to the health of the users of this water would lie in the large amounts of the sulphate, sodium, and magnesium ions. In Maffitt's hypothetical combinations these totaled to the gallon 105 grains of sodium sulphate (Epsom salt) and magnesium sulphate (Glauber's salt). Thus one drinking six glasses (a quart and a half) of the water a day would take in 39 grains daily of these laxatives. A usual dose of either of these salts for gentle laxative effects is from 15 to 30 grains after each meal, or from 45 to 90 grains a day. The continuous use of about 39 grains per day could hardly be considered healthful. The effects, no doubt, would depend on the habit of the user. Those habitually constipated might be temporarily benefited. The first pronounced effects might be expected gradually to wear off. The general effects would be that of the continued use of the Mississippian waters of Colfax Springs, not the public supply but that of the Old M. C. Spring, containing 113 grains per gallon, and the M. R. S. Spring, containing 88 grains per gallon of the same laxatives. It was further pointed out that, if the drift wells of New Sharon's city supply were still used in part, the dilution of the water of the deep well would lessen its deleterious effects.

The following opinion was obtained from Dr. Edward Bartow of the State University of Iowa: "A water with 3,512 parts per million of residue should not be used for a water supply if it is possible to obtain anything else, or if it is possible to improve it.

"With regard to treating the water, that seems impossible. Treating with lime would remove some of the calcium and magnesium, but a considerable part of the sodium sulphate would still remain. People can become accustomed to water of this type, but strangers coming into

[8] Hendrixson, W. S., Iowa Geol. Survey, Vol. XXI, pp. 233-234.

town would probably be quite upset by the water until they got accustomed to it.

"From the information at hand, it would seem to me that the water should not be used for municipal supply if it is possible to get another in any way, or by further casing out of the highly mineralized water to improve this one."

Because of the high mineralization of the water the deep well was finally abandoned, and in October, 1931, the Thorpe Bros. Well Co. put down a Thorpe patent gravel-treated well, 130 feet deep, 12 inches in diameter, with three 6-inch side holes drilled to feed the gravel about the strainer. Water was found at 70 feet and the well is cased to that depth. The yield is 120 gallons per minute.

A letter from New Sharon of date of April 25, 1932, states: "The water tastes the same as the water we had from our old wells and is a little softer. This well solves the water problem here very satisfactorily, and I think we are fortunate in being able to get a well like it after having so much trouble. The deep well is still cased, and we have considered putting a hand pump in it so that those who care to do so can get water there for drinking purposes. The water seems to produce a mild laxative effect and some of our citizens have expressed a desire to use it for that purpose."

TABLE

Analyses of New Sharon and Other Deep Well Waters in Parts Per Million

	New Sharon					North English	Belle Plaine	New London, No. 1	Rippey
Ions	1[a]	2[b]	3[c]	4[d]	5[e]				
Calcium	82.9	1596.0	1205	314.	298.	269	346	86	153
Magnesium	25.1	98.5	83	77.	75.	107	135	35	71
Sodium and Potassium	4.6	48.2	114	G23	549.	62	83	272	214
Sulphate	8.6	3831.6	2606	2256	1951.	1463	1247	492	729
Chloride	7.1	74.4	178	168	136.	64	9	149	110
Bicarbonate	369.5	501.0	788	234	317.	(103 CO_3)	268	261	317
Silica iron and H	3.2	72.0	15	42	31.				
Total Solids	501.0	6221.7	4540	4134	3512	2079	1980	1189	1463

a Water of old city wells in drift, Dr. Nicholas Knight, Cornell College, Feb. 22, 1931.
b-c Waters of deep well, Dr. Nicholas Knight, Cornell College, Oct. 29, 1929, Apr. 10, 1930.
d Water of deep well, H. G. Day, Cornell College, July 22, 1930.
e Water of deep well, Howard Maffitt, Des Moines, Aug. 28, 1930.

Driller's log and record of strata. New Sharon deep well, 1930.

	Depth in Feet
Pleistocene and Recent (135 feet thick; top 870 feet above sea level) —	
"Black soil"	0–3
"Yellow clay"	3–15
"Yellow sandy mud"	15–27

"Yellow clay"	27–41
"Yellow sandy mud"	41–104
"Coarse gravel"	104–112
"Sandy clay"	112–135
Pennsylvanian (95 feet thick; top 735 feet above sea level) —	
"Gray sandstone, a little water"	135–157
"Coal blossom"	157–167
"Gray shale"	167–180
"Red shale"	180–189
"Gray shale"	189–230
Mississippian (undifferentiated, 233 feet thick; top 640 feet above sea level) —	
"Gray limestone"	230–257
"Blue shale"	257–261
"Gray limestone"	261–289
"Black and gray shale"	289–298
"Gray limestone"	298–344
"Blue shale"	344–347
"White limestone"	347–437
"Blue shale"	437–448
"White limestone"	448–463
Kinderhook shale (94 feet thick; top 407 feet above sea level) —	
"Blue shale"	463–557
Devonian (168 feet thick; top 313 feet above sea level) —	
"White limestone"	557–575
"Blue shale"	575–595
"White limestone"	595–603
"Gray and blue shale"	603–625
"Gray limestone"	625–630
"Gray shale"	630–715
"Gray limestone"	715–720
"Gray shale"	720–725
Silurian (371 feet thick; top 145 feet above sea level) —	
"White limestone"	725–1077
"Gray shale"	1077–1081
"Gray limestone"	1081–1096
Ordovician:	
Maquoketa shale (259 feet thick; top 226 feet below sea level) —	
"Mixed shale, blue and gray"	1096–1355
Galena-Plateville (235 feet thick; top 485 feet below sea level) —	
"Gray limestone"	1355–1541
"Blue shale" (Decorah?)	1541–1549
"Gray limestone"	1549–1590
Saint Peter sandstone (33 feet thick; top 720 feet below sea level) —	
"Saint Peter sandstone, hard and fine"	1590–1623
Prairie du Chien: Shakopee (167 feet thick; top 753 feet below sea level) —	
"Gray limestone, hard"	1623–1755
Dolomite, light gray; much blue-green hard fissile shale, probably from Glenwood horizon	1660–1670
Dolomite, as above; 2 samples	1670–1690
No sample	1690–1700
Dolomite, light gray; siliceous oölite	1700–1710
Dolomite, light gray, considerable amount of shale as above; rather large quantity of well-rounded quartz sand	1710–1720
Dolomite, light yellow-gray and light gray; 4 samples; quartz sand noted at 1740	1720–1760
"Crevices, no samples"	1755–1790
Dolomite, very light gray; siliceous oölite	1780–1790
Prairie du Chien: New Richmond sandstone (60 feet thick; top 920 feet below sea level) —	
"Soft sandstone, light, very fine, Richmond"	1790–1875
Sandstone, light gray in mass, fine, irregular grains; some dolomite in equally fine chips	1790–1800

Sandstone, as above; a few grains of oölite noted	1800–1810
Sandstone, light yellow-gray, some larger grains 0.5 to 0.8 mm. diameter, some well-rounded	1810–1820
Sandstone, light gray, very fine irregular grains; 2 samples	1830–1850
Prairie du Chien: Oneota dolomite (236 feet thick; top 980 feet below sea level) —	
Dolomite, in fine meal; much sandstone as above	1850–1860
Dolomite, very light gray, in fine meal; some fine sand; 2 samples	1860–1880
Dolomite, as above, clean	1880–1890
Dolomite, light yellow-gray	1890–1900
Dolomite, light gray to buff, some cherty; 11 samples	1900–2080
"White limestone, sandy"	1875–1935
"Crevices; no sample"	1935–1950
"Sandy limestone, brown"	1950–1970
"Crevices, no sample"	1970–1990
"Brown limestone"	1990–1995
"Crevices in brown limestone; no sample"	1995–2060
"Brown limestone"	2060–2086
Cambrian:	
Trempealeau: Jordan sandstone (53 feet thick; top 1216 feet below sea level) —	
Sandstone, rusted light buff, larger grains rounded, frosted, smaller grains largely irregular and broken, maximum grains 0.7 to 0.8 mm. diameter; 3 samples	2086–2108
Sandstone, as above; some dolomite, whitish; 2 samples	2110–2120
Sandstone, dolomitic cement	2127
Sandstone, as above, rusted buff, some secondary enlargements	2130
Trempealeau: Saint Lawrence (top 1269 feet below sea level) —	
Dolomite, light gray, rusted buff; much quartz sand in cuttings	2139
"Gray limestone"	2139

Notes. — This section is so normal that it requires little comment. One feature, however, deserves special mention here: In this case, the cavities in the Prairie du Chien, though often found in wells that penetrate that formation, are especially pronounced. According to the log, cavities were found at several levels. In one, the lowest, as the driller writes, the drill dropped about 14 feet, bending the jars.

The significance of solution channels in the dolomites of this terrane has been noted several times in earlier reports in connection with the circulation of underground water. However, so far as the writer is aware, they have never been correlated with the unconformity which parts the Prairie du Chien from the Saint Peter. Granting that the Prairie du Chien was long exposed as the country rock during the interval preceding the transgression of the Saint Peter sea, the development of underground drainage channels within the terrane follows as a matter of course. On the other hand, if the channels in the Oneota and Shakopee dolomites were wholly the work of the present circulation of ground water, it would seem as if crevices should be discovered by the drill as frequently in the superior limestone and dolomite terranes as in the Prairie du Chien.

Comparing the New Sharon section with that of Grinnell (City well No. 2), it is seen that all formations, excepting the Maquoketa, from the Kinderhook to the Glenwood inclusive, have thinned notably south-southwestward in the distance of 19 miles — the Kinderhook from 167 to 94 feet, the Devonian from 216 to 168 feet, the Silurian from 414 to 371 feet, and the Galena-Platteville from 291 to 231 feet. The Maquoketa, however, with its erosion surface, is 48 feet thicker at New Sharon than at Grinnell. The thickness of the Saint Peter and of the terranes below is practically the same at both localities.

Newton, Jasper County

A deep well was completed in 1930 at Newton by the Thorpe Bros. Well Co. of Des Moines for E. H. Maytag. The depth is 2,567 feet; the diameters from 16 to 6 inches. The following permanent piping was placed: 12-inch from surface to 183 feet, 10-inch from surface to 702 feet, 8-inch from 1,048 to 1,258 feet, 6-inch from 504 to 1,750 feet.

Driller's Log	Depth in Feet
Pleistocene and Recent (85 feet thick; top 910 feet above sea level) —	
Blue clay	0–7
Yellow clay and boulders	7–35
Sand	35–41
Blue clay	41–75
Yellow clay and boulders	75–80
Blue clay	80–85
Pennsylvanian, Des Moines (96 feet thick; top 825 feet above sea level) —	
Limestone	85–93
Yellow clay	93–98
Black hard pan	98–102
Black shale	102–120
Limestone	120–136
Black shale	136–144
Limestone	144–161
Sandstone (water)	161–181
Mississippian, undifferentiated (261 feet thick; top 729 feet above sea level) —	
Red and blue shale	181–183
Limestone, hard	183–204
Green shale	204–208
Limestone	208–224
Green shale	224–230
Limestone	230–265
Green shale	265–272
Limestone	272–442
Mississippian, Kinderhook shale (93 feet thick; top 468 feet above sea level) —	
Shale	442–535
Devonian (125 feet thick; top 375 feet above sea level) —	
Limestone	535–585
Shale	585–591
Limestone	591–595
Shale	595–603
Limestone	603–611
Shale	611–660
Devonian (?) and Silurian (512 feet thick; top 250 feet above sea level) —	
Limestone	660–1172

Ordovician:

Maquoketa shale (93 feet thick; top 262 feet below sea level) —

Red shale	1172–1188
Limestone	1188–1192
Red shale	1192–1196
Limestone	1196–1198
Red shale	1198–1255
Shaly limestone	1255–1265

Galena-Platteville (435 feet thick; top 355 feet below sea level) —

Limestone	1265–1362
No samples — washed away	1362–1378
Limestone	1378–1570
No samples — washed away	1570–1610
Limestone	1610–1651
No samples — washed away	1651–1656
Limestone	1656–1659
Green shale (Decorah?)	1659–1665
Limestone	1665–1700

Glenwood (8 feet thick; top 790 feet below sea level) —

Green shale	1700–1706
Limestone	1706–1708

Saint Peter (31 feet thick, top 798 feet below sea level) —

Sandstone	1708–1739

Prairie du Chien (472 feet thick; top 829 feet below sea level): Shakopee —

No samples — washed away	1739–1810
Very little sample	1810–1890
Limestone, no grit	1890–1905
No samples — washed away	1905–1910
Limestone	1910–1922
No samples — washed away	1922–1930
Sandy limestone	1930–1965

Prairie du Chien: New Richmond —

Sandstone	1965–1968
Sandy limestone	1968–1985
Sandstone, hard	1985–2000
Sandstone, soft	2000–2015

Prairie du Chien: Oneota —

Limestone, hard	2015–2048
Very little samples — washed away	2048–2135
Limestone	2135–2211

Cambrian:

Trempealeau: Jordan (41 feet thick; top 1301 feet below sea level) —

Sandy limestone	2211–2225
Sandstone	2225–2240
Sandy limestone	2240–2252

Trempealeau: Saint Lawrence (221 feet thick; top 1342 feet below sea level) —

Limestone	2252–2473

Franconia (penetrated 83 feet; top 1563 feet below sea level) —

Shaly limestone	2473–2491
Limestone	2491–2506
Shale	2506–2521
Shaly limestone	2521–2524
No samples — washed away	2524–2551
Shale	2551–2556

Notes. — It is regrettable that no cuttings of this well were taken by the drillers, since at several points the geological section must be left in doubt. For the most part, however, the careful and full log permits a fair degree of certainty.

The basal limestones of the undifferentiated Mississippian probably include the upper beds of the Kinderhook. The Kinderhook shale is surprisingly thin, about one half the thickness found at Grinnell and at Des Moines. The base of the Devonian necessarily is uncertain. On the testimony of nearby wells at least 400 feet of the 512 feet of "limestone" between 660 and 1,172 feet must be given to the Silurian. In all probability cuttings would show by gypsum and anhydrite content that much of this measure should be assigned to the Salina group. There is no evidence that the Hoing sands were encountered.

The amount of red shale in the Maquoketa is exceptional but is about the same as in the Maquoketa at Ogden. The formation is 93 feet thick at Newton and is much thicker toward the east (at Grinnell it measures more than 200 feet); it is thinner to the west and at Des Moines has a thickness of only 33 feet. Cuttings would probably show that the upper beds of the Galena-Platteville are dolomitic, while the basal limestones are of the common "Trenton" facies. The general relations of the section here, including the Glenwood and Saint Peter, are those prevailing in eastern Iowa.

The thickness of the St. Lawrence is rather excessive, and it is quite possible that the lower beds of the "limestone" so assigned may be a sandstone of minute quartzose particles, whose chips much resemble those of the limestones of the Cambrian, and, because they carry glauconite in many samples, are referred to the Franconia.

Palisades-Kepler State Park, Linn County

In 1930 Mr. Charles D. Nolan drilled a deep well near the edge of the north bluff overlooking Cedar River at this park. The depth of the well is 632 feet; its diameters are 8 and 6 inches. The well is cased with a 5-inch casing from 398 feet to the bottom of the well and is perforated for the lower 30 feet to admit water from the upper strata of the Galena limestone. An 8-inch casing extends from the surface to 83 feet. "The well was tested to 35 gallons per minute with no drawdown below 125 feet."

Driller's Log	Depth in Feet
Pleistocene (83 feet thick, top 814* feet above sea level) —	
Yellow and blue clay (loess and glacial till)	0–83
Silurian: Niagaran (272 feet thick; top 731 feet above sea level) —	
White lime	83–105
Yellow lime, shelly and bouldery, broken	105–175

* Authority, M. L. Hutton, Engineer and Superintendent.

White lime	175–205
Yellow lime	205–295
White lime	295–355
Ordovician:	
Maquoketa shale (270 feet thick; top 459 feet above sea level) —	
Blue shale, with occasional streaks of hard lime	355–370
Pink shale	370–384
Light buff shale with occasional strata of lime	384–392
Dark, sandy lime rock, somewhat crystallized	392–398
Dark slaty rock	398–407
Dark shale	407–430
Hard flinty rock	430–435
Light blue shale	435–480
Shale, somewhat darker than above	480–505
Sandy slate	505–525
Dark shale	525–585
Bluish shale	585–605
Light shale	605–625
Galena-Platteville limestone (penetrated 7 feet; top 189 feet above sea level) —	
Water bearing lime rock, mostly sandy	625–632

Sac City, Sac County

In 1930 the Thorpe Bros. Well Co. of Des Moines completed a well for the Iowa Canning Co. at Sac City. The depth of the well is 2,047 feet. At 574 feet, after the Saint Peter sandstone was passed, a test showed a capacity of 100 gallons per minute. The static level then stood at 113 feet below the curb. At 1,872 feet after passing the Jordan sandstone, the well was again tested, and its capacity was then found to be 175 gallons per minute. The static level stood at 123 feet. On completion of the well, the final test showed a capacity of 335 gallons per minute, lowering the head from 128 feet to 280 feet below the curb, where it stood with little variation during the test. The temperature of the water is reported as 50 degrees F.

Record of Strata with Parts of Driller's Log.	Depth in Feet
Pleistocene (383 feet thick; top 1,274 feet above sea level) —	
"Yellow clay"	0–80
"Blue clay"	80–383
Cretaceous (47 feet thick; top 891 feet above sea level) —	
"Black shale"	383–388
Sandstone, gray, fine, irregular grains, dolomitic; limestone, gray, dolomitic, residue of microscopic quartz; chips of vein quartz	388–390
Limestone, light buff, fine-grained, earthy, moderately rapid effervescence in cold dilute HCl; sandstone, gray, minute grains, highly pyritic, dolomitic; chert, gray, fine, granular	390–400
Limestone, etc., as above; considerable amount of drift material	410
Sandstone, medium to coarse, grains irregular, in sand; considerable buff limestone of moderately rapid effervescence; chips of black shale	415
Sandstone, gray, fine- to medium-grained, argillaceous, dolomitic, including grains of cryptocrystalline silica; limestone, gray, argillaceous, slow effervescence; chalcedonic silica; quartz sand; drab shale	420
Mississippian (340 feet thick; top 844 feet above sea level) —	
Dolomite, dark brown, finely crystalline-granular; considerable blue chert; much quartz sand	430

Dolomite and chert as above	435
Limestone, yellow-gray, fine-grained, earthy, in flaky chips; 3 samples	440–460
Limestone, light brown, crystalline-granular, moderately rapid effervescence	470
Limestone, gray and whitish, fine-grained, rapid effervescence, some chalcedony; lump of blue-green shale, calcareous	480
"Shale"	484–488
"Limestone"	488–493
"Shale"	493–496
Limestone, blue-gray, calcilutite, and fine-grained, rapid effervescence, in flaky chips	500
Limestone, yellow-gray, fine-grained, rapid effervescence	510
Limestone, gray and whitish mottled, finely crystalline-granular, rapid effervescence, in flaky chips	520
Limestone, light gray, earthy, rapid effervescence, in flaky chips (harder and in fine chips at 540); 5 samples	530–570
Limestone, grayish buff, finely crystalline-granular, rapid effervescence	580
Limestone, light gray, earthy, rapid effervescence; 4 samples	590–620
Limestone, grayish buff, crystalline-granular, moderately rapid effervescence	630
Limestone, dolomitic, grayish buff, rather slow effervescence	640
Limestone, gray, earthy, rapid effervescence, in flaky chips; limestone, dolomitic, yellow-gray	650
Dolomite, light gray-buff, finely crystalline-granular; white calcite	660
Dolomite, gray, finely crystalline-granular; 2 samples	670–680
Chert, gray; dolomite, gray	690
Chert, blue and gray; some dolomite; 3 samples	700–720
Dolomite, dark gray, vesicular	730
Dolomite, gray	740
Shale, light blue-gray, plastic, calcareous, in concreted masses; 2 samples	750–760
"Shale"	740–765
Devonian, Silurian (280 feet thick; top 504 feet above sea level) —	
Dolomite, yellow-gray, in fine chips; 4 samples	770–800
Dolomite, blue-gray; considerable concreting blue shale	810
Limestone, dolomitic, light yellow-gray, earthy, laminated	820
Dolomite, blue-gray and yellow-gray, much shale, blue and olive-green, calcareous	830
Dolomite, gray and yellow-gray; 4 samples	840–870
"Gray shale"	862–865
"Blue limestone"	865–870
"Gray shale"	870–875
Dolomite, drab	880
Dolomite, drab and blue-gray in mass; 5 samples	890–930
Dolomite, brown in mass; 10 samples	940–1030
Dolomite, gray	1040
Ordovician:	
Maquoketa shale (70 feet thick; top 224 feet above sea level) —	
Shale, blue, in concreted masses with much dolomite in fine chips	1050
Shale, greenish, in splintery chips, feebly calcareous; shale, drab, calcareous; dolomite	1060
Dolomite, gray; shale	1070
Dolomite, brown and gray; shale, light blue-gray in concreting masses	1080
Dolomite, buff; some shale	1090
Limestone, dolomitic, blue-gray	1100
Shale, blue, in concreted masses	1110
"Shale"	1052–1100
Galena-Platteville (350 feet thick; top 154 feet above sea level) —	
Dolomite, brownish gray and gray, highly cherty at 1180, 1190; 8 samples	1120–1190
Dolomite, highly cherty, deeply rusted	1210–1220
Dolomite, gray, cherty	1230
Dolomite, buff with greenish tinge, crushed to fine crystalline sand	1240
Dolomite, gray	1250–1260
Dolomite, gray and buff, largely in meal; 13 samples	1270–1390

Dolomite, gray, crystalline-granular, in fine chips	1400
Limestone, light blue-gray, argillaceous, moderately rapid effervescence, pyritiferous at 1420	1410–1420
Shale, light blue, calcareous	1430–1440
Shale, blue-gray, in splintery chips, calcareous	1450
Limestone, cream-yellow and brownish, in thin flakes, rapid effervescence	1460
Glenwood shale (50 feet thick; top 196 feet below sea level) —	
Shale, blue-green, in hard concreted masses; 5 samples	1470–1510
Saint Peter sandstone (55 feet thick; top 246 feet below sea level) —	
Sandstone, fine, grains of clear quartz well-rounded; much dark gray shale in friable concreted masses	1520
Sandstone, clean, except for splintery flakes of blue-green shale, larger grains well-rounded, frosted, maximum about 0.5 mm. diameter; 4 samples	1530–1560
Shale, blue-green, some brownish interlaminations in the concreted masses	1570
Prairie du Chien (225 feet thick; top 301 feet below sea level) —	
Dolomite, light yellow-gray; much shale and quartz sand	1575
No samples	1575–1600
Dolomite, light buff; shale and quartz sand; 3 samples	1600–1615
Dolomite, light buff; more or less quartz sand, but no imbedded grains observed; 8 samples	1620–1690
Sandstone, grains well-rounded; larger grains 1 mm. diameter; some light yellow dolomite	1700
Dolomite, light gray, gray and buff; considerable quartz sand at 1,710; 9 samples	1710–1790
Cambrian:	
Trempealeau: Jordan sandstone (72 feet thick; top 526 feet below sea level) —	
Sandstone, white, grains well-rounded, frosted, larger about 8 mm. diameter	1800
Sandstone, light yellow in mass, mostly fine and broken grains	1810
Sandstone, stained with ferric oxide, somewhat finer than at 1800 feet	1820–1830
Sandstone, stained with rust, grains fine or broken; 4 samples	1840–1870
Trempealeau: St. Lawrence (68 feet thick; top 598 feet below sea level) —	
Dolomite, minutely arenaceous, pyritic, some larger included grains rounded; or sandstone, dolomitic; shale, green, hard; much coarser quartz sand	1872
Dolomite, buff in mass, highly arenaceous, grains minute, angular	1880
Dolomite, gray-buff, in powder, argillaceous, minutely arenaceous	1890
Dolomite, brown in mass, some fine quartz sand	1900
Dolomite, light gray, some fine quartz sand	1910
Dolomite, light yellow-gray, in crystalline flour	1920
Franconia:	
Dolomite, or dolomitic limestone (effervescence somewhat more rapid than Galena or Le Claire dolomites), gray, highly quartzose with minute angular particles of quartz; glauconitic	1940
Sandstone, darker gray, of minute angular particles of quartz, and cryptocrystalline silica; dolomitic, glauconitic	1950
Dolomite, as at 1940; 4 samples	1960–1990
Sandstone, grains minute, calcareous, glauconitic; flakes of hard gray-green shale	2000
Dolomite, as 1940	2010
Shale, dark green-gray, somewhat calcareous, in moulded masses, slightly quartzose	2020
Sandstone, grains as at 1950, dolomitic; much shale as above in splintery chips	2030
Limestone, light yellow-gray, somewhat quartzose, moderately rapid effervescence; shale as above; some fine quartz sand	2040
As above; some sandstone of minute angular particles; some crypto-crystalline silica with imbedded grains of crystalline quartz	2047

Notes. — At Sac City the top of the Saint Peter sandstone had been estimated to lie a little less than 200 feet below sea level.[9] The formation was struck, however, at 246 feet below sea level, so that the contour of -200 of the map should be drawn north instead of south of the town. Thus the gradient between Sac City and Holstein to the west is somewhat steeper than had been inferred. The thickness assigned to the Glenwood, 50 feet, is not unusual in northwestern Iowa, while it is far greater than obtains in the eastern parts of the state. Only a thin bed of limestone separates the Glenwood from heavy shales which occupy the place of the Decorah and Platteville in large part. For a discussion of the thickness of the Glenwood and its relations, the reader is referred to Deep Wells of Iowa, Iowa Geological Survey, volume XXXIII, pages 33-36.

It is perhaps worth noting that the entire group of formations lying between the base of the Maquoketa and the top of the Saint Peter maintains this far to the west its usual thickness, here 350 feet. The entire group of Paleozoics above the summit of the Saint Peter to the base of the Pennsylvanian, 1,040 feet thick at Sac City, thins about 200 feet to Holstein, where it measures 847 feet. Farther west, at Sioux City, only 260 feet can be assigned to this entire aggregate.

The formations below the Saint Peter at Sac City carry their usual facies. The aggregate thickness of the beds from the base of the Saint Peter to the well-marked glauconitic horizon of the Franconia is 365 feet at Sac City, but at Holstein it has thinned to 240 feet. At Sioux City, however, the interval from the top of the Saint Peter to the glauconitic Franconia measures 410 feet, while the aggregate thickness of the formations from the top of the Saint Peter to the pre-Cambrian floor of crystallines is thicker at Sioux City (670 feet) than at Holstein (590 feet).

Driller's Log	Depth in Feet
Yellow clay	0–80
Blue clay	80–383
Black shale	383–388
Limestone	388–415
Mud and sand	415–435
Limestone	435–484
Shale	484–488
Limestone	488–493
Gray shale	493–496
Limestone	496–740
Shale	740–765
Limestone	765–862
Gray shale	862–865
Blue limestone	865–870

9 Deep Wells of Iowa: Iowa Geol. Survey, Vol. XXXIII, Plate I.

Gray shale	870–875
Limestone	875–1052
Shale	1052–1100
Limestone	1100–1405
Sandy shale	1405–1520
Saint Peter sandstone	1520–1570
Limestone	1570–1605
Sand and lime	1605–1700
Sand	1700–1715
Limestone	1715–1740
Sand	1740–1780
Limestone	1780–1800
Jordan sandstone	1800–1870
Lime and shale	1870–1970
Shale	1970–2015
Limestone	2015–2047

Shellsburg, Benton County

On January 1, 1932, C. W. Varner of Dubuque completed a well 342 feet deep for the town of Shellsburg. This well was part of a system of water works under construction by the Howard R. Green Co. of Cedar Rapids. The diameters are 12 inches down to 41 feet, 10 inches from 41 to 92 feet, and 8 inches thence to the bottom of the well. The well is cased to 92 feet, and from 41 to 92 feet the casing is perforated to admit water. It was estimated that one third of the flow of the well came from these strata, while two thirds came from the limestones below the 92 foot level. Until the well reached a depth of 50 feet, the static level stood at 25 feet; while drilling progressed from 50 to 75 feet the static level rose to 15 feet below the curb. On completion of the well the static level was 12 feet below the curb, with a draw-down of 9 feet when the well was being pumped at 70 gallons per minute.

A Westco Turbine pump was installed with a capacity of 60 gallons per minute against a 50 pound head. The pump delivers water directly to a pneumatic pressure tank which is connected to the distribution system. The turbine is set 130 feet below the curb. The discharge line of the pump is arranged with the air release valve to allow the water to flow back down into the well, filling the line with air every time the pump stops and thus eliminating, it is hoped, the necessity for operating the air compressor.

The hardness of the water totals 13.9 grains per gallon.

The cost of the well complete, including pump, pump house, and engineering services was $3,500.

Record of Strata	DEPTH IN FEET
Pleistocene (21 feet thick; top 776 feet above sea level) —	
Sand, yellow, coarse	0–16
Clay, yellow, sandy, calcareous	16–21

Devonian: Cedar Valley (24 feet thick; top 755 feet above sea level) —
Limestone, blue and yellow-gray, rapid effervescence in cold dilute HCl, highly fossiliferous with fragments of brachiopods, as *Atrypa reticularis, Orthis iowensis, spirifers,* etc. 21–25
Limestone, yellow-gray, fossiliferous, rapid effervescence; 3 samples.. 25–40
Limestone, gray, rapid effervescence 40–45
Upper Davenport (15 feet thick) —
Limestone, blue-gray, fossiliferous, rapid effervescence; 3 samples.... 45–60
Independence (45 feet thick; top 716 feet above sea level) —
Shale, blue, plastic, unctuous, with calcilutite, light brown, conchoidal fracture, very rapid effervescence. Chips of this limestone, of Lower Davenport facies, constitute the mass of the sample........ 60–65
Shale, blue, some drab; some in hard, light blue chips, highly calcareous; pyrite in aggregates of microscopic cubes, drusy crusts, and in minute rods. Considerable calcilutite as above in fine cuttings; some irregular grains of quartz sand; disc of crinoid stem; all concreted in friable masses 65–70
Shale, light blue-green as powder, chips of hard, light blue shale, and much light brown calcilutite; fossiliferous: various fragments, *Tentaculites,* disc of crinoid stem; pyrite 70–75
Shale, and calcilutite as above; crinoid stem disc 75–80
Shale, light blue-gray in mass, with chips of calcilutite as above which constitute most of sample 80–85
Limestone, light yellow-gray and buff, fine granular-crystalline, in flaky chips, moderately rapid effervescence, distintegrating under weak acid into minute crystalline grains; 3 samples 85–100
Sandstone, whitish, grains fine, well-rounded, frosted, with imbedded particles of chalcedonic silica and hard, dark greenish siliceous masses, calcareous cement, passing into arenaceous limestone; limestone, fine-grained, light brown-gray; some shale 100–105
Otis limestone (65 feet thick; top 671 feet above sea level) —
Limestone, light blue-gray, argillaceous, earthy; some sandstone as above, and shale 105–110
Limestone, soft, light blue-gray, argillaceous, finely granular, moderately slow effervescence, disintegrating under weak acid; limestone, brown and gray, rapid effervescence; shale and crinoid stem disc from cave 110–115
Limestone, light blue-gray, in large chips, soft, rather slow effervescence, earthy and argillaceous, distintegrating under weak acid, minutely quartzose; cave: shale as above and valve of *Duovillina variabilis,* Calvin * 115–120
Limestone, as above 120–125
Limestone, light yellow and brownish gray, calcilutite, hard, conchoidal fracture, moderately rapid effervescence, argillaceous residue; 3 samples; at 135-140 as cave: *Duovillina variabilis,* Calvin, and *Duovillina arcuata,* Hall.* 125–140
Limestone, very fine-grained, color as above, rather slow effervescence, disintegrating into fine grains 140–145
Limestone, as above, cave: some shale 145–150
Limestone, light yellow-gray, calcilutite, rather rapid effervescence; cave: *Strophonella reversa,* Hall, juvenile form*; some shale...... 150–155
Limestone, light yellow-gray, rapid effervescence, blue-gray, rapid effervescence, finely arenaceous, highly argillaceous; considerable white chert; shale concreting limestone chips into masses which are friable with difficulty; considerable fine quartz sand, larger grains well-rounded; pyrite; some chips of blue-green shale; 2 samples... 155–165
Shale, blue-gray, calcareous, white and blue-gray chert, pyrite in lumps.. 165–170
Silurian: Niagaran (177 feet penetrated; top 606 feet above sea level) —
Limestone, magnesian, or dolomite, very light yellow-gray, soft, fine-grained, earthy, moderately slow effervescence; much white and gray chert; 2 samples 170–180
Dolomites and cherts; 30 samples (For detailed description of this section see record of strata of Canning Co. well, Shellsburg, Iowa Geol. Survey, Vol. XXXIII, p. 321) 180–342

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* Identified by Dr. M. A. Stainbrook, Texas Technological Institute, Lubbock, Texas.

Notes. — This well section is of signal importance since it offers conclusive proof of the place of the Independence shales in the geologic column of the Iowa Devonian, the first conclusive proof that has come to the attention of the writer. Up to 1932 all students of the Independence, indeed, had assumed that it immediately overlies the Otis limestone of the Wapsipinicon stage. The writer, for example, had summed up at length the arguments in favor of this theory and, identifying the Kenwood shale of the Linn County report with the fossiliferous Independence, had traced the formation from Scott County to Fayette County in numerous outcrops.[10] Yet neither the type locality at Independence nor the outcrops at Linn Junction and Brandon, the only fossiliferous exposures then known, showed base or cover of the formation and could not wholly exclude the possibility that they were outliers of the Lime Creek shales. The similarity of these two faunas, which then was greatly exaggerated, lent some color to the hypothesis.

The recent discovery by Stookey of a shale with a marked Independence fauna, at the extreme western edge of the Devonian area, in the vicinity of Amana and near an outcrop of the Kinderhook, seemed at first sight to strengthen the doubt as to the true place of the Independence. It was, therefore, with close interest that the writer had studied the sections of all deep wells which penetrated the Wapsipinicon. In a number of instances he had arranged with drillers for special sampling over the critical horizons.

Up to 1932, however, these efforts had proved fruitless. Shales, indeed, had been found at the supposed Independence horizon, but they did not offer the testimony of Independence fossils. When it was learned that a second deep well was to be put down at Shellsburg, the writer secured the coöperation of Mr. Howard Green of Cedar Rapids, engineer in charge, resulting in a very complete and ample sampling of the well. Mr. Green's efforts were rewarded by the preservation of several readily identified fossils that are characteristic of the Independence. Since this corroboration was obtained, Stainbrook has communicated to the writer the result of his studies of the Lime Creek and Independence fauna, which disproves the possibility of their identity.

In this well section the lower beds of the Cedar Valley, from 45 to 60 feet, are assigned to the Upper Davenport on account of their tex-

10 Norton, W. H., Wapsipinicon Breccias of Iowa, Iowa Geological Survey, Vol. XXVII, pp. 395-399.

ture and position. At 60 feet the drill entered a wholly different formation, a light brown calcilutite of Lower Davenport facies, mingled in the cuttings with the blue shale of the Independence. This shale, in places fossiliferous, with more or less calcilutite, continued to a depth of 85 feet.

Calcilutite layers in place within the shale have been found in only one locality, Eagle Point in Fayette, among all the numerous outcrops of the Independence in eastern Iowa. Calcilutite fragments referable to the Lower Davenport, however, are in many places intermingled with the Independence, as are fragments of the underlying Otis. Under the strains and stresses of brecciation the thin brittle thin-layered Lower Davenport limestone is readily fragmented, especially as the shales beneath afford a yielding foundation. In numerous localities, though not in this Shellsburg section, the tough massive Upper Davenport limestone is also involved in the brecciation. Its fragments, in some instances having thin plates of Lower Davenport calcilutite attached, are mingled with the Independence shales. Therefore it seems less probable that at Shellsburg the calcilutite fragments in the cuttings from 60 to 85 feet belong to laminae of limestone interstratified with the shale than that they are commingled fragments from the brecciated Lower Davenport beds. In part, of course, they may be due to cave from the limestone in place. As to the first sample, from 60 to 65 feet, a probable interpretation is that it represents a passage from limestone to shale, from which the slush bucket brought up cuttings of both beds.

Below this shale mingled with calcilutite lies 15 feet of impure limestone, of the Kenwood type, but which is found also in the Otis. The presence beneath of a sandstone with cryptocrystalline silica, often found in the Kenwood, favors placing both limestone and sandstone with the Independence and putting its base at 105 feet.

The drill then entered earthy limestones, assigned with no great certitude to the Otis. Unquestionably Otis, however, are the calcilutites which begin at 125 feet. It is also worth noting that here the Otis can not supply the calcilutites present in the Independence cuttings, because of brecciation. The Independence fossils on record from these beds are not native to them. The thin fragile shells are unbroken and, moreover, they inclose shale of the Independence type. Clearly they had fallen, with caving shale from the Independence levels.

The arenaceous limestone, shale, chert, and sandstone, 155 to 270 feet, may be compared with a similar basal conglomerate of the Otis in Bremer and Fayette Counties. They may also be compared with the sandy shale at Iowa City and with the cherty, sandy shale found in the deep wells at Oakdale immediately above the Niagaran. These are now referred by the author to the basal conglomerate of the Devonian.

The Niagaran dolomite is of the Hopkinton facies, the Le Claire being absent, as was to be expected. This well did not reach the level of the exceptional Niagaran basal sandstone found in the Canning Company's well at Shellsburg, which may be compared to the Colmar, or Hoing, sandstone of Illinois.

Sutherland, O'Brien County

C. Rasmussen and Sons of Sioux City report a well drilled by them in 1930 for the town of Sutherland. The depth is 450 feet, of which 410 feet is cased. The diameter at top is 10 inches. The main supply was found at from 410 to 460 feet, probably in the Dakota sandstone. The static level is 225 feet below the curb and the yield 90 gallons per minute.

Driller's Log	Depth in Feet
Yellow clay	0–32
Blue clay	32–175
Sand	175–185
Coarse sand and gravel mixed with clay	185–194
Fine sand	194–197
Sand and clay	197–200
Sand, blue clay and gravel	200–204
Blue clay	204–220
Brown clay	220–235
Brown clay mixed with sand	235–304
White clay	304–326
Fine yellow sand	326–395
Black sticky clay	395–401
Yellow sand, drilled like sandstone but won't stand up	401–410
Yellow sandstone	410–420
White sandstone	420–450

Vinton, Benton County, City Well No. 3

This well is located on the flood plain of the Cedar River at approximately the same elevation as that of the wells drilled in 1889 and 1892. The depth is 1,505 feet, and the diameters are from 12 to 10 inches. Water was found in the Saint Peter sandstone, 912 to 950 feet; in the Jordan sandstone, 1,377 to 1,388 feet; and in the Lodi and St. Lawrence dolomite, 1,450 to 1,485 feet with the main supply at 1,475 to 1,485 feet. On completion in July 1932 the yield was 300 gallons per minute, with a draw-down of 90 feet. Six months later the yield had increased to 330 gallons per minute, with a draw-down of 70 feet. The top bowl of the turbine pump is set at 135 feet, and the suction tail piece extends to about 155 feet.

While the drill was in the drift, the static level stood at 25 feet below the surface; it rose to 20 feet in the Devonian (depth of well 202 feet), and to 15 feet in the Niagaran (depth 224 feet). In the limestones of the Maquoketa (depth 526 feet) it stood at 12 feet, and in the Platteville (depth 850 feet) at 10 feet. It continued to rise as the drilling progressed, standing at eight feet in the Saint Peter (depth 950 feet), and at 6 feet in the Prairie du Chien (depth 1,000 feet). At completion of the drilling at 1,505 feet it stood at 8 feet below the surface, but on the insertion of 660 feet of 12-inch cast-iron casing, footing in the Galena, the static level fell to 41 feet below the surface, showing that the higher heads had been due largely to Devonian, Niagaran, and Maquoketa waters.

Besides the 12-inch casing mentioned above, a 10-inch steel casing was set from 810 to 960 feet, footing in the Upper beds of the Prairie du Chien, and perforated to admit the Saint Peter water. The temperature of the water is reported to be 49 degrees F.

The well was drilled in 1932 by the Thorpe Bros. Well Co. of Des Moines, who supplied the set of samples of the cuttings examined, and the above data were furnished by the H. R. Green Co., engineers, of Cedar Rapids.

Record of Strata	DEPTH IN FEET
Pleistocene and Recent (94 feet thick, top 775 feet above sea level) —	
Soil, blackish, sandy	0–5
Sand, some gravel, gray, coarse	5–20
Sand, dark buff, finer	20–26
Till, blue-gray, predominantly clayey; 6 samples	26–80
Till, dark drab	80–90
Till, gray	90–94
Devonian: Wapsipinicon formation: Otis limestone (126 feet thick; top 681 feet above sea level) —	
Limestone, earthy; and calcilutite, brown and gray, rapid effervescence in cold dilute HCl; some gray chert; in large chips	94–97
Limestone, light yellow-gray, compact, rapid effervescence	97–100
Limestone, light buff, crystalline-granular, soft, in large flaky chips	100–110
Limestone as above, some of moderately slow effervescence; limestone, brown, rapid effervescence	110–120
Limestone, very light gray, fine-grained, compact; some calcilutite with conchoidal cleavage; a considerable amount of blue and drab chert; some shale forming hard lumps with the cuttings	120–130
Limestone, very light gray, very fine-grained; and calcilutite; some white chert; 3 samples	130–160
Limestone, magnesian, or dolomite, light blue-gray, compact, rather slow effervescence, argillaceous residue, in large flaky chips; 2 samples	160–180
Limestone, light greenish gray, earthy, fine-grained, rapid effervescence, argillaceous, in large chips	180–190

Limestone, as above; some dark chert	190–200
Limestone, light yellow-gray, fine-grained, compact, earthy, rapid effervescence; much black chert; 2 samples	200–220
Silurian: Niagaran (126 feet thick; top 555 feet above sea level) —	
Dolomite, light yellow-gray, compact, effervescence rather slow	220–230
Dolomite, blue-gray, vesicular	230–240
Dolomite, gray and blue-gray, much chert at 320, 10 samples	240–346
Ordovician:	
Maquoketa shale (254 feet thick; top 429 feet above sea level) —	
Shale, green, plastic	346–348
Shale, pink and bright buff	348–350
Shale, red and yellow	350–360
Shale, blue	360–370
Shale, greenish gray	370–380
Shale, blue, plastic; 11 samples	380–500
Limestone, drab, crystalline, highly argillaceous; limestone, light gray, crystalline, rapid effervescence; some gray chert; in fine sand and powder; 3 samples	500–530
Limestone, light yellow-gray and drab, soft, earthy, rapid effervescence, argillaceous residue, slightly quartzose with fine irregular grains, cherty	530–540
Dolomite, brownish and drab, soft, earthy, argillaceous, rather slow in effervescence; limestone, gray, rapid effervescence	540–550
Limestone, drab and gray, argillaceous, rapid effervescence	550–560
Shale, drab, with much limestone, drab, earthy, rapid effervescence	560–567
Shale, drab, in concreted masses; 4 samples	567–600
Galena-Platteville (300 feet thick; top 175 feet above sea level) —	
Limestone, light yellow-gray, earthy, rapid effervescence, in flaky chips; 3 samples	600–630
Limestone, light yellow-gray and gray, rapid effervescence, most samples in flaky chips; 12 samples	630–750
Limestone, magnesian, or dolomite, yellow-gray, rather slow effervescence, cherty	750–760
Limestone, magnesian or dolomite, yellow-gray, rather slow effervescence; limestone, lighter gray, rapid effervescence, in larger chips	760–770
Limestone, magnesian or dolomite, as above; limestone, gray, crystalline, rather rapid effervescence	770–780
Limestone, light yellow-gray, compact, some dark gray, argillaceous, both rapid effervescence; buff chert	780–790
Limestone, light yellow-gray and blue-gray, rapid effervescence; 5 samples	790–834
Shale, blue and blue-green, calcareous, in hard concreted masses inclosing chips of shale and limestone	834–843
Limestone, light yellow-gray, gray and blue-gray, rapid effervescence; 6 samples	843–900
Glenwood shale (12 feet thick) —	
Shale, blue-green, in hard concreted masses, calcareous; 2 samples	900–912
Saint Peter sandstone (38 feet thick; top 137 feet below sea level) —	
Sandstone, light yellow-gray in mass from slight amount of powder coating grains, grains of clear quartz, well-rounded, frosted, up to 1 mm. diameter	912–920
Sandstone, white, grains as above; 3 samples	920–950
Prairie du Chien (420 feet thick; top 175 feet below sea level) —	
Dolomite, light brown, cherty at 950, light buff at 990; 5 samples	950–1000
Dolomite, gray	1000–1010
Dolomite, gray; considerable quartz sand in cuttings; 2 samples	1010–1030
Dolomite, very light gray, gray and buff; 6 samples	1030–1090
Dolomite, gray; much sand in cuttings; 2 samples	1090–1110
Sandstone, fine to medium, larger grains well-rounded, in mass very light gray; 2 samples	1110–1130
Dolomite, light gray, blue-gray, and buff; 6 samples	1130–1186
Sandstone, fine to medium, grains well-rounded	1186–1191
Sandstone as above; dolomite, whitish, sporadically arenaceous; 2 samples	1191–1200

Dolomite, cherty at 1250, and 1280–1340, highly cherty 1210 and 1270; 16 samples	1200–1360
Dolomite, light buff, slightly arenaceous	1360–1370
Cambrian:	
Trempealeau: Jordan sandstone (70 feet thick; top 595 feet below sea level) —	
Sandstone, fine to medium, well-rounded frosted grains; dolomite, sporadically arenaceous	1370–1380
Sandstone, as above, dolomite	1380–1385
Sandstone, as above, whitish and light yellow-gray in mass; a little dolomite; 2 samples	1385–1395
Sandstone, fine to medium, white, larger grains well-rounded and frosted; 2 samples	1395–1405
Sandstone, as above, in loose grains; some chips of fine sandstone with dolomitic cement	1405–1410
Sandstone, fine to medium, grains as above; 3 samples	1410–1440
Trempealeau: Lodi and St. Lawrence (penetrated 65 feet; top 665 feet below sea level) —	
Dolomite, in light gray powder, siliceous; or sandstone, dolomitic; quartz in minute irregular particles	1440–1450
Dolomite, blue-gray, in fine chips, minutely quartzose and pyritic	1450–1460
Sandstone, light gray, fine well-rounded grains, somewhat dolomitic, pulverized; 3 samples	1460–1477
Dolomite, light gray, minutely quartzose, in fine meal, trace of siliceous oölite; 2 samples	1477–1485
Franconia:	
Sandstone, microscopically quartzose, dolomitic, glauconitic, in fine gray chips; 3 samples	1485–1505

Notes. — Of the two city wells already drilled in Vinton, well No. 1 was very imperfectly sampled, and the only geological information from well No. 2 was a log at variance at several points from the section of well No. 1. Fortunately, well No. 3 is sampled with exceptional fullness and evident accuracy, and it affords a very reliable geological section.

The Pleistocene part of the section discloses the fact that the wide ancient preglacial or pre-Kansan valley of the Cedar had been cut here to a depth of 94 feet below the present flood-plain level, in marked contrast with such narrow stretches of the present valley as that at Cedar Rapids, where the channel is rock-cut. Before the end of the Kansan this ancient valley had been deeply filled with the ground moraine of a continental ice sheet.

The *Spirifer pennatus* beds of the Cedar Valley stage outcrop in the town. All the Devonian section below this horizon is cut out by the ancient valley as far as the Otis limestone of the Wapsipinicon stage, of which there remains 126 feet. The total thickness to be allowed for the Devonian at Vinton thus reaches the exceptional figure of about 245 feet.

The Niagaran, which at Cedar Rapids was found to be 349 feet thick, has thinned at Vinton to 126 feet. Farther to the northwest, at

Waterloo, it thins to 107 feet, and at Waverly to 50 feet. The basal cherty layers are here unusually thin.

The Maquoketa shale, 254 feet thick, exhibits a thickness somewhat less than that at Cedar Rapids (276 feet), but more than that at Waterloo (215 feet) and at Waverly (150 feet). The intercalated limestones, not uncommon in the Maquoketa, here are in unusual strength. They suggest an alternative reference for any shales in deep well sections which have been interpreted as belonging to the upper beds of the Galena.

The Galena-Platteville at Vinton is notable for the almost complete absence of dolomitization. In none of the deep well sections of Iowa is this condition approximated except at Postville and Manchester. The significance of varying dolomitization in a body of sediments traversed by definite life zones was early pointed out by Norton [11] and much more fully discussed by Calvin.[12] The Saint Peter and the Prairie du Chien run true to form. The Jordan is well marked and shows its customary well-rounded grains. The Lodi and St. Lawrence dolomite is either arenaceous or minutely quartzose. The dolomitic and glauconitic sandstone at 1,485 feet, whose quartz grains are microscopic, has been assigned to the Franconia.

Waverly, Bremer County, City Well No. 2

In July, 1930, Thorpe Bros. Well Co. of Des Moines completed a second deep well for the town of Waverly. The first well, drilled in 1899, with a bottom diameter of 8 inches, could not deliver enough water to meet the town's increasing peak demand of the summer at the canning season. This well had been sunk 480 feet below the base of the Jordan sandstone before drilling was stopped at the advice of this office. The second well evidently should not be drilled to so great a depth, but its diameter should be larger. A capacity of 700 gallons per minute was desired.

The 1930 well is 1,263 feet deep, drilled 60 feet below the Jordan aquifer into the St. Lawrence dolomite for sedimentation. The bottom diameter is 12 inches. Water was found at 260 feet at top of the Galena-Platteville and at 580 feet in the same formation, from 677 to 715 feet in the Saint Peter sandstone, and the main supply in the Jordan sandstone from 1,105 to 1,170 feet.

11 Artesian Wells of Iowa: Iowa Geol. Survey, Vol. VI, pp. 145-147.
12 Geology of Dubuque County: Iowa Geol. Survey, Vol. X, pp. 402-411.

The static level of the well is 42.5 feet below the surface. The advance of thirty years in casing deep wells is seen by comparing the scant 100 feet of casing in the well of 1899, reaching only to within ten feet of the base of the Niagaran limestone, with that of the well of 1930. Here wrought-iron casing 28 inches in diameter was inserted from the surface to 110 feet, resting on basal layers of the Niagaran. Inside this is placed a cast-iron casing 16 inches in diameter extending through the Maquoketa shales to 271.5 feet, where it is bedded in the solid rock of the Galena. The space between these casings is filled with concrete. Thus effectively is prevented the admission of any water from the soluble and creviced limestones overlying the dry impervious Maquoketa shales. From the bottom of the 16-inch casing a 12-inch cast-iron casing extends to 771.5 feet, where it is based in the Shakopee dolomite. It is perforated from 502 to 550 feet to admit water from the Galena-Platteville, and from 694 to 742 feet through the Saint Peter water bed. A packer is set at 692 feet to shut out cave from the Glenwood shale. Pumping tests made on penetrating the Saint Peter showed a yield of nearly 150 gallons per minute. On completion the well yielded 624 gallons per minute with a 200 foot draw-down, and 695 gallons per minute with a draw-down of 233 feet.

The above data were largely supplied by Mr. E. E. Schenk, city engineer.

Driller's Log

	Depth in Feet
Pleistocene and Recent (50 feet thick) —	
Soil	0–3
Yellow clay	3–9
Yellow sand	9–50
Devonian and Silurian (67 feet thick) —	
Loose rock and mud	50–55
Soft rock and yellow clay	55–110
Lime rock, grayish blue	110–117
Ordovician:	
Maquoketa shale (143 feet thick) —	
Blue shale	117–131
Shale and streaks of rock	131–145
Shale (greenish)	145–160
Shale (grayish blue)	160–248
Lime rock and streaks of shale	248–260
Galena-Platteville (400 feet thick) —	
Brown lime	260–375
Gray lime	375–585
Lime and shale	585–660
Glenwood shale (17 feet thick) —	
Shale and thin streaks of rock	660–677
Saint Peter sandstone (41 feet thick) —	
Fine sand	677–718
Prairie du Chien (387 feet thick) —	
Lime rock (Shakopee)	718–895
Soft sand (New Richmond)	895–907

Lime rock (Oneota)	907–1105
Cambrian:	
Trempealeau: Jordan sandstone (95 feet thick) —	
Soft sand and thin hard streaks	1105–1170
Sandy lime	1170–1200
Trempealeau: St. Lawrence (penetrated 63 feet) —	
Limestone	1200–1263

West Point, Lee County

A well 1,154 feet deep was drilled in 1931 for the town of West Point by Thorpe Bros. Well Co. The diameters are from 8 to 6 inches. The only water bed of consequence is the Saint Peter sandstone, yielding on completion of the well about 80 gallons per minute with a draw-down of 50 feet. The lower 54 feet of the well is uncased. Two hundred and forty-eight feet of 8-inch casing is coupled to 842 feet of 6-inch casing. The static level is about 190 feet below the curb.

Driller's Log	Depth in Feet
Pleistocene and Recent (159 feet thick; top 763 feet above sea level) —	
Soil	0–28
Blue clay	28–159
Mississippian, undifferentiated (292 feet thick; top 604 feet above sea level) —	
Limestone and shale	159–240
Brown limestone	240–289
White limestone	289–379
Shale	379–388
Limestone	388–451
Mississippian, Kinderhook shale (274 feet thick; top 312 feet above sea level) —	
Shale	451–725
Devonian-Silurian(?) (134 feet thick; top 38 feet above sea level) —	
Gray limestone	725–727
Brown limestone	727–805
Brown and gray limestone	805–856
Dolomite	856–857
Brown limestone	857–859
Ordovician:	
Maquoketa shale (9 feet thick; top 96 feet below sea level) —	
Gray shale	859–868
Galena-Platteville (217 feet thick; top 105 feet below sea level) —	
Brown limestone	868–1085
Saint Peter sandstone (69 feet thick; top 322 feet below sea level) —	
Sandstone	1085–1153
Shale	1153–1154

Notes. — The geologic section of this well is made out with the help of the Donnellson section, which it closely parallels. The upper beds of the Mississippian may be referred to the Meramec and Keokuk, and the "white limestone" of the log describes a common facies of the Burlington. As at Fort Madison, Burlington, and Mount Clara, the Kinderhook shales are present in great force. They are more than 50 feet thicker than at Keokuk, but some 50 feet thinner than at Donnellson.

In this area the Silurian has apparently feathered out, as at Donnellson and Keokuk. Its presence at West Point is very doubtful, where all the limestones between the Kinderhook and the Maquoketa shales are of Devonian types. The Maquoketa is slightly thicker than at Donnellson. Apparently from the log the same conditions obtain in the Galena-Platteville as at Donnellson, where the entire terrane is dolomitic. Neither limestones of Trenton facies, nor shales representing the Decorah are present, and with them the Glenwood shale also has disappeared. At Keokuk, also, the Platteville and Glenwood are out of the lithologic picture except for some chips of a bituminous shale in one sample of cuttings from the horizon of the Platteville.

The elevation of the top of the Saint Peter, 22 feet higher than at Donnellson, was pretty accurately forecast on our last contour map of this horizon.[13]

Bragieton Farm Well, Calhoun County

This well was drilled for Charles W. Bragieton by J. J. Becker of Fort Dodge in 1931. It is located in the SE¼ section 5, Lincoln Township, Calhoun County, Iowa. The well is 617 feet deep and its diameters range from five to three inches. It is cased to 600 feet with 5-inch to 3-inch casing. A little water was found at 100 feet but no other supply at a greater depth. This well was never finished.

This boring is of special interest in that it practically duplicates, so far as it goes, the highly abnormal geologic section of the deep wells at Manson. It will be recalled that at Manson beneath 200 feet of Pleistocene deposits lay 790 feet of shale with some sandstone, the cuttings mingled with a considerable amount of pebbles and sand largely if not wholly from the drift above. These shales rested on soft arkosic sandstones yielding generously water of a quality altogether exceptional in Iowa deep wells — soft, alkaline, "the solids being mostly alkaline chlorides and sulphates." [14] The explanation of the writer was that a deep erosion channel or basin had been filled in part by continental deposits brought in from igneous rocks to the north; and later it was filled by estuarine clays, Pennsylvanian or Cretaceous in age.[15]

The water bed of arkosic sands in this ancient valley doubtless lies too deep for profitable exploitation by farm wells, but possibly future

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[13] Deep Wells of Iowa: Iowa Geol. Survey, Vol. XXXIII, Plate 1.
[14] Hendrixson, W. S., Underground Water Resources of Iowa: Iowa Geol. Survey, Vol. XXI, p. 174.
[15] Deep Wells of Iowa: Iowa Geol. Survey, Vol. XXXIII, pp. 246-254.

wells of one or more towns in Calhoun and Pocahontas Counties may strike it and extend our knowledge of the abnormal geological conditions of this restricted area.

Record of Strata
By James H. Lees

	Depth in Feet
Pleistocene and Recent:	
Till, glacial clay, calcareous, blue-gray, many limestone pebbles	60–90
Sand, gray, clean, irregular in size, numerous limestone pebbles	100
Sand, similar to above	110–130
Till, glacial, similar to that at 60 to 90, limestone pebbles respond only slowly to acid	140–150
Till, similar to above	160
Till, mostly yellow, some blue-gray, yellow is nearly leached of lime, blue is somewhat limy, a few small gravel bits of limestone, others not limy	170
Sand, glacial, yellow from clay, grains irregular, responds briskly to acid	180
Till, glacial, yellow, very limy	190
Till, buff, limy	200
Till, yellow and gray, limy	210
Till, blue-gray, limy, pebbly	220
Till, like that above, shows sand grains	230
Mississippian:	
Shale, blue-gray, finely sandy, limy, hardly distinguishable from glacial till	240
Same	250
Same	260
Same	270
Same, limy, sandy	280
Same	290
Same	310
Same	325
Shale, gray, very finely gritty, very slightly limy, in small chips; sand, irregular, rounded to angular, some masses like those from 325 and above	350
Shale, gray, limy, similar to that above 325	360
Same	390
Same	400
Same	410
Same	420
Shale, limy, and fine gravel and sand	430
Shale, limy and finely sandy with clean quartz	440
Same	450
Shale, dark gray, fine-textured, limy, mingled with sand and gravel	460
Sand, including grains of flint, quartz, calcite, limestone, dark rock particles, not much shale	470
Same; some fragments concreted with calcite cement	480
Same, some chips of very smooth, nonlimy shale	490
Shale, dark gray, coarsely gritty with sand like that above, very limy; some fragments of white crystalline quartz	510
Sand, similar to that from 470 to 490	530
Same	540
Shale, dark gray, smooth, nonlimy; and sand similar to that above; in equal amounts	550
Shale, dark gray, sandy and limy, with some fragments of sandstone which are only slightly limy	560
Shale, fine-textured, limy, dark gray	570
Same	580
Shale, similar to above; and sand, similar to that above, some fragments of chert	590
Shale, probably like that above; fragments of clay mingled with sand and concreted with lime	600
Same	610

Nixon Farm Well near Stockport

The following is the driller's log of a deep well drilled on the farm of A. Nixon, three and one-half miles southeast of Stockport, Van Buren County, by S. Shearard, Colchester, Illinois. It is noteworthy as confirming the great thickness of the Kinderhook shale in this area.

Driller's Log	Depth in Feet
Pleistocene (40 feet thick) —	
Surface formation	0–40
Mississippian, undifferentiated (280 feet thick) —	
Limestone	40–85
Slate, muddy	85–110
Lime	110–270
Slate	270–272
Limestone	272–320
Mississippian, Kinderhook shale (322 feet thick) —	
Slate and shale	320–380
Limestone, shell	380–385
Blue shale	385–430
Brown shale	430–470
Light blue shale	470–635
Salt water sand	635–642

Titus-Merrill Farm Well, Muscatine County

Three and one-half miles southwest of Muscatine

Driller, W. S. Cole of Plymouth, Ill.

Driller's Log	Depth in Feet
Pleistocene (140 feet thick) —	
Surface gravel	0–90
Gravel rock	90–140
Devonian and Silurian (294 feet thick) —	
Gray lime rock	140–170
White lime rock	170–207
Brown lime rock	207–247
Gray lime rock	247–270
Blue lime, water	270–325
White lime	325–340
Gray shale	340–347
Blue lime, water	347–377
White and gray lime	377–389
Brown lime	389–415
Light brown lime	415–434
Ordovician:	
Maquoketa shale (217 feet thick) —	
Gray shale	434–466
Lime and shale	466–486
Gray shale	486–585
Brown shale, very hard	585–629
Black shale	629–651
Galena-Platteville (penetrated 31 feet) —	
Gray hard lime	651–652
Brown lime	652–656
Light brown lime, water	656–682

Farm Wells, Woodbury County

Mr. C. C. Everhart of Moville supplies the following data of several wells near Moville drilled by C. Blackford. J. H. Wright farm well, E½ sec. 17, T. 89 N., R. 44 W. The main supply was found at 145 feet; the static level is 60 feet below curb.

Driller's Log	Depth in Feet
Loess	0–80
Clay and hardpan	80–125
Coarse sand	125–145

Charles Logan farm well, SW¼ NW¼ sec. 5, T. 88 N., R. 43 W. The main supply of water was found at 312 feet.

Driller's Log	Depth in Feet
Loam, loess, fine sand	0–53
Boulders, etc	53–65
Boulders, black mud	65–105
Hardpan	105–180
Gravel	180–298
Sandrock	312–315 (sic)

Frank Wright farm well, S½ sec. 25, T. 89 N., R. 44 W. The main supply was found at 345 feet, and the well is cased to 344 feet.

Driller's Log	Depth in Feet
Loess	0–60
Sand loess	60–145
Glacial soil, large boulder at 185 feet, mineral water at 217 feet	145–217
Sand rock, gravel, etc.	217–250
Black shale or very hard hardpan	250–336
Large sand pocket, sand black and fine, small section of petrified wood, at 338 feet	336–348

ADDITIONAL DEEP WELLS

by

JAMES H. LEES

CONTENTS

ADDITIONAL DEEP WELLS

In addition to the wells, the records of which have been studied and described by Doctor Norton, information regarding a number of wells has been sent to the office of the Geological Survey at Des Moines. These samples were studied by James H. Lees, the Assistant State Geologist. In some cases he was aided by Dr. A. C. Tester, of the State University of Iowa. These wells are described in the following pages. The interpretation of drillers' logs was made by the author.

By far the deepest boring in this list, and also the deepest well in the state, is the oil and gas prospect which was drilled about four miles south of Clarinda. This well was described in part in Volume XXXIII, pp. 137 and 428, and in condensed form in Volume XXXV, p. 548; because of the interest attaching to this well, however, the complete record is given here.

Dallas Center, Dallas County

This well was drilled for the Dallas Center school by F. S. McCutcheon of Des Moines, Iowa, in March 1931. The elevation at the curb is 1,073 feet. The static head stands at 180 feet but draws down to 300 feet when being pumped at 15 gallons per minute. The Kinderhook shale was reached at 800 feet and was penetrated 10 feet. Samples were collected below the Des Moines shales.

Driller's Log	Depth in Feet
Mississippian —	
Limestone, dark gray, crystalline, contains much fine sand	580
Sandstone, dark gray, mingled fine and coarse, some white and reddish quartz, some black fragments of fine sandstone; a little limestone	650
Shale, very dark gray, finely gritty, slightly limy; a little pale bluish chert; bag says "film of oil on shale"	665
Shale, similar to above, quite limy	680
Shale, limy, or limestone, shaly, dark gray, in finely granular chips, action in acid slow but long continued, much fine white siliceous residue	690
Sandstone, dark gray, firmly cemented, fine-grained; also shale, very dark gray, slightly limy, in small amount	695
Sandstone, similar to above, some glassy quartz	700
Sandstone, similar to above, many clear glassy and white grains; some response to acid, indicating presence of lime	710–720
Sandstone, as above, but with large amounts of bluish and white chert; a small perfect crystal of glassy quartz was observed at 730; rather brisk response to acid below 750; several small geodic cavities in	

fragments from 760; a fragment from 770 is deeply etched by acid but retains its firm texture; lighter gray and in smaller chips at 790; much clay at 800; 8 samples 730–800

Eagle Grove, Wright County

This well was drilled for the Chicago & Northwestern Railway Co. It is located 2,200 feet northwest of the passenger station, near the enginehouse. Its depth is 248 feet. It was drilled 12 inches in diameter and is cased with 142 feet of 12-inch steel casing. The water rises within 14 inches of the surface and draws down to 30 inches below curb while pumping 400 gallons per minute. It rises to its former elevation of 14 inches below curb immediately upon stopping the pump. The altitude of the top of this well is approximately 1,126 feet. This well was begun in October 1929 and completed in March 1930; it was drilled by E. C. Archibald of Sioux City.

Driller's Log	Thickness in Feet	Depth in Feet
Pleistocene and Recent:		
Cinders	4	4
Loam, black	2	6
Clay, blue	68	74
Sand and gravel, water	3	77
Clay, blue, sandy	18	95
Sand	5	100
Clay, blue	37	137
Sand	2	139
Mississippian: undifferentiated —		
Limestone	4	143
Limestone, soft, water	2	145
Sandstone	8	153
Rock, solid	6	159
Limestone, hard	8	167
Limestone, soft	3	170
Limestone and clay	3	173
Limestone, hard	3	176
Limestone, soft	24	200
Limestone and sand	3	203
Limestone and clay	2	205
Limestone, hard	38	243
Dakota sandstone, water	5	248

Chemical analysis of water from Eagle Grove well. Lake Michigan water is used as a standard for comparison.

			Eagle Grove	Lake Michigan Water
	Total solid matter	Grains per gallon	25.29	7.78
	This solid matter consists of:			
A	Carbonate of Lime	" " "	13.88	4.46
A	Carbonate of Magnesia	" " "	6.64	2.20
A	Sulphate of Lime	" " "	0.00	0.30
A	Sulphate of Magnesia	" " "	0.00	
A	Oxides of Iron & Aluminum	" " "	0.07	0.02
A	Silica	" " "	0.70	0.30

B	Alkali Chlorides	"	"	"	0.27	0.22
	Alkali Sulphates	"	"	"	2.07	0.28
	Alkali Carbonates	"	"	"	1.66	

A = Incrusting Solids. B = Nonincrusting Solids.
Pounds of incrusting solids in 1,000 gallons of Lake Michigan water — 1.04.
Pounds of incrusting solids in 1,000 gallons of Eagle Grove, Ia., water — 3.04.
This is fair water for boiler use.

(Signed) H. D. Brown, Engineer of Tests,
Chicago & Northwestern Railway Company.

Estherville, Emmet County

In May 1932 a gravel pack well was drilled for the City of Estherville by Thorpe Bros. Well Co. of Des Moines. Four wells were dug to a depth of 400 feet. The static head stands at 109 feet, with a draw-down of 28 feet when the well pumps 2,045 gallons per minute. Water was first encountered at 260 feet in sandstone, yielding an approximate amount of 4,000 gallons per minute. The well was cased as follows: 323 feet of 20-inch pipe in all four holes to a depth of 323 feet; 249 feet of 8-inch pipe was used in the south hole, 242 feet of 8-inch pipe in the west hole, 239 feet of 8-inch pipe in the north hole, and 237 feet of 6-inch pipe in the east hole. The elevation is approximately 1,290 feet above sea level.

Driller's Log	Thickness in Feet	Depth in Feet
Pleistocene and Recent:		
Black dirt	2	2
Gravel	19	21
Clay, blue	42	63
Clay, yellow	37	100
Clay, blue	12	112
Clay, yellow	35	147
Cretaceous (?):		
Rock	3	150
Clay, blue	24	174
Rock	1	175
Clay, blue	6	181
Clay, brown	9	190
Mississippian:		
Shale, gray	12	202
Shale, brown	9	211
Shale, gray	3	214
Shale, brown	13	227
Limestone	4	231
Shale, gray	12	243
Sandstone	17	260
Sandstone	10	270
Sandstone	11	281
Sand and sandstone	34	315
Sand and shale	3	318
Sandstone	24	342
Rock	1	343
Shale	3	346
Sandstone, hard	54	400

Farnhamville, Calhoun County

This well was drilled by Frank McCutcheon, Des Moines, in June 1932. It was drilled on the site of an older well, 165 feet deep. This well is yielding 35 gallons per minute in daily use.

Driller's Log	Depth in Feet
Old well, all in drift	165
Sand, fine, muddy	198
Shale, black	214
Sandstone	216
Shale, mixed	280
Limestone, broken, with shale	290
Limestone	330
Shale, strip	333
Limestone	405
Limestone, soft streaks	413
Limestone	732
Sandstone, water-bearing	770
Shale	776

Fort Dodge, Webster County, Well No. 9

In August 1931 Well No. 9 for Fort Dodge was completed by Thorpe Bros. Well Co. of Des Moines. The well was drilled to a depth of 269 feet with diameters of 20 and 16 inches. The static level is above surface, and the well yields 1,925 gallons per minute with a draw-down of 89 feet. Water was first encountered at 262 feet in sandstone, the approximate amount being 6 gallons per minute. After Well No. 12 was completed it was the opinion of the driller that Well No. 9 should be drilled down to 541 feet, the same depth as No. 12. The well was cased as follows: 69 feet of 20-inch pipe from the surface to 69 feet; 236 feet of 16-inch pipe from 3 feet above surface to 239 feet; 60 feet of 12-inch pipe from 207 to 267 feet.

Driller's Log	Thickness in Feet	Depth in Feet
Pleistocene and Recent:		
Soil, black and yellow clay	20	20
Gravel, fine, and sand	10	30
Pennsylvanian:		
Shale, blue and black	46	76
Mississippian:		
Limestone	4	80
Limestone, argillaceous	22	102
Shale, black	18	120
Limestone, argillaceous	59	179
Limestone	3	182
Shale, red	24	206
Limestone	5	211
Shale, red	4	215
Limestone	4	219
Shale, green	8	227
Shale, red	6	233

Shale, green	7	240
Limestone	21	261
Sandstone	6	267
Limestone, arenaceous	2	269

Fort Dodge, Webster County, Test Hole

In September 1931 a test hole was dug for the City of Fort Dodge by Thorpe Bros. Well Co. of Des Moines. The depth of the well was 422 feet, and the diameters were from 10 to 6 inches. It was a flowing well with a yield of 200 gallons per minute. Water was first encountered at 254 feet in sandstone. The flow increased about fifty percent from 391 to 410 feet. The well was cased as follows: 18 feet of 10-inch pipe from 1 foot below the surface to 19 feet; 120 feet of 8-inch pipe from surface to 120 feet; 242 feet of 6-inch pipe from 1 foot below surface to 243 feet. The altitude at the curb was 976 feet.

Driller's Log	Thickness in Feet	Depth in Feet
Pleistocene and Recent (21 feet thick; top 976 feet) —		
Black soil	4	4
Gravel to sand	14	18
Hardpan	3	21
Mississippian and Pennsylvanian:		
Clay and shale, blue-black	52	73
Limestone	13	86
Shale, black	34	120
Limestone	3	123
Shale, black	46	169
Limestone	7	176
Shale, red	41	217
Limestone	2	219
Shale, red and green	23	242
Limestone	10	252
Sandstone	12	264
Limestone	79	343
Shale, green	5	348
Limestone	74	422

Fort Dodge, Webster County, Well No. 11

In September 1931 a test hole was drilled for the City of Fort Dodge by Thorpe Bros. Well Co. of Des Moines. The well was drilled to a depth of 530 feet, and the diameters were from 10 to 6 inches. It was a flowing well with a yield of 600 gallons per minute. Water was first encountered at 25 feet in sandstone, with an approximate yield of 3 gallons per minute. Eighty percent of the flow was found between 335 and 525 feet. The well is cased as follows: 28 feet of 10-inch pipe from the surface to 28 feet; 122 feet of 8-inch pipe from the surface to 122 feet; 243 feet of 6-inch pipe from 1½ feet below the surface to 243 feet. The altitude of the curb is about 976 feet.

Driller's Log	Thickness in Feet	Depth in Feet
Pleistocene (60 feet thick; top 976 feet) —		
Clay, black and yellow	12	12
Gravel and sand	12	24
Clay, blue and yellow	16	40
Hardpan	2	42
Clay, blue	18	60
Mississippian:		
Shale, black	16	76
Limestone	3	79
Sandstone, calcareous	11	90
Shale, black to gray	27	117
Limestone, argillaceous	9	126
Shale, calcareous, black and gray	51	177
Limestone	8	185
Shale, gray	4	189
Shale, red	26	215
Limestone	11	226
Shale, red and green	16	242
Limestone	8	250
Sandstone, soft	3	253
Limestone	32	285
Shale, blue	3	288
Limestone	22	310
Limestone, water bearing	35	345
Limestone (samples washed away)	183	528
Limestone, brown	2	530

Fort Dodge, Webster County, Well No. 12

This well was drilled for the city of Fort Dodge by Thorpe Bros. Well Co. of Des Moines in 1931. This well, which is No. 12, is a drilled well and has a depth of 541 feet. It was begun in October and completed in December, 1931. It was started with a 20-inch hole and finished with a 12-inch hole. The flow of the completed well was 800 gallons per minute. The water flows above the curb. Flow was first encountered at 253 feet in sandy limestone, and the approximate amount was 371 gallons per minute. Eighty percent of the flow came from 335 to 534 feet below curb. A 16-inch pipe extends 246 feet, and a 10-inch pipe extends 64 feet to a depth of 310 feet below the curb. In the 64 feet of pipe there is 19 feet of perforated pipe and a 2.8-foot nipple. The altitude at the curb is 1,011 feet.

Driller's Log	Thickness in Feet	Depth in Feet
Pleistocene and Recent:		
Soil, black and yellow	12	12
Gravel and sand	12	24
Clay, blue and yellow	16	40
Hardpan	2	42
Clay, blue; shale, black	34	76
Mississippian and Devonian:		
Limestone	3	79
Sandstone, calcareous	11	90
Shale, black and gray	12	102
Limestone, blue	24	126

Shale, black	7	133
Limestone	57	190
Shale, red	25	215
Limestone	11	226
Shale, green	16	242
Limestone	11	253
Limestone, arenaceous	37	290
Shale, green	3	293
Limestone, arenaceous	42	335
Sandstone	7	342
Limestone	16	358
Sandstone	4	362
Limestone	78	440
Limestone, arenaceous	25	465
Limestone	8	473
Limestone (samples washed away)	29	502
Limestone (samples washed way)	7	509
Limestone (samples washed away)	25	534
Limestone, brown	.7	541

Fraser, Boone County, Well No. 2

In October 1933 a well was drilled for Fort Dodge, Des Moines & Southern Railway by Thorpe Bros. Well Co. of Des Moines. The well was drilled to a depth of 314 feet, and its diameters were from 10 to 6 inches. The well had a natural flow of 1.5 gallons per minute. Water was first encountered at 17 feet in gravel. This supply was shut off. The first 173 feet of the well was cased with 6-inch standard black pipe.

Driller's Log

	Depth in Feet
Pleistocene and Recent:	
Cinder fill	0–2
Yellow clay	2–9
Sandy clay	9–17
Gravel	17–23
Pennsylvanian:	
Gray shale	23–29½
Dark gray shale	29½–33½
Coal	33½–36
Fire clay	36–38½
Light gray shale	38½–44½
Dark gray shale	44½–46½
Coal	46½–47½
Fire clay	47½–51
Light gray shale	51–61
Sandstone	61–66
Gray shale	66–74½
Dark gray shale	74½–76½
Coal	76½–79½
Fire clay	79½–81
Gray shale	81–116
Shale and lime streaks	116–127
Dark gray shale	127–155
Light gray shale	155–166
Soft lime and sandstone	166–171½
Solid limestone	171½–195½
Green shale	195½–199

Mississippian:	
Solid limestone	199–287
Gray shale	287–289
Porous limestone	289–314

Garfield, Appanoose County

In July 1933 a deep well was completed for Mr. Baumeister of Garfield by Thorpe Bros. Well Co. The depth was 351 feet, and the diameters are from 6 to 4 inches. The static head stands at 165 feet, and there is a draw-down of 20 feet. Water was first encountered at 330 feet in white sandstone, the approximate yield being about 3 gallons per minute. The well was cased as follows: 6-inch standard pipe from the surface to 112 feet, 4⅝-inch inserted joint pipe from 112 feet to 240 feet, and 4-inch inserted joint pipe from 240 feet to 351 feet. The elevation at the curb was approximately 1,011 feet.

Driller's Log	Depth in Feet
Pleistocene and Recent:	
Black soil	0–4
Yellow sandy clay	4–20
Sand, yellow and fine	20–41
Gray drift, sandy	41–43
Sand, fine and yellow	43–50
Gray drift, sandy	50–56
Pennsylvanian:	
Sand; red color, fine, dry	56–60
Blue clay	60–100
Mixed shale	100–195
Coal	195–198
Dark gray shale	198–236
Sandstone, band	236–237
Mixed shale	237–330
Sandstone, soft	330–350
Brown limestone	350–351

Garner, Hancock County

In January 1932 a well was drilled for the town of Garner by E. A. Ford of Marshalltown. The well was drilled to a depth of 225 feet. The approximate elevation is about 1,216 feet above sea level. Samples were submitted by J. J. Becker of Fort Dodge.

Record of Strata	Depth in Feet
Mississippian:	
Limestone and sand, in about equal parts, gray	79–82
Similar, but in fine grains of about equal size	82–85
Limestone, medium dark gray, briskly effervescent	95
Limestone, shaly, drab, fine-textured	100
Limestone, finely granular, gray	108
Limestone, dark gray, granular, evidently dolomitic	116
Shale, fine-textured, light gray, slightly limy	125
Limestone, gray, granular, dolomitic	131–140

Limestone, similar	145
Limestone, tan, sample in very fine grains	145
Limestone, gray, sugary texture, in coarse grains and chips	150
Limestone, of two types, one granular and sugary, like that above, with considerable insoluble sandy residue, the other pale blue, fine-grained, with much clay residue	150–155
Limestone, light gray, granular, dolomitic, considerable siliceous residue	155–160
Limestone, similar to above	163–165
Limestone, similar to above	175–180
Limestone, similar to above but fine in texture	180–185
Limestone, similar to sample above and in smaller grains	185–190
Limestone, tan colored, finely granular, sample in chips and grains	195
Limestone, tan, finely granular, sample in small grains, much sandy residue after treatment with HCl	200
Limestone, medium dark gray, sugary, in small grains	205
Limestone, mingled light and dark gray, finely sugary, sample in coarse chips	210
Limestone, similar to above	215
Limestone, light gray, rather finely granular, probably somewhat dolomitic, with a good deal of white flinty residue after heating in acid	220
Limestone, gray, granular, with much calcite, residue similar to that of sample above. Probably most if not all of these granular limestones are dolomitic and contain silica	225

Lisbon, Linn County

In September 1932 a well was drilled for the city of Lisbon by Thorpe Bros. Well Co. of Des Moines. Its depth was 350 feet, and its diameters from 16 to 10 inches. The well yielded 238 gallons per minute with a draw-down of 145 feet. The static head stood at 24 feet. Water was first encountered at 298 feet in limestone. Sixty feet of 10-inch cast-iron pipe was used in casing the well.

Driller's Log	DEPTH IN FEET
Pleistocene and Recent:	
Clay	0–7
Silurian:	
Broken limestone, very hard	7–50
Solid limestone	50–145
White limestone	145–270
Hard blue limestone	270–297
Very hard limestone, some water channels	297–300
Limestone	300–336
Hard limestone, water at 338 to 348	336–350

Mason City, Cerro Gordo County, Well No. 10

In December 1932 a city well was completed for Mason City by Thorpe Bros. Well Co. of Des Moines. This well was drilled to a depth of 1,243 feet with diameters from 26 to 12 inches. The static head stands at 150 feet below the surface. A 26-inch hole was drilled to 99 feet; a 19-inch hole from 99 to 250 feet. The hole tapered from 19 inches in diameter at 250 feet to 17 inches at 420 feet. A 15-inch hole was drilled from 420 to 743 feet, and a 12-inch hole from 743 feet to the bottom. The well was cased as follows: 101 feet of 20-inch pipe from the surface to 99 feet; 109 feet of 12-inch pipe to 143 feet. Water stood at the 35 to 40 foot level until a depth of 990 feet was reached. Then the water level lowered gradually to 150 feet at the 1,075-foot level and remained there.

In spite of the large number of wells that have been drilled at Mason City, comparatively few samples have been saved and hence interpretation of the geologic section must still be made largely from the drillers' logs.

Driller's Log	Thickness in Feet	Depth in Feet
Pleistocene and Recent (17 feet thick; top 1077 feet above sea level) —		
Fill	17	17
Devonian and Silurian (188 feet thick; top 1060 feet above sea level) —		
Limestone with shale streaks	73	90
Shale	4	94
Limestone, hard	111	205
Ordovician:		
Maquoketa and Galena (455 feet thick; 872 feet above sea level) —		
Limestone	455	660
Platteville (69 feet thick; 417 feet above sea level) —		
Shale	55	715
Rock	14	729
Glenwood (11 feet thick; top 348 feet above sea level) —		
Shale	6	735
Limestone with shale streaks	5	740
Saint Peter (60 feet thick; top 337 feet above sea level) —		
Sandstone	60	800
Prairie du Chien (350 feet thick; top 277 feet above sea level) —		
Limestone and dolomite, crevices from 990 feet	350	1150
Cambrian:		
Trempealeau: Jordan (70 feet thick; top 73 feet below sea level) —		
Sandstone	70	1220
Trempealeau: Lodi (23 feet thick; top 143 feet below sea level) —		
Limestone, sandy, and dolomite; crevices	23	1243

Mason City, Cerro Gordo County, Decker Well No. 3

In May 1933 a well was completed for Jacob Decker & Sons of Mason City by Thorpe Bros. Well Co. This was a rock well. The depth of the well is 1,260 feet, and the diameters are from 28 to 12 inches. The well is cased with 28-inch pipe from the surface of the well to 12 feet; 20-inch pipe from 12 feet to 50 feet; 12-inch pipe from 50 feet to 726 feet. The curb of the well is approximately 1,125 feet above sea level.

Driller's Log

	Thickness in Feet	Depth in Feet
Devonian; Silurian; Ordovician (Maquoketa, Galena, and Decorah):		
Limestone and dolomite	648	648
Ordovician:		
Platteville (70 feet thick; top 477 feet above sea level) —		
Shale	60	708
Limestone	10	718
Glenwood (9 feet thick) —		
Shale	9	727
Saint Peter (73 feet thick; top 398 feet above sea level) —		
Sandstone	73	800
Prairie du Chien (330 feet thick; top 325 feet above sea level) —		
Limestone and dolomite, crevices from 990 to 1130	330	1130
Cambrian:		
Trempealeau: Jordan (70 feet thick; top 5 feet below sea level) —		
Sandstone, 1130 to 1190 coarse sand	70	1200
Trempealeau: Lodi and St. Lawrence (penetrated 60 feet; top 75 feet below sea level) —		
Limestone and dolomite	60	1260

Mitchellville, Polk County

The deep well for the Training School for Girls at Mitchellville was completed in June 1932 by Thorpe Bros. Well Co. The well was drilled to a depth of 2,410 feet, and the diameters are from 23 to 10 inches. On completion the well yielded 1,000 gallons per minute with a draw-down of 151 feet. The static head stood at 191 feet. Water was first encountered at 610 feet in limestone with an approximate yield of 10 gallons per minute. Water was found in the Saint Peter sandstone and in crevices of the New Richmond, but the largest supply was found in the Jordan sandstone. The well was cased as follows: 16-inch pipe to 412 feet, 12-inch pipe to 816 feet, and 10-inch pipe to 1,475 feet.

Driller's Log

	Depth in Feet
Pleistocene and Recent:	
Fill	0–10
Blue clay	10–67
Yellow clay	67–88
Blue clay	88–101
Sand	101–104
Pennsylvanian:	
Gray shale	104–112
Red shale	112–120
Gray shale	120–147
Gray shale with rock streaks	147–210
Black shale	210–330
Gray shale with streaks of hard rock	330–395
Limestone with streaks of shale	395–515
Mississippian:	
Limestone	515–610
Shale, greenish gray	610–710

Devonian:	
Limestone with shale streaks	710–768
Limestone, hard	768–815
Silurian:	
Limestone	815–1355
Ordovician:	
Red shale	1355–1380
Blue shale	1380–1465
Limestone	1465–1820
Green shale	1820–1822
Limestone	1822–1835
Green shale	1835–1838
Limestone	1838–1878
Shale	1878–1883
Saint Peter sandstone	1883–1918
Limestone	1918–2131
Sandy limestone	2131–2151
Sand	2151–2181
Limestone	2181–2261
Open lime	2261–2281
Limestone	2281–2381
Sand	2381–2410

Mineral Analysis

Silica	.327	Grains per U. S. Gallon
Oxides of Iron and Aluminum	.046	" " " "
Carbonate of Lime	8.295	" " " "
Sulphate of Lime	9.685	" " " "
Carbonate of Magnesia	7.325	" " " "
Sodium & Potassium Sulphates	35.062	" " " "
Sodium & Potassium Chlorides	5.600	" " " "
Sodium & Potassium Nitrates	Trace	
Loss, etc.	.104	" " " "
Total Sol. Mineral Solids	66.444	" " " "
Organic Matter	Trace	
Total Sol. Incrusting Solids	25.678	" " " "
Total Sol. Non-incrusting Solids	40.766	" " " "
Pounds Sol. Incrusting Solids per 1,000 U. S. Gallons		3.66
Pounds Sol. Non-incrusting Solids per 1,000 U. S. Gallons		5.82

Remarks: Appearance of water — colorless, slight suspension.

Moravia, Appanoose County, School Well

This well is 559 feet deep. It is cased with 6-inch casing to 138 feet and with 5-inch casing from 116 to 354 feet. The static head is 265 feet below surface, and the well yields 12 gallons per minute. It was drilled by F. S. McCutcheon of Des Moines. The elevation is about 1,000 feet above sea level.

Driller's Log	Thickness in Feet	Depth in Feet
Pleistocene and Recent:		
Drift, yellow	40	40
Drift, grade	90	130
Mud, sea	6	136
Pennsylvanian:		
Shale, gray	14	150
Shale, light	80	230
Shale, dark	17	247

Shale, gray	5	252
Sandstone	5	257
Shale, light	23	280
Shale, dark	4	284
Rock, hard, black	1	285
Shale, light	5	290
Shale, dark	5	295
Shale, gray, trace of coal	8	303
Shale, light	10	313
Shale, gray	40	353
Sandstone	6	359
Limestone	12	371
Shale, sandy, gray	49	420
Shale, dark	8	428
Mississippian:		
Sandstone, gray	32	460
Sandstone, water bearing	60	520
Limestone, white	10	530
Shale	2	532
Limestone	8	540
Limestone, soft	9	549
Limestone	10	559

Muscatine, Muscatine County

Well No. 1 was an oil prospect dug under the direction of A. L. Madden of Muscatine. The prospect was started April 4, 1931, and was completed June 5, 1931.

Driller's Log	Thickness in Feet	Depth in Feet
Pleistocene and Recent:		
Surface gravel, sand	90	90
Gravel	50	140
Silurian:		
Limestone, gray	30	170
Limestone, white	37	207
(Dry gas 15 feet; wet gas and oil 25 feet)		
Limestone, brown	40	247
Limestone, gray	23	270
Limestone, blue water	55	325
Limestone, white	15	340
Ordovician:		
Maquoketa —		
Shale, gray	7	347
Limestone, blue water	30	377
Limestone, white and gray	12	389
Limestone, brown	26	415
Limestone, brown	19	434
Shale, gray	32	466
Limestone and shale	20	486
Shale, gray	99	585
Shale, brown, very hard	44	629
Shale, black	22	651
Galena-Platteville —		
Limestone (Trenton), gray, hard	1	652
Limestone, brown; oil showing	4	656
Limestone, light brown; water, some salt	26	682

Persia, Harrison County

In November 1933 a well was drilled for the water supply of Persia by Thorpe Bros. Well Co. of Des Moines. The depth was 250 feet, with a diameter of 6 inches. It yielded five gallons per minute, with a draw-down to the bottom of the well. The static head stood at 65 feet. Water was first encountered at 54 feet in a dirty sand with an approximate yield of 15 gallons per minute.

Driller's Log	Depth in Feet
Pleistocene and Recent:	
Soil	0–2
Clay, yellow	2–35
Clay, blue	35–54
Sand, dirty	54–69
Clay	69–118
Pennsylvanian:	
Sandstone	118–124
Clay	124–134
Limestone	134–146
Shale	146–154
Limestone	154–166
Shale	166–174
Limestone	174–178
Shale	178–187
Limestone	187–191
Shale	191–250

Stratford, Hamilton County

This well, which was started in December 1930 and completed in March 1931, was drilled by Thorpe Bros. Well Co. of Des Moines for Chicago North Western Railway Co. Its depth is 634 feet, and its diameters from 12 to 6 inches. The static level was 150 feet below curb. The well yielded 36 gallons per minute with a draw-down of 130 feet. Approximately 5 gallons per minute was encountered from 50 to 69 feet in fine sand. The water was unsatisfactory and so this well was abandoned.

Driller's Log	Thickness in Feet	Depth in Feet
Pleistocene and Recent:		
Soil	5	5
Clay, yellow	11	16
Clay, arenaceous, bluish gray	42	58
Sand, fine, gray	11	69
Clay, gray, some rock	206	275
Sand, very fine	3	278
Pennsylvanian:		
Shale and thin streaks of rock	162	440
Mississippian:		
Limestone, light color	60	500
Limestone, light gray	131	631
Shale, light blue	3	634

Stratford, Hamilton County, Town Well

In 1930 a town well was completed for Stratford, Iowa. It is located about 600 feet from the railroad station, with an elevation of approximately 5 feet above the railroad. The well was started with a 15-inch diameter and finished with a 10-inch diameter. The depth is 495 feet. The well was cased with 319 feet of 12-inch casing and 170 feet of 10-inch casing. The static head stands at 180 feet, and there is practically no draw-down. The yield is 215 gallons per minute. The elevation of the well is approximately that of the railway station, which is 1,113 feet.

Driller's Log	Thickness in Feet	Depth in Feet
Clay, sand, fine	275	275
Sand, fine	37	312
Shale, and thin streaks of rock	38	350
Rock, and thin streaks of shale	50	400
Shale and rock, alternating	20	420
Shale	40	460
Rock and thin streaks of shale	35	495

Williams, Hamilton County

This well was drilled for the town of Williams by J. J. Becker of Fort Dodge. The static head stands 50 feet from the curb. The well yield is 125 gallons per minute with a draw-down of two feet. An 8-inch pipe was set to 300 feet; 6¼-inch casing to 750 feet; 5-inch pipe to 1,000 feet; 40 feet of 4½-inch casing at 1,500 feet; 80 feet of 4-inch casing at about 1,600 feet.

Record of Strata	Depth in Feet
Ordovician:	
Glenwood shale (20 feet thick; top 289 feet below sea level) —	
Shale, bright blue-green, fissile, abundant pyrite, slight effervescence	1500–1515
Saint Peter sandstone (50 feet thick; top 309 feet below sea level) —	
Sandstone, white quartz sand with less than 1 percent of iron oxide grains, quartz grains well rounded, and average diameter between ¼ and ½ millimeters in diameter	1520–1570
Prairie du Chien: Shakopee dolomite (118 feet thick; top 359 feet below sea level) —	
Dolomite, calcareous, gray to drab, granular and in cuttings contains no fragments of rock, effervesces freely, contains grains of quartz and iron oxide in the dolomite	1572–1595
Dolomite, effervesces slowly, samples contain small chips of light gray to drab dolomite which is firmly coherent, contains many rounded quartz grains	1600–1610
Dolomite, light gray and more compact than that of the bed immediately above	1620
Dolomite, coarsely granular, gray-buff, contains chips of rock in the cuttings	1630–1640
Dolomite, light gray, fine grains, no chips from the cuttings, effervesces slowly	1650–1660
Dolomite, light buff, coarsely granular and crystalline, cuttings contain some chips, effervesces slowly	1670–1680
Dolomite, gray-buff-colored, some chips of hard compact rock, effervesces slowly	1688
Prairie du Chien: New Richmond sandstone (40 feet thick; 477 feet below sea level) —	

Sandstone, white to light buff due to some iron oxide grains; most of the grains are well-rounded quartz although some show their original angularity. The slight effervescence appears to be from dolomite carried down from above	1700–1728
Prairie du Chien: Oneota dolomite (30 feet to the bottom of the well; 517 feet below sea level) —	
Dolomite, light buff, the buff color due to a small percentage of iron oxide on some of the grains; effervesces slowly; no chips of the rock in the fine sandy cuttings	1740–1758

Berry Well, Ringgold County

This well was drilled by G. H. Rose & Son, contractors and drillers of Clarinda, Iowa. It is located one mile west and one-half mile north of Redding, Ringgold County. The diameters were from 10 to 12 inches and the well was drilled to a depth of 715 feet. A 10-inch casing was set at 200 feet, and 8-inch was set at 700 feet. The first water was encountered at a depth of 40 feet.

Driller's Log	Thickness in Feet	Depth in Feet
Soil	5	5
Clay, yellow	10	15
Clay, blue	8	23
Quicksand, water	15	38
Shale, light	14	52
Limestone, white	5	57
Shale, light	13	70
Limestone, gray	5	75
Shale, light	20	95
Shale, white	10	105
Limestone, white	10	115
Shale, dark	1	116
Limestone, gray	5	121
Shale, dark	4	125
Limestone, gray	15	140
Shale, black	6	146
Limestone, white	4	150
Shale, dark	8	158
Shale, red	10	168
Limestone, white; shale	17	185
Limestone, white	13	198
Shale, blue	10	208
Shale, light	5	213
Limestone, gray	25	238
Shale, light	7	245
Limestone, white	5	250
Shale, dark	2	252
Limestone, gray	8	260
Shale, black	3	263
Limestone, white	27	290
Shale, dark	4	294
Limestone, white	21	315
Shale, light	3	318
Limestone, gray	5	323
Shale, light	12	335
Limestone, gray	17	352
Limestone and shale	15	367
Limestone	4	371
Shale, light	5	376

Shale, dark	27	403
Limestone, gray	5	408
Shale, black	4	412
Shale, light	23	435
Shale, red	7	442
Limestone	3	445
Shale, light	12	457
Shale, black	15	472
Limestone, gray	5	477
Shale, dark	8	485
Limestone and shale	35	520
Shale, light	20	540
Red rock	2	542
Shale, light	53	595
Shale, brown	8	603
Limestone	1	604
Shale, dark	6	610
Limestone	1	611
Limestone and shale	4	615
Shale, light	20	635
Limestone	2	637
Limestone and shale	38	675
Shale, dark	40	715

Well of Louis Charon, Webster County

This well was drilled in Fort Dodge for Louis Charon, one mile north of Central Ave. and 5th Street, 20 rods from the Des Moines River. The depth of the well is 94 feet and the water stands 3 feet from the curb. The samples were received from J. J. Becker of Fort Dodge, 1930.

Driller's Log	Depth in Feet
Pleistocene and Recent:	
Glacial drift, yellowish brown, pebbly, highly calcareous, evidently Wisconsin till	10–30
Mississippian:	
Limestone, gray, rather fine-grained, in small chips, some yellow calcite; sand grains, clear, rounded, nearly colorless; some clay, probably from above, which cements the other materials. Limestone and sand probably belong to the St. Louis	35
Sand grains, similar to those above, some small masses of sand concreted with calcareous cement; much calcite in grains and powder; all light gray	50
Sand, similar to above but dark gray, some iron pyrite, much calcite	60
Limestone, gray, in small chips and grains of calcite, with some clear quartz sand and some pyrite	70
Limestone, dark gray, granular, some in white crystals of calcite	80
Limestone, dark gray, in fine sand, some white calcite	90–94

Moline Oil and Gas Co. Well, Rock Island County, Illinois

This oil prospect was drilled on the Christensen Bros. farm in the southwest corner of SE¼ SE¼ section 8, Twp. 17 N., R. 1 E., Hampton Township, Rock Island County, Illinois. The samples were studied by M. Blair and D. M. Delo of Illinois Geological Survey in January 1933. The record was given to the Iowa Geological Survey by Merlyn

Buhle (student in the Department of Geology, State University of Iowa).

Record of Strata

	Thickness in Feet	Depth in Feet
Pennsylvanian:		
Shale, carbonaceous, micaceous, sandy, pyritic, dark blue-gray, weak	30	30
Siltstone, micaceous, brown-gray; sandstone, calcareous, gray, fine, fragment of coal; interbedded shale, sandy, dark gray and weak	33	63
Sandstone, very shaly, calcareous, micaceous, gray, fine, coherent; 75-foot hole fills with water	24	87
Shale, slightly sandy, micaceous, carbonaceous, dark gray and weak	18	105
Shale, noncalcareous, carbonaceous, laminated, dark blue-gray and firm	15	120
Siltstone, calcareous, gray, very fine, compact, grading to shale, micaceous, dark gray, weak, and sandstone, calcareous and fine	32	152
No sample	3	155
Devonian:		
Dolomite, light buff, fine to very finely crystalline, compact to partly porous	35	190
No sample	5	195
Silurian:		
Niagaran —		
Dolomite, light gray, very finely crystalline, partly porous	60	255
Dolomite, white, very finely crystalline, partly porous (gas at 326 feet)	101	356
Dolomite, white, very finely crystalline, partly porous with much vug quartz; dolomite, argillaceous, light gray-brown, very fine, partly porous	13	369
Dolomite, cherty, light gray-brown, finely crystalline, partly porous, bluish, secondary silica	66	435
Dolomite, cherty, light gray-brown, finely crystalline, partly porous; shale, silty, very dolomitic, gray, small black spots, very firm	29	464
Ordovician:		
Maquoketa —		
Dolomite, argillaceous, dark mottled gray, finely granular, fossiliferous, compact; shale, dolomitic, greenish gray, weak	29	493
Shale, dolomitic, greenish gray, weak	25	518
Dolomite, mottled brown and dark gray, finely granular, fossiliferous, compact with interbedded shale, greenish gray, weak	48	566
Dolomite, argillaceous, brown to dark brownish gray, fine, compact, fossiliferous; little shale, greenish gray	58	624
Dolomite, argillaceous, brown to very dark, fine, compact, grading to shale, very dolomitic, very dark, very firm	29	653
Galena —		
Dolomite, light brown, finely crystalline, partly porous, calcite inclusions, disseminated pyrite	47	700
Dolomite, light buff, little chert, white and buff, 819-900	200	900
Platteville —		
Dolomite, light brown, few gray spots, finely crystalline chert, brown to buff, finely pyritic near top (Decorah 900-926; L. E. Workman.)	87	987
Glenwood —		
Sandstone, light buff-gray, medium to fine, incoherent	15	1002
Shale, greenish-gray, firm, pyritic; sandstone, fine, incoherent with interbedded shale, sandy at base	14	1016

Saint Peter —		
Sandstone, white, fine to coarse, incoherent	64	1080
Shale, light green and gray, sandy, weak	5	1085
Prairie du Chien (447 feet thick; top 470 feet below sea level) —		
Shakopee (185 feet thick) —		
Dolomite, white to light buff, finely crystalline, partly oölitic; little chert, light buff, partly oölitic	15	1100
Sandstone, white, fine to medium, incoherent	5	1105
Dolomite, light buff-gray, finely crystalline, partly oölitic	16	1121
Sandstone, fine to medium, white, incoherent	4	1125
Sandstone, same, and dolomite, light buff, slightly sandy interbedded	50	1175
Sandstone, as above, but with white chert	14	1189
Dolomite, light gray; shale, dolomitic, pinkish brown, firm	6	1195
Dolomite, light buff-gray, (light brown at base) very finely crystalline	18	1213
Dolomite, white, finely crystalline, silty; chert, white, oölitic	14	1227
Shale, dolomitic, pinkish brown, firm; dolomite as above but pinkish	21	1248
Dolomite, light buff-gray, very finely crystalline	22	1270
New Richmond (45 feet thick) —		
Sandstone, fine to medium, transparent, incoherent	22	1292
Sandstone, same as above; dolomite as above	23	1315
Oneota (217 feet thick) —		
Dolomite, white, very finely crystalline, few pink and green spots	18	1333
Chert, buff and white; little dolomite as above	5	1338
Dolomite, white, very fine; chert, white	14	1352
Dolomite, same; little chert, white; (few pink and buff spots)	71	1423
Chert, buff and white as above, little dolomite	7	1430
Dolomite, very finely crystalline; little chert, white, some good geode quartz	70	1500
Dolomite, light gray to buff, very finely crystalline, little chert, buff to white	32	1532
Cambrian (1450 feet plus; top 917 feet below sea level) —		
Trempealeau (287 feet thick) —		
Jordan (29 feet thick; from 917 to 946 feet) —		
Sandstone, white, fine to medium, incoherent	19	1551
Sandstone, same but cherty, white chert	10	1561
Lodi and St. Lawrence (258 feet thick; from 946 to 1204) —		
Dolomite, white, finely crystalline, cherty, white chert	23	1584
No sample	9	1593
Sandstone, very fine to fine, incoherent	5	1598
Dolomite, light buff, finely crystalline	58	1656
Dolomite, same, little pyrite	42	1698
Dolomite, same, white chert, porous	32	1730
Dolomite, same, slightly glauconitic, few pink spots	66	1796
Dolomite, same, no chert, partly light gray	23	1819
Franconia (120 feet thick; from 1204 to 1324) —		
Dolomite, argillaceous, glauconitic, sandy, red and gray	6	1825
Sandstone, argillaceous, dolomitic, light gray, partly pink and green, glauconitic, fine	13	1838
Shale, dolomitic, very fine sand, glauconitic, gray, weak	16	1854
Sandstone, argillaceous, light gray, fine, dolomitic, glauconitic, buff-gray, sandy, pyritic, slightly glauconitic	25	1879
Sandstone as above, no dolomite	28	1907
Dolomite, sandy (fine sand), light buff-gray, finely crystalline, slightly glauconitic	10	1917
Shale, weak, gray, dolomitic, sandy, very fine sand	17	1934

Dolomite, very sandy, fine sand, gray, pink and green spots, glauconitic	5	1939
Dresbach:		
Galesville (136 feet thick; from 1324 to 1460) —		
Sandstone, slightly dolomitic, light gray, fine to very coarse, incoherent	14	1953
Sandstone, nearly white, fine to very coarse, incoherent	57	2010
Sandstone, nearly white, fine to very coarse, incoherent; dolomite, light gray, sandy and crystalline	10	2020
Sandstone, nearly white, fine to very coarse, incoherent; dolomite, light gray, sandy and crystalline	45	2065
Sandstone, brownish, very fine and fine, incoherent, few flakes of white chert	10	2075
Eau Claire (225 feet thick; from 1460 to 1685) —		
Sandstone, white to brown, slightly glauconitic, partly coherent	15	2090
Sandstone, white and brown, medium, slightly glauconitic, incoherent	10	2100
Sandstone, slightly dolomitic, and glauconitic, light pinkish gray, very fine to medium, incoherent	5	2105
Sandstone, slightly glauconitic, white to yellow, fine to very fine, incoherent	19	2124
Sandstone, same, but very fine to coarse, partly coherent, little shale, greenish gray, firm	5	2129
Sandstone, pink to red, slightly glauconitic, very fine to coarse, incoherent	8	2137
Sandstone, silty, white, very fine, coherent, glauconitic	8	2145
Shale, silty, red and a little green, flaky, weak	5	2150
Shale, silty, white to pink, very fine, coherent, grading into siltstone	43	2193
Sandstone; shale, gray, partly reddish and green, firm, micaceous	25	2218
Sandstone, dolomitic, light gray, very fine, coherent, glauconitic	17	2235
Sandstone, dolomitic, light gray, few pink spots, fine, coherent, thin flakes of brown material imbedded	10	2245
Sandstone, dolomitic, light gray, fine, mostly incoherent	28	2273
Sandstone, light gray to yellowish, very fine to coarse, incoherent	10	2283
Sandstone, white, medium, incoherent, fragments of dolomitic, sandy, brownish gray, pyritic	17	2300
Mount Simon (682 feet thick; from 1685 to 2367 plus) —		
Sandstone, white to yellow-brown, incoherent	17	2317
Sandstone, white to yellow, fine, and coarse, incoherent	153	2470
Sandstone, pink and yellow, fine and coarse, incoherent	87	2557
Sandstone, white and yellow, coarse and very coarse, incoherent	20	2577
Sandstone, pink and yellow, coarse and very coarse, incoherent	13	2590
Sandstone, yellow and white, fine to coarse, incoherent	55	2645
Sandstone, pink and white, fine to very coarse, incoherent	5	2650
Sandstone, red, fine, incoherent	18	2668
Sandstone, pink, white, yellow, fine to coarse, incoherent, with a few flakes of white chert	14	2682
Sandstone, red, fine to coarse, incoherent	13	2695
Sandstone, white to yellow, very fine to medium, incoherent	10	2705
Sandstone, gray to brown	277	2982

Des Moines County Asylum Well, Burlington

Driller's Log	Thickness in Feet	Depth in Feet
Drift	43	43
Shale, gray, with strips of limestone	47	90
Limestone, Burlington, white	100	190
Shale	4	194
Limestone, gray	21	215
Shale, Kinderhook	303	518
Limestone, Devonian	144	662
Shale	2	664
Limestone	11	675
Shale, Maquoketa	61	736
Limestone, Trenton	182	918

Des Moines Dairy Farm, Polk County

In July 1933 a deep well was completed for the Des Moines Dairy Farm by Thorpe Bros. Well Co. The depth of the well is 770 feet, and its diameters are from 10 to 6 inches. Water was first encountered at 380 feet in limestone with an approximate yield of two gallons per minute. On completion the well yielded 20 gallons per minute with a draw-down of 250 feet. The static head stood at 105 feet. The well is cased with 6-inch steel pipe to 443 feet, and with 4-inch pipe from 443 feet to 770 feet.

Driller's Log	Depth in Feet
Pleistocene:	
Black subsoil	0–5
Yellow clay	5–15
Sand and gravel	15–20
Sea mud	20–45
Pennsylvanian:	
Gray shale	45–100
Red shale	100–125
Light shale	125–150
Brown shale	150–240
Black shale	240–315
Light shale mixed with rock	315–335
Lime (little water, 2.5 gallons per minute)	335–420
Green shale	420–443
Mississippian:	
Shelly limestone	443–460
Shale	460–465
Gray limestone	465–565
Green shale	565–567
Shelly limestone	567–582
Gray shale	582–607
Dark limestone	607–710
Green shale	710–740
Limestone	740–770

Well at Fitch Farm, Polk County

Record of well at Fitch Farm in NE¼ NW¼ section 26, Crocker Township, Polk County. One mile south of Ankeny.

Driller's Log	Depth in Feet
Pleistocene and Recent:	
Drift	92
Pennsylvanian:	
Shale with thin sandstone bands	92–375
Mississippian:	
Meramec: Saint Louis —	
Limestone, brown, sandy	375–510
Limestone, gray, very little shale	510–592
Kinderhook —	
Shale, light gray, with hard bands	592–598

Record of Strata	Depth in Feet
Limestone, dark gray, fine-grained, much opaque light gray flint, some transparent colorless calcite showing good cleavage	512
Limestone, dark gray, some flint, brisk response to acid	525
Limestone, dark gray, in fine chips and grains, some dark gray limy shale	547
Limestone, similar to above, a little lighter gray; flint in small chips, not noticeable	552
Limestone, light gray, fine grains, much flint in small chips	560
Limestone, light gray, and much flint in light gray to white chips	565
Limestone, light gray, some flint and a little dark gray shale	570
Limestone, similar to above but a little darker; flint and quartz chips	575
Limestone, like sample above	580
Limestone, similar to sample at 575	585
Limestone, gray, angular grains, some white flint, some shale	590

Henkel Well, Wapello County

Senator Roy E. Stevens of Ottumwa furnished the following log of a well that was drilled on the Henkel farm, in the west half of section 30, Highland Township, Wapello County. This well is on the upland four miles north of Ottumwa and adjoins the Stevens farm on the east. The elevation of the Des Moines valley at Ottumwa is 645 feet; that of Rutledge, on the Chicago, Milwaukee, St. Paul and Pacific Railroad, is 832 feet on the upland near the Stevens and Henkel farms. The depth of the well is 278 feet. The well furnishes 23 gallons per minute under the pump.

Driller's Log	Thickness in Feet	Depth in Feet
Pleistocene and Recent (72 feet thick; top about 832 feet above sea level) —		
Clay, joint	44	44
Clay, blue	28	72
Pennsylvanian, Des Moines series (124 feet thick; top 760 feet above sea level) —		
Shale, red	4	76
Shale, blue	50	126
Shale, red	6	132
Shale, blue	25	157
Shale, red	28	185
Shale, blue	11	196
Mississippian, Ste. Genevieve and St. Louis (?) formations (penetrated 82 feet; top 636 feet above sea level) —		
Limestone	23	219
Sandstone	4	223

Limestone	15	238
Sandstone	40	278

In the earlier reports of this Survey the "St. Louis" formation included all the Mississippian limestone and sandstones that lie just below the Pennsylvanian strata, or, where these are absent, below the drift. This classification was followed by Leonard in his report on Wapello County in volume XII, the report for 1901. In more recent reports, however, the uppermost Mississippian strata are separated from the St. Louis beds and are classified as Ste. Genevieve or Pella. These beds, in southeastern Iowa, include typically a basal sandstone about 5 or 6 feet thick and fairly thick beds of limestone interbedded with thin shales. These beds are 25 or 30 feet thick. It does not seem reasonable to attempt any subdivision of the Mississippian beds as they were penetrated in the Henkel well. Perhaps the lower beds belong in the St. Louis formation, as the thickness penetrated, 82 feet, seems to be too great for the Ste. Genevieve alone. The uppermost layers of the Ste. Genevieve are, or were, exposed in the floor of the valley of a stream in the north edge of Ottumwa known as Harrows Branch. The exposure was just above the mouth of the valley and was at the same level as the Des Moines valley.

Larson Well, Webster County

This farm well was drilled for Sam Larson by J. J. Becker of Fort Dodge. It is located in the NE¼ section 25, Badger Township, Webster County, two miles north of Industry. It is 459 feet deep, and the static head stands between 40 and 50 feet.

Record of Strata	Depth in Feet
Shale, pink to red and light blue, limy, gritty	116
Limestone, gray, crystalline, responds readily to cold acid; a little shale, darker gray	140
Limestone, gray, sample in fine grains and powder, with much sand in fine rounded grains many of which are frosted	145
Limestone, a little darker gray and very fine-textured, sample in somewhat coarser grains than that at 145 but still with much sand	160
Limestone, light gray, finely granular, sample in fine grains, much fine sand, 2 samples	170–180
Limestone, dark gray, finely granular sample in coarse grains and chips; some sand, 190 and 200; fine grains and powder at 210 and 220; 4 samples	190–220
Shale, blue-gray, fine-textured; and limestone, gray, both in chips and powder; 230; more shale at 240 and 250; more limestone at 260 and 270; 5 samples	230–270
Limestone, gray, finely oölitic (round, egg-like nodules) with almost colorless cement. Much shale, like that above, may be fallen from above	290

Limestone, light gray, oölitic texture not prominent; much shale. Limestone in fine grains at 340, no chips; a little coarser, sugary at 350 to 380; sugary and somewhat oölitic at 390; fine grained at 400 and 410; buff colored, sample in very fine grains and powder at 420; grains tan colored and sugary at 430, some white flakes; darker gray and finely granular at 440 and 450; lighter gray but otherwise similar at 459; 17 samples -- 300–459

East of Mitchellville, Well No. 1

In October 1932 a well was completed for WHO Radio Station near Mitchellville by Thorpe Bros. Well Co. It is located in the NE¼ sec. 13, township 79 N., R. 22 W., Jasper County. The well was drilled to a depth of 1,150 feet, with diameters from 10 to 5 inches. The static head stood at 150 feet below surface. The well yielded 27 gallons per minute with a draw-down of 330 feet. Water was first encountered at 6 feet in clay, with an approximate yield of 3 gallons per minute. The casing is as follows: 130 feet of 10-inch heavy pipe from the surface to 130 feet; 255 feet of 8-inch steel pipe from 110 to 365 feet, perforated at water zones; 396 feet of 6-inch pipe from 344 to 740 feet perforated at water zones; 197 feet of 5-inch pipe from 718 to 915 feet, perforated at water zones. The elevation at the curb is approximately 970 feet.

Driller's Log	Thickness in Feet	Depth in Feet
Pleistocene and Recent (85 feet thick):		
Soil	3	3
Clay	67	70
Sand	3	73
Clay, hard	5	78
Clay, sandy	7	85
Pennsylvanian (215 feet thick):		
Shale	215	300
Mississippian (370 feet thick):		
Limestone	45	345
Shale	5	350
Limestone	40	390
Shale and lime streaks	115	505
Limestone, hard	65	570
Limestone, and shale streaks	35	605
Shale	65	670
Devonian (115 feet thick):		
Limestone	90	760
Shale	25	785
Silurian (365 feet thick):		
Limestone	80	865
Limestone, soft, sandy	10	875
Limestone	275	1150

Reilly Well, Webster County

This well is located three-fourths mile northwest of the County Farm, Fort Dodge, in section 4, Elkhorn Township. The well was dug for Miss Anna Reilly and is 246 feet deep. The diameter of the well is 5 inches, and it is cased with 5-inch S & S casing to 198 feet. The first water was found at a depth of 230 feet. The static level is at 118 feet below curb. The altitude of the well is 1,140 feet, about 120 feet above the river. Samples of the drillings were received from J. J. Becker, 1930.

Record of Strata	Depth in Feet
Pleistocene (90 feet thick; top 1140 feet above sea level) —	
Glacial drift clay and sand, gray	40
Glacial drift clay, yellow, pebbly	60
Glacial drift clay, very sandy, yellow, not much lime	75
Glacial drift clay, similar to that above; and shale, black	90
Pennsylvanian (100 feet thick; top 1,050 feet) —	
Shale, black and gray, fine textured, limy	100
Shale, similar to above	105
Shale, black, smooth	110
Shale, gray, finely gritty, some iron pyrite	120
Shale, gray, reddish, yellow, slightly limy	130
Shale, red, limy	140
Shale, similar to above	150
Shale, like above, limy, some light blue-gray	160
Shale, mostly blue-gray, some red, limy	170
Shale, mixed red and light blue, finely sandy	180
Shale, chiefly greenish blue and red, finely sandy, limy	190
The strata from 90 to 190 feet belong to the Coal Measures.	
Mississippian (56 feet; top 950 feet) —	
Limestone, light gray, in powder and sand, some iron pyrite and some silica in form of chert	198
Limestone, light gray, in chips and powder, fine-grained	205
Limestone, light gray, in fine powder, with much clear colorless sand in fine rounded smooth grains	210
Sandstone, in fine clear grains; with a little limestone, light gray	220
Limestone, gray in chips and powder, with some white clay and fine clear sand grains	230
Water came in here	
Sandstone, fine clear grains, some limestone	240
Sandstone, very fine clear grains, little limestone	246
The limestones and sandstones belong to the St. Louis stage.	

Well of John Scripps, Webster County

This well was drilled for John Scripps by J. J. Becker of Fort Dodge in May 1931. The location is NE¼ section 35, Douglas Township, Webster County, 1,650 feet from the north line and 1,250 feet from the east line of section 35. The depth is 486 feet, and the static head stands at about 60 feet. The well is five inches in diameter and yields about 7½ gallons per minute with no draw-down. No record was kept of the first 148 feet.

Driller's Log	Thickness in Feet	Depth in Feet
Permian:		
Gypsum	10 or 12	148
Mississippian:		
Clay, red	52	200
Rock	50	250

Rock, loose	37	287
Limestone	113	400
Limestone, light gray, finely crystalline, effervesces freely in acid	10	410
Limestone, light buff, very finely granular	10	420
Limestone, very similar to that at 410	10	430
Limestone, like that at 430	10	440
Limestone, like sample above	10	450
Limestone, light buff, very fine-grained, effervesces slowly in cold acid	10	460
Limestone, like sample above	10	470
Limestone, as above	16	486

Winterset, Madison County

A prospect hole for coal was dug seven miles north of Winterset on Highway 169. The depth is 195 feet. It was dug by F. S. McCutcheon of Des Moines.

Driller's Log	Thickness in Feet	Depth in Feet
Pleistocene and Recent:		
Drift, yellow	11	11
Gravel	5	16
Drift, gray	72	88
Wood and boulders in layers	4	92
Pennsylvanian:		
Rock, hard	2	94
Limestone, "Missouri"	29	123
Shale, light gray	9	132
Limestone	3	135
Shale, dark	4	139
Shale, gray	11	150
Shale, dark	2	152
Coal	½	152½
Shale, gray	5	157½
Sandstone, hard	4	161½
Shale, light gray	10	171½
Rock, hard	1	172½
Shale, gray	18½	191
Sandstone	1½	192½
Shale, dark, and coal	1½	194
Shale, light	1	195

Clear Lake State Park, Cerro Gordo County

This well was drilled by McCutcheon Well Co. of Des Moines and was completed April 29, 1933. The depth of the well is 160 feet, and it is cased with 125 feet of 6-inch Standard casing, which is driven one foot into solid limestone. Sandy broken limestone was found from 135 to 152 feet, and shale from 152 to 160 feet. The head of water in the completed well was 26 feet below curb. When pumping 15 gallons per minute the draw-down was 6 feet, and when pumping 25 gallons per minute the draw-down was 8 feet. The elevation is approximately the same as that of the railway station, which is 1,236 feet. The elevation at Mason City is 1,130 feet. At Mason City the bedrock is practically at the surface, while at Clear Lake the drift extends to a depth of 107 feet. This seems to indicate that the surface of the bedrock is practically horizontal between the two towns, while the surface rises one hundred feet at Clear Lake.

Driller's Log	Thickness in Feet	Depth in Feet
Pleistocene and Recent:		
Drift, yellow	6	6
Sand, coarse	4	10
Sand, sugary	22	32
Drift, gray	75	107
Devonian:		
Shale, yellow	4	111
Limestone, broken, drilled easily, pushed up into pipe, water	6	117
Shale, yellow, very finely sandy	4	121
Shale, gray, hard bands	3	124
Limestone	28	152
Shale, light	8	160

Record of Strata	Depth in Feet
Sand, grains irregular in size, ranging from fine to one-half inch, mostly light gray, some dark green, red, almost black; rounded; vigorous response to acid, indicating lime. Evidently lake sand	10
Sand, fine, uniform in texture, except for a few pebbles, tan-colored; much lime	20
Sand, very fine, or finely gritty clay, tan-colored, texture uniform; brisk response to acid but much finely sandy residue	30
Clay, gray, gritty, pebbly, strongly limy; typical unleached Wisconsin glacial till	40, 50, 60
Clay, very similar to sample above	70, 80
Clay, similar to samples above	90
Clay, slightly more yellowish than samples above, texture similar; only slight response to acid, indicating less lime	100
Clay, yellowish or greenish gray, very fine-textured, a few black pebbles, some yellow iron concretions; practically no reaction with acid. Evidently mostly preglacial shale	110
Sand, mostly dark gray angular limestone pebbles, mostly less than one-sixteenth inch in upper part, as large as one-eighth inch in lower part. Driller says this rock drilled very readily but was evidently vesicular, porous limestone, not gravel; water rose rapidly within 40 feet of curb. Casing would not sink faster than the drill	111–117
Shale, yellowish green, fine- and uniform-grained, not pebbly like glacial drift; not limy, no reaction with acid. Evidently this shale and the limestone above it are the upper Devonian beds that outcrop at Mason City	117–119
Limestone, dolomitic, gray, sugary texture, in coarse chips up to one-fourth inch in diameter; effervescence slow in cold acid, brisk in hot acid. Some clear glassy quartz chips, some black, not glassy, hard	125
Limestone, similar to above, chips up to one-half inch in diameter	135
Limestone, similar to samples above, in coarse powder and small chips	145
Limestone, grading into shale, much clay residue, medium gray; the harder chips are sugary	150
Shale, light gray, very fine texture, much lime	155

Dolliver State Park Well, Webster County

This well yields 32 gallons per minute with a pressure of 19 pounds. The curb of the well is 40 feet above the Des Moines River. Most of the supply of water comes from the bottom. This well was drilled by F. S. McCutcheon of Des Moines in April, 1931.

Record of Strata	Depth in Feet
Mississippian:	
Limestone, light tan, in coarse chips, brisk effervescence in acid	112
Sandstone, light gray, very fine and even in grain, glassy or white; a little reaction with acid showing presence of some lime	120
Limestone, dolomitic, gray, rather fine-grained, almost entirely soluble in hot acid	130
Limestone, darker gray, finely granular, much residue after treatment in hot acid	200
Limestone, gray, in fine grains and powder, nearly all soluble in acid	220
Limestone, in somewhat coarser chips, otherwise similar	250
Limestone, similar to above; a large fragment consists of red and bluish white chert, similar to some seen in Dallas Center well at 650 feet	275
Limestone, light gray, brisk response to acid, a fragment of crinoid stem, in small chips	300
Limestone, in fine white and light gray grains, nearly all soluble in acid	340
Limestone, dark gray, finely granular, mostly soluble in acid; some chips of fine-grained sandstone	360–370
Limestone, light gray, in chips and granules which respond briskly to acid	375

Lacey-Keosauqua State Park, Van Buren County, Well No. 2

This well was located about six feet south of Drilled Well No. 1 and about 100 feet south of the southeast corner of the State Park Lodge. It was finished about June 1, 1932. The elevation of the drilling curb is 720 feet, and the curb of the finished well is 714 feet. A 10-inch casing extends from the top of the well to 104 feet below drilling curb with a driving shoe at the bottom. There is a lead packer at the top of the 8-inch casing and a burlap packing at 187 feet below curb. The 8-inch casing is perforated between depth of 188 and 207 feet. There is no casing in the well below the bottom of the 8-inch casing. The depth of the well is 455 feet and the yield is 13 gallons per minute. It was drilled by Thorpe Bros. Well Co. of Des Moines.

Driller's Log	Depth in Feet
Pleistocene:	
Clay, yellow; sandy between 30 and 40 feet	0–100
Pennsylvanian:	
Shale, black, with some coal	100–120
Mississippian:	
Ste. Genevieve —	
Limestone, white	120–139
Shale, light	139–148
Sandstone	148–150
Limestone	150–155
Shale, light	155–157
St. Louis —	
Limestone, white and gray	157–170
Limestone, magnesian (dolomite), containing water	170–202

Warsaw—	
Shale, gray, with some gray limestone, containing water in lower interval	202–259
Keokuk (Geode beds)—	
Limestone, gray; shale with chalcedonic silica	259–270
Limestone, gray	270–280
Shale, gray	280–283
Keokuk—	
Limestone and shale, gray	283–301
Shale, light gray, containing water	301–305
Limestone, with chert	301–365
Limestone, buff, porous, containing water	365–373
Burlington—	
Limestone, light, carrying water in lower interval	365–425
Kinderhook—	
Limestone, gray	425–443
Shale, gray	443–455

Pammel State Park, Madison County

This well was drilled to a depth of 696 feet, and the altitude at the curb is 955 feet. A 6-inch casing was put in to a depth of 398 feet; 178 feet of 5-inch casing extends from 377 to 555 feet; 174 feet of 5-inch casing extends from 514 to 688 feet. The static water level is 70 feet from the surface. Pumping 10 gallons per minute resulted in a draw-down 140 feet from the surface; pumping 15 gallons per minute lowered the water 177 feet from the surface; pumping 18 gallons per minute lowered the water to 207 feet from the surface.

Driller's Log	Thickness in Feet	Depth in Feet
Drift	17	17
Limestone	7	24
Shale, red	66	90
Rock, hard brown	2	92
Gray and black shale	32	124
Limestone	8	132
Shale, gray, with hard bands	68	200
Sandy lime rock	3	203
Gray shale	58	261
Gray sand shale	8	269
Gray shale	24	293
Hard bands	2	295
Gray shale	20	315
Sand rock	5	320
Red shale	4	324
Gray shale	9	333
Sand shale	5	338
Sand rock	2	340
Gray shale hard bands	12	352
Red shale	48	400
Gray and black shale	10	410
Coal	1	411
Mixed shale	52	463
Sandstone	20	483
Gray and dark shale	31	514
Coal	2	516
Light shale	4	520
Dark shale	29	549

Dark sand shale with sand rock bands	71	620
Shale and hard bands	40	660
White sand rock	32	692
Light gray shale	4	696

Record of Strata	Depth in Feet
Pennsylvanian:	
Limestone, light gray, coarse chips, finely granular	124–132
Limestone, similar to sample above	201–205
Limestone, darker gray than sample above, response to cold acid slight, stronger in hot acid, suggesting dolomite	317–322
Sandstone, light gray, fine-grained, tiny specks of white mica	340–342
Sandstone, similar to above, except that sample is all in powder	465–473
Sandstone, like sample above, also a little shale	473–480
Sandstone, dark gray, very fine and uniform; a little mica; a good deal of dark gray shale; no lime in shale, some in sandstone	665–675
Sandstone, like sample above	675–685
Mississippian:	
Sandstone, gray, fine, in chips; and limestone, gray, granular, quick response to acid (This seems to be the top of the St. Louis limestone)	685–692

Rush Lake State Park, Palo Alto County

The Rush Lake State Park well, in Booth Township, was drilled by McCutcheon Well Co. of Des Moines. It was drilled to a depth of 345 feet and finished in white sand. The well was cased with 4½-inch wrought steel standard weight pipe from the surface to 340 feet. A 4½-inch by 5 foot No. 14 slot Johnson Well Screen was fitted with a 17-foot length of 3-inch well casing threaded into shoe at bottom of screen, and collar was welded at top of screen, the pipe being perforated in side of screen. The 3-inch casing part of screen assembly is fitted at top with a 3½-inch standard pipe coupling turned to fit snugly inside of the 4½-inch well casing.

The water headed 126 feet below the surface, and it tested 30 gallons plus per minute.

Driller's Log	Thickness in Feet	Depth in Feet
Pleistocene and Recent:		
Soil and clay	20	20
Drift, gray	60	80
Sand, in streaks	30	110
Drift, gray	105	215
Drift, hard, yellow	25	240
Drift, bluish gray	90	330
Cretaceous:		
Sand, white		
Sandstone, Dakota?	15	345

Clarinda, Page County

On November 5, 1928, Iowa's First Oil Developing Company of Clarinda began the drilling of Wilson No. 1 oil prospect hole. It is on the bottom lands of Nodaway River four miles south of Clarinda, on the Wilson farm, in the southeast quarter, southeast quarter, section 24, T. 68 N., R. 37 W., in Page County. The drillers were G. H. Rose and Son of Maryville, Missouri. The well was begun with a diameter of 15½ inches and was lined with 15½-inch casing to 25 feet. Thence the hole is 12½ inches in diameter to 506 feet and is cased with 12½-inch pipe to that depth. Below this point the diameter is 10 inches to 912 feet with 10-inch casing. At 912 feet the well was reduced to 8 inches with casing of the same size, and at a greater depth was reduced to 6⅝ inches.

A set of samples was furnished the Iowa Geological Survey by the driller. The samples were studied also by several geologists of Kansas and Oklahoma, among them Mr. Anthony Folger and Mrs. Fanny C. Edson. Many of their findings are incorporated in this record.

Record of strata of Wilson No. 1 oil prospect of Iowa's First Oil Developing Co., Clarinda.

	Depth in Feet
Pleistocene and Recent (25 feet thick; top about 988 feet above sea level):	
Glacial clay, yellow, sandy, noncalcareous	0–10
Pennsylvanian: Missouri series (690 feet thick; top 963 feet above sea level) —	
Limestone, gray, fine-textured, in light gray powder and chips, responds readily to acid; 25 to 31 and	33–36
Shale, blue, gray, drab, sandy	36–40
Shale, dark gray, calcareous, some small clear specks may be selenite (gypsum)	51–60
Limestone, light gray, finely crystalline	70–80
Limestone, dark gray, finely granular, some Fusulina	80–83
Limestone, or limy shale, in fine strongly calcareous concreted powder, light gray, some sand grains which may be from above	83–94
Limestone, light gray, fine-grained	94–102
Shale, bluish gray, very fine-grained, very slightly calcareous	102–140
Limestone, dark gray, very finely granular	140–144
Limestone, light gray, finely sugary, many small specks of pyrite	144–150
Shale, very smooth feel, rather light gray, noncalcareous	150–160
Limestone, light gray, finely sugary	160–165
Shale, dark gray, very finely gritty, limy; 2 samples	340–349
Limestone, dark gray, very fine-grained	353
Shale, bluish, purplish, fine-grained, limy; 4 samples	355–372
Limestone, gray, in fine powder and grains. Label says "salt water." Sample of water is decidedly salty	385–392
Shale, gray, limy, chips of limestone at 435; some bluish and whitish at 450; 6 samples	418–450
Limestone, light gray, finely sugary, some darker flakes are hard shale like that at 440; "top of lime below No. 27"	450
Shale, light and dark gray, finely gritty, limy; 3 samples	452–460
Limestone, dark gray, soft, very fine-grained, much very fine dark clay residue	462–465
Shale, dark gray, fine-textured, very little lime	465–467
Limestone, light gray, finely sugary	467–470
Limestone, white and light gray, in fine powder which is almost entirely soluble in cold acid	470–473
Limestone, gray, sugary texture; 2 samples	473–477
Limestone, blue-gray, fine texture	477–480

Limestone, gray, finely sugary texture	480–484
Limestone, dark gray, almost black when wet, finely sugary texture, some shale; 2 samples	484–493
Shale, finely gritty, dark gray, limy; sand grains 495–499; 3 samples	493–499
Shale, light gray, very finely gritty, limy; 2 samples	499–504
Limestone, light gray, in coarse powder, effervesces very freely in cold acid, some residue probably siliceous	504–505
Shale, limy, dark gray, soft, very smooth feel, also dark green, very finely granular, hard	505–510
Shale, light gray, finely gritty, limy	510–515
Limestone, light gray, in chips and powder, briskly effervescent, a very little light colored residue	515–519
Limestone, light gray, in grains and chips, packed with Fusulina and spines	519–523
Shale, dark gray, gritty with very fine sand; grains of limestone mingled in shale	523–530
Limestone, dark gray, somewhat shaly, granular, several specimens of fusulinids	530–535
Shale, dark gray, very finely gritty, quite limy	535–540
Limestone, dark gray, crystalline-granular	540–545
Limestone, dark gray, fragments oölitic, strongly effervescent, some dark residue	545–550
Limestone, light gray, crystalline-granular, in grains and chips, some of which contain Fusulina and other light colored masses, numerous black specks, 565-571; 4 samples	550–571
Shale, dark gray, finely gritty, limy	571–577
Limestone, dark gray, in small chips; some black fragments which do not respond to acid probably are black shale	577–581
Limestone, light gray, granular, readily effervescent; darker gray, 594–604; 4 samples	581–604
Shale, black, hard, laminated, numerous specks, probably mica, on parting planes	604–610
Shale, very limy, or limestone, shaly, dark gray, ready response to acid, but much dark very finely divided residue	610–615
Limestone, light gray, fine-grained	615–621
Limestone, light gray, sugary texture	621–627
Limestone, similar to above; and shale, black, hard, very fine-textured, mica specks	627–634
Shale, black, similar to above, noncalcareous, some reaction from mingled limy matter	634–640
Shale, light gray, noncalcareous, finely gritty, hard	640–645
Limestone, light gray, crystalline; 2 samples	645–652
Shale, gray, hard, finely gritty, nonlaminated	652–655
Limestone, light gray, similar to that at 645–652	655–660
Shale, gray, noncalcareous, hard, some effervescence from powder in sample	660–665
Limestone, brown, crystalline, briskly effervescent; a little dark residue perhaps silica	665–670
Limestone, brown, with large clay content; and shale, greenish, fine-textured, limy, hard; much of sample is in powder concreted to hard masses; 2 samples	670–680
Limestone and shale, greenish gray, limestone subcrystalline, shale finely gritty, rather hard	680–685
Shale, gray, fairly hard, very fine-textured, very small lime content; some gray powder is briskly effervescent	685–691
Limestone, dark gray, fine-grained, with large clay content	691–695
Limestone, gray; and shale, dark gray and brown, slightly calcareous	695–702
Limestone, in white and gray crystalline granules very freely responsive to cold HCl; shale, blue-gray, chocolate-colored, hard, not limy; pyrite; 2 samples	702–712
Limestone, some clayey, some granular, readily soluble in cold HCl, light to dark gray; much shale, soft, greenish, reddish, gray, limy	712–715

Pennsylvanian: Des Moines series (895 feet thick; top 273 feet above sea level) —

Shale, gray and chocolate-colored, finely gritty, somewhat calcareous; samples contain some fragments of bright shiny brittle coal at 735–741 (bag says "Hit coal at 738–743, no cap rock") and at 741–745; 4 samples -- 715–745
Limestone, gray, clayey, fine-grained, in angular chips and flakes, brisk effervescence; shale, gray, finely gritty, perhaps one-fourth of sample 745–748, one-half of samples 748–750 and 750–755, some dark gray and brown in second sample; 3 samples ------------ 745–755
Shale, black and dark gray, laminated, strongly calcareous above, less below; 5 samples -- 755–785
Shale, dark brown, hard, slightly limy; some fragments of hard gray finely granular limestone ------------------------------------ 785–791
Limestone, light gray, fine-grained, very brisk effervescence, slight residue; shale, dark gray, limy, carbon streaks, mica specks; 4 samples -- 791–804
Shale, light gray, soft, calcareous, some flakes of dark gray limestone 804–808
Limestone, dark gray, hard; shale, dark gray, hard, limy; darker 822–827; probably some differences were detected by the driller, as noted in his log, but the samples are very similar; 7 samples -- 808–841
Shale, light and dark gray, some calcareous, some not, very fine-textured; 5 samples -- 841–876
Shale, similar to above, noncalcareous; sandstone, fine, light gray, noncalcareous; 2 samples ------------------------------------ 876–885
Shale, black, finely laminated, noncalcareous, some in large flakes; limestone, light gray, fine-textured ------------------------ 885–894
Shale, gray, very fine-textured, mostly noncalcareous; calcareous with some dark brown noncalcareous 904–906, mostly dark brown, noncalcareous 906–915, some gray limestone 915–920, somewhat calcareous 924–928, almost black 928–955, a few fragments limestone and sandstone 955–964; 18 samples ---------------------- 894–990
Sandstone, medium gray, composed of fine subangular clear grains of quartz, numerous white mica specks; shale, very dark gray, fine-grained, a few large chips 990-1000, abundant small chips 1000–1005, 1010–1018; 5 samples ---------------------------- 990–1021
Sandstone, like that of sample above; shale, a few dark gray flakes, noncalcareous, but mostly in concreted masses of light gray, limy, fine-textured material ---------------------------------1021–1025
Shale, light and dark as above but noncalcareous; a few grains of quartz sand, perhaps from above -----------------------------1025–1034
Shale, light tan to light blue, gritty, calcareous; limestone, some small light gray chips --1034–1044
Limestone, light gray, fine-grained, briskly effervescent in cold HCl; shale, light and dark gray, very fine-textured, noncalcareous; residue fine, hard, whitish grains probably chert --------------1044–1050
Shale, black, very fine-textured; a few fragments of bright coal (log says "Coal, very inferior, 1044–1057"); powder of sample gives some reaction with acid, residue includes chert ----------------1050–1057
Shale, as above; sandstone, gray, fine-grained, in grains and small pebbles; a few grains of limestone ----------------------------1057–1065
Shale, light to dark gray, finely gritty, calcareous 1065–1075, mostly noncalcareous below; some sandstone 1113–1119; thin films and lenses of limestone 1119–1125; concreted calcareous masses 1130–1140, quartz sand 1145–1170, 1193–1206; nearly black 1206–1245; 25 samples --1065–1245
Sandstone, medium gray, composed of fine subangular clear quartz grains; some bluish black shale, nearly gritless ---------------1245–1251
Shale and sandstone as above, in approximately equal amounts ------1251–1265
Shale, dark gray, similar to above, no sandstone; calcareous 1287–1292; some samples concreted into hard masses, some in small chips; powder slightly calcareous 1320–1330, strongly so 1340–1350, but chips noncalcareous; black 1345–1350, dark tan 1350–1357, mixed black and tan 1364–1371, tan 1371–1377; 20 samples ------------1265–1384
Shale, gray and black, former finely gritty, latter almost gritless, all noncalcareous; sandstone, similar to those above, nearly equal

to shale in amount; powder contains some effervescent particles; 4 samples ---------- 1384–1410

Shale, very dark gray, finely gritty, noncalcareous, pyrite, a few small chips of coal 1417–1422; in small chips and grains, with some sand in fine rounded to subangular grains 1422–1427; more sandstone, in small gray pebbles 1427–1433; 4 samples ---------- 1410–1433

Sandstone, gray, grains fine to very fine, subangular to rounded, clear to translucent, a few white; a very little black shale 1433–1435; tan, grains more even in size 1435–1461; somewhat calcareous 1468–1474; some black shale and pyrite 1490–1495; 8 samples ---------- 1433–1495

Shale, black and dark gray, in small chips, almost noncalcareous, some pyrite; sandstone, grains similar to those in sandstones above, small amounts 1495–1503, equal to shale 1503–1512; mostly black shale, with much pyrite 1512–1530; 4 samples ---------- 1495–1530

Shale, very dark gray, fine-textured, smooth feel, no lime; sand in fine frosted grains of irregular sizes; some concreted fragments of whitish powder which effervesces freely in acid but leaves a large residue of very fine material, probably "gypsum" of driller. Mostly shale at 1540 and 1563–1568; mostly sand at 1540–1545 and 1568–1575; about equal, 1545–1563; some fragments of shale show small pockets of fine sand and lime. Six samples ---------- 1540–1575

Shale and limestone, dark gray, shale finely gritty, some fragments black ---------- 1575–1580

Mississippian (406 feet thick; top 622 feet below sea level):

Meramec and Osage (315 feet thick) —

Limestone, light gray, finely crystalline; some dark gray shale in small fragments; some sand like that above (Driller's log shows that limestone begins at 1,610 feet) ---------- 1610–1614

Limestone, gray, very finely crystalline, in powder to small chips, response to acid prompt and long continued, 1614–1624; in powder and fine grains, with much sand in fine rounded frosted grains, 1624–1642; somewhat coarser granular chips below 1642 feet; darker gray, some chert, not much sand, 1647–1657; 9 samples ---------- 1614–1657

Limestone, dark gray, very finely granular, some pyrite, ready response to acid; 2 samples ---------- 1657–1667

Limestone, bluish gray, in rounded chips and granules, a good deal of powder of gray shale ---------- 1667–1674

Limestone, similar to above except for absence of shale, in small angular subcrystalline fragments ---------- 1674–1680

Limestone, pepper and salt gray, in fine angular crystalline fragments, effervescence fairly rapid, fine white siliceous residue, 1680–1689; finer, rather slow reaction in acid, 1689–1697; somewhat darker gray, some clayey material, 1697–1702; prompt reaction, 1702–1712; brownish cast, 1702–1725; a large amount of white chert, 1721–1734; somewhat lighter gray and coarser, 1725–1729; some clay, less flint, 1729–1740; pepper and salt gray, clean, with much flint, sand grains and crystalline silica, 1740–1749; finer and more uniform, sample nearly all silica, 1749–1754; 16 samples ---------- 1680–1754

Limestone, similar to above, rather dark gray, with much light gray chert and some darker insoluble fragments; a little pyrite; limestone finely sugary texture; a little finer, lighter and more uniform of grain, 1765–1769, 1778–1792; larger chips of light chert, 1773–1778, 1792–1796; some chips of greenish shale, 1773–1787; chert same dark gray color as limestone, 1805–1810; nearly all chert and crystalline silica, 1810–1827; 15 samples ---------- 1754–1827

Shale and limestone; shale dark greenish, gritty, noncalcareous, in chips and powder; limestone gray, in powder and small chips, briskly effervescent; 3 samples ---------- 1827–1842

Limestone and shale, similar to above, except that limestone is predominant; chert abundant ---------- 1842–1845

Limestone, rather light gray, briskly effervescent, very finely granular; much chert, a few small chips of green shale, in fine grains, 1845–1853; somewhat more irregular sizes, pepper and salt gray with light chert and darker gray limestone, 1853–1862; finer, more uniform grains, 1862–1875; somewhat clayey, 1871–1879; chert in irregular chips, 1879–1885, 1890–1896; all fine and uniform, 1885–1890; brownish cast, much insoluble residue, partly silica, partly clay, 1896–1904; 13 samples ---------- 1845–1904

Shale, in green chips; limestone, in gray powder that effervesces rapidly; probably about equal parts ---------- 1904–1908

Limestone, light gray chips and dark gray grains and powder; shale, in green chips, subordinate in quantity ---------- 1908–1912

Limestone, light gray, in small grains, brisk effervescence, some siliceous residue; a few chips of green shale, possibly from above ---------- 1912–1916

Limestone, dark gray chips and powder, some flint; shale in gray chips and powder; 2 samples ---------- 1916–1925

Mississippian-Kinderhook (91 feet thick; top 937 feet below sea level) —

Shale, light bluish gray, very fine-textured, strongly calcareous; less calcareous below 1943; dark gray, 1950–1955; same as at 1925 but not so highly calcareous, 1959–1968; 10 samples ---------- 1925–1968

Shale, mostly light brick red, very fine-textured, strongly calcareous; dark brick red, 1976–1979; powder of all shale samples is more calcareous than lumps; 3 samples ---------- 1968–1979

Shale, gray to blue-gray, fine-textured, noncalcareous; limestone, light gray, briskly effervescent, crystalline; apparently about equal, 1979–1988; mostly shale, 1988–1996; practically all shale, light blue, calcareous, 1996–2000; blue-gray, hard, fine-textured, chips show no reaction in dilute HCl, but when powdered they respond fairly briskly, as does the powder of all samples, 2000–2004; at 2004–2010 chips show no reaction, even when powdered and heated; somewhat calcareous, 2010–2016; 9 samples ---------- 1979–2016

Devonian (85 feet thick; top 1,028 feet below sea level):

Limestone, with some shale, 2016–2021; light gray, crystalline, in chips and powder, with some blue flint, 2021–2030; 3 samples ---------- 2016–2030

Limestone, rather dark greenish gray, finely sugary texture, ready effervescence in cold HCl; much dark greenish shale; all in chips and powder; a greater proportion of shale at 2047–2054; not many shale chips at 2068–2173 but much insoluble residue after treatment with acid; sample nearly all in grains, 2073–2076; many flakes of gray shale, 2076–2086, 2094–2097; numerous fragments of calcite may represent "gypsum" of driller's log; sample darker gray, 2081–2090; some light gray limy concreted masses, 2090–2094 (Mrs. Edson's slide 2090–2094 shows crinoid stems, some fragments of pitted surface, and other fossil); 15 samples ---------- 2034–2097

Limestone, very light gray, in fine crystalline granules which react vigorously in cold acid, more so in hot acid, and all of which are soluble, leaving only a little very fine dark residue; much iron pyrite ---------- 2097–2101

Silurian: Niagaran series (454 feet thick; top 1113 feet below sea level) —

Limestone, dolomitic, dark gray, finely crystalline, slowly responsive to cold acid but briskly so on heating; some white calcite; some dark fine residue; some chips of greenish shale may be from above; 3 samples ---------- 2101–2116

Limestone, lighter gray, with much residue in chips, perhaps of chert; 3 samples ---------- 2116–2130

Dolomite, dark brownish, finely crystalline, in small grains to fine sand which responds but slowly to cold acid but very briskly to hot acid; a few fragments of white calcite; in fine brown sand with fine white residual grains, 2144–2151; somewhat lighter sand with more fine silica, 2151–2161; residue much fine brownish silica, 2161–2175; only a little white siliceous residue, 2180–2186; lighter buff (finer, very little residue, 2198–2205; at 2212–2215 numerous flakes of bright black material, brown on exposed surfaces, does not melt or burn in flame but grows red and then returns to original color; light gray, much residue, 2215–2221; dark brown, little residue, 2221–2223; light gray, little residue, 2223–2225; dark gray, little residue, 2225–2232; lighter gray, little residue, some rounded sand grains, 2232–2251. No gypsum observed in any samples; 24 samples 2130–2251

Dolomite, dark gray and finely granular, light gray and more finely granular, all responding slowly to cold acid, briskly to hot acid; some white calcite which is strongly effervescent; a good deal of dark green shale as in many of the samples above. All in fragments one-eighth inch in diameter to fine powder. Residue is mostly shale with a little fine white powder which probably is siliceous, 2251–2258; more uniformly fine powder, some rounded sand grains, 2258–2263; a little coarser again, 2263–2269; more of the light gray dolomite, giving pepper and salt aspect, 2269–2275; more than half shale, remainder chiefly light gray dolomite, 2280–2290; 7 samples 2251–2290

Shale, dark green, as above, with perhaps one-fourth light gray dolomite, 2290–2295; about half shale, most of remainder red-brown dolomite and smaller part light gray dolomite, in fragments one sixteenth inch or less in diameter, 2295–2300; similar composition but in uniformly fine grains, 2300–2307; 3 samples 2290–2307

Dolomite, rather light gray, in very fine subangular crystalline granules; a little greenish shale; considerable residue of fine white silica. Bag says "Unable to catch cuttings for 15 feet, 2307–2323." Lighter gray, almost no shale, nearly all soluble in acid, 2321–2340; still lighter and flourlike, almost entirely soluble, 2340–2374; sample at 2374–2380 is similar except that it yields much dark residue, which is very light and flocculent and in this condition occupies twice the bulk of the original sample; a little coarser, 2390–2420; sample mostly silica in small clear angular grains, 2395–2400; finer and more flourlike, a little cherty residue, 2420–2430. Evidently the rock from 2307–2430 is a unit, as all samples are similar except for minor details as noted; 24 samples 2307–2430

Dolomite, light gray, in very fine granules, slow reaction in cold acid, very similar to samples above, a little siliceous residue; finer and more flourlike, small residue, 2445–2449; large fine white residue, 2451–2455; concreted masses of light gray flourlike material and slightly coarser, darker gray, nonconcreted dolomitic sand, "could not catch cuttings at 2460," 2455–2465; much cherty residue, 2479–2484; slightly darker and coarser, 2500 to 2505; grains sugary, 2520–2528; mixture of light and dark gray fragments, much light gray chert, 2547–2551; dark gray, much chert, all in small grains, 2551 to 2555. All the above samples are similar to each other as well as to those from 2307–2430; 27 samples 2430–2555

Ordovician:

Maquoketa formation (40 feet thick; top 1,567 feet below sea level) —

Shale, light bluish gray powder, very fine textured; with limestone in fine grains which give the mass a finely gritty feel (Mrs. Edson's slide 2555–2581 shows bryozoa, round plates with boss in center.) .2555–2560

Shale, dark green, in large chips which are decidedly gritty between the teeth. In hot acid the chips show some reaction and disintegrate into small insoluble fragments. This sample is more argillaceous and siliceous than the one above 2560–2565

Shale, medium green, finely gritty, some reaction in hot acid, numerous grains of pyrite. In dry powder and small chips, some concreted masses, 2565–2568; grayish, otherwise similar, 2568–2571, bag says "Taken off end of bit;" 2 samples 2565–2571

Shale and limestone mingled, shale in small green chips and flakes which react somewhat in hot acid; limestone in subangular sugary granules which effervesce strongly in hot acid but only slightly in cold acid, showing that they are dolomitic. The two elements are present in about equal parts, 2571–2575; similar, but more dolomite, 2575–2578; 2 samples 2571–2578

Dolomite, light gray, in fine powder and concreted flakes, brisk reaction in hot acid but large residue, 2578–2581; similar but in somewhat coarser granules, 2581–2585; darker gray, a few fragments of white hard brittle substance probably chert, 2585–2590; similar, some translucent chert, a little pyrite, 2590–2595 (Mrs.

Edson's slide at 2585–2590 shows fragments that may be bryozoa. She calls them Galena); 4 samples ---------------------------2578–2595

Galena, including Maysville-Eden? (328 feet thick; top 1,607 feet below sea level) —

Quartz, white and gray, mostly granular, some clear crystalline fragments; a little limestone or dolomite; pyrite, samples similar to that from 2578–2581, 2595–2615; similar but in smaller fragments and more quartz, 2620–2628; coarser again, 2628–2633; concreted lumps and rather fine powder of quartz and dolomite. Effervescence in hot acid brisk but of short duration, much residue of quartz chips, 2633–2636; range of sizes somewhat less, chips to coarse powder, 2636–2640; more than half of sample is quartz, not much dolomite, 2640–2656; some flint, a little pyrite and dolomite, 2656–2669; mostly quartz in small angular fragments, some dolomite, 2669–2681. (Some chips of shale intermingled in these samples are thought to be fallen from above.) 10 samples ------2595–2681

Quartz, gray, finely granular, chips and powder, chips show a little effervescence as if they contained some dolomite; some pyrite, 2681–2690; quartz, in more uniform fine granules, 2690–2716; some calcite, silica in crystalline granules, 2716–2723; a fragment one-fourth inch diameter shows that the rock is composed of subcrystalline granules, is minutely cavernous and contains a little dolomite; mostly of quartz, in small white granules, 2723–2727; some white calcite, a little finely granular quartz; some pyrite, 2727–2736; more calcite and silica, 2736–2745; some chert in white angular fragments, no calcite fragments evident, a little dolomite, 2745–2751; mostly white chert, 2751–2754; chert, a little crystalline quartz, 2754–2764; mostly chert, 2764–2769; some chert, a little granular quartz, 2769–2774; a little calcite and granular quartz, no chert observed, 2774–2784; mostly chert, a little quartz, a little reaction with acid, 2784–2793; quartz, 2793–2802; quartz and chert in small fragments, 2802–2806; 26 samples ----------2681–2806

(The driller states that cavings from shale about 2,575 feet have been falling and mingling with the lower cuttings. Perhaps most or all of the shale noted in samples has fallen from that layer. Hole at 2,900 feet was open from 2,010. Rock drilled very slowly through the cherty beds.)

Chert, milky white, in sharply angular fragments, apparently same as that in previous samples; a few rounded grains of clear quartz, a few fragments of finely crystalline quartz; a little pyrite; slight reaction in hot HCl, indicating a very little dolomite; a little shale in small chips, may be cave, as suggested above; 3 samples------2806–2822

Chert, mingled white and brownish gray, with a little gray and brownish gray dolomite, 2822–2828; slightly more reaction, only a little white chert, 2828–2837; 3 samples --------------------------2822–2837

Chert, white, similar to that above 2822, a little more dolomite, 2837–2841; a large amount of gray to white calcite and dolomite in subcrystalline granules, some crystalline quartz, 2841–2845; 2 samples --2837–2845

Dolomite, light gray, finely granular, fragments small, some rounded, some subangular; a little white chert. This sample is gradational from those above. Half of the sample dissolves in hot acid, 2845–2849; similar but with more calcite and dolomite, 2849–2852; almost all dolomite and calcite, very little chert, not much residue, 2852–2857; similar but darker, brownish, much shale, which is of same character as in all samples above, 2857–2862; similar brown, 2862–2873; much shale in sample, 2866–2873; driller says this is cavings; 6 samples --2845–2873

Dolomite, similar to samples above, brownish gray, crystalline-granular, strong reaction in hot acid; some white calcite; some shale and a few crystals of pyrite, 2870–2875; very similar but with some white chert in angular fragments, 2875–2883; similar but lighter gray, 2883–2891; dolomite in smaller granules, silica in white hard chalklike rounded fragments, also a little angular chert, 2891–2894; similar but darker gray, 2894–2923; dolomite, about same color as at 2875, in fine crystalline gray powder, nearly all of which dissolves in hot acid, except the fine shale, increasingly finer in the lower samples, 2923–2945; coarser, brownish, similar to samples above 2923; samples show much shale and pyrite, some response in cold acid, brisk in hot acid, 2945–2950 (Mrs. Edson's slide at 2910–2915 shows more of the round embossed plates, also other rounded fragments like cephalopods or gastropods); 17 samples ---------- 2873–2923

Decorah formation, Ion, Guttenberg and Spechts Ferry members (36 feet thick; top 1,935 feet below sea level) —

Dolomite, as above, in fine gray and brown crystalline granules, and shale, brown, fine-textured, on heating in test tube gives off heavy gray fumes and brown oily droplets, with petroleum odor ---------- 2923–2959

Platteville (33 feet thick; top 1971 feet below sea level) —

Dolomite, similar but with very little of brown shale, 2959–2964; similar, no brown shale evident, 2964–2979; some white chert, rounded frosted colorless quartz grains, milky white quartz fragments, along with much shale from above, 2979–2992. All of these samples in unwashed condition are brownish, aside from the green shale, which has fallen from above and which is present in nearly all samples. However, washed fragments of dolomite are gray and brown (Mrs. Edson's slide at 2950–2995 shows fragments of fossils, a possible ostracod, bryozoa, gastropods, and other forms); 8 samples ---------- 2959–2992

Saint Peter sandstone (30 feet thick; top 2,004 feet below sea level) —

Sand and dolomite, in about equal parts; sand in fine rounded frosted colorless grains; dolomite appears to be very similar, also in powder (Bag says "hit at 2999"), 2995–3006; very little reaction, almost all sand grains, 3017; some white granular calcite and a little colorless dolomite, 3018–3022; 4 samples ---------- 2995–3022

Prairie du Chien formation:

Shakopee dolomite (103 feet thick; top 2,034 feet below sea level) —

Dolomite, essentially similar to that above 2,995, brownish gray, granular; a little white calcite; a little chert; some sand grains like those above; much green shale fallen from above, 3022–3033; dolomite in fine gray concreted granular powder which responds somewhat to cold acid, briskly to hot acid, with a very fine suspended residue; sample similar to those from 2923–2945, 3033–3038; somewhat coarser loose dark gray powder, some granular insoluble residue, 3038–3041; fine powder, like that at 3033–3038; light gray, 3042–3050; slightly coarser, mostly nonconcreted, a little siliceous residue, 3050–3060; 5 samples ---------- 3022–3060

Sample consists chiefly of sand, etc., from concrete with which hole had been filled; numerous chips of green shale from above; some small whitish masses of rather fine powder, evidently from dolomite. These dissolve slowly in cold acid with very little residue; 4 samples ---------- 3060–3079

Still includes abundant chips of green shale and some concrete but most of sample is small fragments of white calcite, or perhaps dolomite, as they dissolve rather slowly in cold acid; 2 samples -- 3079–3085

Almost all dolomite in fine clear or whitish granules, very little residue (very few shale chips below 3,100); a fragment of oölitic chert at 3120–3125 ---------- 3085–3125

New Richmond (38 feet thick) —

Some glassy frosted rounded grains of sand, 3125–3129; these constitute nearly half the sample at 3139–3143; sample at 3157–3163 whitish because of presence of much white powder, but mostly soluble in hot acid; some sand in clear rounded grains, some concrete ---------- 3125–3163

Oneota dolomite (182 feet thick) —

Dolomite, small chips, 3163–3168; sample shows rock to be nearly white, translucent, very finely granular dolomite; dolomite, as above, no sand seen, 3168–3172; a little darker and coarser at

3172–3187; same, in sparkling crystal fragments, 3187–3192; very fine again at 3197–3203; darker gray, chips of green shale from above, 3203–3213; light gray, fine-grained, 3217–3238; a little darker, 3238–3243; very fine-grained, entirely soluble, 3243–3259 -- 3163–3259

No samples; driller says cuttings too fine to catch ---------------- 3259–3270

Dolomite, light to dark gray, in very fine grains, similar to samples above, 3270–3303; a little white residue, probably siliceous, 3303–3321; no sand grains, silica in white brittle masses; 10 samples -- 3270–3321

Dolomite, similar to above, light gray, in very fine fragments, showing that rock is crystalline, a little very fine siliceous residue---- 3321–3345

Cambrian:

Trempealeau formation —

Jordan sandstone (30 feet thick; top 2,357 feet below sea level) —

Sandstone, more or less rounded grains, fine residue of dolomite somewhat abundant, 3345–3349; brownish gray and with a fair amount of fine clear sand in rounded grains, 3349–3353; no sand grains, very little residue, in samples below; 12 samples ---------------- 3345–3375

Lodi member (25 feet thick) —

Dolomite, brownish gray, still in very fine fragments, very small residue. Mr. Bednar says cuttings for 65 feet were so fine they floated away; reddish tinge at 3394, due to film of iron oxide on grains; sample at 3400 mainly chips of white granular dolomite with sparkling faces -- 3375–3400

St. Lawrence member (68 feet thick) —

Chips at 3405 similar to those at 3400 but darker gray; fragments from 3412 "Bailing with sand pump, no cuttings;" sample at 3423 brownish gray, similar to that at 3390, almost no residue; light gray, very fine and flourlike, coheres in cakes, 3431; darker again but still very fine at 3438 and 3442, light gray at 3449–3451, no residue; a little more brownish but otherwise similar at 3457–3463, a few gray chips at 3468, most of sample fine grains, no sand or shale -- 3400–3468

Franconia formation (108 feet thick; top 2,480 feet below sea level):

Dolomite, similar to that above but with much dark green noncalcareous shale in small chips, a little residue of white silica but no sand grains, 3473–3478; similar, only in coarser fragments and darker gray with pinkish tinge, some fragments "off the bit" show clear crystal faces, 3482; shale forms perhaps one-fourth of these samples; 3 samples ------------------------------------ 3473–3482

Shale and dolomite; several large fragments show the two intermingled in the natural state. Small rhombohedral crystals are embedded in the green shale. Sample is one half dolomite ---------- 3482–3484

Shale and dolomite; shale dark green, gritty, noncalcareous; dolomite light gray, angular, as in samples above, forms three quarters or more of sample, 3486; more shale, perhaps one-third at 3491, giving darker gray aspect to sample; similar but finer, 3494; more shale, some chips one-fourth inch in diameter, 3498; "No cuttings 3498–3502; shale and rhombic dolomite crystals intermingled, some flakes of impure iron ore(?) 3507; less dark shale, dolomite pinkish, 3520–3537; finer, less shale, 3543–3552; coarser, still pinkish, more shale, a little pyrite, as in most samples of this shale, 3556–3576 -- 3486–3576

Dresbach formation (435 feet thick; top 2,588 feet below sea level):

Galesville member (54 feet thick) —

Probably one-half sand, in fine grains, mostly rounded and clear, a few angular, a few frosted, 3582; sandstone, fine clear grains, not many frosted, many angular; very little shale or dolomite, 3587; more shale and dolomite at 3593. Mr. Bednar says "We got (the sand) at 3582 and had 8 feet of it and then went into another lime shell. The last sample, marked 3593, is another sand"------- 3576–3593

Sandstone, many grains colorless, rounded and frosted, some broken and subangular, many coated with red film of iron oxide, fragments of the rock are seen to be composed of many of these grains; a little dolomite in white rhombic crystals, from above;

some green shale, fallen from above; the entire set of samples has a distinct red-brown color; a little finer, with concreted masses of almost flourlike grains of clear quartz and brick-red dust, at 3581–3598 ---3600–3630

Eau Claire member (255 feet thick) —

Sandstone, as above, a little dolomite in rhombic crystals, and a little shale as above, an occasional flake of muscovite mica; more red dust at 3625, 3632, 3655, and becoming gradually but distinctly lighter in shade below 3655 so that below 3700 the samples have a buff or pinkish tinge, also fewer grains are coated with iron oxide; grains finer at 3718. The entire deposit so far seems to be uniform; there are no divisions below 3570. The grains are not so even in size as are those of the typical Saint Peter, and the broken condition of many of them suggests rather firm cementation; 29 samples ---3635–3794

Sandstone, grains rather small but irregular in size, many rounded, some frosted, but more clear and glassy, some broken and subangular, some pinkish like rose quartz, very few grains showing coating of iron oxide, sample has light pink tinge, essentially like samples described above; a few fragments of white dolomite and a few flakes of green shale; an occasional flake of muscovite mica; a little finer and more uniform at 3808, 3814, 3885 -------------3801–3885

Mount Simon member (126 feet thick) —

Sandstone, with fragments of white dolomite and a little green shale; occasional flake of muscovite mica; original fragments of rock crush easily under a knife blade or even with the fingers -------3885–3914

Sandstone, grains mostly clear or nearly so, mostly rounded, some subangular as if broken from larger pieces, a few white, grains generally more uniform in size than in some samples above, otherwise similar to material within the overlying three hundred feet or so; a few pink to dark red fragments are seen to be composed of an aggregate of fine grains with red shaly cement and a few mica flakes; the whole sample has pinkish tinge; a few small cleavage pieces of white dolomite and a few fragments of green shale, 3920; a little more material that is coarser, making sample less uniform, 3926, 3933, 3939, 3948, 3962, 3967, coarser still at 3957, somewhat finer at 3972. A duplicate sample from 3926 is a concreted mass of quartz grains and red shale. This and the fragments mentioned above probably represent fairly well the character of the original rock. The cleaner sands are washed samples; 10 samples --3920–3972

Shale, sandy, or shaly sandstone, consists of sand grains as above with red shale matrix, in concreted blocks, sand grains irregular in size, shale very finely gritty. This material probably is similar to that above except that the shale has not been washed out of these lower samples; 2 samples -----------------------------3979–3991

Sandstone, many grains very fine, some a little coarser, in general finer than samples above 3979 but otherwise similar in color and content; numerous flakes of muscovite mica; 4 samples, 3997, 4002, 4006 --3997–4011

Red Clastic series, probably Middle Cambrian or earlier (penetrated 1,275 feet; top 3,023 feet below sea level):

Sandstone, grains mostly clear, some stained reddish or pinkish, some frosted, irregular in size, from powder to grains one-eighth inch in diameter; a few crystals of dolomite, a few fragments of green shale; a few flakes of mica; some samples a little finer and more uniform; a few small hard brittle whitish to pinkish fragments are perhaps feldspar, as they show smooth cleavage faces and no response to acid; more red clay at 4110 and much more at 4116, a little less at 4126–4134. These samples are very similar to those described previously and evidently belong to the same formation. Mr. Bednar writes: "This shale is running in streaks, I think, and thicker in places." The presence of mica and feldspar with the quartz sand and shale suggests that this rock was formed from the erosion and partial decay of granitic rock at no great distance from here, perhaps in southern Minnesota, or on Nemaha Island, part of the now buried ridge in eastern Nebraska; 18 samples 4011–4134

Shale, dark pinkish red, finely sandy, gritty but noncalcareous, some sand grains over one-sixteenth inch in diameter, 4143; many coarser grains at 4149; fine-grained and brick-red at 4154, 4159, 4166 (this sample mostly shale); dark pinkish red, about equal parts sand and shale, 4184; dark red sandy shale, 4216; pinkish red finely sandy shale, 4271. Samples mostly sand, grains irregular in size, very fine to one-sixteenth inch and over, some clear, some frosted, many rounded, some broken, a few fragments probably feldspar, a few flakes of mica, very little clay, samples pinkish, 4164 (Bag says "1½ feet, sand, rest shale"), 4200, 4209, 4255 (much green laminated shale caved "from about 1000 feet up"), 4234, 4244, 4254 (more pinkish shale), 4262 (some shale), 4280; 17 samples 4143–4280

(These samples evidently represent a part of the same formation as do the 18 samples previously described. There is no definite change in character, though shale is more in evidence than in higher layers. The red color of this shale and the character of the sand grains suggest rocks broken down under somewhat arid conditions.)

Shale, finely sandy, dark pinkish red, similar to material above, 4287; similar but lighter pink, 4295; still light red, sandy material coarser, some grains over one-eighth inch in diameter and angular, a rounded black diorite pebble one-fourth inch in diameter, 4305; sand a little finer, 4314; very fine-textured, 4334, 4351, 4361; slightly coarser, similar in color, 4372; more coarse sand, up to one-sixteenth inch or over, 4381. Sample all sand, grains small, none over one-sixteenth inch in diameter, nearly all clear, some pinkish, mostly rounded, some more or less angular, a few angular fragments of white quartz, a few flakes of mica, 4324; similar but somewhat coarser in grain, sample pinkish from clay, 4341; quartz fragments up to one-eighth inch in diameter, otherwise similar, 4390; few grains exceeding one-sixteenth inch, enough red clay to give pinkish color to sample, 4397. Most of the samples contain a few flakes of green shale, some of them fine-grained and all clay, perhaps from the Maquoketa. Other fragments are filled with the small crystals of dolomite that are characteristic of the Franconia in this prospect. 13 samples 4287–4397

(These samples are alternatingly more or less sandy red shales, which have been quite similar all the way below 3560 feet.)

Shale, sandy, or shaly sandstone, light red, clay matter ranges from more than half to almost nothing; sand grains mostly colorless, glassy, some rounded and frosted, some irregular; fine powder to one-sixteenth inch in diameter; 4408, 4426, 4434, 4450.

Samples mostly sand, grains similar to those just described, a few flat pieces of laminated micaceous fine-grained sandstone, which doubtless supplied the flakes of clear colorless mica seen in the loose sand; most of these samples have a pinkish tinge, due largely to clay powder, 4415, 4441 (Bag says "sandy shale," shale evidently washed out), 4456; samples mostly sand, some clay, 4468, 4477; more clay at 4485, 4505.

Sand, fairly clear, as in samples above, except that some grains are stained red, some fine brown powder imparts its color to the samples, some white fragments of dolomite react with hot acid, 4488; sample again light pinkish like those above the previous one, very slight reaction to hot acid, 4496; all sand, 4513, 4531, 4559, (a grain of pyrite), 4574.

Samples mostly sand at 4522, 4538, 4546 (some white dolomite grains); a little more clay at 4568, 4581; 22 samples 4408–4578

(These samples are still similar to those above. Fragments of shale with tiny dolomite crystals are found in most of the samples and so reaction to acid may be expected in any of them. The response to acid at 4461, however, seems to be from some dolomite in place. No lime was found at 4559.)

Sand, gray, grains irregular in size, one-eighth inch to flourlike particles, clear and glassy, very slight reaction with acid from white specks of dolomite which may be from shaly material from above, as masses of shale with included dolomite crystals are present, some fragments of pink feldspar and muscovite mica, 4585, 4591; grains finer and more uniform, brownish from iron rust apparently, numerous flakes of mica, some chips of fine-grained greenish gray micaceous sandstone, 4594; similar, most grains clear, some white, some pinkish, many perfect rhombohedrons of dolomite from shale above, 4599; grains fine and uniform at 4605; reddish tinge, some concreted masses of sand and pink clay, 4616.

Shale, pink, very finely gritty, no lime, 4621, 4624, 4628.

Sand, brownish red, grains small, mostly clear, some white, a little mica, some reddish clay, 4631; similar, except that clay makes about one half of bulk, 4635; similar at 4638, a little lime present, several pieces of greenish gray dolomite with some perfect rhombohedral crystals, also some darker greenish fragments, more laminated and with some shale, 4638; all reddish fine sand, some lime reaction, 4662.

Shale, dark red, finely sandy, contains some lime, 4668, 4674.

Sand, dark red, very fine, mica flakes, some lime, 4671, 4677; light pink, somewhat coarser, very little lime or clay, 4683; dark red again, much clay, a little lime, 4686; gray, very fine, some brown rust, either from iron in matrix of sandstone or from some introduced iron, a little lime, 4688; dark red, very fine, numerous flakes of mica, strong reaction for lime, 4690; gray, fine to rather coarse, one-sixteenth inch, some lime present, 4699, 4704; dark red with brown rust, very fine, strong lime reaction, 4708; 25 samples ----4585–4708

Samples received July 13, 1932.	Depth in Feet
Clay, dark red, very finely sandy, no lime, corrected depth	4710
Clay, more sandy than above, red-brown	4716
(Both of these samples give off a faint odor of sulphur on being heated and become lighter in color, perhaps due to oxidation of some organic matter.)	
Sand, light brown, with small rounded grains of quartz, some clear, some white; a few grains are angular; some fine tan-colored powder may be feldspar; a few grains of muscovite mica; much magnetic iron, which may be from the drill or may be native to the rock; largest grains are not over one-sixteenth inch in diameter	4723
Sand, dark brown, in fine grains, many of which are angular; some flat fragments of iron oxide; some fine brown powder, iron as above	4730
Clay, dark red-brown, sandy, similar in all respects to first two samples, sticky, stains fingers	4735
Sand, very dark brown, fine grains, some angular, some rounded, some fine powder, of which the black portion is magnetic; some grains are clear quartz, some opaque as if of other minerals, many are iron oxide. Gives off sulphur odor	4737
Sand, similar to above, much magnetic iron in powder	4740
Sandstone, red, in angular grains and fragments, some clear quartz, some white, but most grains are really fragments composed of many fine grains; some small muscovite mica flakes	4745
Sandstone, red, rather soft, fine uniform grains	4749
Sandstone, similar to above, but sample is mostly pulverized (June 23, 1932)	4755
Sandstone, red, similar to above, mostly very fine red grains but some	

clear glassy angular quartz	4773
Sand, clayey, or sandy shale, red, similar to above, but in finely gritty powder and concreted lumps; a few chips show this rock to be similar to that above; 3 samples	4797, 4800, 4803
Sandstone, bright red, fine-grained, much material that is a little coarser, irregular in size, subangular to rounded, clear quartz, white fragments perhaps chalcedony, muscovite flakes, pellets of smooth red clay like pipestone, but practically no clay in matrix	4810
Sandstone, red, similar to above, but more red clay pellets and white granular quartz	4814
Sandstone, similar to above, except that more quartz is in clear subangular grains	4822
Sandstone, light red, fine-grained, grains subangular; none of the red clay pellets; might be quartzite (July 4, 1932)	4829
Sandstone, similar to above but brown in color	4832
Sandstone, or quartzite? red, like sample at 4829	4834–4840
Sandstone, red, like two above; with chips of light blue-gray sandstone, rather soft. Probably this is what driller calls "green shale" at this depth	4850
Sandstone, brick red, very fine-grained, numerous mica flakes; 3 samples	4860, 4865, 4869
Sandstone, red, similar to above, but grains irregular in size, very few clear quartz grains; some greenish sandy shale flakes; some concreted masses of very fine light red sand or shale	4874
Sandstone, brick red, very fine like that at 4860–4869; 2 samples	4880–4885
Sandstone, light red or brown, rather fine grains ranging from powder to one-sixteenth inch in diameter, angular to subangular, clear quartz, also some opaque fragments; muscovite mica	4890
(This sample looks much like those above 4670 that were called quartzite. Very little clay is present in the samples from 4880 and 4885. Nearly all of the sample is sand, a good deal of it in very fine grains.)	

Samples received October 6, 1932.	Depth in Feet
Sand, or sandstone, brown, grains small, subangular, mostly clear and glassy, some reddish; brown color of sample is due to some dark clay matter. Some muscovite mica in flakes up to one-eighth inch in diameter. One small fragment of rock is a brownish red sandstone	4890
(This sample is from the same depth as the last one in the previous shipment, which is much brighter reddish. Possibly this was a washed sample, as the one just received is more reddish after being washed.)	
Sandstone, similar to that above, with addition of several thin flakes of magnetic iron, which seem too brittle to be metallic, from tools, 4895 and 4900; lighter pinkish brown at 4904; more reddish at 4908; darker red at 4912 and 4916 and with many flakes of iron, some of them more than half an inch long; six samples	4895–4916
Sandstone, light reddish or brownish, very similar to the first samples at 4890; numerous flakes of muscovite mica; a few pieces of iron as in samples above; perhaps washed	4923
Sandstone, in very fine grains, dark brown, similar to that about 4900, some flakes of iron; a small fragment is composed of fine grains of sand and is finely laminated. The dark color of the sample is due to red-brown clay. White limy shale in fine powder	4930
Sandstone, or quartzite, light reddish, many angular fragments of glassy quartz, appear as if broken from the mass, some grains are subrounded; some mica flakes. This sample appears more like typical quartzite than do most of those immediately above. It resembles that from 4923, and like that one it may have been washed	4936
Shale, brownish, very finely gritty, with numerous small white masses which are limy, soft and even more fine-grained than the brown-	

ish part. The driller describes this as "chalk white shale, did not test for lime." The brownish material is not limy. Some mica ---4936–4941

Shale, white, exceedingly fine-grained, responds readily to acid, showing a large percentage of lime, but with much residue. Described by the driller as "white shale, or chalk, white, shaly" ----------4936–4941

Shale, dark red-brown, fine-textured, concreted into lumps. After being washed the sample shows some fine grains of sand, some clear, some red, also small fragments of red sandstone, not hard enough to be quartzite; a small green fragment that looks like shale with specks of pyrite; white limy shale at 4941; 2 samples--4941–4947

Sandstone, dark red-brown, without enough clay to bind the sand together. Grains very small and uniform, stained red. Several large fragments show the rock to be a fine- and uniform-grained dark red sandstone with fine mica flakes on the bedding planes and some greenish shaly patches; 2 samples ----------------------4953–4959

Shale, dark brown with shade of reddish, in concreted lumps, much very fine sand; some fragments of gray rather soft sandstone and one of dark red shale with smooth feel. A few flakes of magnetic iron similar to that from 4895–4930 ---------------- 4964

Sandstone, red-brown, composed of very fine red sand grains with enough clay to form some lumps. Several flakes of red shale with green patches -- 4969

Sandstone, dark red, mostly fine red sand grains with some clear ones; many small fragments of dark red sandstone, also some large chips of dark red, very fine-grained sandy shale -------------- 4975

Shale, dark red-brown, similar to that at 4964 ------------------- 4978

Sandstone, dark red, grains fine, but irregular in size, mostly rounded, mostly red, some clear; a number of fragments of dark red fine sandstone, some shaly. White limy shale ---------------------- 4982

Sandstone, dark reddish brown, very fine-grained and uniform, some clay --- 4985

Shale, similar to sample above but with more clay, samples have a gritty feel from fine sand; washing this material reduces it greatly but leaves a residue of very fine red sand; 4 samples ----------4991–5004

(Very few of these samples from 4890–5004 have the characteristic quality of quartzite — the breaking through the grains rather than around them. Most of the sands seem to be from sandstone of average hardness; some samples are clay shales — all strongly stained red by iron. No trace of lime was found except in the concreted masses of white shaly powder in the samples from 4930, 4941 and 4982 and in the sample of white shale from 4936–4941.)

Shale, dark reddish brown, very fine-grained, a few small specks of mica; similar to samples above; 4 samples --------------------5009–5023

Sandstone, dark red-brown, grains fine but irregular, some rounded, many subangular, mostly dark red, some clear. Some fragments of dark red fine-grained sandstone; some small specks of mica. Sample marked "washed" ----------------------------------- 5029

Shale, black, very finely gritty, concreted into lumps; gives off distinct sulphur odor when heated slightly and turns brown on further heating, while light colored fumes are driven off. On digestion with ether a yellowish greasy scum remains on the dish. This will burn in the flame. After being washed the residue is fine red sand, like that above. The samples appear to be similar to those above except that they may have been stained by oil from the drilling machinery or some such means; 2 samples --------------5034–5039

Sandstone or shale, dark brown, very fine-grained, similar to sample above except that it has a larger percentage of sand and is not black. Gives off a slight sulphur odor when heated. Residue after washing is very fine red-brown sand. Lower sample contains more clay; 3 samples ---5044–5055

Samples taken from 5055 to 5150 feet deep, sent November 24, 1932.

	Depth in Feet
Grains of quartz mica, probably metallic iron, and some brownish shale. Most of the sample is attracted by the magnet. Sample bag says "cavings off walls after standing a month"	5055
Shale, dark brown with reddish tint. Some flakes of mica, some metallic iron and some iron oxide, also a little very fine quartz	5060–5065
Shale, reddish brown, a little metallic iron and iron oxide, flakes of mica	5070–5093
Shale, light reddish brown, similar to samples above	5098–5113
Shale, light reddish brown, similar to samples above	5117–5122
Shale, light reddish brown, some metallic iron and iron oxide similar to above	5125–5129
Shale, light reddish brown, like that between 5117 and 5122 feet. Minerals similar to those in other samples	5134
Shale, light reddish brown like that between 5070 and 5093 feet. Similar to samples above	5140
Shale, light reddish brown, like that of several beds above. Minerals like those above	5145–5150

Samples from Clarinda Prospect. Received May 19, 1933.
Depth of samples, 5150 to 5250 feet.

	Depth in Feet
Shale, very fine texture, reddish brown, ocher-like, very little metallic iron, a few mica flakes, mostly fine quartz grains; three samples	5156–5164
Shale, similar to samples above but a little more coarsely sandy	5173
Shale, similar to sample above but finer, like those from 5156–5164; 3 samples	5175–5184
Shale, similar to three samples above, but very slightly coarser	5186
Shale, similar to above, but slightly finer	5189
Shale, a little finer than sample above, a number of white mica specks	5194
Quartz sand, mostly clear fragmental quartz, with enough iron rust to give reddish color to the sample, some black magnetic iron, some whitish soft fragments, may be kaolin, some mica flakes	5201
Sand, similar to sample above, except for smaller amount of black iron and absence of white kaolin?	5206
Sand, grayish, otherwise like sample above; a few fragments of shale, red, mostly very fine, with thin films of mica flakes, at 5212; 2 samples	5212–5217
Sand, reddish, mostly quartz, some rusted, much mica in small flakes	5220
Sand, similar to above sample, some flakes of shaly material, grayish green, fine texture	5222
Sand, reddish gray, similar to samples above	5226
Sand, similar to sample above but more grayish; two samples	5234–5236
Sand, dark brownish gray, very fine and uniform grains, much mica, as in all the samples from 5201 down	5240
Sand, dark reddish brown, with gray tinge, somewhat coarser than sample above. Several slabs of greenish gray rock, micaceous, schistose, very fine texture, as if it were an altered shale	5244
Sand, brownish gray, fine and uniform texture, otherwise similar to samples above	5248
Sand, brownish gray with red tinge, grains rather coarse and irregular, minerals about same as in all samples below 5201 — quartz, mica, iron rust, some black material that is not magnetic	5250

All the samples from 5201 feet are quite similar and evidently belong to the same kind of rock. They have the appearance of a decayed granite, although no feldspar was noted.)

Driller's Log, Wilson No. 1 Oil Prospect.

	Thickness in Feet	Depth in Feet
Soil	10	0–10
Sand and gravel, lots of water	15	10–25

Limestone	6	25–31
Shale, dark	2	31–33
Limestone	3	33–36
Shale, dark	4	36–40
Shale, light	3	40–43
Shale, blue	3	43–46
Limestone	5	46–51
Shale, gray	19	51–70
Limestone	10	70–80
Coal and shale (inferior coal)	3	80–83
Shale, light	11	83–94
Limestone	8	94–102
Shale, black	38	102–140
Shale, calcareous	4	140–144
Limestone	6	144–150
Shale, dark	10	150–160
Limestone	5	160–165
Shale	1	165–166
Limestone	6	166–172
Shale, gray and black	8	172–180
Limestone	28	180–208
Shale, dark	16	208–224
Limestone, white	4	224–228
Shale, light	8	228–236
Rock, red	14	236–250
Shale, light	70	250–320
Shale, brown	20	320–340
Shale, dark, sandy	9	340–349
Limestone and shale, broken	7	349–356
Shale, brown	19	356–375
Limestone	10	375–385
Sand, water salty	12	385–397
Shale, black	8	397–405
Shale, blue	4	405–409
Shale, brown	4	409–413
Shale, blue	31	413–444
Shale, white	1	444–445
Limestone, white, broken	2	445–447
Limestone, white, hard	4	447–451
Shale, dark	11	451–462
Limestone, black	7	462–469
Shale, white	4	469–473
Limestone, hard (white to gray to black to brown)	15	473–488
Shale, light and sticky	11	488–499
Shale, light and sticky	5	499–504
Limestone, white	6	504–510
Shale, light	4	510–514
Limestone, white	10	514–524
Shale, dark	14	524–538
Limestone	36	538–574
Shale, dark	4	574–578
Limestone, white	30	578–608
Shale, dark	8	608–616
Limestone, white	18	616–634
Shale, white	12	634–646
Limestone	14	646–660
Shale, dark	10	660–670
Shale, light	10	670–680
Limestone, white	10	680–690
Shale, light	12	690–702
Shale, brown and red	23	702–725
Shale, light blue	10	725–735
Shale, blue	3	735–738
Coal	5	738–743

Limestone	2	743–745
Shale	2	745–747
Limestone, hard	8	747–755
Shale, black	25	755–780
Shale, blue	5	780–785
Limestone, white	17	785–802
Shale, light gray	20	802–822
Shale, calcareous and also dark	8	822–830
Limestone (water enough to drill with)	22	830–852
Shale, light	53	852–905
Shale, dark	7	905–912
Limestone, white	6	912–918
Shale, light to dark	77	918–995
Sand, water salty	25	995–1020
Shale, white	14	1020–1034
Shale, dark	4	1034–1038
Limestone, arenaceous, soft	4	1038–1042
Shale, light	2	1042–1044
Coal (very inferior)	13	1044–1057
Shale, dark	188	1057–1245
Sand, water (break in the middle)	15	1245–1260
Shale, dark	65	1260–1325
Lime shell	2	1325–1327
Shale, black	64	1327–1391
Lime shell	1	1391–1392
Shale, dark	18	1392–1410
Shale, arenaceous, light	10	1410–1420
Coal	2	1420–1422
Shale, dark	13	1422–1435
Sand, water (show of oil in top of sand)	42	1435–1477
Shale, black	2	1477–1479
Sand, water	3	1479–1482
Shale, brown	2	1482–1484
Sand, water	46	1484–1530
Sand, water	5	1530–1535
Limestone, gypsum, sand and dark shale	30	1535–1565
Shale and pyrites	10	1565–1575
Shale, black	15	1575–1590
Pyrites of iron	5	1590–1595
Shale, dark	15	1595–1610
Limestone, arenaceous	64	1610–1674
Shale, light	4	1674–1678
Limestone	2	1678–1680
Sandstone, fresh water	20	1680–1700
Brown lime flint (salt water)	32	1700–1732
Shale, sandstone, broken limestone	1	1732–1733
Limestone	2	1733–1735
Limestone, streaked with sandy shale	3	1735–1738
Limestone, brown	12	1738–1750
Limestone, gray, very fine, drills like sand	40	1750–1790
Limestone, coarse	11	1790–1801
Limestone, hard	4	1801–1805
Limestone, coarse	26	1805–1831
Shale, hard, gray	4	1831–1835
Limestone, hard	2	1835–1837
Shale mixed with streaks of limestone	8	1837–1845
Limestone, fine and very hard	53	1845–1898
Shale, brown	2	1898–1900
Limestone, very fine	14	1900–1914
Limestone, coarse	5	1914–1919
Limestone, streaks of shale	2	1919–1921
Limestone, hard	13	1921–1934
Shale, black, mixed with lime shells	36	1934–1970
Shale, red	1	1970–1971

Limestone	2	1971–1973
Shale, a trifle more red than above	6	1973–1979
Limestone, gray, hard	17	1979–1996
Shale, hard, grayish blue	4	1996–2000
Shale, blue	3	2000–2003
Limestone, gray, hard, very fine	18	2003–2021
Limestone, blue, hard, coarse, mixed with gray and brown	9	2021–2030
Limestone, coarse, hard, blue	4	2030–2034
Limestone and gypsum	5	2034–2039
Limestone, very hard, gray	23	2039–2062
Limestone, fine, brown	6	2062–2068
Shale	9	2068–2077
Limestone, coarse, brown	8	2077–2085
Limestone, arenaceous, gray and brown	21	2085–2106
Limestone, fine, gray and brown	18	2106–2124
Sand and limestone, light gray	6	2124–2130
Limestone, arenaceous, dark brown	19	2130–2149
Limestone, dark brown, fine	26	2149–2175
Dolomite, brown, fine lime	58	2175–2233
Limestone, coarse, brown	18	2233–2251
Limestone, coarse, brown, streaked with blue shale	4	2251–2255
Limestone, brown, coarse to fine	25	2255–2280
Limestone, white; shale, green	5	2280–2285
Limestone, fine, brown	32	2285–2317
Limestone, medium dark gray, chalky, floats	83	2317–2400
Limestone, gray, sharp, fine	15	2400–2415
Limestone, white, chalky, hard to catch	10	2415–2425
Limestone, chalky, some gypsum cuttings hard to catch, strong smell of gas	19	2425–2444
Limestone, coarse, brown	16	2444–2460
Limestone, fine, dark gray	29	2460–2489
Limestone, fine, light gray	7	2489–2496
Limestone, coarse, hard, gray	4	2496–2500
Limestone, fine, light gray	50	2500–2550
Limestone, fine, medium light gray	5	2550–2555
Limestone, dark, coarse grain	5	2555–2560
Shale, bluish green, not compact, cavy	5	2560–2565
Shale and limestone, dark and light gray and white, some gypsum and pyrite, cavy	8	2565–2573
Limestone, dolomitic, fine-grained, gray	55	2573–2628
Limestone, dark gray, very coarse grain	12	2628–2640
Limestone, light gray, very fine	4	2640–2644
Limestone, arenaceous, medium coarse	4	2644–2648
Limestone, brown, dark	28	2648–2676
Limestone, dark gray, fine	44	2676–2720
Limestone, light gray, fine-grained	10	2720–2730
Gypsum, white, hard, sticky drilling	3	2730–2733
Limestone, coarse, hard, flinty	12	2733–2745
Limestone, with gypsum, white	1	2745–2746
Crevice	1	2746–2747
Limestone with asphalt	4	2747–2751
Limestone, coarse, white	19	2751–2770
Limestone, coarse, light gray	25	2770–2795
Limestone, dark gray, fine	30	2795–2825
Limestone, coarse, brown	15	2825–2840
Shale, brown	10	2840–2850
Chert and silica	10	2850–2860
Dolomite	2	2860–2862
Limestone, brown	28	2862–2890
Limestone, gray	20	2890–2910
Limestone, brown	8	2910–2918
Limestone, dark gray turning to blue, very fine grain	27	2918–2945
Limestone, brown, medium-grained	35	2945–2980
Shale, blue	2	2980–2982

Limestone, white, coarse, water	8	2982–2990
Limestone, brown, coarse	9	2990–2999
Sandstone, fine, gray, much water	26	2999–3025
Shale, gray	2	3025–3027
Limestone, brown, and gypsum, fine	9	3027–3036
Sandstone, fine, gray, salty	5	3036–3041
Dolomite and gypsum, water	9	3041–3050
Sandstone, very fine, water	5	3050–3055
Dolomite, gray, fine	3	3055–3058
Dolomite, gray	42	3058–3100
Limestone, brown; dolomite, fine	24	3100–3124
Dolomite, solid, brown, medium	6	3124–3130
Dolomite, light gray and fine	10	3130–3140
Sand, white, medium to fine	25	3140–3165
Dolomite, dark and fine	15	3165–3180
Dolomite, light and fine	39	3180–3219
Dolomite, light, coarse	56	3219–3275
Dolomite, red-brown, fine	1	3275–3276
Shale, black, oil showing	4	3276–3280
Sand, brown, oil showing	30	3280–3310
Dolomite, white and gypsum	7	3310–3317
Sand, brown, broken, and lime	5	3317–3322
Limestone; brown	38	3322–3360
Limestone, gray, some gypsum, fine as flour (no cuttings), hard	50	3360–3410
Dolomite, gray, fine and hard	37	3410–3447
Limestone, gray, coarse	1	3447–3448
Limestone, gray	4	3448–3452
Dolomite, gray	13	3452–3465
Limestone and shale, green-gray, fine to medium	3	3465–3468
Shale, and granite, brown	2	3468–3470
Limestone and shale	13	3470–3483
Limestone and shale, green	12	3483–3495
Limestone and shale, white and green	20	3495–3515
Limestone, brown; shale, green	8	3515–3523
Limestone, gray; shale, green	12	3523–3535
Limestone, gray; shale, green; some dolomite and gypsum, medium	10	3535–3545
Limestone, gray; shale, green; some dolomite	15	3545–3560
Sandstone	8	3560–3568
Limestone, gray; gas showing	2	3568–3570
Sandstone, white, coarse	3	3570–3573
Sandstone, coarse, brown	4	3573–3577
Sandstone, red, coarse	3	3577–3580
Shale, red	3	3580–3583
Sandstone, glassy, reddish brown	10	3583–3593
Shale, arenaceous, red, fine	7	3593–3600
Sandstone, red, some silica, fine streaks of red shale and gypsum	116	3600–3716
Limestone, gray	4	3716–3720
Sandstone, red, coarse, and lime shells	35	3720–3755
Limestone, arenaceous, white and brown, fine to coarse to fine, siliceous	30	3755–3785
Same as above with strips of red shale	100	3785–3885
Shale, arenaceous, red; sand, reddish brown, thin layers of shale. Silica in quartzites at times, medium and coarse, changeable, thin lime shells between	123	3885–4008
Sand, reddish, thin layers of red shale, silica in quartzite, cuttings fine at times, medium, then coarse, lime shells now and then	106	4008–4114
Shale, reddish brown, hard	48	4114–4162
Sandstone, red; shale	58	4162–4220
Shale, red	40	4220–4260
Sandstone, red, strips of red shale, sand predominates	5	4260–4265

Shale, red, some pretty sandy, broken sand both fine and coarse	35	4265–4300
Sandstone, red, medium	6	4300–4306
Shale, red; sandstone, broken	114	4306–4420
Sandstone, red, fine	40	4420–4460
Limestone, arenaceous, brown, very hard	3	4460–4463
Shale, red; sandstone	63	4463–4526
Limestone and dolomite, sharp	2	4526–4528
Shale, red; sand	35	4528–4563
Shale, arenaceous, red	2	4563–4565
Sand and red shale, dries to reddish brown, silica predominating	35	4565–4600
Shale, red and muddy; limestone, arenaceous, brown, very fine, cuttings heavy and settle fast	28	4600–4628
Shale, red	2	4628–4630
Limestone, arenaceous, but light, drills awfully hard	4	4630–4634
Shale and limestone, red, cuts very fine; shale consists of a green-blue and bright red, and is dolomitic	6	4634–4640
Sandstone, white	28	4640–4668
Limestone, brown and gray, responds to cold acid, and drills very fine	2	4668–4670
Limestone, sandy and black	38	4670–4708
Set 4,708 feet of 5 3/16 casing and shut out all water at this point. Bailed the hole dry and now carrying an absolutely dry hole. Dumping water to drill with.		
Sand, brown, oil showing black and heavy appearances of dead oil	8	4708–4716
Sandstone, gray	7	4716–4723
Sand, brown, fine-grained	15	4723–4738
Shale, sandy with hard drilling shells every few feet, brown to an almost red color	91	4738–4829
Sandstone, light brown	11	4829–4840
Shale and sandstone, reddish brown	4	4840–4844
Shale, arenaceous, red, variegated with green shale	6	4844–4850
Shale, arenaceous, light reddish brown	35	4850–4885
Sandstone, thin strips of shale, brown	5	4885–4890
Shale, brown	5	4890–4895
Shale, arenaceous, brown	28	4895–4923
Shale, arenaceous, light brown	13	4923–4936
Chalk, white shaly	5	4936–4941
Shale, arenaceous, brown	35	4941–4976
Chalk, limestone, white	4	4976–4980
Shale, and sandstone, brown	30	4980–5010
Shale, arenaceous, dark brown to dark gray	40	5010–5050
Shale, brown and blackish gray	5	5050–5055
Some of the brown shales carry a conglomerate or different colors of shales, namely white, brown, green to blue, and red.		

Notes. — The Mississippian shows normal facies in this well — chiefly limestone with some shale in the Osage and Meramec series; it is mostly shale with some limestone in the Kinderhook series. The same is true of the Devonian system, which is mostly limestone with some shale. The Silurian seems to be a unit and to belong to the Niagaran series. It is nearly all dolomite, with some shale. Some microfossils seem to be characteristic of the formations in which they occur. In this prospect the Maquoketa shale is rather thinner than typical. The

Galena is typical in thickness and character. The Decorah is very distinctive; petroleum is very easily distinguishable. Evidently the Platteville is absent at this location. The Saint Peter is persistent, though not thick. It is followed by the three members of the Prairie du Chien in order, with about the usual thickness. The persistence of thin members across the state is remarkable. The Maquoketa is a good example; it is thinner than at Fort Dodge, where it is 300 feet thick, or at Sac City, where it is 70 feet thick. The dip of the beds is well shown between Sac City, where the Saint Peter is 246 feet below sea level, and Clarinda, where it is 2,004 feet below sea level — a drop of 1,760 feet in 120 miles to the south. At Fort Dodge, 40 miles farther east, the strata are at the lowest level for this latitude — 400 feet below sea level.

The recent classification of the Cambrian makes the Trempealeau a formation and makes the Jordan, Lodi, and St. Lawrence members. The Jordan is rather thin at Clarinda and not so typical as at some places; it consists of sandstone with some dolomite. The Lodi is usually shaly, but here it is mainly dolomite.

The drill entered the Upper Cambrian at a depth of 3,345 feet. So far as these studies determine, the base of the Upper Cambrian lies 4,011 feet below the surface — 3,023 feet below sea level. All drilling below this point to the bottom of the hole at 5,286 feet was in the Red Clastics, probably of Middle Cambrian age — of course far below any possibility of oil or gas and getting farther with every added foot.

INDEX

N

O

P

R

S

T

U

V

W

MINERAL PRODUCTION IN IOWA IN 1930, 1931, and 1932

by

JAMES H. LEES

MINERAL PRODUCTION IN IOWA IN 1930, 1931, and 1932

MINERAL PRODUCTION IN 1930 *

OUTLINE

The upward trend in mineral production, which seemed so promising in 1928, had flattened out considerably in 1929, and a disappointing downward trend began in 1930. Production during 1928 had increased more than two million dollars worth over that of 1927, but production in 1929 increased only a few hundred thousand dollars above that of 1928, and that for 1930 was more than two million dollars less than that for 1929. Table I will make clear the comparative conditions in Iowa during 1928, 1929, and 1930.

From 1928 to 1929 there was a decrease of about a million dollars in the value of cement shipments, a decline of about $700,000 in the value of gypsum sold, and a decline of nearly $200,000 in the value of limestone and lime produced. On the other hand, in the same period, clay wares increased in value about $740,000, coal nearly $1,500,000, and sand and gravel over $100,000.

From 1929 to 1930, as just stated, production decreased about two and a half million dollars. The value of the cement shipped increased more than $300,000, limestone and lime nearly $300,000, and sand and gravel over $300,000. The decrease was in clay wares, coal, and gypsum, and these decreases were too great to be offset by the increases in other materials.

These conditions in Iowa were reflected in mineral industries the nation over. From 1928 to 1929 production increased a few hundred

* Statistics are collected by the U. S. Bureau of Mines, co-operating with the Iowa Geological Survey, except in the case of Clay Wares, which are gathered by the Bureau of the Census.

TABLE I

Mineral Production in Iowa in 1928, 1929, and 1930

Product	Unit	1928			1929			1930		
		Producers	Quantity	Value	Producers	Quantity	Value	Producers	Quantity	Value
Cement	bbl	6	6,880,731	$10,734,838	6	6,586,111	$9,781,159	6	7,035,252	$10,107,584
Clay wares		55		5,048,774	42		5,791,175			4,713,448(a)
Coal	ton	222	3,683,635	10,525,000	201	4,241,069	11,948,000	233	3,892,571	10,385,000
Gypsum	ton	7	719,736	5,355,214	8	670,203	4,668,856	8	458,992	3,741,319
Limestone and lime	ton	35	1,666,270	1,742,252	41	1,625,000	1,560,066	43	1,814,291	1,850,832
Sand and gravel	ton	80	3,423,619	2,094,955	80	4,043,609	2,211,752	76	4,333,737	2,546,337
				$35,501,033			$35,961,008			$33,344,520

(a) The total clay figures given for 1929 are those published by the Bureau of Mines. The figure given for the value of clay wares in 1930 is that published by the Bureau of Census.

thousand dollars, but Table I-A shows that from 1929 to 1930 the total value of production decreased more than a billion dollars.

TABLE I-A

Mineral Production in the United States in 1929 and 1930

* SUMMARY	1929	1930
	Value	Value
Total value of metallic products	$1,475,990,000	$ 982,550,000
Total value of nonmetallic products (exclusive of mineral fuels)	1,210,653,000	1,008,900,000
Total value of mineral fuels	3,190,527,000	2,764,500,000
Total value of "unspecified" (metallic and nonmetallic) products (partly estimated)	10,430,000	8,850,000
Grand total approximate value of mineral products	5,887,600,000	4,764,800,000

* This table is taken from Mineral Resources, 1930 — Part I, A8.

CEMENT

TABLE II

Production of Cement in Iowa

	1929	1930
Production, bbls.	6,373,330	7,088,108
Stock, Dec. 31, bbls.	1,347,144	1,400,000
Shipments, bbls.	6,586,111	7,035,252
Shipments, value	$9,781,159	$10,107,584
Average price per bbl.	$1.49	$1.44
Estimated consumption, bbls.	5,462,534	6,411,595
Estimated consumption per cap., bbls.	2.25	2.59
Surplus production, bbls.	1,123,577	623,657
Annual capacity, bbls.	9,592,900	10,293,900

Table II shows that production and shipment of cement increased notably from 1929 to 1930; however, the price received per barrel was slightly less in the later year. Evidently the cement-using public took advantage of this small drop in price, as nearly one million barrels more were used in 1930 than had been used in 1929. This naturally brought up the per capita consumption, and it also had the effect of reducing the surplus production. The same plants were in existence in 1930 as in 1929, and the reason for the difference in annual capacity is not well understood; possibly it was due, in part at least, to improvements in equipments and methods of manufacture.

In the cement manufacturing district which includes eastern Missouri, Iowa, Minnesota, and South Dakota, production increased from 15,697,000 to 16,693,900 barrels and the shipment increased from 15,984,000 to 16,886,000 barrels. The value of these shipments rose from $23,430,800 to $24,061,000, an increase of 2.6 percent.

Conditions the country over seem to have been somewhat less favorable than they were in our state, for both production and shipments declined somewhat in 1930. The same plants were in operation during both years, and stocks on hand at the end of the year were more than two million barrels greater in 1930 than in 1929.

Iowa ranked tenth among the states of the Union in the making of cement in 1929 and eighth in 1930; in shipments it ranked 10th in both quantity and value in 1929, but in 1930 it had risen to 8th in quantity and 9th in value.

TABLE II-A

Production of Cement in the United States

	1929	1930
Production, bbls.	170,646,036	161,197,228
Shipments, bbls.	169,868,322	159,059,334
Shipments, value	$252,153,789	$228,779,756
Stocks, Dec. 31, bbls.	23,700,533 (a)	25,838,427
Plants active	163	163

(a) This figure has been revised and differs slightly from the one given in Mineral Production in Iowa in 1928 and 1929 in volume XXXV.

CLAY AND CLAY PRODUCTS

In 1930 eight companies produced raw clay, four of them being in Webster County. The amount produced was 6,219 tons, with a value of $41,816.

Probably all readers of this report know that statistics for most mineral products are collected by the Bureau of Mines coöperating with the various state geological surveys. Figures for clay products, however, are collected by the Bureau of the Census without such coöperation and the Bureau feels that it can not furnish the state geological surveys with data on production by counties. It has, however, furnished the Iowa Geological Survey with information concerning production of clay wares by classes during 1930, as well as during 1929 and 1931. These figures are given in Table III. The Bureau of Mines collects data concerning the amount of clay sold, either raw or prepared, but not manufactured into ware. These figures for 1930 are as follows: fire clay, molding clay, and miscellaneous clay, 6,219 tons, valued at $41,816. It will be seen that these figures differ slightly from those given by the Bureau of the Census for the same year. Whether these figures duplicate those given by the Bureau of the Census or whether they are for different producers is not known. It will be noted

TABLE III

Production of Clay Products, by Class, Quantity, and Value: 1929 and 1930.

CLASS AND YEAR	QUANTITY	VALUE
Total value:		
1930		$4,713,448
1929		5,814,109
Common brick:	Thousands	
1930	53,100	600,394
1929	55,522	640,393
Face brick:		
1930	23,906	389,275
1929	24,548	428,806
Hollow building tile:		
(a) Partition, load-bearing, etc.	Tons	
1930	212,372	1,523,298
1929	234,201	1,597,173
(c) Floor arch, etc.:		
1930	(1)	(1)
1929	48,936	384,606
Draintile:		
1930	114,500	897,344
1929	200,224	1,525,082
Sewer pipe:		
1930	45,763	675,757
1929	57,640	719,519
Flue lining:		
1930	3,648	42,938
1929	4,622	49,535
Wall coping:		
1930	774	13,511
1929	1,010	13,194
Clay sold, raw or prepared:		
1930	4,181	41,961
1929	2,289	23,984
Other clay products, including pottery:		
1930		528,970
1929		431,817

1 Included in "Other clay products" in order to avoid disclosing approximations of data supplied by individual establishments.

that the output of clay wares in 1930 was valued at more than a million dollars less than that for 1929. Evidently this was a reflection of the general tightening of business conditions which began late in 1929 and continued through 1930.

COAL

Table IV shows that the depression mentioned above took a severe toll from the coal industry. The tonnage mined in 1930 was 350,000 less than in 1929, and the value was over 1½ millions of dollars less in 1930. This decrease was due not only to the smaller tonnage, but to the decline of 15 cents per ton received at the mine. It seems somewhat anomalous that in spite of this decrease in both tonnage and value, more men should have been employed than in 1929. The tonnage re-

TABLE IV

Production, Value, Men Employed, Days Worked, and Output Per Man Per Day at Coal Mines in Iowa in 1930 [a]

(Exclusive of product of wagon mines producing less than 1,000 tons)

County	Net tons				Value		Number of employees: Underground				Average number of days worked	Average tons per man per day
	Loaded at mines for shipment	Sold to local trade and used by employees	Used at mines for power and heat	Total quantity	Total	Average per ton	Miners, loaders, and shot firers	All others	Surface	Total		
Adams	------	9,631	800	10,431	$ 39,000	$3.74	25	2	4	31	165	2.04
Appanoose	512,151	73,188	787	586,126	1,478,000	2.52	1,387	263	151	1,801	122	2.66
Boone	352,237	56,658	3,889	412,784	1,204,000	2.92	718	176	58	952	163	2.66
Dallas	380,909	18,380	2,155	401,444	1,091,000	2.72	497	120	36	653	181	3.39
Davis	------	3,823	----	3,823	11,000	2.88	9	4	3	16	116	2.06
Greene and Webster	------	7,066	----	7,066	28,000	3.96	18	8	5	31	141	1.62
Guthrie	------	6,878	----	6,878	25,000	3.63	26	8	6	40	99	1.74
Jasper	------	55,437	2,700	58,137	146,000	2.51	89	15	18	122	195	2.44
Jefferson and Keokuk	------	4,799	----	4,799	12,000	2.50	13	4	3	20	167	1.44
Lucas	541,780	5,163	11,350	558,293	1,417,000	2.54	524	151	50	725	148	5.21
Mahaska	89	53,462	100	53,651	134,000	2.50	113	12	26	151	140	2.53
Marion	472,530	50,806	14,421	537,757	1,619,000	3.01	607	221	64	892	174	3.47
Monroe	350,767	29,780	1,986	382,533	864,000	2.26	521	102	52	675	178	3.19
Page	700	22,408	----	23,108	96,000	4.15	37	10	6	53	211	2.07
Polk	207,027	366,411	10,655	584,093	1,536,000	2.63	822	180	80	1,082	170	3.17
Taylor	809	8,673	----	9,482	36,000	3.80	34	7	4	45	124	1.70
Van Buren	3,038	3,216	66	6,320	21,000	3.32	15	2	4	21	121	2.48
Wapello	300	83,988	685	84,973	223,000	2.62	143	35	26	204	139	2.99
Warren	106,795	28,120	6,217	141,132	352,000	2.49	217	57	25	299	152	3.10
Wayne	4,386	15,151	204	19,741	53,000	2.68	68	11	9	88	99	2.27
Total 1930	2,933,518	903,038	56,015	3,892,571	$10,385,000	$2.67	5,883	1,388	630	7,901	155	3.18
Total 1929	3,383,801	800,029	57.239	4,241.069	$11,948,000	$2.82	5,408	1,348	539	7,295	195	2.98

(a) The figures relate only to active mines of commercial size that produced coal in 1930. The number of such mines in Iowa was 233 in 1930; 201 in 1929; and 222 in 1928.

Methods of mining in 1930: The tonnage by hand was 515,942; shot off the solid, 2,152,824; cut by machines, 1,185,627; not specified, 38,178.

Size classes of commercial mines in 1930: There were 4 mines in Class 1 B (200,000 to 500,000 tons) producing 24.6 per cent of the tonnage; 8 in Class 2 (100,000 to 200,000 tons) with 29.1 per cent; 10 in Class 3 (50,000 to 100,000 tons) with 17.1 per cent; 34 in Class 4 (10,000 to 50,000 tons) with 18.8 per cent; 177 in Class 5 less than 10,000 tons) producing 10.4 per cent.

covered per man per day was greater in 1930 than in the preceding year, but the number of days worked was much less.

Some rather surprising changes took place in the relative standing of the different counties. Marion County, which had been leader for several years in both tonnage and in the value of the coal produced, dropped to fourth place in tonnage, although retaining first place in value. Polk was second in both tonnage and value in 1930. Appanoose was third in value, although it rose to first in tonnage. Lucas was third in tonnage and fourth in value. Each of these counties produced 500,000 tons or more; Boone County held fifth place in tonnage and value, but with rather a long gap between it and the county next above, as it produced only a little over 400,000 tons. Monroe dropped back considerably in 1930, both in amount produced and in relative position.

As to methods of mining, it is perhaps noteworthy that the tonnage mined by hand increased over that so mined in 1929, while less coal was shot off the solid in 1930 than during the previous year. The amount of coal cut by machines also was less in 1930 than in 1929.

It seems significant that in 1930 twelve mines produced over half of the tonnage mined in the entire state. These with ten other mines produced over 70 percent of the total tonnage raised from 233 mines in this state.

The small field in southwestern Iowa, while not very important in tonnage as compared with the Des Moines valley field, is of considerable local importance because it furnishes a supply to the neighboring communities at lower prices than they would be obliged to pay for coal shipped in from more distant coal fields. This fact offers one of the reasons why such a small field with such a thin vein can continue to operate to advantage and with some measure of profit. Another important reason is the fact that the bed of coal is very persistent; it occupies many square miles with a uniform thickness and constant characters. On this account mining is fairly easy and the tonnage is fairly certain. The thickness of the bed is about 16 inches.

Coal produced in the United States showed a decline similar to that mentioned in Iowa. Bituminous coal in the United States in 1929 amounted to 534,988,000 tons with a value of $952,781,000. Figures for production in 1930 are given in Table IV-A by the Bureau of Mines.

The first 15 states rank as follows in production: Pennsylvania, West Virginia, Illinois, Kentucky, Ohio, Indiana, Alabama, Virginia,

TABLE IV-A

Production, Value, Men Employed, Days Worked, and Output Per Man Per Day at Coal Mines in The United States in 1930.

(Exclusive of product of wagon mines producing less than 1,000 tons)

State	Total quantity net tons	Total value	Average per ton	Number of employees	Average number of days worked	Average tons per man per day
Alabama	15,570,058	$ 31,616,000	$2.03	24,393	189	3.38
Alaska	120,100	631,000	5.25	99	294	4.13
Arizona	9,084	29,000	3.19	24	196	1.94
Arkansas	1,533,434	5,153,000	3.36	4,626	115	2.87
Calif., Idaho, Oregon	18,538	100,000	5.39	138	74	1.81
Colorado	8,196,910	21,485,000	2.62	11,091	169	4.38
Georgia	7,092	18,000	2.54	60	71	1.66
Illinois	53,731,230	93,484,000	1.74	53,603	156	6.42
Indiana	16,489,962	26,178,000	1.59	13,881	157	7.56
Iowa	3,892,571	10,385,000	2.67	7,901	155	3.18
Kansas	2,429,929	5,231,000	2.15	4,855	126	3.96
Kentucky	51,208,995	76,186,000	1.49	56,674	187	4.83
Maryland	2,270,593	3,690,000	1.63	3,299	197	3.50
Michigan	661,113	2,323,000	3.51	1,294	187	2.73
Missouri	3,853,150	8,967,000	2.33	5,700	166	4.07
Montana	3,022,004	6,043,000	2.00	2,085	172	8.45
New Mexico	1,969,433	6,017,000	3.06	2,902	176	3.85
North Carolina	28,500	100,000	3.51	70	290	1.40
North Dakota	1,700,157	2,768,000	1.63	1,258	180	7.50
Ohio	22,551,978	31,643,000	1.40	25,574	189	4.67
Oklahoma	2,793,954	7,768,000	2.78	5,424	148	3.49
Pa. bituminous	124,462,787	213,584,000	1.72	130,150	198	4.82
South Dakota	12,810	31,000	2.42	43	109	2.73
Tennessee	5,130,428	8,417,000	1.64	7,535	196	3.48
Texas	833,872	1,307,000	1.57	1,305	181	3.53
Utah	4,257,541	10,515,000	2.47	3,504	168	7.23
Virginia	10,907,377	17,520,000	1.61	11,709	200	4.66
Washington	2,301,928	7,439,000	3.23	2,801	205	4.01
West Virginia	121,472,638	181,722,000	1.50	105,988	204	5.61
Wyoming	6,088,133	15,133,000	2.49	5,216	188	6.20
Total bituminous, 1930	467,526,299 (a)	$795,483,000	$1.70	493,202	187	5.06
Total bituminous, 1929	534,988,593	$952,781,000	$1.78	502,993	219	4.85

(a) The figures relate only to active mines of commercial size that produced bituminous coal in 1930. The number of such mines in the United States was 5,891 in 1930; 6,057 in 1929; and 6,450 in 1928.

Methods of mining in 1930: The tonnage by hand was 55,489,908; shot off the solid, 29,105,549; cut by machines 362,425,163; mined by stripping, 19,842,359; not specified, 663,320.

Colorado, Wyoming, Tennessee, Utah, Iowa, Missouri, Montana. The rank in value differs slightly — Pennsylvania, West Virginia, Illinois, Kentucky, Ohio, Alabama, Indiana, Colorado, Virginia, Wyoming, Utah, Iowa, Missouri, Tennessee, and Oklahoma.

GYPSUM

The gypsum industry suffered a further serious decline in 1930. Tonnages were less in almost every department in the industry, and values were less in every case.

TABLE V

Production of Gypsum in Iowa in 1929 and 1930

	1929		1930	
	Tons	Value	Tons	Value
Crude gypsum mined	718,503	$	484,047	$
Sold crude — cement mills	147,330	232,846	154,860	211,645
Agriculture	1,112	5,888	902	4,057
Total sold crude	148,442	238,734	155,762	215,702
Sold calcined — neat and sanded plaster	39,114	208,416	22,178	208,341
Fibered plaster	276,033	1,276,645	153,576	1,136,208
Plaster board and wall board	126,018 (c)	2,240,024	66,900 (c)	1,671,805
Partition tile	54,468	356,160	31,022	224,083
Other building (a)	17,173	274,823	9,174	141,211
Plaster of paris (b)	8,955	74,054	20,380	143,971
Total sold calcined	521,761	4,430,122	303,230	3,525,617
Total sold	670,203	$4,668,856	458,992	$3,741,319

(a) Includes: Roofing tile, special tile, insulating, fireproofing, other building materials.

(b) The 1929 figures include Keene's cement, sold to plate glassworks. The 1930 figures include sold to plate glassworks, and other purposes.

(c) 1929: Equals 151,961,741 square feet, or 3,489 acres, or 5.45 square miles. 1930: 83,312,425 square feet, or 1912 acres, or 2.99 square miles.

The sales of crude gypsum for use as retarder in cement mills, and sales of plaster of paris were the only items in the gypsum industry which showed an improvement in 1930 over sales for 1929. Unfortunately, lower prices for crude gypsum caused the total amount received for this material to be less than it had been the year before. Sales of plaster of paris increased more than 100 percent in amount and nearly 100 percent in value. This seems to be the one bright spot in the picture. No doubt the great decline in building was the chief reason for the falling off in the business transacted by the gypsum manufacturers. Gypsum has come to be an indispensable material in building construction, and with improvement in business conditions we may look for a return of prosperity to the gypsum industry.

A study of the table giving production of gypsum in the United States shows that this reflects on a larger scale the decrease in production in Iowa. The quantity of crude gypsum mined decreased 31 percent from 1929 to 1930. The value of the sales of gypsum by producers was 14 percent less than in 1929, and 16 percent less than in 1928. New York continued to be the largest producer of gypsum, but showed a notable decrease in 1930. Michigan ranked second in production of gypsum, and Iowa was third. Table V-B gives some details of production in the various manufacturing states.

TABLE V-A

Table of Gypsum in the United States for 1929 and 1930.

	1929		1930	
Plants active	59		56	
	Tons	Value	Tons	Value
Total mined	5,016,132		3,471,393	
Sold crude	1,065,697	$ 2,096,779	989,591	$ 1,886,254
Sold calcined	3,361,580	29,196,190	2,191,376	25,165,230
Total sales	4,427,277	31,292,969	3,180,967	27,051,484

TABLE V-B

Gypsum Mined and Uncalcined and Calcined Gypsum Sold in the United States in 1930.

State	Number of active operators	Total quantity mined (short tons)	Sold by producers				
			Without calcining		Calcined		Total value
			Short tons	Value	Short tons	Value	
Iowa	7	481,047	155,762	$ 215,702	303,230	$ 3,525,617	$ 3,741,319
Michigan	5	519,225	182,050	292,881	300,524	3,462,750	3,755,631
Nevada	5	165,279	49,801	137,214	97,530	839,436	976,650
New York	10	912,070	275,294	597,938	573,602	6,461,170	7,059,108
Ohio	3	255,337	11,460	30,017	243,566	3,064,478	3,094,495
Texas	5	359,315	54,146	84,883	255,727	3,436,860	3,521,743
Utah	3	26,694	(a)	(a)	(a)	(a)	185,148
Other States (b)	18	752,426	(c) 261,078	(c) 527,619	(c) 417,197	(c) 4,374,919	4,717,390
Total, 1930	56	3,471,393	969,591	$ 1,886,254	2,191,376	$25,165,230	$27,051,484
Total, 1929	59	5,016,132	1,065,697	$ 2,096,779	3,361,580	$29,196,190	$31,292,969

(a) Included in "Other States."
(b) Includes Arizona, California, Colorado, Kansas, Montana, Oklahoma, South Dakota, Virginia, and Wyoming.
(c) These figures include also sales from Utah.

LIMESTONE AND LIME

The production of stone and lime in Iowa had declined slightly from 1928 to 1929, but this decline was more than made up in 1930. Table VI shows that increase in the production of stone amounted to over 200,000 tons in 1930, while the increase in value was nearly $300,000. This is, indeed, an encouraging feature in the midst of so many discouraging declines in mineral production. The increase in production of limestone was shared in by most branches of the industry. The ones which showed a decline in 1930 were building stone and stone for fluxing. All other classes of limestone were produced in larger quantities, most of them, it is true, only slightly larger, but in the case of railroad ballast, very notably larger.

The leading kinds of stone produced in 1930, in the order of their tonnages are: 1, stone for concrete and road building; 2, stone for

TABLE VI

Production of Stone and Lime in Iowa, 1929 and 1930.

Kind	1929			1930		
	Plants	Tons	Value	Plants	Tons	Value
Building } Curbing, flagging, paving }	3	12,510 (a)	$ 13,839	3	3,936	$ 4,074
Rubble	3	2,110	2,952	5	6,172	6,885
Riprap	12	92,660	103,777	9	98,780	85,704
Concrete and road metal	29	1,158,490	1,182,773	27	1,160,390	1,297,836
Railroad ballast	5	107,390	45,809	6	258,787	217,727
Flux and Other Uses }	2	58,190	40,841	3	33,545	43,397
Glass and sugar factories }	6			2		
Agriculture	19	193,050	159,752	27	268,720	197,788
		1,625,000	$1,560,066		1,830,320	$1,853,411

(a) The figures for curbing, flagging, and paving were not combined with the Building totals in 1929, but were combined in 1930. These items were not reported for 1929.

agriculture; 3, railroad ballast; 4, riprap. The values of different kinds of stone differed considerably in rank from the rankings in tonnage, and were as follows: 1, stone for concrete and roadbuilding; 2, railroad ballast; 3, stone used in agriculture; 4, riprap. Table VI shows the production of stone during 1929 and 1930 by classes, while Table VII shows production by counties.

Among the counties, Madison was the leader in both tonnage and value, with the Hawkeye Portland Cement Co. the largest operator. This company has its office and cement plant in Des Moines. (As is true in all of these reports, the limestone that is discussed under this topic is separate from that used for cement making.) The other leading counties were Scott, Marshall, Black Hawk, Clayton, and Johnson in tonnage, and Black Hawk, Marshall, Scott, Johnson, and Clayton in value.

Lime was burned during 1929 and 1930 at only one plant — the Hurst estate at Hurstville near Maquoketa in Jackson County. The

TABLE VI-A

Stone sold or used by producers in the United States, 1929 and 1930, by uses

Use	1929		1930	
	Quantity in short tons	Value	Quantity in short tons	Value
Building and monumental stone	3,013,640	$ 59,753,249	2,612,370	$ 52,269,077
Paving blocks, curbing, and flagging	724,470	7,453,939	638,410	6,551,388
Rubble, riprap, crushed stone	97,842,060	100,743,302	92,469,510	93,215,413
Other uses (a)	39,529,410	34,742,272	31,276,050	26,912,733
Total (quantities approximate in short tons)	141,109,580	$202,692,762	126,996,340	$178,948,611

(a) Other uses include furnace flux, refractory stone, agricultural limestone, manufacturing industries, and miscellaneous stone used.

TABLE VII

Production of Limestone and Lime in Iowa in 1930.

Counties	Plants	Building stone, rubble, riprap		Concrete, road metal		Other uses (a)		Total	
		Tons	Value	Tons	Value	Tons	Value	Tons	Value
Allamakee (2), Winneshiek (1)	3			43,515	$ 54,938	(b)	(b)	43,515	$ 54,938
Black Hawk (3), Bremer (1)	4			146,646	180,721	31,859	$ 19,152	178,505	199,873
Cass (1), Madison (1), Van Buren (2)	4	(b)	(b)	314,510	349,677	48,525	27,713	363,035	377,390
Cerro Gordo (1), Fayette (1), Hardin (1), Marshall (2)	5			153,050	173,306	303,233	274,985	456,283	448,291
Clayton (3), Dubuque (3), Jackson (2)	8	79,016	$ 62,887	162,000	175,890	43,235	38,853	284,251	277,630
Clinton (4), Scott (2)	6	(b)	(b)	158,642	132,156	83,317	65,682	241,959	197,838
Floyd (1), Jones (3)	4	13,320	13,981	8,372	8,372	11,107	11,466	32,799	33,819
Johnson (1), Linn (3)	4			158,694	175,381	17,173	12,576	175,867	187,957
Lee	5	8,195	9,503	39,863	60,416	6,048	5,756	54,106	75,675
Totals for 1930	43	100,511	$ 86,371	1,185,292	$1,310,857	544,497	$456,183	1,830,320	$1,853,411
Totals for 1929	41	107,280	$120,568	1,158,490	$1,182,773	359,230	$251,652	1,625,000	$1,560,066

(a) Includes: Railroad ballast, flux, sold to sugar factories, agricultural limestone, railroad fills.
(b) Included in Concrete.

figures regarding production are combined with those for the output of limestone.

Production of limestone decreased in United States as a whole. In 1930 the output amounted to 88,741,440 short tons valued at $100,-002,114, a decrease of 12 percent in both quantity and value from 1929. Table VI-A shows the production of different classes of stone during 1929 and 1930.

SAND AND GRAVEL

Table VIII shows a gratifying increase in the total production of both sand and gravel during 1930. The price per ton for some classes was slightly less in 1930, and consequently the increase in value is somewhat less than the increase in tonnage. The more important increases in 1930 were in building sand, which increased 140,000 tons; paving and road sand, where increase amounted to 100,000 tons; building gravel, which increased nearly 170,000 tons; and paving and road gravel, which increased about 150,000 tons.

There were slight declines in the production of molding sand, grinding and polishing sand, engine sand, miscellaneous sands, and railroad and miscellaneous gravel counted together.

TABLE VIII

Summary of Sand and Gravel Production in Iowa, 1929 and 1930.

Materials	1929				1930			
	Pits	Tons	Value	Ave. Price	Pits	Tons	Value	Ave. Price
Sand								
Molding	3	48,558	$ 32,911	$ .68	5	28,343	$ 27,030	$ .95
Building	39	442,491	224,833	.51	49	583,949	292,721	.50
Paving and roads	42	1,294,148	538,416	.42	39	1,397,207	562,809	.40
Grinding, polishing	3	18,676 (a)	41,050		3	2,788 (b)	4,137	1.48
Engine	10	44,338	22,146	.50	10	31,184	15,396	.49
Filter	0				4	3,172	1,939	.61
Railroad ballast	3	26,345	5,726	.22	4	56,260	18,670	.33
Other	7	12,723	2,965	.23	4	7,433 (c)	1,710	
Total sand	62*	1,887,279	$ 868,047		66*	2,110,336	$ 924,412	
Gravel								
Building	40	317,719	254,666	.80	54	485,792	496,261	1.02
Paving and roads	44	1,600,895	973,893	.61	50	1,749,235	1,113,549	.64
Railroad ballast	7	224,204	93,587	.42	6	(d)		.36
Other	4	13,572	21,559	1.60	1	176,608	64,885	2.00
Total gravel	64*	2,156,330	$1,343,705		76*	2,411,635	$1,674,695	
Total output		4,043,609	$2,211,752			4,521,971	$2,599,107	

(a) The figures for 1929 include filter sand and blast sand with grinding and polishing.
(b) This figure includes grinding, polishing, and blast sand.
(c) The totals for fire and furnace sand are included in other sand.
(d) Included in other gravels.
* This figure is not the sum of the numbers given above. It is the total number of different pits in the state. The same pit may produce sand or gravel that is used for several different purposes.

These reports have previously called attention to the fluctuations of sand and gravel in different counties during a period of years. These fluctuations were well illustrated during 1930. In that year the leading counties in tonnage were: first, Sac, followed in order by Cerro Gordo, Polk, Muscatine, Butler, Sioux, and Mahaska.

In value the ranking of the first seven counties was slightly different: Cerro Gordo, Sac, Polk, Mahaska, Muscatine, Butler, and Sioux.

Reports show that Muscatine has declined from first in tonnage and value in 1929 to fourth in tonnage and fifth in value in 1930. Sac advanced from fourth in tonnage and third in value in 1929 to first in tonnage and second in value in 1930. Cerro Gordo made a slight advance; from second in both tonnage and value in 1929 it remained second in tonnage and became first in value in 1930.

Tables IX and X show the production of sand and gravel respectively by counties. It is regrettable that so many counties must be grouped together, but this is necessary in order not to reveal individual production.

Table VIII-A shows the production of different classes of sand and gravel in the United States in 1929 and 1930. Production of sand and gravel in 1928 was the highest in the nation's history thus far. In 1929

TABLE VIII-A

Sand and Gravel Sold or Used by Producers in the United States 1929 and 1930 by Uses

Use	1929		1930	
	Short Tons	Value	Short Tons	Value
Sand:				
Glass	2,219,677	$ 3,788,471	1,849,101	$ 3,210,973
Molding	6,195,343	6,410,343	3,336,855	3,547,154
Building	41,161,013	23,309,238	33,599,524	18,850,936
Paving	40,801,991	21,131,731	36,367,468	18,674,649
Grinding and Polishing	1,636,464	2,303,652	1,115,915	1,613,022
Fire or Furnace	440,679	483,551	258,241	333,727
Engine	2,318,931	1,487,906	1,773,204	1,219,070
Filter	100,081	199,838	80,326	167,947
Other (a)	4,378,875	1,686,627	5,277,984	2,104,075
	99,253,054	60,801,357	83,658,618	49,721,553
Gravel:				
Building	32,448,800	23,813,885	28,271,902	21,346,251
Paving	60,029,164	38,695,207	64,408,274	37,349,936
Railroad Ballast (b)	30,840,887	9,525,530	20,712,932	6,758,803
	123,318,851	72,034,622	113,393,108	65,454,990
Grand Total	222,571,905	$132,835,979	197,051,726	$115,176,543

(a) Includes some sand used for railroad ballast, fills, etc.
(b) Includes some gravel used by the railroads for fills and other purposes. The quantity of gravel reported as used exclusively for railroad ballast was as follows: 1929, 27,332,529 tons, valued at $8,804,082; 1930, 16,227,543 tons, valued at $5,554,684.

TABLE IX

Production of Sand and Gravel in 1930 — Sand

Counties	Producers	Structural sand		Paving sand		Other sand (a)		Total sand	
		Tons	Value	Tons	Value	Tons	Value	Tons	Value
Allamakee (1), Clayton (2), Dubuque (2), Fayette (1)	6	44,663	$ 29,473	35,295	$ 13,147	(c)	(c)	79,958	$ 42,620
Appanoose (1), Lee (2), Marion (1)	4	19,613	8,872	6,700	3,272	(b)(c)	(b)(c)	26,313	12,144
Black Hawk (3), Butler (3)	6	66,030	37,193	152,906	54,029	(c)	(c)	218,936	91,222
Boone (2), Dallas (1), Story (1)	4	12,160	8,567			(c)	(c)	12,160	8,567
Buena Vista (0), Cherokee (1), Palo Alto (1), Pocahontas (1)	3			112,032	19,856	(b)	(b)	112,032	19,856
Cerro Gordo (2), Floyd (1), Grundy (0), Mitchell (0)	3	263,110	122,020	(c)	(c)	(c)	(c)	263,110	122,020
Clay (1), Sioux (4)	5	76,400	30,740	71,700	26,530	20,420	7,480	168,520	64,750
Clinton	3	56,168	19,214	(c)	(c)			56,168	19,214
Crawford (0), Harrison (1), Sac (3), Webster (1)	5	(b)	(b)	172,605	66,105			172,605	66,105
Des Moines (1), Muscatine (3), Scott (1)	5	28,878	21,251	162,827	57,319	(c)	(c)	191,705	78,570
Emmet (1), Lyon (1), Osceola (0), Plymouth (1)	3	18,162	6,798					18,162	6,798
Franklin (1), Hancock (1), Humboldt (1), Wright (0)	3	134,639	53,570	(c)	(c)	(c)	(c)	134,639	53,570
Jackson (1), Johnson (2)	3	19,195	9,034	40,500	17,450	(d)	(d)	59,695	26,484
Linn (2), Mahaska (1), Marshall (0), Tama (1), Van Buren (1)	5	110,526	59,512	209,047	110,958	(c)	(c)	319,573	170,470
Polk	8	84,574	44,542	192,186	97,480	(c)	(c)	276,760	142,022
Totals for 1930	66	934,118	$449,786	1,155,798	$466,146	20,420	$ 7,480	2,110,336	$924,412
Totals for 1929	60	442,491	$224,833	1,294,148	$538,416	150,640	$104,798	1,887,279	$868,047

(a) Includes: Molding, cutting and grinding and blast, engine, filter, railroad ballast, and other sands.
(b) Included with paving sand.
(c) Included with structural sand.

TABLE X

Production of Sand and Gravel in 1930 — Gravel

Counties	Producers	Structural gravel		Paving and other gravel		Total sand and gravel		Total quantity washed	
		Tons	Value	Tons	Value	Tons	Value	Tons	Value
Allamakee (1), Clayton (2), Dubuque (2), Fayette (1)	6	19,050	$ 9,950	99,484	$ 52,844	198,492	$ 105,394	75,990	$ 56,395
Appanoose (0), Lee (2), Marion (1)	3	5,224	5,599			31,537	17,743	30,923	17,614
Black Hawk (3), Butler (2)	5	11,281	13,769	148,685	153,321	378,902	258,312	374,177	255,687
Boone (2), Dallas (1), Story (1)	4	4,337	3,796	130,749	48,236	147,246	60,599	97,725	55,709
Buena Vista (1), Cherokee (1), Palo Alto (2), Pocahontas (1)	5	(b)	(b)	368,642	83,026	480,674	102,882	74,880	24,700
Cerro Gordo (2), Floyd (0), Grundy (1), Mitchell (1)	4	62,034	73,605	156,429	170,630	481,573	366,255	481,034	366,005
Clay (1), Sioux (5)	6	46,585	47,993	87,500	48,750	302,605	161,493	232,500	129,983
Clinton	5	45,224	34,760	52,104	24,500	142,552	78,474	120,257	64,344
Crawford (2), Harrison (2), Sac (6), Webster (0)	10	197,401	184,351	243,609	88,124	613,615	338,580	527,407	325,722
Des Moines (1), Muscatine (3), Scott (1)	5	11,230	26,685	213,250	150,989	416,185	256,244	396,738	242,004
Emmet (1), Lyon (2), Osecola (1), Plymouth (1)	5	11,239	5,707	81,309	16,852	110,710	29,357	37,292	16,039
Franklin (1), Hancock (1), Humboldt (1), Wright (1)	4	11,259	14,836	70,836	45,498	216,734	113,904	143,905	105,120
Jackson (1), Johnson (2)	3	8,195	5,858	78,231	54,609	146,121	86,951	146,121	86,951
Linn (1), Mahaska (1), Marshall (1), Tama (1), Van Buren (0)	4	15,304	20,009	121,081	155,017	455,958	345,496	449,800	344,136
Polk	7	37,282	49,320	74,081	86,061	388,123	277,403	353,221	248,725
Totals for 1930	76	485,645	$496,238	1,925,990	$1,178,457	4,521,971	$2,599,107	3,541,970	$2,339,134
Totals for 1929	64	317,719	$254,666	1,838,611	$1,089,039	4,043,609	$2,211,752	3,089,611	$1,992,835

(b) Included with paving gravel.

production increased 6.4 percent over that of 1928. This industry, however, was feeling the effects of the worldwide depression in 1930, and the output decreased 11 percent in quantity and 13 percent in value from that of 1929.

In Table IX-A is shown the production of sand and gravel in ten leading states during 1929 and 1930. Iowa ranked sixteenth in tonnage produced and fourteenth in value for 1930. This compares with a rank of fifteenth in production and sixteenth in value during 1929.

TABLE IX-A

Sand and Gravel Production in Leading States in 1929 and 1930

State	1929		1930	
	Tons	Value	Tons	Value
New York	21,061,094	$ 14,919,658	20,865,866	$ 12,710,172
Illinois	18,256,203	9,071,258	17,398,693	8,382,025
Michigan	16,844,099	7,928,744	11,389,119	5,161,176
California	15,688,545	8,371,263	12,604,051	7,354,506
Ohio	14,250,141	9,182,862	12,679,854	8,173,741
Pennsylvania	12,674,320	13,658,328	11,012,512	11,107,825
Indiana	10,901,798	5,528,832	9,838,757	4,667,771
Wisconsin	10,727,632	4,574,182	7,082,063	2,801,713
Texas	9,409,295	5,765,943	8,803,929	5,567,127
New Jersey	6,721,498	5,585,285	5,969,479	5,009,866
Total for U. S.	222,571,905	$132,835,979	197,051,726	$115,176,543

Iowa ranked sixteenth in tonnage and fourteenth in value.

MINERAL PRODUCTION IN 1931

OUTLINE

The record of mineral production in 1930 did not offer much encouragement in comparison with the record for 1929, for there was a decrease of over two million dollars in the value of the output in the later year. But what shall we say for 1931? The record for this year shows a drop from 33 million to 21 million dollars. This is the most serious decline that has occurred since this Survey began collecting mineral statistics.

In the first place, the number of operators was less in nearly every branch of the mineral industry. In the second place, the value of materials produced and sold was less in every division of the industry in 1931 — in some cases nearly 50 percent less. The most serious declines were in cement, where values dropped from $10,100,000 in 1930 to $5,450,000 in 1931; in clay wares, where the drop was from $4,700,000 to $2,280,000; and in sand and gravel, where values declined from $2,545,000 to $1,511,000. While these conditions are decidedly discouraging, they are only a part of a nation-wide and even worldwide situation.

The mineral industry, in turn, merely reflects conditions in other lines of business; this industry will improve as other business comes back to normal.

TABLE I

Mineral Production in Iowa in 1930 and 1931

Product	Unit	1930			1931		
		Producers	Quantity	Value	Producers	Quantity	Value
Cement	bbl.	6	7,035,252	$10,107,584	5	5,790,087	$ 5,453,320
Clay Wares	ton			4,713,448			2,287,903
Coal	ton	233	3,892,571	10,385,000	231	3,388,355	8,575,000
Gypsum	ton	8	458,992	3,741,319	6	309,200	2,588,126
Limestone and Lime	ton	43	1,814,291	1,850,832	43	1,271,710	1,210,705
Sand and Gravel	ton	87	4,333,637	2,545,287	75	3,403,396	1,511,278
				$33,343,470			$21,626,332

TABLE I-A

Mineral Production in the United States in 1930 and 1931

Summary	1930	1931
	Value	Value
Total value of metallic products	$ 982,550,000	$ 567,200,000
Total value of nonmetallic products (exclusive of mineral fuels)	1,008,900,000	699,700,000
Total value of mineral fuels	2,764,500,000	1,892,400,000
Total value of "unspecified" (metallic and nonmetallic) products (partly estimated)	8,850,000	7,300,000
Grand total approximate value of mineral products	$4,764,800,000	$3,166,600,000

Table I gives a comparison of conditions in Iowa in 1930 and 1931. Table I-A shows a summary of mineral production in the United States for the same years. This table brings out the facts that metallic products decreased in value nearly one half — from almost one billion dollars to a little over one-half billion dollars; nonmetallic products except fuels decreased from one billion dollars to almost 700 million dollars. Mineral fuels decreased from nearly $2\frac{3}{4}$ billion dollars to a little less than 2 billion dollars. The total mineral production decreased from a value of nearly $4\frac{3}{4}$ billion dollars to a little over 3 billion dollars.

CEMENT

The portland cement industry suffered in 1931 what was undoubtedly the most serious reverse of its history in Iowa. The decrease in the number of barrels shipped amounted to slightly over one million. This was serious enough in itself, but, added to a drop of 50 cents per barrel in the average price received at the mills, it brought about a fall in value amounting to about 44 percent.

The Gilmore City Plant of the Northwestern States Portland Cement Co. was idle. The other five plants were operating, but on a scale far below their real capacity. The following companies were operating during 1930 and 1931:

Davenport, Dewey Portland Cement Co., Kansas City, Mo.
Brand — Dewey.
Des Moines, Hawkeye Portland Cement Co., Des Moines.
Brand — Hawkeye.
Gilmore City, Northwestern States Portland Cement Co., Mason City.
Brand — Northwestern. (In 1930 only)
Mason City, Lehigh Portland Cement Co., Allenton, Pa.
Brand — Lehigh.
Northwestern States Portland Cement Co., Mason City.
Brand — Northwestern.
Valley Junction, Pennsylvania-Dixie Cement Corporation, Des Moines.
Brand — Pyramid.

All of the plants except the Mason City plant of the Northwestern States Portland Cement Co. are now operating by the wet process rather than by the dry process, which all of the older plants formerly used. These data are given in detail in Table II.

TABLE II

Production of Cement in Iowa

	1930	1931
Production, bbls.	7,088,108	5,804,462
Stock, December 31, bbls.	1,400,000	1,414,375
Shipments, bbls.	7,035,252	5,790,087
Shipments, value	$ 10,107,584	$ 5,453,320
Average price per bbl.	$1.44	$0.94
Estimated consumption, bbls.	6,411,595	
Annual capacity, bbls.	10,293,900	10,293,900

Production of portland cement in the United States in 1931 showed a decrease of 21 percent from 1930. Shipments from mills during 1931 — 127,150,000 barrels, valued at $140,976,000 — decreased 20 percent in quantity and 38 percent in value. The average factory price per barrel in 1931 was $1.11, a decrease of 33 cents per barrel as compared with 1930. A summary of the statistics for the cement industry in 1931 is given in Table II-A.

TABLE II-A

Production of Cement in the United States

	1930	1931
Production, bbls.	161,197,228	125,429,071
Shipments, bbls.	159,059,334	127,150,534
Shipments, value	$228,779,756	$140,976,450
Stock, December 31, bbls.	25,838,427	24,177,159
Plants active	163	163

CLAY AND CLAY PRODUCTS

The production of clay was much decreased in 1931 from that of

1930. 1,271 tons were reported in quantity and $13,322 in value.

If the situation in the cement industry was discouraging in 1931, the condition of the clay wares industry was even less satisfactory. Production in this industry in Iowa dropped off slightly more than 50 percent in value, from $4,700,000 to less than $2,300,000. Naturally, the different classes of clay wares showed similar declines, such, for instance, as common brick from a value of $600,000 to $400,000; and drain tile from $900,000 to $250,000. In fact, every branch of the clay-working industry showed a similar decline. Details of production showing quantities and values for 1931 are shown in Table III.

TABLE III

Production of Clay Products, by Class, Quantity, and Value, 1930 and 1931

Class and Year	Quantity	Value
Total value:		
1931		$2,287,903
1930		4,713,448
Common brick:	Thousands	
1931	33,814	403,547
1930	53,100	600,394
Face brick:		
1931	16,024	239,036
1930	23,906	389,275
Hollow building tile:		
(a) Partition, load-bearing, etc. —	Tons	
1931	112,890	694,789
1930	212,372	1,523,298
(c) Floor arch, etc. —		
1931	35,651	186,365
1930	(1)	(1)
Draintile:		
1931	34,697	256,354
1930	114,500	897,344
Sewer pipe:		
1931	29,017	392,208
1930	45,763	675,757
Flue lining:		
1931	2,243	22,280
1930	3,648	42,938
Wall coping:		
1931	362	6,723
1930	774	13,511
Clay sold, raw or prepared:		
1931	978	11,721
1930	4,181	41,961
Other clay products, including pottery:		
1931		74,880
1930		528,970

(1) Included in "Other clay products" in order to avoid disclosing approximations of data supplied by individual establishments.

The list of clay ware producers in Iowa is given below.

Appanoose County — Centerville Brick & Tile Co., Centerville.
Cerro Gordo County — Mason City Brick & Tile Co., Mason City.

Dallas County — Adel Products Co., Redfield; Redfield Brick & Tile Co., Redfield; United Brick & Tile Co., Adel.
Floyd County — Rockford Brick & Tile Co., Rockford.
Franklin County — Sheffield Brick & Tile Co., Sheffield.
Jackson County — Bellevue Pottery Co., Bellevue.
Keokuk County — Nelson & Sons, What Cheer.
Polk County — Des Moines Clay Co., 25th & Aurora Sts., Des Moines; Flint Brick Co., 907 Bankers Trust Bldg., Des Moines; Goodwin Brick and Tile Co., 410 Shops Bldg., Des Moines; United Brick & Tile Co., 412 Hubbell Bldg., Des Moines.
Story County — Nevada Brick & Tile Works, Nevada.
Tama County — Gladbrook Press Brick & Tile Co., Gladbrook.
Wapello County — Morey Clay Products Co., Ottumwa.
Webster County — Johnson Clay Works, Fort Dodge; Kalo Brick & Tile Co., Fort Dodge; Kalo Brick & Tile Co., Otho; Lehigh Sewer Pipe & Tile Co., Fort Dodge; M. J. M. Norton, Fort Dodge; Vincent Clay Products Co., Fort Dodge.
Woodbury County — Sioux City Brick & Tile Co., Sioux City.

COAL

The picture of coal operations in 1931 is of itself none too bright, it is true; however, in contrast with some other portions of the mineral industry, it does offer some relief from the rather dreary picture of the mineral industry in general. Coal production declined about half a million tons in 1931. Of course this was serious enough, but it was rather slight as compared with the declines in cement and clay shipments.

The decline in average price per ton from $2.67 to $2,53 was one of the important factors in the decline of nearly two million dollars in the value of the coal sold. The number of employees was practically the same each year, but the average number of days worked was 13 less in 1931 than in 1930. The average tonnage mined by each man was also less in 1931. Only two mines produced between 200,000 and 500,000 tons each, as compared with four mines of that rank in 1930. Six mines produced between 100,000 and 200,000 tons each, as compared with eight such mines the previous year. Nine mines produced between 50,000 and 100,000 tons each, while ten mines ranked in this class in 1930. There were 36 mines in the 10,000 to 50,000 tons class in 1931, as compared with 34 in the previous year. The remainder of the 231 mines, those producing less than 10,000 tons each, numbered 178 in 1931, and 177 in 1930.

Among the different coal-producing counties of the state, Appanoose mined the most tons, followed by Polk, Lucas, Marion, Dallas, Boone, Monroe. As is always the case, in value the rank was slightly different; Polk was the leader with these counties following in order — Appanoose, Lucas, Boone, Dallas, Marion, Monroe.

These facts are shown graphically in Table IV.

TABLE IV

Production, Value, Men Employed, Days Worked, and Output Per Man Per Year at Coal Mines in Iowa in 1931.[a]

(Exclusive of product of wagon mines producing less than 1,000 tons)

County	Net tons				Value		Number of employees				Average number of days worked	Average tons per man per year[b]
	Loaded at mines for shipment	Sold to local trade and used by employees	Used at Mines for power and heat	Total quantity	Total (thousand dollars)	Average per ton	Underground		Surface	Total		
							Miners, loaders, and shot firers	All others				
Adams	------	13,380	------	13,380	$ 41	$3.06	31	10	8	49	171	273
Appanoose	477,591	66,202	738	544,531	1,248	2.29	1,502	264	153	1,919	120	284
Boone	288,144	74,548	2,994	365,686	1,188	3.25	789	175	69	1,033	141	354
Dallas	356,361	18,031	1,750	376,142	992	2.64	537	97	35	669	149	562
Davis	------	1,254	------	1,254	4	3.19	9	2	4	15	57	84
Greene and Webster	------	18,053	10	18,063	57	3.16	51	10	13	74	97	244
Guthrie	------	9,256	------	9,256	31	3.35	29	12	8	49	146	189
Jasper	------	56,204	3,062	59,266	153	2.58	92	31	18	141	160	420
Jefferson and Keokuk	------	4,420	------	4,420	11	2.49	11	5	3	19	136	233
Lucas	460,380	4,254	6,131	470,765	1,192	2.53	469	157	52	678	142	694
Mahaska	56	48,836	180	49,072	115	2.34	92	24	27	143	143	343
Marion	340,173	44,766	7,723	392,662	918	2.34	578	187	70	835	148	470
Monroe	312,822	29,321	2,772	344,915	731	2.12	502	95	61	658	159	524
Page	1,320	24,376	------	25,696	92	3.58	58	19	8	85	174	302
Polk	156,942	347,405	7,210	511,557	1,273	2.49	703	187	70	960	171	533
Taylor	870	7,772	------	8,642	30	3.47	36	8	5	49	135	176
Van Buren	236	8,685	150	9,071	26	2.87	17	6	5	28	99	324
Wapello	375	78,826	870	80,071	210	2.62	141	35	29	205	144	391
Warren	43,537	37,549	3,580	84,666	215	2.54	145	51	20	216	127	392
Wayne	3,570	14,170	1,500	19,240	48	2.49	48	12	12	72	118	267
Total 1931	2,442,377	907,308	38,670	3,388,355	$ 8,575	$2.53	5,840	1,387	670	7,897	142	429
Total 1930	2,933,518	903,038	56,015	3,892,571	$10,385	$2.67	5,883	1,388	630	7,901	155	493

(a) The figures relate only to active mines of commercial size that produced coal in 1931. The number of such mines in Iowa was 231 in 1931; 233 in 1930; 201 in 1929. Size classes of commercial mines in 1931: There were 2 mines in Class 1 B (200,000 to 500,000 tons); 6 in Class 2 (100,000 to 200,000 tons); 9 in Class 3 (50,000 to 100,000 tons); 36 in Class 4 (10,000 to 50,000 tons); 178 in Class 5 (less than 10,000 tons). Methods of mining in 1931: The tonnage by hand was 402,157; shot off the solid, 1,894,751; cut by machine, 1,055,711; not specified, 35,736.

(b) The output per man per day for the State as a whole, calculated by dividing the tonnage by the product of the number employed at each mine times the number of days worked by the mine, was 3.02 tons in 1931; and 3.18 in 1930.

It is, perhaps, worthy of note that two of the counties in the southwestern Iowa coal field, mining the Nodaway seam, increased their output slightly in 1931. Adams County raised its production from 10,000 to 13,000 tons, and Page County increased its output about 2,600 tons. Taylor County, however, suffered a slight decline of 800 tons. Certainly the field as a whole compared well with the larger field in the Des Moines valley. The list of coal operators for 1931 in Iowa is as follows:

Adams County
- Black Diamond Coal Co., Route 1, Nodaway
- John G. Henton, R.F.D. 1, Carbon
- Larson & Turner, Route 6, Corning
- McKee Coal Co., Route 6, Corning
- Smith & Drake, Carbon

Appanoose County
- Appanoose County Coal Co., Centerville
- Bert Arbogast, Numa
- Armstrong Coal Co., Cincinnati: office Commerce Bldg., Kansas City, Mo.
- Barrett Coal Co., Mystic
- Battle Creek Coal Co., Route 2, Mystic
- Big Slope Coal Co., Route 3, Centerville
- Bradshaw Coal Co., Dean
- Buban Coal Co., Route 1, Mystic
- Frank Casale, 517 E. Walnut St., Centerville
- Center Coal Co., Centerville
- Centerville Block Coal Co., Centerville
- Centerville Coal Co., Centerville
- Citizens Coal Co., Centerville
- Clarke Coal Co., Centerville
- J. A. Colgan Coal Co., Mystic
- Columbus Coal Co., Centerville
- Continental Coal Co., Centerville
- Diamond Lump Coal Co., Centerville
- Domestic Coal Co., Cincinnati
- Duff Coal Co., Mystic
- Curt Ellis, Centerville
- Empire Coal Co., Centerville
- Enterprise Coal Co., Numa
- Enterprise Coal Co., Rathbun
- Fairlawn Coal Co., Centerville
- Friendship Coal Co., Cincinnati
- Guinn Coal Co., Coal City
- Hafner Coal Co., Cincinnati
- Helman Bros. Coal Co., Centerville
- Herr Coal Co., Plano
- Hi-Test Coal Co., Mystic
- Iowa Block Coal Co., Centerville
- Johnson Coal Co., Mystic
- Kincaide Coal Co., Centerville
- J. A. Koontz, Centerville
- Liberty Coal Co., Mystic
- Little Walnut Coal Co., Mystic
- W. W. Lowe, Brazil
- Maddalozzi Coal Co., Mystic
- McConville Coal Co., Centerville
- Monitor Coal Co., Centerville
- New Egypt Coal Co., Mystic
- New Rock Valley Coal Co., Centerville
- New Star Coal Co., Route 1, Centerville
- North Hill Coal Co., Centerville
- Numa Coal Co., Numa
- Old King Coal Co., Centerville
- Peacock Coal Co., Brazil
- Prospect Coal Mine, J. F. Daniels, Exline
- Rathbun Coal Co., Rathbun
- Red Bird Coal Co., Seymour
- Simatovich Coal Co., Route 3, Centerville
- Star Coal Co., Mystic
- Sunshine Coal Co., Centerville
- Thistle Coal Co., Cincinnati
- Byte Coal Co., Centerville
- Walnut Creek Coal Co., Jerome
- Water Lily Coal Co., Rathbun
- White Oak Coal Co., Exline

Boone County
- Benson Coal Co., Boone
- Boone Coal Co., Inc., Boone
- Fort Dodge, Des Moines & Southern R. R. Co., Ogden
- Ogden Superior, Ogden
- Kristianson Bros., Route No. 1, Ogden
- Scandia Coal Co., Madrid: office 606 Grand Ave., Des Moines

Dallas County
- Dallas Fuel Co., Granger: office Insurance Exchange Bldg., Des Moines
- Norwood-White Coal Co., Moran: office 907 Bankers Trust Bldg., Des Moines
- Scandia Coal Co., Des Moines
- Shuler Coal Co., Waukee: office So. Surety Building, Des Moines

Davis County
- Henderson & Goodwin Coal Co., Floris
- Lunsford Bros. Coal Co., Bloomfield
- Mitchell Bros. Coal Co., R.F.D. No. 2, Floris
- Van Patten Coal Co., Floris

Greene County
- Greene County Coal Co., Jefferson
- Harold McElheny Co., Rippey
- Riverside Coal Co., Rippey

Guthrie County
- Butler Coal Co., Guthrie Center
- John Mansell Coal Co., Guthrie Center
- Elmer Renslow Coal Co., Guthrie Center
- Lloyd Renslow Coal Co., R.R. 3, Guthrie Center
- W. H. Scott, R.R. 5, Guthrie Center
- H. M. Sipe Coal Co., Guthrie Center
- Thomas Coal Co., Guthrie Center

Jasper County
- Colfax Coal Co., Colfax
- Hopkins Coal Co., Colfax
- Jackson Coal Co., R.F.D. 4, Newton
- Newton Coal Co., Newton
- Oswalt Coal Co., Colfax
- Prairie Coal Co., 904 E. 29th St., Des Moines
- Acklin & Peterson, R.F.D. 3, Monroe

Jefferson County
- Bonnett Coal Co., Fairfield
- Star Coal Co., R.F.D. 7, Fairfield

Keokuk County
- Carson Bros., What Cheer

Lucas County
- Central Iowa Fuel Co., Williamson: office 1209 So. Surety Bldg., Des Moines
- Consolidated Indiana Coal Co., mine near Williamson: office 139 West Van Buren St., Chicago, Ill.
- Mederais Coal Co., R. 1, Lacona
- Union Coal Co., Lucas

Mahaska County
- Charles Ahrweiler, Oskaloosa
- Ball & Co., What Cheer
- Blomgren Bros. Coal Co., R.F.D., Lovilia
- Cromwell & Wilson, Givin
- De Frehn & Son, Oskaloosa
- Edwards Bros. Coal Co., Oskaloosa
- Thomas H. Edwards, Beacon
- A. M. Ellis Coal Co., Givin
- Evans Bros. Coal Co., Eddyville
- Evans Coal Co., Evans
- Steve & Joe Gasper, Truax
- Givin Coal Co., Givin
- Hynick Coal Co., R.R. 1, Givin
- Thomas Lewis, Givin
- Lockhart Coal Co., R.F.D., Oskaloosa
- Mathes Coal Co., Givin
- Frank Mathews, Oskaloosa
- Mitchell Coal Co., 902 1st Ave. W., Oskaloosa
- J. M. Mitrisin, Oskaloosa
- Oskaloosa Coal Co., Oskaloosa
- Owens & Griffith, Beacon
- O. E. Price & E. Snook, University Park
- Roberts Bros. Coal Co., Oskaloosa
- Swanson & Lewis Coal Co., Oskaloosa
- Sweitzer Coal Co., Eddyville
- Thatcher Coal Co., Oskaloosa
- White Bros. Coal Co., Rose Hill
- Williams Coal Co., New Sharon

Marion County
- Bishop Coal Co., R.F.D., Knoxville
- Bradley Bros. Coal Co., R.R. 1, Knoxville
- Consolidated Indiana Coal Co., Melcher: office 139 West Van Buren St., Chicago
- Cox Bros., R. R. 3, Knoxville
- Deitrich & Clark, Cordova
- Chas. Fortner Coal Co., R.F.D., Knoxville
- Hamilton Coal Co., Hamilton
- Hayes Bros. Coal Co., Knoxville
- Horse Shoe Coal Co., Bussey
- Johns Bros. Coal Co., Bussey
- Walter McElrea, Dallas
- McNeish Bros., Knoxville
- Pershing Coal Co., Pershing: office 648, Ins. Exch. Bldg., Des Moines
- Red Rock Coal Co., Melcher: office 1219 So. Surety Bldg., Des Moines
- Riggens Coal Co., Harvey
- Ben Rowley, Knoxville
- Success Coal Co., Otley

Monroe County
- Avery Valley Coal Co., Monroe
- Blackstone Coal Co., R.R. 1, Lovilia
- Carbon Coal Co., Albia
- City Coal Co., Albia
- De Ross Coal Co., R.R. 3, Albia
- Graham Coal Co., Avery
- Lovilia Coal Co., Lovilia
- Monroe Block Coal Co., Albia
- Midwest Coal Co., Albia
- Plainview Coal Co., Albia
- Rex Fuel Co., Albia
- Smoky Hollow Coal Co., Albia
- Smith Bros., Monroe

Page County
- Clarinda Coal Co., Clarinda
- Evans Coal Co., Clarinda
- Pearson Coal Co., Clarinda
- Sawmill Coal Co., Clarinda

Polk County
- Beck Coal & Mining Co., Des Moines
- Bennett Bros. Coal Co., Des Moines
- Capital City Coal Co., Box 864, Des Moines
- Carbon Mining Co., 907 Bankers Trust Bldg. Des Moines
- Central Service Co., 100 E. Maple St., Des Moines
- Clover Leaf Coal Co., Des Moines
- Des Moines Coal Co., Valley National Bank Bldg., Des Moines
- Economy Coal Co., Des Moines
- Four Mile Coal Co., 42nd & Easton Blvd., Des Moines
- Gibson Coal Co., Rider: office 225 Iowa Bldg., Des Moines

Independent Coal Co., Bankers Trust Bldg., Des Moines
Norwood-White Coal Co., Herrold: office Des Moines
Standard Coal Co., 2456 East Grand Ave., Des Moines
Robert Stanford Coal Co., Des Moines
Urbandale Coal Co., Des Moines

Taylor County
Ankeny Coal Co., New Market
Bean Coal Co., New Market
Carbon Coal Co., New Market
New Market Coal Co., New Market

Van Buren County
Barr & Sons, R.R. 1, Birmingham
R. A. Carmichael, Birmingham
J. Daniels & Sons, Douds
Ratcliff Coal Co., Douds

Wapello County
Airline Coal Co., 415 S. Willard St., Ottumwa
Best Coal Co., R.F.D., Ottumwa
Big Four Coal Co., Ottumwa
Carr Bros. Coal Co., Eldon
Gibb Coal Co., R.F.D., Ottumwa
Glendale Coal Co., 1317 Castle Street, Ottumwa
Happy Hollow Coal Co., R.F.D., Ottumwa
Hartwig Bros. Coal Co., Eldon
Indian Head Coal Co., Ottumwa
Kirkville Coal Co., Ottumwa
Miers & Houk Coal Co., R.R. 8, Ottumwa
Munterville Coal Co., Blakesburg
Henry Rowley, R.R. 3, Blakesburg
Sickles Coal Co., Eldon
Simpson Bros. Coal Co., Ottumwa
Stribling Coal Co., Eldon

Warren County
Great Western Coal Co., Orillia: office Polk Bldg., Des Moines
Indian Valley Gloss Coal Co., Hartford: office Ins. Exch. Bldg., Des Moines
Oak Hill Coal Co., Carlisle
Ridge Block Coal Co., Carlisle
Scotch Ridge Coal Co., R.F.D., Carlisle

Wayne County
L. E. Bennett, R.R. 1, Promise City
Hayhurst Coal Co., R.R. 2, Promise City
Rissler Coal Co., R.R. 3, Melrose
Violet Valley Coal Co., Seymour
Whalen Coal Co., Seymour

Webster County
Marcey Coal Co., Lehigh

Conditions in the United States as a whole were very similar to those in Iowa. Production fell 85 million tons, and the value decreased 207 million dollars. The decrease in value was due partly to the decrease in tonnage and partly to a drop of 16 cents in the average price per ton received at the mines. The average number of workers was less by forty-three thousand in 1931, and the average number of days worked was 27 less. One notes with mixed feelings that the miners in some states produced as high as 1,400 tons per year per man, while in Iowa the average per man per year was 429 tons. This larger tonnage was no doubt due to thicker seams of coal, more use of machinery, or other less laborious working conditions. Certainly there is no reason to suppose that Iowa miners are any less capable or industrious than workers in other states.

Table IV-A gives an analysis of the important statistics of the coal industry in 1931 in the United States.

The seven leading states in coal production in 1931 were in order: West Virginia, Pennsylvania, Illinois, Kentucky, Ohio, Indiana, and Alabama. Iowa ranked 13th. In value they ranked Pennsylvania, West Virginia, Illinois, Kentucky, Ohio, Alabama, and Indiana, with Iowa 11th.

TABLE IV-A

Production, Value, Men Employed, Days Worked, and Output Per Man Per Day at Coal Mines in the United States in 1931.

State	Total quantity net tons	Total value	Average per ton	Number of Employees	Average number of days worked	Average tons per man per year
Alabama	11,998,781	$ 21,866,000	$1.82	22,973	136	522
Alaska	105,900	556,000	5.25	80	277	1,324
Arizona	7,120	42,000	5.90	27	115	264
Arkansas	1,153,555	3,511,000	3.04	4,733	95	244
Calif., Ida., Nev., Ore.	17,385	88,000	5.06	116	86	150
Colorado	6,604,369	15,944,000	2.41	10,028	142	659
Georgia	21,580	45,000	2.09	62	180	348
Illinois	44,303,295	75,527,000	1.70	49,685	136	892
Indiana	14,295,165	20,735,000	1.45	12,311	146	1,161
Iowa	3,388,355	8,575,000	2.53	7,897	142	429
Kansas	1,986,870	3,771,000	1.90	3,813	123	521
Kentucky	39,963,621	50,745,000	1.27	47,766	159	837
Maryland	2,005,773	2,907,000	1.45	3,224	190	622
Michigan	359,403	1,094,000	3.04	1,372	96	262
Missouri	3,620,497	7,248,000	2.00	5,362	142	675
Montana	2,378,052	4,299,000	1.81	1,672	153	1,422
New Mexico	1,552,822	4,597,000	2.96	2,830	145	549
North Carolina	2,363	9,000	3.81	32	83	74
North Dakota	1,519,307	2,155,000	1.42	1,300	166	1,169
Ohio	20,410,995	25,371,000	1.24	25,085	174	814
Oklahoma	1,908,394	4,614,000	2.42	4,634	115	412
Pa. (bituminous)	97,658,698	155,060,000	1.59	116,726	169	837
South Dakota	27,485	64,000	2.33	56	127	491
Tennessee	4,721,548	6,942,000	1.47	7,448	171	634
Texas	716,020	1,070,000	1.49	1,148	140	624
Utah	3,350,044	7,442,000	2.22	3,268	140	1,025
Virginia	9,698,680	14,060,000	1.45	11,357	175	854
Washington	1,846,461	5,800,000	3.14	2,662	170	694
West Virginia	101,473,172	132,762,000	1.31	97,787	176	1,038
Wyoming	4,993,686	11,996,000	2.40	4,759	154	1,049
Total bituminous 1931	382,089,396	$588,895,000	$1.54	450,213	160	849
Total bituminous 1930	467,526,299	$795,483,000	$1.70	493,202	187	948

GYPSUM

Gypsum, like other products in Iowa, experienced a serious decline in 1931. Both the gypsum sold crude and that sold calcined fell off about one third in quantity. The value of the gypsum sold crude declined more than that of the gypsum sold calcined. Table V shows the production of the different classes of gypsum in Iowa in 1930 and 1931.

The list of gypsum companies operating in 1931 is given below.

United States Gypsum Co., Centerville.
Certainteed Products Corp., Fort Dodge. Office 100 E. 42d St., New York.
Universal Gypsum & Lime Co., Fort Dodge. Offices 1535 Conway Bldg., Chicago.
United States Gypsum Co., Fort Dodge. Offices 300 W. Adams St., Chicago.
Hawkeye Gypsum Products Co., Fort Dodge.
Wasem Plaster Co., Warden Apts., Fort Dodge.
Cardiff Gypsum Plaster Co., 903 Central Ave., Fort Dodge.

TABLE V

Production of Gypsum in Iowa in 1930 and 1931.

	1930		1931	
	Tons	Value	Tons	Value
Crude gypsum mined	484,047		321,627	
Sold crude — cement mills	154,860	$ 211,645	85,700	$ 112,312
Other purposes (a)	902	4,057	12,774	21,816
Total sold crude	155,762	215,702	98,474	134,128
Sold calcined — neat and sanded plaster	22,178	208,341	13,194	113,936
Base coat plaster (e)	------	------	116,002	917,793
Finished and molded plasters (e)	------	------	11,590	79,773
Plaster board and wall board	66,900	1,671,805	41,438	1,114,861
Partition tile (d)	31,022	224,083	18,473	139,241
Other building (b)	9,174	141,211	5,812	58,906
Plate glass works	------	------	6,349	26,219
Terra cotta and pottery works (c)	------	------	1,781	54,266
Total sold calcined	303,230	3,525,617	210,726	2,453,998
Total sold	458,992	$3,741,319	309,200	$2,588,126

(a) Other Purposes: The figures for 1931 include the gypsum sold for agriculture, but the figures for 1930 are for agriculture alone.
(b) Includes: Roofing tile, insulating materials, and other tiles. The 1930 figures include plate glass, but this is given separately in 1931.
(c) Includes: Calcined gypsum sold for other purposes than those listed.
(d) 1930: Equals 83,312,425 square feet, or 1912 acres or 2.99 square miles. 1931: 54,209,044 square feet, or 1.94 square miles.
(e) Figures for these plasters were not given for 1930.

Production of gypsum in the United States showed a decline similar to that experienced in Iowa. The amount of gypsum sold crude decreased a little over one fifth, while that sold calcined decreased almost one third. The total sales decreased from 3,180,000 to 2,300,000 tons.

TABLE V-A

Gypsum Production in the United States in 1930 and 1931

	1930		1931	
Plants active	56		54	
	Tons	Value	Tons	Value
Total mined	3,471,393		2,559,017	
Sold crude	989,591	$ 1,886,254	773,185	$ 1,565,367
Sold calcined	2,191,376	25,165,230	1,593,753	19,235,990
Total sales	3,180,967	27,051,484	2,366,938	20,801,357

Table V-A summarizes production of gypsum in the United States. Iowa holds third place among the states, New York being first and Michigan second.

LIMESTONE AND LIME

The story of limestone production in 1931 is very similar to that of other branches of the mineral industry — sharp declines in every class of material, both in tonnages and in values. For instance, riprap production decreased from 98,000 tons to 31,000 tons, a decline of over two thirds; in value the decline was a little less. Limestone for concrete and road metal declined from 1,160,000 tons to 1,020,000 tons, while the values dropped from nearly $1,300,000 to a little less than $1,000,000. Railroad ballast declined nearly three fourths in tonnage and about four fifths in value. Agricultural stone suffered a decrease of about one half in tonnage and value. The decline in general was a little over one fourth in tonnage, and about one third in value.

The production of different classes of stone and lime in 1931 is shown in Table VI, while the production by counties is shown in Table VII.

TABLE VI

Production of Stone and Lime in Iowa in 1930 and 1931.

Kind	1930			1931		
	Plants	Tons	Value	Plants	Tons	Value
Building stone	2	10,108 (a)	$ 10,959	1	4,730	$ 5,046
Rubble	8			3		
Riprap	9	98,780	85,704	8	31,850	31,176
Concrete and road metal	27	1,160,385	1,297,836	34	1,020,030	994,608
Railroad ballast	6	258,787	217,727	5	66,360	38,320
Agriculture	27	268,721	197,788	26	126,610	105,554
Flux	1	33,539	43,397	1	22,030	36,001
Sugar and glass factories	1			2		
Other uses	2			2		
Totals		1,830,320	$1,853,411		1,271,610	$1,210,705

(a) Curbing, flagging, and paving are included in building stone in the figures given in 1930. Curbing, flagging, and paving figures are not included in building stone for 1931 as none was reported.

Table VI-A gives the production of limestone in the United States in 1931.

TABLE VI-A

Production of Limestone in the United States in 1931

Building stone (cut stone) cubic feet	8,973,080
Value	$10,540,845
Average value per cubic foot	$1.17
*Other limestone, value	$699,453
Total value	$11,240,298

* Includes rough construction stone, rubble, curbing, and flaggings.

As in 1930, Madison County again had the largest tonnage and value, with the Hawkeye Portland Cement Co. of Des Moines again the leading producer. Madison County added another producer in 1931 — the Winterset Stone Co. The other leading counties in order of tonnage were Scott, Marshall, Linn, Black Hawk, and Johnson; in value they ranked: Linn, Scott, Black Hawk, Marshall, and Johnson. Linn County, which was a minor producer in 1930, almost doubled its production in 1931 and more than doubled its value. This brought it up to fourth place in tonnage and second place in value in 1931.

The Hurst estate at Hurstville, Jackson County, was the sole pro-

TABLE VII

Production of Limestone and Lime in Iowa in 1931.

Counties	Plants	Building stone, rubble, riprap, lime		Concrete, road metal		Other uses (a)		Total	
		Tons	Value	Tons	Value	Tons	Value	Tons	Value
Allamakee (2), Clinton (3), Winneshiek (2)	7			55,898	$ 50,365	500	$ 800	56,398	$ 51,165
Black Hawk (2), Bremer (1), Floyd (1), Woodbury (1)	5			167,501	165,906	18,528	15,741	186,029	181,647
Buchanan (1), Cerro Gordo (1), Dubuque (2)	4			90,886	92,219	30,680	42,775	121,566	134,994
Clayton (3), Jackson (2), Madison (2)	7	20,142	$19,882	252,881	283,554	9,799	6,199	282,822	309,635
Hardin (1), Keokuk (1), Lee (3), Mahaska (1)	6			87,829	96,916	26,619	25,481	114,448	122,397
Johnson (1), Marshall (2), Van Buren (1)	4	7,019	6,946	137,913	113,355	68,539	35,656	213,471	155,957
Jones (3), Scott (2)	5	9,812	11,344	126,823	83,941	40,193	29,593	176,828	124,878
Linn	5			100,298	108,352	19,850	21,680	120,148	130,032
Totals for 1931	43	36,973	$38,172	1,020,029	$ 994,606	214,708	$177,925	1,271,710	$1,210,705
Totals for 1930	43	101,177	$86,371	1,168,817	$1,308,278	544,497	$456,183	1,814,291	$1,850,832

(a) Includes: Railroad ballast, flux, sold to sugar factories, agricultural limestone, railroad fills.

ducer of lime in this state in 1931. The figures for production are combined with those for limestone.

The list of limestone companies operating in 1931 is given below.

Allamakee County
Hess Bros., Lansing
H. L. Leas, Elkader
Appanoose County
Wm. B. Swan, Plano
Black Hawk County
The Builders Material Co., Cedar Rapids. Brandon (Hawkeye Quarry)
Waterloo Dredging Co., W. Mullan Ave., Waterloo
Bremer County
Schild Bros., Waverly
Buchanan County
Lewis V. T. Francis
Cerro Gordo County
Stoddard Stone Products Co., Mason City
N. W. States Portland Cement Co., Mason City
Clayton County
Elmer J. Krozel
E. C. Schroeder & Co., McGregor
U. S. Engineer Office, Box J, Commercial Sta., St. Paul, Minn. Quarry at McGregor
Clinton County
C. T. Hanrahan, Charlotte
J. R. Kane, Charlotte
John Ponolishta
Dubuque County
Dubuque County, Highway Dept., Dubuque. Quarry at Waupeton
Dubuque Stone Products Co., Dubuque
Hardin County
Iowa Limestone Co., 907 Bankers Trust Bldg., Des Moines. Quarry at Alden
Jackson County
Isaac Voepell, Baldwin
A. A. Hurst, Maquoketa. Quarry at Hurstville (near Maquoketa)
Johnson County
River Products Co., 20-21 Schneider Bldg., Iowa City. Quarry at Coralville (Conklin Quarry)
Jones County
Men's Reformatory, Anamosa
Columbia Quarry, Cedar Rapids. Quarry at Stone City
H. Dearborn Sons, Stone City
Keokuk County
Keokuk County Engineer, Sigourney
Lee County
Driscoll & Hayes, Belfast, via Farmington
McManus Quarries Co., Inc., 112 Masonic Bldg., Keokuk. Quarry at Ballinger Station
Keokuk Quarry & Constr. Co., 1325 Main St., Keokuk
Linn County
Builders' Material Co., Cedar Rapids
Dewees & Whitney, Springville
Lanning & Fulkerson, Marion
Larimer & Shaffer, Inc., Cedar Rapids
Linn County Engineer, Cedar Rapids
Madison County
Hawkeye Portland Cement Co., 802 Hubbell Bldg., Des Moines. Quarry at Earlham
Winterset Stone Co., Winterset
Mahaska County
Mahaska County, County Engineer, Oskaloosa
Marshall County
Chicago & North Western Ry. Co., 400 W. Madison St., Chicago, Ill. Quarry at Le Grand
Le Grand Lime Stone Co., Le Grand (Main office, 29 S. La Salle St., Chicago, Ill.)
Scott County
Dolese Bros. Co., 205 W. Wacker Drive, Chicago, Ill. Quarry at Buffalo
Linwood Cement Co., 713 Kahl Bldg., Davenport. Quarry at Linwood
Van Buren County
Douds Stone Co., Douds
Winneshiek County
Orlando Bakke
M. O. Weaver, Webster City. Quarry at Decorah
Woodbury County
Interstate Construction Co., Sioux City

In the United States, constructional limestone was produced to the amount of 8,973,000 cubic feet, with a value of $10,540,000, a decline from 15$\frac{3}{4}$ million cubic feet and 18$\frac{1}{2}$ million dollars in 1930.

SAND AND GRAVEL

The sand and gravel industry in Iowa showed the same decrease that was recorded in other branches of the mineral industry. Serious declines are to be noted in the production of building sand, of paving and road sand, of building gravel, and of paving and road gravel. Some compensations are found in the increase of the output of railroad ballast sand, of other sands, and of other gravel. However, the total output dropped 1,118,000 tons and $1,087,000. This amounts to a decline of nearly 25 percent in tonnage and more than 40 percent in value.

Table VIII gives the production of sand and gravel by classes in 1930 and 1931. The production in county groups is shown in Tables IX and X. The counties that produced the most sand and gravel in

TABLE VIII

Summary of Sand and Gravel Production in Iowa, 1930 and 1931.

Materials	1930				1931			
	Pits	Tons	Value	Ave. Price	Pits	Tons	Value	Ave. Price
Sand								
Molding	5	28,343	$ 27,030	$ .95	3	11,321	$ 9,917	$ .88
Building	49	583,949	292,721	.50	40	360,907	144,373	.40
Paving and roads	39	1,397,207	562,809	.40	31	825,061	277,210	.34
Grinding, polishing, and blast sand	3	2,788	4,137	1.48	1	(a)		1.66
Engine	10	31,184	15,396	.49	10	22,356	9,182	.41
Filter	4	3,172	1,939		2	(a)		
Railroad ballast	4	56,260	18,670	.33	5	59,638	73,660	
Other	4	7,433	1,710		4	15,539	6,017	
Total sand		2,110,336	$ 924,412			1,294,822	$ 469,208	
Gravel								
Building	54	485,792	496,261	1.02	40	209,288	190,256	
Paving and roads	50	1,749,235	1,113,549	.64	42	1,496,078	778,051	
Railroad ballast	6	(b)		.36	8	(b)		.18
Other	1	176,608	64,885			403,208	73,763	
Total gravel		2,411,635	$1,674,695			2,108,574	$1,042,070	
Total output		4,521,971	$2,599,107			3,403,396	$1,511,278	

(a) Included in other sand.
(b) Included in other gravel.

1931 were in order: Polk, Dickinson, Emmet, Sac, Cerro Gordo, and Pocahontas; in value, Dickinson and Pocahontas dropped out of the first six, and the list included: Emmet, Polk, Cerro Gordo, Mahaska, Sac, and Muscatine. The largest producers in tonnage were: Chicago, Milwaukee & St. Paul Railway Co. in Dickinson County, Concrete Materials Corporation of Emmet County, and Pocahontas County Highway Department; in value the leaders were: Co-operative Concrete Materials Corporation of Emmet County and Concrete Materials Corporation of Mahaska County.

It is worthy of note that, as the southern part of the state is approached, gravel is of much less importance, and most of the material

TABLE IX

Production of Sand and Gravel in 1931 — Sand

Counties	Producers	Structural sand		Paving sand		Other sand (a)		Total sand	
		Tons	Value	Tons	Value	Tons	Value	Tons	Value
Allamakee (1), Clayton (1), Dubuque (2), Fayette (0)	4	27,030	$ 12,248	65,825	$ 20,550	(c)	(c)	92,855	$ 32,798
Appanoose (1), Muscatine (3)	4	16,657	10,103	46,629	12,632	(c)	(c)	63,286	22,735
Black Hawk (3), Tama (1)	4	24,990	13,028	43,943	24,382	(c)	(c)	68,933	37,410
Boone (2), Calhoun (0), Crawford (0), Story (1)	3	22,882	14,182			(c)	(c)	22,882	14,182
Buena Vista (0), Clay (1), Lyon (1), Sioux (2)	4	14,705	5,027					14,705	5,027
Butler (3), Hancock (1), Humboldt (1)	5	22,412	9,950	101,695	16,094			124,107	26,044
Cerro Gordo (2), Floyd (1), Mitchell (0), Wright (0)	3	105,737	37,119	(c)	(c)	(c)	(c)	105,737	37,119
Cherokee (2), Sac (3)	5	41,804	12,553	146,706	44,743	(b)	(b)	188,510	57,296
Clinton (2), Jackson (1), Scott (1)	4	33,607	16,045	33,712	13,844	(c)	(c)	67,319	29,889
Des Moines (1), Lee (2), Mahaska (1), Marion (1)	5	20,309	6,899	74,077	30,623	(b) (c)	(b) (c)	94,386	37,522
Dickinson (0), Harrison (0), Pocahontas (0)	0								
Emmet (2), Palo Alto (0), Plymouth (1)	3	154,951	54,883	(c)	(c)	(c)	(c)	154,951	54,883
Johnson (2), Linn (2)	4	42,736	19,089	38,346	22,683	(c)	(c)	81,082	41,772
Polk	5	90,338	31,911	125,731	40,620	(b) (c)	(b) (c)	216,069	72,531
Totals for 1931	53	618,158	$243,037	676,664	$226,171			1,294,822	$469,208
Totals for 1930	66	934,118	$449,786	1,155,798	$466,146	$ 20,420	$ 7,480	2,110,336	$924,412

(a) Includes: Molding, cutting and grinding and blast, engine, filter, railroad ballast, and other sands.
(b) Included with paving sand.
(c) Included with structural sand.

TABLE X

Production of Sand and Gravel in 1931 — Gravel

Counties	Producers	Structural gravel		Paving and other gravel (f)		Total sand and gravel		Total quantity washed	
		Tons	Value	Tons	Value	Tons	Value	Tons	Value
Allamakee (0), Clayton (0), Dubuque (2), Fayette (1)	3	32,855	$ 16,193	(e)	(e)	115,820	$ 43,057	67,205	$ 20,848
Appanoose (0), Muscatine (3)	3	14,606	10,851	81,941	$ 52,386	159,833	85,972	159,632	85,622
Black Hawk (3), Tama (1)	4	6,430	11,720	12,819	12,474	88,182	61,604	87,983	61,557
Boone (2), Calhoun (1), Crawford (2), Story (1)	6	3,712	3,056	142,440	18,320	169,034	35,558	26,869	17,458
Buena Vista (2), Clay (1), Lyon (2), Sioux (0)	5	(d)	(d)	15,236	6,376	195,671	22,453	19,045	9,303
Butler (2), Hancock (1), Humboldt (1)	4	9,381	10,359	46,276	25,798	179,764	62,201	81,889	53,326
Cerro Gordo (2), Floyd (0), Mitchell (1), Wright (1)	4	24,456	21,996	92,096	84,102	222,289	143,217	213,743	141,656
Cherokee (2), Sac (5)	7	9,700	6,995	221,520	135,393	419,730	199,684	347,605	175,934
Clinton (3), Jackson (1), Scott (0)	4	47,373	30,230	22,560	12,451	137,252	72,570	137,107	72,515
Des Moines (1), Lee (1), Mahaska (1), Marion (1)	4	13,836	15,323	86,507	109,617	194,729	162,462	193,229	161,362
Dickinson (1), Harrison (1), Pocahontas (1)	3			558,155	64,097	558,155	64,097		
Emmet (2), Palo Alto (2), Plymouth (1)	5	2,981	3,157	296,436	222,479	454,368	280,519	439,909	276,320
Johnson (2), Linn (1)	3	18,287	14,854	(e)	(e)	99,369	56,626	99,369	56,626
Polk	4	45,185	55,094	147,946	93,633	409,200	221,258	406,377	220,986
Totals for 1931	59	228,802	$199,828	1,723,932	$ 837,126	3,403,396	$1,511,278	2,279,962	$1,353,513
Totals for 1930	76	485,645	$496,238	1,925,990	$1,178,457	4,521,971	$2,599,107	3,541,970	$2,339,134

(d) Included with paving gravel.
(e) Included with structural gravel.
(f) Includes paving and roadmaking, railroad ballast, other gravels.

is fine river sand. An inspection of Tables IX and X will show the truth of this statement.

The list of sand and gravel companies operating in 1931 is given below.

Allamakee County
Northeastern Iowa Sand & Gravel Co., Harpers Ferry

Appanoose County
A. M. Houser, Centerville

Black Hawk County
Black Hawk County, County Engineer, Waterloo
Concrete Materials Corp., 504 Lafayette Bldg., Waterloo
Iowa Foundry Sand Co., 106 Western Ave., Waterloo
Waterloo Dredging Co., 85 W. Mullan, Waterloo
Waterloo Sand & Gravel Co., P. O. Box 553, Waterloo

Boone County
McHose Sand & Tile Co., Boone. Pit at Fraser
Markey River Sand Co., Boone

Buena Vista County
Buena Vista Highway Dept., County Engineer, Storm Lake
L. L. Walton, Linn Grove
Chicago & North Western Ry. Co., 226 W. Jackson St., Chicago, Ill. Pit at Sioux Rapids

Butler County
Aplington Cement Tile & Block Works, Aplington
Concrete Materials Corp., 504 Lafayette Bldg., Waterloo. Pit at Clarksville
Waverly Gravel & Tile Co., Waverly. Pit at Shell Rock

Calhoun County
Calhoun County Highway Dept., Rockwell City
P. C. Fulkerson

Cerro Gordo County
Clear Lake Sand & Gravel Co., Clear Lake
Ideal Sand & Gravel Co., Mason City

Cherokee County
Iowa Gravel Products Co., 3330 Maynard St., Cleveland, Ohio. Pit at Cherokee
Northwestern Gravel Co., Lake View. Pit at Cherokee

Clay County
Spencer Cement Block Works, Lock Box 344, Spencer

Clayton County
Langworthy Silica Co., 902 Federal Bank Bldg., Dubuque. Pit at Clayton

Clinton County
A. F. Barber, R.D. 2, Grand Mound
Camanche Sand & Gravel Co., United Light Bldg., Davenport
Clinton Sand & Gravel Co., 604 Wilson Bldg., Clinton

Crawford County
James Ballantine, Arion
Crawford County, County Engineer, Denison

Des Moines County
Burlington Sand & Gravel Co., Burlington

Dickinson County
Chicago, Mil. St. P. & P. R. R. Co., New Union Sta., Chicago, Ill. Pit at Milford

Dubuque County
Dubuque Stone Products Co., Dubuque
Molo Sand & Gravel Co., Foot of 3d St., Dubuque

Emmet County
Cement Products Co., Estherville
Concrete Materials Corp., Lafayette Bldg., Waterloo

Fayette County
Clermont Brick & Sand Co., Clermont

Floyd County
Iowa Foundry Sand Co., Waterloo. Pit at Floyd

Hancock County
Hancock County Highway Dept., Garner

Harrison County
Rogers Brothers, Dunlap

Humboldt County
Concrete Materials Corp., Waterloo. Quarry at Humboldt

Jackson County
Bellevue Sand & Gravel Co., Bellevue

Johnson County
Hawkeye Material Co., Iowa City
Schmidt Sand & Gravel Co., R.F.D. 4, Iowa City

Lee County
Jos. Jaeger, Montrose. Pit at Fort Madison
Keokuk Sand Co., Ft. of Bank St., Keokuk

Linn County
Kings Crown Plaster Co., 98 First Ave., NW., Cedar Rapids
Larimer & Shaffer, 931 1st St., NW., Cedar Rapids

Lyon County
Lyon County, County Engineer, Rock Rapids

Miller Sand & Gravel Co., Box 101, Doon

Mahaska County

Concrete Materials Corp., Eddyville

Marion County

Wilson Sand & Gravel Co., Harvey. Pit at Tracy

Mitchell County

Burton Stacy, Osage

Muscatine County

Automatic Gravel Products Co., Box 34, Muscatine

Hahn Sand & Gravel Co., 207 W. Front St., Muscatine

Pearl City Gravel Co., Muscatine

Palo Alto County

County Highway Dept., Emmetsburg

Chicago, Rock Island & Pacific Ry. Co., Chicago, Ill. Pit at Graettinger

Plymouth County

Big Sioux Gravel Co., Akron

Pocahontas County

Pocahontas County Highway Dept., County Engineer, Pocahontas

Polk County

Coon River Sand Co., 501 Hubbell Bldg., Des Moines

The Des Moines Sand & Fuel Co., 510 Grand Ave., Des Moines

Doty Sand & Gravel Co., Des Moines

Hawkeye Co-operative Sand & Gravel Co., 822 W. 9th St., Des Moines

Flint Crushed Gravel Co., Des Moines. Pit at Granger

Sac County

Lake View Concrete Tile Co., Lake View

Le Grand Limestone Co., 29 S. La Salle St., Chicago, Ill. Pit at Sacton (Lake View)

Northwestern Gravel Co., Lake View

Sac County, County Engineer, Sac City

W. H. Schnirring, Sac City

Scott County

Builders Sand & Gravel Co., 626 W. Front St., Davenport. Pit at Buffalo

Sioux County

D. A. Sorgdrager, R. D. 1, Alton

Alton Cement Works, Alton

L. G. Everist, Inc., 2100 E. 4th St., Sioux City. Pit at Hawarden

Story County

R. E. Carr Sand & Gravel Co., E. 16th St., Ames

Story County, County Engineer, Nevada. Pit at Ames

Tama County

Standard Gravel Co., 907 Bankers Tr. Bldg., Des Moines. Pit at Tama

Wright County

Chicago, R. I. & Pacific Ry. Co., 902 La Salle St. Sta., Chicago, Ill. Pits at Belmond

Chicago Great Western R. R. Co., Chicago, Ill. Pit at Belmond

TABLE VIII-A

Sand and Gravel Industry in the United States in 1931

Sand sold or used by producers, by uses:		
Glass	short tons	1,677,882
Molding	do	2,138,305
Building	do	25,178,572
Paving	do	27,459,581
Grinding and polishing	do	607,589
Engine	do	1,604,123
Fire or furnace	do	88,189
Filter	do	55,319
Other (a)	do	5,683,266
Gravel sold or used by producers, by uses:		
Building	do	21,426,814
Paving	do	56,716,230
Railroad ballast (b)	do	10,843,174
Total sand and gravel		153,479,044

(a) Includes some sand used for railroad ballast, fills, and similar purposes.
(b) Includes some gravel used for fills and other purposes; in 1931, 8,814,907 tons of gravel, valued at $2,898,598 were used exclusively for ballast.

The production of sand and gravel in the United States in 1931 is given in Table VIII-A. It amounted to 153,479,044 tons; this is to be compared with 197,051,726 tons produced in 1930.

MINERAL PRODUCTION IN 1932

OUTLINE

In studying the record of mineral production in Iowa in 1932, we find the general aspect less discouraging than that of 1931. While there was still a decrease in value of production, the decline was very much less than that of the previous year. There were lowered values in the output of cement, clay, clay wares, and gypsum, but in contrast with these there were increased values in coal, limestone, and sand and gravel. Whereas the decrease in 1931 was about 35 percent, the lessening of values in 1932 was only about 14 percent. The sale of bituminous coal is considered an indication of industrial activity, and in the United States as a whole it dropped 20 percent from the previous year; 42 percent from 1929; and, in fact, the demand was less than it had been for about a quarter century. In contrast with this, it is pleasing to note that Iowa showed a substantial increase in the tonnage of coal produced. Mineral production in Iowa declined about 14 percent, while it dropped about 22 percent in the United States. Table I and Table I-A show summaries of mineral production in Iowa and throughout the nation.

TABLE I

Mineral Production in Iowa in 1931 and 1932

	Unit	1931			1932		
		Producers	Quantity	Value	Producers	Quantity	Value
Cement	bbl.	5	5,790,087	$ 5,453,320	5	4,373,642	$ 3,907,427
Clay Wares	ton			2,287,903			805,375
Coal	ton	231	3,388,355	8,575,000		3,862,435	9,254,000
Gypsum	ton	6	309,200	2,588,126	7	169,719	1,468,414
Limestone and Lime	ton	43	1,271,710	1,210,705	45	1,591,235	1,389,465
Sand and gravel	ton	75	3,403,396	1,511,278	87	5,230,562	1,706,874
Totals				$21,626,332			$18,531,555

TABLE I-A

Mineral Products of the United States, 1931 and 1932

Summary	1931 Value	1932 Value
Total value of metallic products	$ 567,200,000	$283,700,000
Total value of nonmetallic products (exclusive of mineral fuels)	699,700,000	430,700,000
Total value of mineral fuels	1,892,400,000	1,722,600,000
Total value of "unspecified" (metallic and nonmetallic) products (partly estimated)	7,300,000	6,000,000
Grand total approximate value of mineral products	$3,166,600,000	$2,443,000,000

CEMENT

The cement industry in 1932 continued the downward trend which was so serious in 1931. Production fell off 1,500,000 barrels and shipments dropped almost as much in amount and more than that in value. The average price per barrel was five cents less than in 1931. The production was only slightly more than 40 percent of the annual capacity. The number of plants was the same in both years. The Gilmore City plant, being the smallest in the state, is operated less economically than the larger plants, and therefore is shut down whenever business conditions do not permit operations at a profit. This plant is owned by the Northwestern States Portland Cement Co. at Mason City, and naturally operations are conducted more economically at one plant than at two during times like those prevailing in the last two years. Table II summarizes the cement industry in Iowa.

TABLE II

Production of Cement in Iowa

	1931	1932
Production, bbls.	5,804,462	4,270,739
Stock, December 31, bbls.	1,414,375	1,311,472
Shipments, bbls.	5,790,087	4,373,642
Shipments, value	$5,453,320	$3,907,427
Average price per bbl.	$0.94	$0.89
Annual capacity, bbls.	10,293,900	10,293,900
Plants active	5	5

When we compare conditions in Iowa with those prevailing over the United States, we find some cause for congratulating ourselves. As compared with a decline of 24 percent in shipments in this state, there was a decline of 36 percent the country over — from 127 million barrels to 80 million. Throughout the nation the decline in value was almost 43 percent. This was caused by the combination of smaller shipments with an average decline in value of 11 cents per barrel. This was in spite of the fact that the government was making a great effort to relieve unemployment by appropriations for highways and public works. One optimistic feature was a slight increase in price during the latter half of the year. A comparison of the industry in the United States for 1931 and 1932 is shown in Table II-A.

TABLE II-A

Production of Cement in the United States

	1931	1932	Percent Change: 1932 from 1931	Percent Change: 1932 from 1923-25 Average
Production, bbls.	125,429,071	76,509,000	—39.0	—48.8
Shipments, bbls.	127,150,534	80,579,000	—36.6	—45.0
Shipments, value	$140,976,450	$80,835,000	—42.7	—69.7
Stock, December 31, bbls.	24,177,159	20,205,000	—16.4	—40.0

CLAY AND CLAY PRODUCTS

In 1932 six companies produced raw clay in Iowa; these companies were located in Dallas, Hardin, and Webster Counties, three of them being in Webster County, two in Dallas, and one in Hardin. Their output amounted to 3,433 tons, valued at $9,354. Part of this was fire clay, and the rest was classified as miscellaneous clay.

TABLE III

Annual Census of Clay-Products Industries — 1932

Production, by Kind, Quantity, and Value, for Iowa

	Number of establishments	Quantity (Thousands)	Value	Stocks on hand Dec. (Thousands)
Common brick	24	11,059	$112,272	14,216
Face brick	19	8,065	112,074	7,386
Hollow building tile:		(Tons)		(Tons)
Partition, etc.	20	58,541	294,535	48,974
Floor arch, silo, etc.	8	4,337	28,787	3,037
Draintile	23	13,632	82,805	16,811
Sewer pipe	3	7,558	104,622	16,621
Flue lining	3	1,763	17,027	845
Clay sold, raw or prepared, including fire-clay dust	5	1,150	8,930	-----
Other clay products:				
Vitrified brick	4	(a)	(a)	(a)
Hollow brick	1	-----	------	(a)
Roofing tile	1	(a)	(a)	(a)
Wall coping	3	(a)	(a)	(a)
Clay products (not specified)	1	-----	(a)	-----
Red earthenware	1	-----	(a)	-----
Art pottery	1	-----	(a)	-----
Saggers	1	-----	(a)	-----
Total of other clay products			$ 44,323	
Total			$805,375	

(a) Withheld to avoid disclosing, exactly or approximately, data reported by individual establishments.

In the United States, as well as in Iowa, the industrial depression caused continued decrease in both the quantity and value of clay produced. The production in the entire United States for 1932 was 1,618,380 tons, with a value of $5,636,000, a decrease of about one third from the output of 1931.

Table III shows the production of clay wares in Iowa for 1932. A study of a similar table for 1931 will show that the decrease in value of production in 1931 from that of 1930 was a little over one half; the decrease in 1932 amounted to nearly two thirds. In common brick the drop was from 33 million to 11 million; face brick from 16 million to 8 million; partition tile from nearly 113 thousand tons to 58 thousand; drain tile from 34 thousand tons to 13 thousand; and other clay products dropped in value from nearly $75,000 to $44,000. Data are not available for giving the output of clay wares by counties. It will be seen that the clay wares industry has been cut by the financial depression more drastically than any other mineral in Iowa.

COAL

The coal industry presents a pleasing contrast with other parts of mineral production in Iowa. In comparison with these other minerals, coal showed a noteworthy increase, both in the quantity produced and in its value. The number of workers was larger by 189, and there was an increase of nine in the average number of days worked. Production increased 474 thousand tons, and this sold at the mines for an increase of $679,000. This increase is all the more noteworthy because of the fact that it occurred in the face of a drop of 13 cents per ton.

The same counties produced in 1932 as in 1931, with the addition of Webster County, which produced less than a thousand tons in 1931, but over 21,000 tons in 1932. The increase is partly accounted for by the opening of a large mine near Fort Dodge by Beck Bros., who have operated for many years near Des Moines.

The leading counties in production in 1932 were: Appanoose, Marion, Polk, Lucas, Boone, Monroe, and Dallas.

In value the counties ranked: Appanoose, Boone, Polk, Lucas, Marion, Dallas, and Monroe.

The details of coal production in Iowa are shown by Table IV, and Tables IV-A and IV-B show similar statistics for the coal industry in the United States. Production of coal in the United States decreased over 70 million tons, and the value decreased 180 million dollars. The

TABLE IV

Production, Value, Men Employed, and Days Worked at Coal Mines in Iowa in 1932 [a]

(Exclusive of product of wagon mines producing less than 1000 tons)

County	Net Tons					Value		Number of Employees			
	Loaded at mines for shipment	Trucked to distant points	Sold to local trade and used by employees	Used at mines for power and heat	Total quantity	Total (thousand dollars)	Average per ton	Under-ground	Surface	Total	Average number of days mine was active
Adams		4,000	11,733	127	15,860	$ 48	$3.03	56	9	65	132
Appanoose	540,079	15,991	55,624	790	615,238	1,419	2.31	1,584	234	1,818	133
Boone	296,147	14,300	89,498	3,650	403,595	1,320	3.27	983	67	1,050	143
Dallas	349,765	5,556	24,472	1,984	381,777	928	2.43	611	38	649	156
Davis and Lucas	479,433		6,084	4,228	489,745	1,112	2.27	636	48	684	155
Greene		16,000	14,008	270	30,278	85	2.81	85	11	96	99
Guthrie			9,784	51	12,435	44	3.54	58	8	66	148
Jasper		35,231	26,920	2,055	64,206	147	2.29	143	20	163	192
Jefferson and Keokuk		280	9,528	30	9,838	20	2.03		28	28	126
Mahaska	8,005	8,100	44,152	1,139	61,396	119	1.94	109	54	163	155
Marion	465,947	8,564	50,438	4,956	529,905	1,082	2.04	694	99	793	157
Monroe	357,933	3,043	32,343	2,238	395,557	860	2.17	616	61	677	187
Page	400	26,424	11,059		37,883	116	3.06	89	10	99	215
Polk	117,628	1,463	390,625	4,308	514,024	1,234	2.40	896	83	979	152
Taylor	450	8,000	4,355	28	12,833	38	2.96	73	7	80	125
Van Buren	147	1,350	5,023	110	6,630	16	2.41	23	5	28	143
Wapello	1,715	14,665	66,801	2,072	92,700	192	2.07	200	44	244	166
Warren	28,985	52,680	45,912	3,839	139,463	342	2.45	206	41	247	154
Wayne	5,120	11,200	10,829	350	27,499	61	2.22	94	15	109	117
Webster		530	21,016	27	21,573	71	3.29	27	21	48	142
Total, 1932	2,651,754	227,377 [b]	930,204	32,252	3,862,435	$9,254	$2.40	7,183	903	8,086	151
Total, 1931	2,442,377		907,308	38,670	3,388,355	$8,575	$2.53	7,227	670	7,897	142

(a) The figures relate only to active mines of commercial size that produced coal in 1932. The number of such mines in Iowa was 212 in 1932; 231 in 1931; 233 in 1930.

(b) In addition 20,848 tons was mined which went less than ten miles from the mines.

TABLE IV-A

Bituminous Coal Industry in the United States

	1931	1932
Production ---tons	382,089,396	309,709,000
Value at mines---	$588,895,000	$406,677,000
Average value per ton---	$1.54	$1.31
Stocks on hand: (a)		
January 1---tons	37,200,000	35,500,000
December 31--- do	35,500,000	29,666,000
Consumption (calculated)--- do	371,869,000	306,917,000

(a) Figures represent consumers' stocks.

TABLE IV-B

Production Summary of Coal Produced, Value, Men Employed, Days Operated, and Output Per Man Per Day, by States, in 1932.

State	Total quantity net tons	Total value	Average per ton	Number of employees	Average number of days worked	Average tons per man per day
Alabama	7,856,939	$ 12,138,000	$1.54	20,443	107	3.60(a)
Alaska	102,700	514,000	5.00	120	189	4.53
Arizona	6,877	33,000	4.80	17	251	1.61
Arkansas	1,033,471	2,831,000	2.74	4,325	92	2.61
Calif., Ida., Ore.	16,319	60,000	3.68	141	69	1.69
Colorado	5,598,721	12,237,000	2.19	8,749	142	4.51
Georgia	27,208	48,000	1.76	64	208	2.04
Illinois	33,474,553	51,316,000	1.53	47,597	112	6.30
Indiana	13,323,573	17,267,000	1.30	10,639	145	8.65
Iowa	3,862,435	9,254,000	2.40	8,086	151	3.17
Kansas	1,952,885	3,420,000	1.75	3,591	130	4.19
Kentucky	35,299,582	34,892,000	.99	42,267	155	5.41
Maryland	1,428,937	1,827,000	1.28	3,105	150	3.07
Michigan	446,149	1,219,000	2.73	940	159	2.98
Missouri	4,069,598	6,654,000	1.64	5,677	161	4.45
Montana	2,125,225	3,527,000	1.66	1,525	145	9.64
New Mexico	1,263,386	3,321,000	2.63	2,602	127	3.82
North Carolina	1,900	6,000	3.16	26	55	1.33
North Dakota	1,739,658	2,200,000	1.26	1,311	186	7.12
Ohio	13,909,451	15,418,000	1.11	23,280	127	4.71
Oklahoma	1,255,466	2,646,000	2.11	3,063	120	3.40
Pa. bituminous	74,775,862	100,361,000	1.34	104,532	154	4.66
South Dakota	49,074	87,000	1.77	84	126	4.65
Tennessee	3,537,882	4,670,000	1.32	7,525	148	3.18
Texas	636,590	904,000	1.42	699	152	6.00
Utah	2,852,127	5,685,000	1.99	2,842	176	5.69
Virginia	7,692,180	9,280,000	1.21	10,376	144	5.16
Washington	1,591,426	4,759,000	2.99	2,816	161	3.51
West Virginia	85,608,735	90,786,000	1.06	85,765	168	5.93
Wyoming	4,170,963	9,317,000	2.23	4,173	150	6.65
Total bituminous, 1932	309,709,872	$406,677,000	$1.31	406,380	146	5.22
Total bituminous, 1931	382,089,396	$588,895,000	$1.54	450,213	160	5.30

(a) Using a "calculated" method.

average price per ton decreased 23 cents, and the total number of employees was less by about 44 thousand. As usual, Pennsylvania and West Virginia were again leaders both in tonnage and value. Iowa ranked twelfth in tonnage and eleventh in value, though Wyoming and

Virginia were only slightly higher in value. Considering the industry as a whole, it will be seen that conditions in Iowa were much above the average.

GYPSUM

Like most other mineral products in Iowa, gypsum experienced a serious decline in 1932, as it had in the previous year. Table V shows that the amount of crude gypsum mined was reduced from 321,000 tons to 178,000 tons, a drop of somewhat less than 50 percent. The gypsum sold crude, however, showed a somewhat smaller decline, amounting to about one third in both tonnage and value. The gypsum sold calcined in 1932 was almost exactly one half of that sold calcined in the previous year, and its value was a little more than one half. Figures are not available showing the different classes of gypsum ware. Seven operators were active in the state in 1932.

TABLE V

Production of Gypsum in Iowa in 1931 and 1932.

	1931		1932	
	Tons	Value	Tons	Value
Crude gypsum mined	321,627		178,087	
Sold without calcining	98,474	$ 134,128	63,931	$ 91,267
Sold calcined	210,726	2,453,998	105,788	1,377,147
Total sold	309,200	2,588,126	169,719	1,468,414

Gypsum is used almost entirely in connection with building enterprises, and so the demand for it varies in direct ratio to the building business. Since building has been sharply curtailed during the recent financial stringency, it was to be expected that the production of gypsum would suffer a similar lessening. As soon as business conditions improve we may expect an increase in gypsum production both in the amounts sold and in the prices received.

In the United States the gypsum industry experienced the greatest recession in tonnage output since the beginning of the century. A decrease of 47 percent was reported in the production of crude gypsum. This is a reflection of a drop of 56 percent in the value of building contracts since 1931 and 79 percent from those of 1926. In the latter part of the year there was a slight increase due to repairs and remodeling urged by civic organizations, but these could have little effect in counterbalancing the very great decline in large building projects.

Iowa was again third in the United States in the production of crude gypsum, New York and Michigan again leading. These three states, with Texas and Nevada, reported 71 percent of the total production for 1932.

Table V-A shows the condition of the gypsum industry in 1931 and 1932.

TABLE V-A

Gypsum Production in the United States in 1931 and 1932.

	1931		1932	
Plants active	53		54	
	Tons	Value	Tons	Value
Total mined	2,559,017		1,355,219	
Sold crude	773,185	$ 1,565,367	437,808	$ 919,085
Sold calcined	1,593,753	19,235,990	836,428	11,488,534
Total mined	2,366,938	20,801,357	1,274,236	12,407,619

LIMESTONE

In 1932 the production of limestone showed an encouraging increase. While there was a decrease in some of the smaller items, this was more than counterbalanced by road metal, concrete, and railroad ballast, which showed an increase of 389,328 tons with an increased value of $250,785.

The total increase in tonnage and value of limestone was 319,625 tons and $178,760. The operators increased in number from 43 to 54.

The production of building limestone in the United States declined from nearly nine million cubic feet to six and one-half million; and the value declined from ten million to six million dollars. Rough con-

TABLE VI

Production of Limestone in Iowa in 1932.

Kind	Plants	Tons	Value
Building	4	1,672	$ 1,929
Rubble and flux (a)	3	2,329	3,088
Riprap	9	23,686	19,069
Road metal and concrete, and railroad ballast	47	1,475,718	1,283,713
Agriculture	24	67,663	50,983
Other Limestone (b)	4	20,167	30,683
Total	45	1,591,235	$1,389,465

(a) One operator produced flux, and two operators produced rubble.
(b) Other limestone includes that sold to sugar factories.

TABLE VI-A

Production of Limestone in United States in 1931 and 1932.

	1931	1932
Limestone:		
Building stone (cut stone) — cubic feet	8,973,080	6,640,000
Value	$10,540,845	$6,535,000
Average value per cubic foot	$1.17	$0.98
Other limestone, value (a)	$699,453	$433,700
Total value	$11,240,298	$6,968,700

(a) Rough construction stone, rubble, curbing, and flagging.

TABLE VII

Production of Limestone in Iowa in 1932.

Counties	Producers	Building stone, rubble, riprap		Road metal, concrete, railroad ballast		Other uses (a)		Total	
		Tons	Value	Tons	Value	Tons	Value	Tons	Value
Allamakee (1), Louisa (1), Winneshiek (1)	3	-----	-----	34,501	$ 33,000	------	------	34,501	$ 33,000
Black Hawk (5), Bremer (1)	6	-----	-----	95,781	74,842	5,150	$ 4,448	100,931	79,330
Buchanan (1), Clayton (4), Floyd (2)	7	(b)	(b)	94,684	77,305	5,758	6,303	100,442	83,608
Cerro Gordo (1), Hardin (1), Marshall (2)	4	-----	-----	139,259	118,790	29,098	34,027	168,357	152,817
Clinton (2), Scott (3)	5	(b)	(b)	145,792	101,704	20,788	13,828	166,580	115,532
Dubuque (4), Jackson (1), Van Buren (1)	6	(b)	(b)	129,657	116,837	7,053	8,873	136,710	125,710
Johnson (2), Mahaska (1)	3	-----	-----	154,853	127,544	------	------	154,853	127,544
Jones (3), Washington (1)	4	4,289	$ 4,266	25,820	20,643	7,078	5,372	37,187	30,281
Keokuk (1), Madison (2), Pottawattamie (1)	4	(b)	(b)	124,429	109,090	3,104	1,862	127,533	110,952
Lee (3)	3	6,080	6,577	55,972	64,946	10,956	8,830	73,008	80,353
Linn (6)	6	-----	-----	167,553	129,155	(b)	(b)	167,553	129,155
Webster (1), Woodbury (2)	3	-----	-----	323,580	321,183	------	------	323,580	321,183
Totals for 1932	54	10,369	$10,843	1,491,861	$1,295,039	89,005	$ 83,583	1,591,235	$1,389,465
Totals for 1931	43	36,693	$38,172	1,020,029	$ 994,606 (c)	214,708	$177,925	1,271,610	$1,210,705

(a) Includes: Flux, sold to sugar factories, agricultural limestone, and railroad fills.
(b) Included in road metal and concrete for purpose of concealment.
(c) In 1931 railroad ballast was included in other uses, but in 1932 it was included with road metal and concrete. In comparing the total figures this must be taken into consideration.

struction, including rubble, curbing, and flagging, showed a somewhat proportionate decline.

Tables VI and VII show the production of limestone in Iowa, and Table VI-A summarizes the limestone statistics for 1932 in the United States.

SAND AND GRAVEL

There were four more companies producing sand in Iowa in 1932 than in 1931, but their output on the whole was less by about one fifth; this was not so serious a drop as that which took place in many industries. A large decrease in structural sand was partly counterbalanced by an increase in paving sand. Grouping of counties to conceal individual production prevents a comparison of the ranking of the different counties.

The number of gravel producers increased by 19; the tonnage of structural gravel increased about one third, and there was an increase of $28,000 in value; the tonnage of paving and other gravel was more than doubled, and the value increased over $300,000. The total sand and gravel produced was 1,727 thousand tons larger in 1932 than in 1931, and 700 thousand tons larger than in 1930. The value was less than in 1930, but $195,000 more than in 1931. This picture seems

TABLE VIII

Summary of Sand and Gravel Production in Iowa, 1932.

Materials	Pits	Tons	Value
Sand			
Molding (a)	1		
Structural (b)	39	289,666	$ 119,666
Paving and roads	39	827,883	204,192
Cutting, grinding	5	6,111	8,315
Engine (c)	12	24,909	18,266
Filter (d)	2		
Railroad ballast	3	45,054	14,933
Other	6	10,545	3,279
Total sand, 1932		1,204,168	$ 368,651
Total sand, 1931		1,294,822	469,208
Gravel			
Structural	35	289,349	$ 219,651
Paving and roads	55	3,422,195	1,063,008
Railroad ballast	4	308,059	52,806
Other	3	6,791	2,758
Total Gravel, 1932		4,026,394	$ 1,338,223
Total Gravel, 1931		2,108,574	1,042,070
Total Output, 1932		5,230,562	$1,706,874
Total Output, 1931		3,403,396	1,511,278

(a) Included with structural sand.
(b) Includes molding sand.
(c) Includes filter sand.
(d) Included with engine sand.

especially prosperous when compared with sand and gravel production in the United States as a whole.

Table VIII shows the production of sand and gravel in Iowa by classes, and Tables IX and X show the production by counties.

The large decrease in building and highway construction in the United States was reflected in the output of sand and gravel in 1932. The total sale of sand dropped 44 percent, while that of gravel dropped 41 percent. For the last ten years gravel has formed an increasing part of the sales of sand and gravel. The total value of sand and gravel sold or used by producers declined 46 percent from that of the previous year. The production of sand and gravel in United States is given in Table VIII-A.

TABLE VIII-A

Sand and Gravel in the United States for 1931 and 1932.

		1931	1932	Change, percent
Sand sold or used by producers, by uses:[a]				
Glass	Short tons	1,677,882	1,330,000	-21
Molding	" "	2,138,305	1,100,000	-49
Building	" "	25,178,572	11,200,000	-56
Paving	" "	27,459,581	17,000,000	-38
Grinding and polishing	" "	607,589	400,000	-34
Engine	" "	1,604,123	1,300,000	-19
Fire or furnace	" "	88,189	52,000	-41
Filter	" "	55,319	38,000	-31
Other	" "	5,683,266	3,830,000	
Gravel sold or used by producers, by uses:[b]				
Building	Short tons	21,426,814	10,500,000	-51
Paving	" "	56,716,230	36,250,000	-36
Railroad ballast[c]	" "	10,843,174	6,000,000	-45
Total		153,479,044	89,000,000	

(a) Figures for 1932 estimated from data available on consuming markets; checked by preliminary reports from producers.
(b) Includes some sand used for railroad ballast, fills, and similar purposes.
(c) Includes some gravel used for fills and other purposes; in 1931, 8,814,907 tons of gravel, valued at $2,898,598, were used exclusively for ballast.

TABLE IX

Production of Sand and Gravel in 1932—Sand

Counties	Pits	Structural Sand		Paving Sand		Other Sand (a)		Total Sand	
		Tons	Value	Tons	Value	Tons	Value	Tons	Value
Allamakee (1), Black Hawk (3), Winneshiek (1)	5	11,954	$ 5,527	45,481	$ 43,558	(b)	(b)	57,435	$ 49,085
Appanoose (1), Des Moines (1), Lee (2), Van Buren (1)	5	19,994	10,140	(b)	(b)	(b)	(b)	19,994	10,140
Boone (2), State of Iowa (0), Story (1), Webster (1)	4	2,825	1,669	-----	-----	(b)	(b)	2,825	1,669
Buena Vista (0), Dickinson (0)	0	-----	-----	-----	-----	-----	-----	-----	-----
Butler (3), Grundy (0), Hardin (1), Tama (1)	5	3,550	1,450	44,127	16,867	-----	-----	47,677	18,317
Cerro Gordo (2), Hancock (1), Mitchell (0), Wright (0)	3	(c)	(c)	179,349	35,349	-----	-----	179,349	35,349
Cherokee (2), Sac (3)	5	7,320	2,360	66,610	21,325	(c)	(c)	73,930	23,685
Clay (2), Lyon (1), Plymouth (1), Sioux (0)	4	(d)	(d)	(e)	(e)	-----	-----	-----	-----
Clayton (1), Clinton (1), Jackson (1)	3	34,640	7,672	64,172	11,718	-----	-----	98,812	19,390
Crawford (0), Harrison (0), Woodbury (1)	1	-----	-----	(e)	(e)	-----	-----	-----	-----
Dubuque (2), Fayette (1)	3	9,037	2,084	17,000	3,145	-----	-----	26,037	5,229
Emmet (1), Humboldt (1), Palo Alto (0), Pocahontas (0)	2	(d)	(d)	(e)	(e)	-----	-----	-----	-----
Johnson (2), Linn (2)	4	23,700	14,100	19,158	12,721	(c)	(c)	42,858	26,821
Mashaska (1), Marion (1), Wapello (1)	3	34,886	20,058	62,183	22,748	(c)	(c)	97,069	42,706
Muscatine (4), Scott (1)	5	31,620	25,451	273,160	21,211	(b) (c)	(b) (c)	304,780	46,662
Polk (5)	5	54,208	24,014	34,227	10,249	(b)	(b)	88,435	34,263
Total 1932 (f)	57	233,734	$114,525	805,467	$198,891	-----	-----	1,039,201	$313,316
Total 1931	53	618,158	$243,037	676,664	$226,171	-----	-----	1,294,822	$469,208

(a) Includes molding, cutting and grinding, engine, filter and railroad ballast sand.
(b) Included with structural sand.
(c) Included with paving sand.
(d) Included with structural gravel.
(e) Included with paving gravel.
(f) Totals for sand do not exactly agree with totals by classes, because some sand is included with gravel for purpose of concealment.

TABLE X

Production of Sand and Gravel in 1932 — Gravel

Counties	Pits	Structural gravel (a)		Paving and other gravel		Total sand and gravel		Total quantity washed	
		Tons	Value	Tons	Value	Tons	Value	Tons	Value
Allamakee (1), Black Hawk (4), Winneshiek (0)	5	2,545	$ 1,876	60,837	$ 21,170	120,817	$ 72,131	61,718	$ 53,856
Appanoose (0), Des Moines (1), Lee (2), Van Buren (0)	3	4,140	2,940	-----	-----	24,134	13,080	24,105	13,078
Boone (2), State of Iowa (2), Story (1), Webster (3)	8	3,938	3,115	1,444,968	452,886	1,451,731	457,670	7,131	5,065
Buena Vista (2), Dickinson (1)	3	-----	-----	477,642	57,504	477,642	57,504	5,000	400
Butler (2), Grundy (1), Hardin (1) Tama (2)	6	4,835	2,730	57,052	37,138	109,564	58,185	98,199	56,614
Cerro Gordo (2), Hancock (1), Mitchell (1), Wright (1)	5	(c)	(c)	173,677	112,311	353,026	147,660	241,288	134,979
Cherokee (3), Sac (6)	9	7,622	6,061	257,210	74,117	338,762	103,863	206,410	82,353
Clay (2), Lyon (2), Plymouth (1), Sioux (1) (d) (e)	6	14,246	6,453	82,095	26,393	96,341	32,846	35,493	22,079
Clayton (0), Clinton (2), Jackson (1)	3	59,907	19,526	154,191	53,250	312,910	92,166	312,660	92,075
Crawford (1), Harrison (1), Woodbury (2) (e)	4	-----	-----	237,204	42,060	237,204	42,060	117,104	38,060
Dubuque (2), Fayette (1)	3	13,081	4,137	-----	-----	39,118	9,366	4,618	2,976
Emmet (2), Humboldt (1), Palo Alto (2), Pocahontas (1) (d) (e)	6	154,779	103,944	363,007	109,610	517,786	213,554	239,357	153,739
Johnson (2), Linn (1)	3	12,440	9,550	(b)	(b)	55,298	36,371	55,298	36,371
Mahaska (1), Marion (1), Wapello (2)	4	19,919	17,345	15,883	12,255	132,871	72,306	128,581	71,856
Muscatine (4), Scott (1)	5	13,081	9,751	413,612	108,293	731,473	164,706	711,868	157,625
Polk	5	36,055	41,450	107,395	57,793	231,885	133,406	216,315	126,398
Total, 1932	78	346,588	$228,878	3,844,773	$1,164,780	5,230,562	$1,706,874	2,465,145	$1,047,524
Total, 1931	59	228,802	$199,828	1,723,932	$ 837,126	3,403,396	$1,511,278	2,279,962	$1,353,513

(a) Structural gravel includes some paving gravel and paving gravel includes some structural gravel.
(b) Included in structural gravel.
(c) Included in paving gravel.
(d) Includes some structural sand.
(e) Includes some paving sand.