SiO_2	84.35 per cent
Al_2O_3	8.62 " "
$FeO+Fe_2O_3$	5.59 " "
CaO	.88 " "
H_2O+loss	.43 " "

The Red Rock sandstone constitutes the most important source of building stone in the county. There are unlimited quantities available and it merits a much wider use than it has at present.

The Coal Measures sandstone in Jasper county, as elsewhere, is not sufficiently indurated for high grade crushed stone products. As the county is near enough to draw on the Des Moines river supply of sand and gravel expensive development work for stone is scarcely warranted.

JEFFERSON COUNTY.

Sand and Gravel.

With the exception of a few exposures of dirty sand and gravel sparingly distributed in the eastern tier of townships, Jefferson county is practically devoid of water-laid materials. Most of the cement and concrete materials used in the county are shipped from Ottumwa.

In reference to gravels, Mr. J. A. Udden in a report on Jefferson county* says: "In the eastern part of the county a few places were noted where gravels and sands rest on bed rock and are covered by bowlder clay. The most extensive exposure of this kind is at the southwest corner of section 1, Walnut township, in the south bank of a ravine which is fed by a number of springs that issue from the gravel at intervals for a distance of some thirty rods. The deposit is fully twenty feet thick and lies at an elevation of about 100 feet above Skunk river. To the west it is covered by bowlder clay and for a mile in this direction there are wells in which the water comes from the same gravel, and has a strong mineral taste. The deposit is highly ferruginous and almost ocherous, brownish yellow in color, and in places cemented into a soft stone. The

*Iowa Geological Survey, Volume XII.

lower part is gravel, but the upper fifteen feet are evenly bedded, laminated sand of variable texture, with here and there silty seams. Deposits like this, but more silty, were noted in the base of the drift at two other localities in this region; on the wagon road at a shallow draw near the center of the west line of the northwest quarter of section 12 in Walnut township and at the base of the bluff in the wagon road which leads down to the ford across Skunk river in the east southeast quarter of section 11 in Lockridge township. Some indurated brown gravel or sand was again noted in the south bank of a ravine above the wagon bridge near the southeast corner of section 24 in Round Grove township. The section at this place was as follows:

		FEET.
4.	Bowlder clay (interbedded with No. 3).	
3.	Sand and gravel, yellow, quite evenly bedded	5
2.	Sandstone, brown, hard enough to be used for building stone	1½
1.	Sand and gravel, slightly indurated, brown	4

"The same gravel occurs in the two next streams which cross the east boundary of the county to the south of this place, and it was also noticed resting on the bed rock in two ravines running into Cedar creek in the southwest quarter of section 35 of Lockridge township."

The age of these gravels is problematical. From their stratigraphic position they could be either a glacial or a preglacial formation. Pebbles of igneous origin are a point in favor of glacial origin, but the fact that out of 500 of them none were found scored is strongly against such origin. Another fact supporting a preglacial age is that the proportion of different rocks is quite variable for different localities and in glacial deposits this proportion is fairly constant in the same region. Mr. Udden also notes that, "The degree of induration and the thoroughness of oxidation and leaching also indicate a considerable age for these gravels." Calcareous materials are almost entirely absent. Some unique pebbles testify to this extreme leaching. On section 1 in Walnut township, the gravel contains some pebbles of limonite which are hollow. They are the shape and size of an empty shell of a hazel nut. Presumably these limonite shells have been formed as incrustations around calcareous pebbles, which afterward have been leached out by slow percolation through the crust, leaving this empty. The overlying bowlder clay resembles the Kansan, but an earlier clay may have been removed. Since some of the facts are contradictory and others prove nothing either way the age and origin of these gravels is uncertain.

Gravel is unknown save in the three eastern townships, and the same can be said of sand with one exception. Part of the sand used in Fairfield comes from a small creek a mile and a half south of town, while the rest is shipped in from Ottumwa.

STONE.

Jefferson county belongs to the region of thick drift, which, according to Udden, averages one hundred and fifteen feet in thickness over the entire county. Both the drift and the Coal Measures have been completely removed by the principal streams in Penn, Walnut and Lockridge townships in the northeast, and to a less extent in Round Prairie, Cedar and Liberty townships bordering on the south line of the county. Numerous outcrops of Saint Louis limestone appear in all of these townships. As a rule, such exposures are of small extent and often much obscured by the heavy talus almost everywhere present. While the county has produced a large quantity of stone for local use, and is capable of producing much more, there is not a single worker in the county who depends upon the quarry industry for a livelihood.

The following sections will give a fair idea of the natural resources of the county along this line.

Walgren's Quarry, southwest quarter of the southeast quarter of section 3, Lockridge township.

		FEET.
4.	Soil and drift of variable thickness.	
3.	Clay and marl, yellow	$3\frac{1}{2}$
2.	Limestone, dark gray, porous, somewhat cherty in places	7
1.	Limestone, grayish yellow, exposed	5

Monson's Quarry, northeast quarter of the northwest quarter of section 8, Lockridge township.

		FEET.
6.	Soil and drift of variable thickness.	
5.	Limestone, compact, fine-grained, almost lithographic in texture, pyritic	1⅓
4.	Limestone, soft, gray, in thin beds	2
3.	Limestone, gray, in a single ledge	2¼
2.	Limestone, dark gray, compact and slightly bituminous	½
1.	Marl, blue, shaly, exposed	¼

Numerous sections are exposed along Walnut and Burr Oak creeks and their tributaries in the three northeastern townships. The hard beds are quite generally brecciated and are associated with marly and shaly layers.

In the southern portion of the county outcrops are fewer. Near the south line of Round Prairie township, a quarry has been opened in the southwest quarter of the southeast quarter of section 34. The section is given herewith.

		FEET.
4.	Soil and drift of variable thickness.	
3.	Marl, gray, fossiliferous	2
2.	Limestone, white, with a ledge of very fine, almost lithographic texture	2
1.	Limestone, gray, in ledges varying from six inches to one foot in thickness, with shaly parting near the middle	5

Other exposures occur in Round Prairie, Cedar and Liberty townships. Quarrying has also been done to the northeast of the center of section 10, in Liberty township. The beds worked are as follows:

		FEET.
7.	Soil and drift of variable thickness.	
6.	Shale, green, pockety, belonging to Coal Measures.	
5.	Limestone, gray, weathering into rounded bowlders, in places with small crevices filled with calcite, fossiliferous	4
4.	Marl, light colored, with occasional stone concretions, fossiliferous	2
3.	Limestone, gray	⅔
2.	Marl, similar to number 4	3
1.	Limestone, gray, pyritic	3

Practically all good quarry stone belongs to the Pella beds, and comprises heavy ledges of compact limestone, alternating, especially above, with seams of greenish, marly shales. Occasionally the limestone is slightly broken up and brecciated, but to a much less extent than the Verdi beds below. Some of the beds are almost lithographic in character. The beds are usually more or less pyritic throughout.

JOHNSON COUNTY.

SAND AND GRAVEL.

Sand and some gravel may be obtained from Iowa river in the vicinity of Iowa City. Good gravel is relatively scarce. Sand of fair quality may be found in low terraces, sand flats and bars along the river and its immediate tributaries. Sand deposits also occur in the Iowan drift area southeast of Solon. Sand is scarce in the southwestern portion of the county.

While the older gravels are believed to be present, they are almost wholly concealed by the later drifts and are, therefore, not available.

STONE.

The Niagaran limestone occupies a small triangular area in the northeast corner of the county. The two phases of the Gower stage, well marked in other counties, are represented in section 2 along Cedar river in Cedar township. The hard, fine-grained, subcrystalline, light cream-colored dolomite, aggregating twenty feet in thickness, represents the LeClaire beds, while the massive, vesicular, laminated dolomite, aggregating forty feet in thickness, is referred to the Anamosa stage.

A complete section of the bluff which faces Cedar river in sections 2 and 3 in Cedar township is as follows:

		FEET.
5.	Loess, arenaceous, light colored	2-4
4.	Drift, pebbly, containing a large number of bowlders from one to three or four feet in diameter	4-6
3.	Limestone, laminated, without definite partings, cherty	30
2.	Limestone, yellow, nonlaminated, in layers from four to eleven inches in thickness	10
1.	Dolomite, light colored, subcrystalline	20

Number 1 represents the LeClaire horizon and is essentially a pure dolomite admirably adapted for the manufacture of a high grade of lime. Numbers 2 and 3 belong to the Anamosa beds and have long found favor with the quarrymen, although the beds have never been developed extensively on account of lack of transportation facilities.

Rocks of Devonian age immediately underlie the drift over more than half of the county. Numerous exposures occur along Iowa river and its more important tributaries. The beds represented are referred to three well known substages of the Devonian. The lowest belong to the brecciated stage of the Wapsipinicon and are exposed at only a few points in the northeastern portion of the county. These beds have been quarried in a small way at Solon and near Elmira. The layers are much shattered as a rule, and the blocks obtainable are rough and poorly shaped for structural purposes. The stone supplied from these beds is of local interest only.

The Cedar Valley stage is well developed and affords the largest number of outcrops. Quarries have been opened and operated at numerous points. A few, only, are given for reference. The majority of the openings are without transportation facilities but show the latent wealth of the county in structural materials. A quarry opened south of the old Terrill mill in Iowa City shows the following succession of beds:

TERRILL MILL SECTION.

		FEET.
8.	Hard, ferruginous, reddish brown sandstone of Des Moines stage, Upper Carboniferous	6
7.	Limestone, whitish gray, fine-grained	8
6.	Idiostroma beds, containing as usual many massive stromatoporoids and some coralla of Acervularia	15
5.	Limestone, heavy, tough ledge	4
4.	Limestone, bluish gray, weathering yellow, containing large coarse-ribbed Atrypas and the small branched, small celled Cladopora found at same horizon in Eicher's quarry	8
3.	Limestone, bluish gray, in two ledges, first ledge containing many crinoid stems	4
2.	Coral reef	2
1.	Limestone, bluish, with great numbers of broken, crushed, detached valves of *Spirifer parryanus* and the robust, large celled Cladopora (*C. iowensis* Owen sp.) described as *Striatopora rugosa* by Hall	2

The coral reef bed is very persistent and constant. The beds above the reef vary considerably. In places they are hard bluish gray limestone, in other places, partly on account of weathering, they are yellow limestone and in still other localities they present the appearance of yellow calcareous shales. At the old railway quarry on the west bank of the river north of Coralville, the following beds may be seen beneath the overlying loess and drift:

CORALVILLE SECTION.

		FEET.
5.	Limestone, white	12
4.	Limestone, stratum crowded with casts of *Straparollus cyclostomus* Hall	1½
3.	Limestone weathering into thin fragments, containing some specimens of Idiostroma and colonies of a cylindrical Favosites	4
2.	Limestone, gray, crowded with Idiostroma and other stromatoporoids. This with No. 3 represents the Idiostroma beds of preceding sections	8
1.	Limestone, hard, blue, containing some large coralla of Acervularia	4

These beds were formerly worked by the Rock Island Railway Company for crushed stone. A switch was extended to the quarry and a large amount of railway ballast produced. One of the most extensive quarry sections may be observed on the east bank of Iowa river in the northwest quarter of section 27, Newport township. The following beds below the loess and drift are exposed:

		FEET.
9.	Limestone, brown, with crinoid stems, a Cladopora related to the form described by Hall as *Striatopora rugosa*, but having the branches and polyp tubes very much smaller, and a large coarsely ribbed variety of *Atrypa reticularis*	4
8.	Limestone, drab, granular, no fossils	8
7.	Coral reef composed chiefly of coralla of *Acervularia davidsoni* E. & H., but containing many coralla of Favosites and Ptychophyllum	2
6.	Limestone, moderately hard bed with crinoid stems, *Spirifer parryanus*, *Atrypa reticularis*, Favosites, Cyathophyllum, Cystiphyllum, etc.	1½
5.	Limestone, shaly, with many small crinoid stems, *Chonetes scitula* Hall, *Spirifer parryanus* Hall, *Tentaculites hoyti* White, and *Monticulipora monticola* White	1½
4.	Limestone, hard ledge with many small crinoid stems, Cladopora, Ptychophyllum and some large coralla of Acervularia	2
3.	Limestone, yellow shaly bed with Atrypa, Orthis, etc.	2
2.	Limestone, yellow and gray, shaly, without fossils	13
1.	Limestone, moderately hard, intersected by a number of oblique joints, light colored, laminated, with many stem segments and some perfect calyces of Megistocrinus and other species characteristic of the Megistocrinus fauna. Megistocrinus beds	15

The quarry north of the iron bridge in section 25, Jefferson township, shows some modifications of the succession of strata occurring farther down the river. The section is as follows:

		FEET.
10.	Loess	2-10
9.	Pebbly drift, Kansan	3
8.	Limestone, decayed, with bowlders of disintegration embedded in highly oxidized dark reddish brown residual clay	3
7.	Limestone, light colored, evenly bedded, fine-grained	10
6.	Coral breccia, composed of coralla of Acervularia, small cylindrical Favosites, a peculiar Diphyphyllum, a very elongated Cyathophyllum, Idiostroma and massive stromatoporoids	5-8
5.	Reef of closely crowded masses of Acervularia	2
4.	Limestone, regular heavy layers of fairly good quarry stone, containing coralla of Acervularia and Favosites sparsely distributed	5
3.	Limestone, blue, in layers from 6 inches to 2 feet thick, composed of fragments of crinoids and broken shells of brachiopods	7
2.	Shale and shaly limestone	1½
1.	Limestone, heavy, blue, with concretions of pyrites	2

Nearly all of the beds given in the above sections supply materials suitable for foundations and rough masonry and have been so used to some extent at one time or another.

The uppermost member of the Devonian as developed in the county has been named the State Quarry Limestone by Professor Calvin, and is not known to occur in any other county in the state. The formation is assigned to the Upper Devonian and attains a thickness of forty feet, and while it has been recognized at a number of points in the county, it is typically developed at the State Quarries, or North Bend quarries, in sections 5 and 8 of Penn township. On fresh fracture the State Quarry rock is light gray in color. In texture it varies somewhat in different beds but near the middle of the formation it is composed of coarse, imperfectly comminuted fragments of brachiopod shells cemented together, the spaces being filled with interstitial calcite. The shells, or fragments of shells, making up the limestone are not embedded in a matrix but are simply piled on each other and cemented.

PLATE XXIV—State quarry beds, State Quarry, Johnson county.

Near the middle of the formation the rock consists of thick ledges which, some years ago, were worked extensively. From these beds came the large limestone blocks used in the foundation of the new state capitol. Although the ledges show no definite lamination, and split as readily in one direction as another, the weathered surfaces on opposite sides of the numerous joints often show obscure signs of oblique bedding. The chief quarry ledge is five feet thick and rests on a four foot ledge which is not used. The next usable ledge in ascending order is also five feet in thickness and is separated from the first by two or three feet of talus. The fourth ledge is four feet thick and is very fine-grained. Above this the beds range from six inches to two feet in thickness; these beds are made up wholly of crinoidal remains. Below the first heavy ledge mentioned rock is thinly bedded.

While there is still a large amount of excellent material for bridge work and massive masonry available the lack of proper transportation facilities has caused the temporary abandonment of the quarry.

JONES COUNTY.

Sand and Gravel.

The gravel deposits along Maquoketa river in Delaware county are continued into Jones at least as far south as Monticello. In the northern part of Monticello township terraces are not prominent but there are great quantities of sand along the river valley. In the south half of section 9 the Chicago, Milwaukee & Saint Paul Railway has opened up an immense pit in these sands. The pit is forty feet deep and the top of the bed is at the same level as the adjoining prairie. The sand is fresh, fine and clean, without bowlders, and with no foreign pebbles over an inch in diameter although some chert fragments are mingled with the finer material.

About one-half mile southeast of the pit, in the northeast quarter of section 16, a small gully in the roadside shows red, oxidized gravels resembling those of Buchanan age. There seems to be considerable sand and gravel in this neighborhood

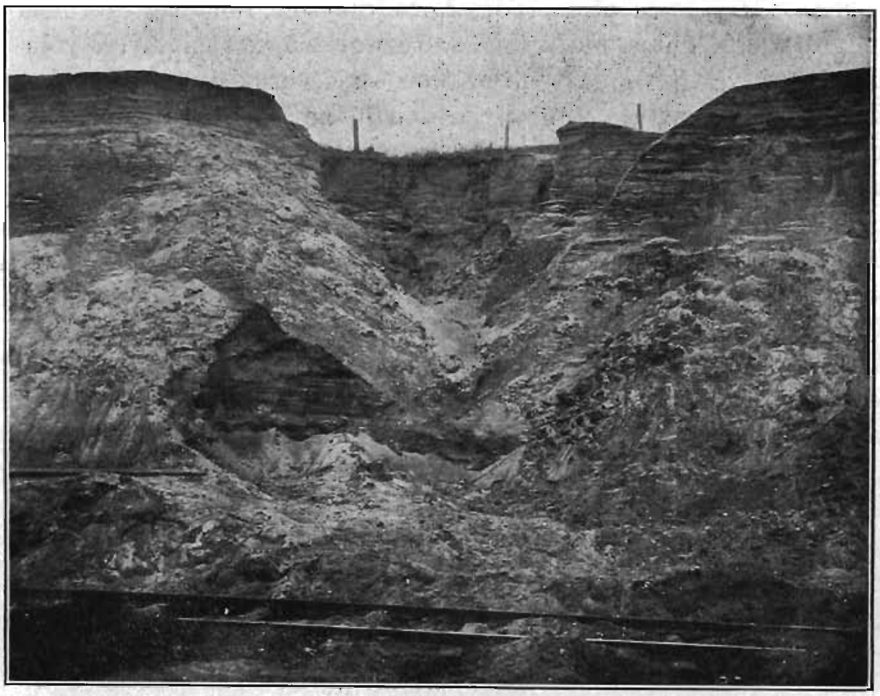


FIG. 44—Chicago, Milwaukee & St. Paul Railway sand and gravel pit. Monticello, Jones county.

but as the surface of the deposit blends with the general level its extent cannot be determined. A little nearer the river is a stone quarry in which the stone rises nearly to the surface while across the road a cemetery which lies between the gravel exposure and the river shows gravel, geest and loose rock in the excavations. It seems probable that whatever beds of gravel there are in this vicinity are banked against an old rock-walled valley and probably do not extend very far back from the present valley wall.

A large part of the city of Monticello is built upon a broad, rather low flood plain. In a few places Buchanan gravels are exposed in excavations but there do not seem to be any well marked terraces or other deposits. On the left bank of the river below the lower bridge is a large terrace deposit and at the power plant Mr. H. J. Lang has opened a pit for the purpose of securing gravel for making concrete for reenforcing

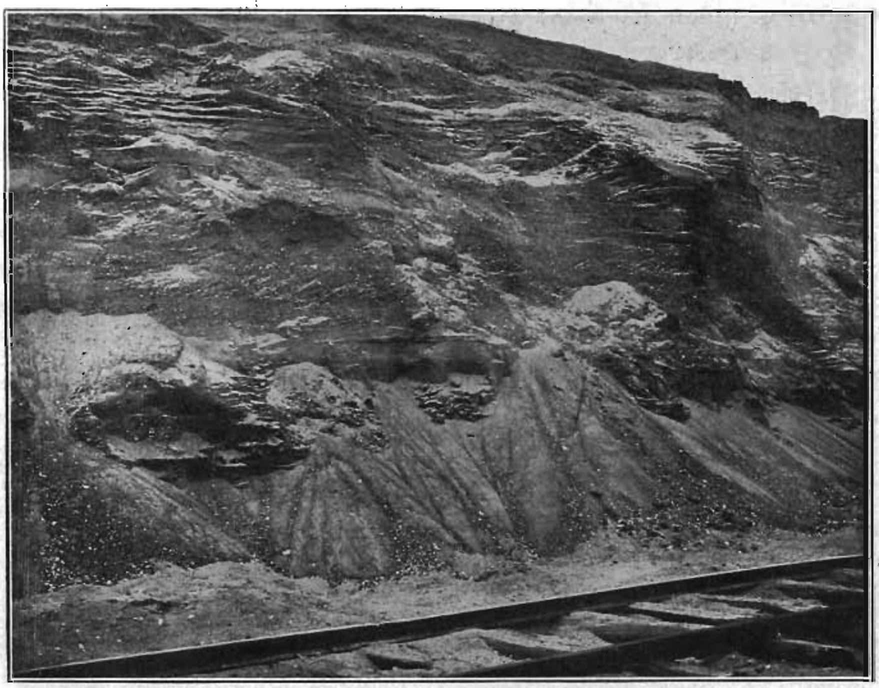


FIG. 45—Chicago, Milwaukee & St. Paul sand pit, Monticello, Jones county.

the dam. This gravel is said to have given excellent satisfaction. One part of cement was used to six or eight of gravel. The pit shows about one foot of loam at the top, probably chiefly alluvium, then one to three feet of sand and clayey sand. Below this bed are four to eight feet of gravel considerably stained and cemented with iron oxide in the upper part but clean below. The coarser material shows a considerable proportion of limestone and chert, and the whole deposit is quite irregularly bedded. This gravel bed becomes finer below and grades into sand at the bottom of the pit. Both the gravel and the underlying sand are very free from clay or similar impurities.

This terrace extends back from the river for several hundred feet and also for a considerable distance along the valley. It must contain a practically exhaustless quantity of material of excellent quality for road and especially for concrete and plastering purposes. Most of the gravel at present used in the town is taken from the river, but this terrace material is said to give better results.

Gravels and sands occur along Wapsipinicon river between Anamosa and Hale although not so abundantly as along other streams. Near the northeast corner of section 14 and near the center of the east line of section 13, Fairview township, are exposed beds of gravel near the river, and in the wide plain between Newport and Olin fine sands are spread out. Similar sands are found along the road across the north part of section 9, Hale township.

Gravels of the upland phase occur at numerous localities. In the extreme northeast corner of section 36, Jackson township, a bed has been cut into to a depth of several feet in grading the road. Similar gravels show along the road leading west and northwest from Monticello across Monticello township and sections 24, 14, 15, and 9 of Castle Grove township. Here they occur on the hills and also near the streams.

STONE.

The Niagaran limestone series comprises the country rock over the entire county and excellent exposures may be viewed along the principal streams. While each stage of the Niagaran furnishes construction materials suitable for some economic use, the Anamosa stage and the evenly bedded horizon near the top of the Hopkinton, furnish the only building stones of commercial importance, while the hard, subcrystalline, irregularly bedded LeClaire affords an inexhaustible supply of material suitable for high grade limes.

The building stone beds of the Hopkinton stage afford some excellent material, particularly in the neighborhood of Clay Mills, Canton and Temple Hill. Near Clay Mills the ledges vary from three to fourteen inches in thickness. The stone is generally of good color, it is firm, compact, without laminæ, and in the most trying situations, it resists admirably the action of the weather. All the exposures of the Hopkinton stage building stone are unfortunately located, so far as relates to facilities for transportation. Their only use for many years to come will be the furnishing of building material to supply local demands.

The commercial quarries are all dependent on the evenly bedded, finely laminated strata of the Anamosa phase of the Gower stage. The most important quarries of this phase are located near the western border of the county in Fairview and Cass townships.

The evenly bedded stone in the river bluffs west of Anamosa early attracted attention. The first extensive use of it was made by the United States army in constructing military roads while Iowa was yet a territory. Some of the old bridge piers built under the direction of the military engineers, are still standing and bear conclusive testimony to the durability of stone from this horizon. For some time the quarries were worked on a small scale and supplied only a local trade, but the market widened as the qualities of the stone became better known, and long wagon hauls were made in order to secure this material for use in structures of sufficient importance to justify such expensive methods of transportation. In 1852 stone was hauled from what is now Stone City to Mount Vernon for use in construction of one of the first buildings belonging to Cornell College.

Shipments by rail began from this locality in 1859, and after that time the stone industry of the region increased rapidly. From supplying a very restricted local trade, the business of quarrying and shipping stone has grown until it now reaches markets distributed throughout Iowa, Illinois, Wisconsin, Minnesota, South Dakota, Nebraska, Kansas and Missouri. Many of the most important structures in the several states named are built of Anamosa stone. It competes in Chicago and Minneapolis with the product of quarries more advantageously located, so far as distance is concerned. All the important railways of the northwest have used Anamosa stone in the construction of bridge piers. The stone has been used extensively in erecting the shops and other buildings at the Rock Island Arsenal. Iowa and Nebraska have both used it in building hospitals for the insane. It meets the requirements of all grades of architectural work from the humblest to the highest.

The Anamosa limestone varies locally, but in general it is composed of evenly bedded, perfectly laminated layers of impure dolomite that ranges in color through shades of buff to gray on the one hand, and almost white on the other. The beds are broadly undulating, but may be practically horizontal. The same beds thicken and thin gradually, but for limited distances are essentially parallel faced. The stone splits much more easily along bedding planes than in other directions, although clay partings are not common. Vertical joints are few and far between although more numerous in some quarries than in others. Texturally the stone varies considerably, from fine-grained, compact, nonlaminated beds to somewhat vesicular, coarse-grained and evidently laminated beds. At Stone City the Anamosa beds have an aggregate thickness of sixty feet and are divided into two nearly equal parts by a porous, worthless ledge. The lower thirty feet is known as the "gray limestone" while the beds in the upper half constitute the "white limestone." The most valuable quarry stone comes from the lower or gray limestone. The upper beds are imperfectly cemented, and the cleavage along lamination planes is more perfect than in the beds below, for which reason the rock in this part of the quarry tends to split into thin slabs, and long exposure to the weather reduces it to chipstone. As a consequence its range of usefulness is somewhat limited, but it gives good service when used in ordinary masonry. The lower beds, on the other hand, lie below the level of the ground water, are more perfectly cemented, and furnish excellent material for almost all kinds of structural purposes. There are some planes in this division, however, along which the rock is vesicular, the cavities being of rather indefinite shape and ranging up to two or even three inches in diameter. Some of these are decorated with crystals of calcite or quartz or both. Cherty concretions are found in the upper limestone.

The most important quarries are located along the Wapsipinicon in Stone City and vicinity, and along Buffalo creek about three miles west of Anamosa, where the State quarries are located.

PLATE XXV—Champion quarry showing track and derrick arrangements and channeler. Stone City, Jones county. Crushed stone is the chief product at present.

STONE CITY.

Four important companies are operating here at the present time, as follows:

J. A. Green & Son; H. Dearborn & Sons; J. A. Erickson; and John Ronen.

All of the quarries exhibit about the same sequence of beds, and all of the companies have about the same equipment. All have railway connections, own and use one or more channelers (single gang) and a number of steam drills, steam derricks, pumps for hydraulic stripping, and a crusher plant each to utilize the refuse. All of the quarries furnish crushed stone, riprap, rubble, bridge stone, flagging, and all grades of dimension stone. Professor Calvin has worked out a detailed section for Champion quarry No. 1, which fairly represents the district and also classifies the various ledges according to their uses. The section is given herewith. The quarry was opened by Mr. Green in 1867.

CHAMPION QUARRY No. 1. SECTION.

		FEET.	INCHES.
26.	Loess, varying in thickness, maximum	20	....
25.	Fine sand associated with loess, the sub-loessial sand of Norton	2-6	....
24.	Drift and residual clay	1	....
23.	"Shelly stone" the partially decomposed beds of the upper, or white limestone, broken into thin flakes or chips	2-10	....
22.	"White stone" splitting readily into smooth surfaced slabs, used chiefly for riprap	16	....
21.	"Rotten layer," a soft vesicular ledge of poor quality which separates the gray from the white limestone	2	4
20.	Compact fine-grained ledge, good building stone	1	5
19.	Same as 20	1	5
18.	Ledge of good building stone	..	11
17.	Same as 18	..	11
16.	Upper bridge stone, coarse	2	6
15.	Inferior layer containing many small cavities lined with calcite	..	10
14.	Fine-grained building stone	1	1
13.	Ledge containing at base a thin layer of very fine-grained, compact limestone, which cracks into angular fragments under the action of frost (the bands of very fine-grained limestone differing from the ordinary granular dolomite are called "flint" by the quarrymen)	1	3
12.	Ledge with bands of "flint"	1	11

11.	Solid ledge of good building stone................	1	4
10.	Compact ledge, best quality afforded by the quarry	1	2
9.	"Wavy ledge" good for ordinary masonry; the laminæ are more or less undulated...............$2\frac{1}{2}$-3		....
8.	Good building ledge	..	11
7.	"Flint ledge," compact limestone, breaking into angular fragments on exposure to weather....	$\frac{1}{2}$-1	4
6.	Flagging ledge, easily split.....................	1	4
5.	Ledge containing cavities lined with crystals......	1	....
4.	Ledge of good building stone.....................	..	11
3.	Lower flagging ledge..............................	2	....
2.	Lower bridge stone ledge, very durable, though occasionally containing cavities lined with crystals	2	4
1.	Ledge that may again be split into blocks convenient for building purposes......................	3	....

Below the quarry stone there are here, as everywhere in this region, massive beds of the LeClaire limestone. The uppermost ledge of the LeClaire at the Champion quarry ranges from two and one-half to three feet in thickness and was formerly quarried to a limited extent for use in heavy bridge piers.

The principal output of the Green quarry at the present time is crushed stone. Two sizes are produced and are used for both macadam and concrete. The crusher plant has a daily capacity of eight cars of twenty-two cubic yards each. The upper ledges from the west end are harder than the others, are a dark gray dolomite, some ledges finely vesicular and granular with no laminæ while other ledges are distinctly laminated. The softer ledges are lighter gray to buff. All of the material is rather soft for road work, but gives good satisfaction for concrete.

STONE CITY QUARRIES.

The Stone City quarries were opened by Mr. H. Dearborn in 1869. They are now owned and operated by H. Dearborn & Sons. They are located near the middle of the south half of the northeast quarter of section 6, Fairview township. The quarry face forms a long sweeping curve about a quarter of a mile in length and nearly parallel with the sweep of Wapsipinicon river that here flows close to the foot of the bluffs in which the quarries were opened. The quality of the stone and the succession of ledges are essentially the same as at the quarries

PLATE XXVI—John Ronen quarry, showing arrangement of tracks, derricks and crusher plant. Stone City, Jones county.

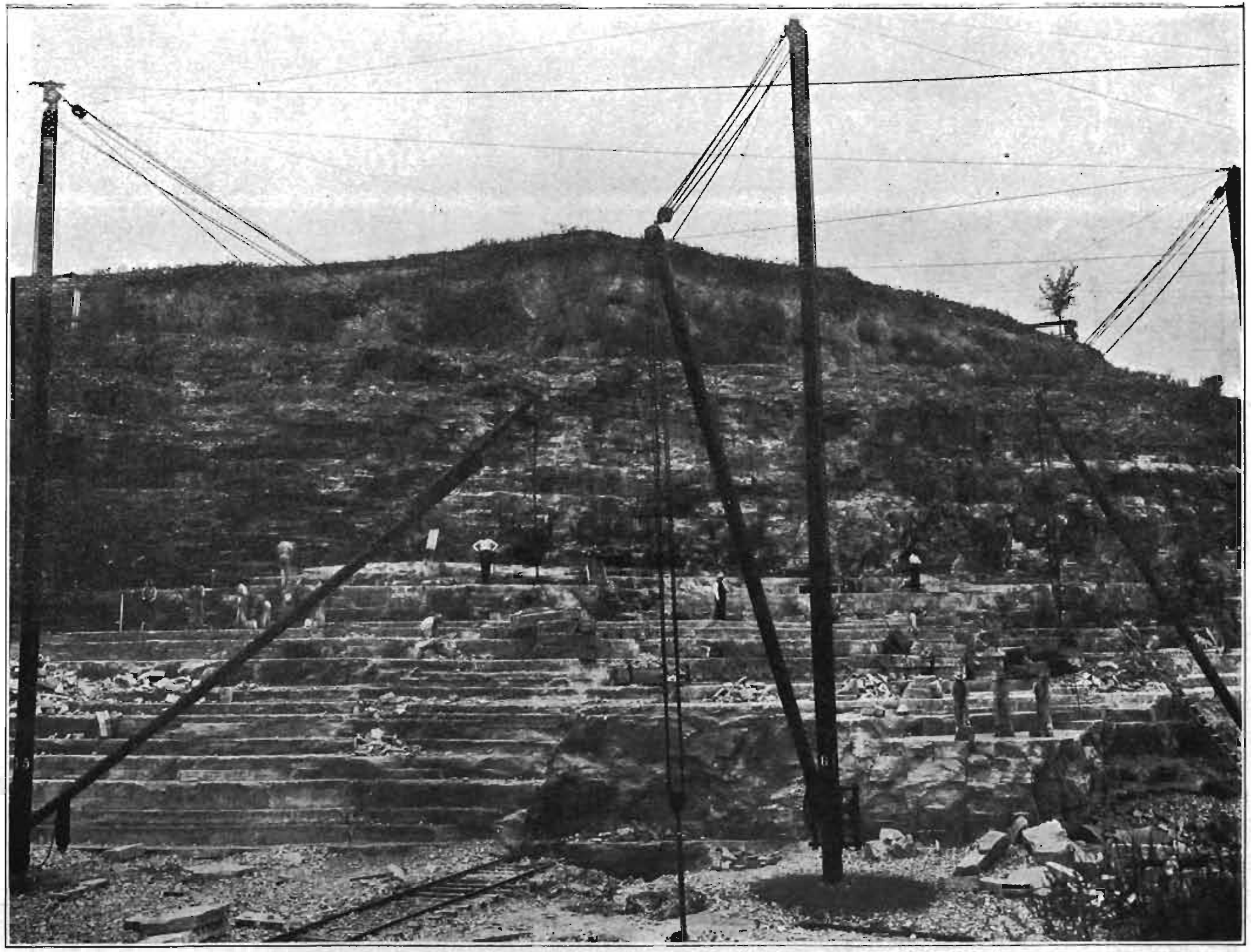


PLATE XXVII—State quarry, Anamosa, Jones county. This quarry is unique among the larger quarries of the state in the absence of improved machinery. All power is hand power.

already described. Overlying the stone is a bed of loess, sand and drift, with an average thickness of five feet and a maximum thickness of fifteen feet. Some six or eight feet of stone at the top of the quarry are to be counted with the refuse, the beds being broken into small angular pieces as a result of weathering prior to the deposition of the superficial drift and loess. These quarries expose the whole thickness of the "gray stone" or lower half of the Anamosa beds, above which are serviceable beds of the "white stone," or upper half, having a thickness of ten or fifteen feet. The beds are worked out down to heavy ledges of nonlaminated LeClaire. The quarries are capable of furnishing dimension stone from three to thirty-three inches in thickness, and of any desired length and width.

The spalls and other waste materials from the entire quarry are utilized as crushed stone. A Gates No. 5 crusher does the work.

ANAMOSA QUARRY.

The Anamosa quarry was the first in this locality to ship stone abroad, the first shipments by rail being made in 1859. The quarry was opened by David Graham, but its present owner is Mr. J. Ronen, who has operated it since 1881. The Anamosa quarry is located near the northwest corner of the southwest quarter, section 5, Fairview township. Mr. Ronen's quarry is indeed double, for there are two openings a short distance apart. At the first opening the amount of clay stripping is very small. Beneath the clay there are a few feet of nonlaminated worthless rock belonging to the Bertram stage. Then in descending order there follow fragmentary beds of the "white limestone," "shell rock," then the usual succession of ledges down to the lower bridge layer, or No. 2 of the Champion quarry section. Owing to the eastward dip of the beds at this locality, the lower bridge rock at the second Ronen quarry is too low to be worked, the lowest workable beds being about the level of the "flint ledge," or No. 7 of the section at the Champion.

STATE QUARRY.

In 1884, the present State quarry, or Penitentiary quarry, was opened. Formerly the stone for the penitentiary buildings at

Anamosa was obtained from what is known as Champion quarry No. 2. In the year named the state bought property on Buffalo creek, in the southwest quarter of section 33, Cass township, and began operating the present quarry. The quarry is worked altogether by convict labor. Above the stone is a bed of loess and drift varying in thickness from a few inches to ten or twelve feet. Below the drift there are a few feet of decayed and broken "shell rock" belonging to the upper part of the "white stone" of the Anamosa phase. Lower in the quarry the ledges present the same features as in corresponding parts of other exposures. The Anamosa beds dip strongly to the north to accommodate themselves to the uneven upper surface of the LeClaire. Most of the work at this quarry is done by hand. There are several large derricks for handling the stone, but they are all operated by hand power. The State quarry uses no crusher, but breaks some rock by hand. Most of the rock is used for structural purposes. The spalls and other waste are broken up at the Reformatory. Each city and road district of the state is entitled to rock from this quarry upon payment of the freight. Over twenty cars were shipped on this account in 1908, but the freight is too high to permit of long shipments. The Chicago and North Western Railway takes out riprap and similar rock, paying $5 per car, for its own use. Dirt and such waste from quarrying is given to the road. The stone is shipped over a spur of the North Western Railway, which runs up the valley of the Buffalo and accommodates all the quarries in this part of the Anamosa stone basin.

Other quarries have been opened in the vicinity, but show no new features worthy of mention.

In addition to the Anamosa and Stone City district, there are several small areas where the Anamosa beds are available and are being developed on a small scale. The two worthy of notice are near Olin and Hale. The Rummel quarry near Olin in Rome township may be taken as a type in the district. (Northeast quarter of the southeast quarter of section 24, township 83 north, range III west.) The quarry is opened in the low buff on the west side of the valley of Sibyl creek. The stone belongs to the Anamosa phase of the Gower stage, and, except that it is buff in color, it corresponds well with the "gray stone," or lower portion of the formation as seen near Stone City. There are no definite bedding planes, but the rock cleaves readily along any of the planes of lamination. The surfaces of the laminæ are not so smooth and true as they are at the corresponding horizon near Stone City, but are irregularly undulated, apparently as a result of wave action at the time the beds were forming. The strata dip southeast at an angle of 5°.

In quarrying, only the simplest tools are used. Drills, crowbars, wedges, picks, shovels and wheel barrows make up the equipment. The soil or clay overlying the stone is only a few inches in thickness. For two or three feet below the soil the beds are broken into chips or spalls by weathering. With better means for quarrying, the greatest part of the exposure would furnish marketable stone. The present method of quarrying, however, involves the use of large quantities of powder in a single blast. Drill holes are filled, or nearly filled, with powder, and the firing of such a blast loosens up great masses which are further separated and removed with pick, crowbar and sledges. The firing of these great blasts shatters the stone badly, rendering much of it worthless, and leaving even the best of it in condition suited for use in only the cheaper grades of masonry. Were the demand such as to justify the expense of putting in improved machinery, stone of high grade for many purposes might easily be obtained.

Several other quarries have been opened in the immediate vicinity but present no new features of importance.

The Hale quarry located near the center of section 11, Hale township, three-fourths of a mile east of the village of Hale, may be taken as a type of the district of the same name. The stone in the Hale quarry is finer than that in the quarries near Olin, but it resembles the Olin stone in the uneven, wave-marked surface of the several beds. The stone comes practically to the surface, there being only a few inches of soil overlying the upper beds. For about six feet at the top of the quarry the stone is much broken and disintegrated, as a result of weathering. Below the weathered portion the rock is solid and shows the characteristic lamination of this horizon. Partings between the beds are inconspicuous. The flexures of the beds and the dip in all directions (quaquaversal dip) forming a low dome near the north end of this quarry, are interesting features. The quarry supplies local trade only.

Quarries have also been opened south of the town and south of the river. An enormous amount of excellent material is available, but at the present time is not being utilized.

The following paragraphs describe a few of the principal openings of the county not previously noted.

East of Hale about a mile is the C. O. Woodard quarry. The lower beds here are buff, nonlaminated, vesicular ledges, while the upper beds are gray, banded, fine-grained dolomite, slightly softer than the lower-lying layers. Waste material is taken out of the quarry by the township and put on the roads. The larger fragments are broken up on the road. The sandy spots are being improved in this way.

In Anamosa a number of streets have been paved with crushed rock mingled with fine material. Surfacing is done with cinders and the result is an excellent, durable roadway.

Across Maquoketa river from Monticello in the southeast quarter of the northeast quarter of section 22, Monticello township, are the H. J. Lang quarries, both small openings in the river bluff. They are located just below the electric light plant and are fairly easy of access. One of the quarries shows below a foot or two of soil several feet of loose and waste rock, which in a part of the quarry is mixed with clay, probably geest. This material is said to make a good quality of road metal, as it packs well and is durable. It has been used to good advantage on roads in the vicinity. Below this material are six to ten feet of very hard, heavy-bedded gray dolomite, coarsely vesicular, sugary, containing Cerionites, corals, brachiopods and various other fossils. There is a considerable amount of flint in the upper layers of the quarry.

The rock of the other quarry is somewhat softer when first removed, but it hardens on exposure. Otherwise it is similar to that of the first quarry.

Northeast of town in the northwest quarter of section 23 is the Stumbaugh quarry, sixty feet above the Lang openings. Its face presents below about two feet of sandy soil four feet of waste rock fairly hard, some of it broken up. This has been used on roads in town and over the neighboring country, and is said to pack well and afford good satisfaction when mixed with some dirt. Some of the rock is softer and needs no clay. Below are four to six feet of solid gray rock used for buildings. The quarry is located on the hill by the roadside and is very easily reached.

Immediately below the bridge, on the north bank of the river, on the west line of section 15, is the Rickell quarry, which lies at approximately the same level as the Lang quarries. The rock here exposed is a gray sugary dolomite, vesicular, with numerous flint nodules, some of them quite soft, between the layers. Stratification is better developed here than in the Lang quarries. On top are six feet of waste rock with very little soil. At the time the quarry was visited (October, 1908) the quarry was being exploited for the purpose of obtaining macadam for use on the streets of Monticello.

At Oxford Junction waste rock from the Niagaran has been used for street improvement, apparently with satisfactory results.

KEOKUK COUNTY.

Sand and Gravel.

Sand and gravel deposits are found only in the channels of the present streams and then only in small units. Both branches of Skunk river are in the old age stage, and as a consequence are characterized by mud banks and flats. The tributaries of Skunk river and South English river and its tributaries carry some sand and gravel—mostly dirty sand which is used locally and serves a useful purpose. The individual deposits are small and widely scattered, but when considered in the aggregate, are worthy of consideration. Extensive improvements which require sand and gravel in quantity must depend on outside sources of supply. At present Eddyville is the chief source.

Stone.

The Osage limestone is believed to occupy a triangular area in the northeast corner of the county and several patches are known to occur in the interior of the county. The most important outcrops may be seen along Rock creek and Skunk river north to northwest of Ollie. The formation rises forty feet above the river. The stone varies from light brown or white to gray in color. It is medium to coarse-grained, subcrystalline, and lies in ledges usually three to ten inches in thickness, separated by clay and chert bands. It is highly fossiliferous, oftentimes consisting largely of a shell breccia and fragments of crinoid stems. The most extensive section occurs in the vicinity of Manhattan Mills. The following sequence was determined by Bain:

		Feet.
7.	Soil and drift of indefinite thickness	2-40
6.	Sandstone, quartzose, in part calcareous, soft, yellow	1½
5.	Limestone, finely brecciated	1
4.	Limestone, compact, gray, cherty	20
3.	Limestone, earthy, brown, containing numerous chert nodules	15
2.	Limestone, coarsely subcrystalline, blue and gray in color, fossiliferous, in ledges 9 to 20 inches thick, separated by shales 6 to 8 inches in thickness; bands of chert nodules 3 to 10 inches thick near the top	26
1.	Limestone, as above	14

Numbers 1 and 2 in the above section belong to the Osage, the first being exposed in the Weber quarry near the mill, while number 2 comprises the chief formation in the Cook quarry. Number 3 is referred to the Springvale beds, and outcrops above the quarry tracks, while numbers 4 to 6 inclusive belong to the Verdi beds of the Saint Louis stage and are exposed along the old right of way leading to the Cook quarry.

The railway switch has long since been abandoned and the steel removed. Quarrying is carried on only to supply the local demand. In a local quarry still in openation, the following beds are displayed:

		Feet.
4.	Loess, waste and drift	1-5
3.	Limestone ledge, similar to number 1	1¼
2.	Limestone, thinly bedded, concretionary and cherty; shaly	3
1.	Limestone, blue-gray, evenly bedded, about five ledges exposed, varying from 6 to 12 inches in thickness; sometimes there is a shaly parting near the middle; fossiliferous	3

Numbers 1 and 3 afford a good quality of stone for coursing and rubble work. The several other exposures of Osage limestone present no new features.

The Saint Louis limestone immediately underlies the drift over three-fourths of the county. While its three divisions are represented, only the Verdi beds are of sufficient importance to merit consideration commercially. The Springvale beds have been recognized at Springvale Mills, in the upper portion of the Cook quarries north of Ollie, and at one or two other points along Skunk river. These beds comprise a blue, earthy limestone of marked shaly character, which weathers readily into a soft, brown to buff limestone. It is magnesian and often presents an arenaceous facies. Clean cut exposures are rare on account of its weathering properties. The beds occasionally present a pseudo-conglomeratic character as seen in the Cook quarries. They rest unconformably on the Osage limestone, and aggregate twenty to twenty-five feet in thickness.

The middle member of the Saint Louis, the Verdi beds, covers the larger portion of the county, and affords the principal limestone outcrops, and the only limestone quarries in the county with the exception of those northwest of Ollie. Typical exposures may be viewed along both branches of Skunk river, English river, and along the creeks north and west of Sigourney.

The beds present comprise fine-grained, light colored, calcareous sandstones in bands two to six feet in thickness, interbedded with the limestone. In places, however, clean sandstones of much greater thickness, up to thirty or even forty feet, with limestone above and below, are seen. The most usual type of limestone is of a light ash to buff color, fine-grained, exceedingly compact and hard, almost cherty in character. This is the limestone found interbedded with the sandstone. A second equally well known type comprises the brecciated beds. In these beds, the limestone is broken up into irregular fragments and cemented together, the whole forming a distinct calcareous conglomerate or breccia. The usual cementing material is calcareous, though ferruginous material is sometimes present. The rock fragments appear to possess the characteristics of the Saint Louis limestone itself.

They vary greatly in size, ranging from grains a fraction of an inch in diameter to slabs and blocks four feet long and six to eight inches in thickness. The brecciated blocks are usually one or two inches in diameter. Local uncomformities, false bedding, and other irregularities are not uncommon structural features.

A few of the numerous sections exposed are given below and are believed to be fairly representative.

The following beds are exposed in a railway cut about one and a half miles west of Ollie:

		FEET.
7.	Soil and bowlder clay	10
6.	Sandstone, cross-bedded, yellow, fine-grained; becoming harder for six inches and apparently calcareous below	6
5.	Limestone, compact	⅔
4.	Marl and limestone	½
3.	Limestone, fine-grained, grading into number 2	⅓
2.	Limestone, finely brecciated, in places almost oölitic	2
1.	Limestone, compact, exhibiting conchoidal fracture, exposed to track	6

Several small quarries have been opened from time to time along Sugar creek near Showman station. Here the beds are very irregular and false bedding on a large scale is well shown. A typical section is about as follows:

		FEET.
6.	Soil and drift of variable thickness	0-30
5.	Limestone in fairly even ledges	4
4.	Talus, shale or marl	3
3.	Limestone in heavy ledges, shaly below, shows a decidedly concretionary facies when weathered	4
2.	Limestone, hard ledge, separated from number 1 by a shaly parting, brittle and compact	1½
1.	Sandstone, cross-bedded and unevenly indurated, dip of bedding planes inconstant, but ranging up to 35 degrees	10

Number 5 furnishes the principal quarry rock of the neighborhood. Number 2 apparently rests uncomformably upon number 1.

Numerous small quarries have been worked at one time or another north and west of Sigourney. The Miller quarry, located about two miles north of town, may be taken as an example:

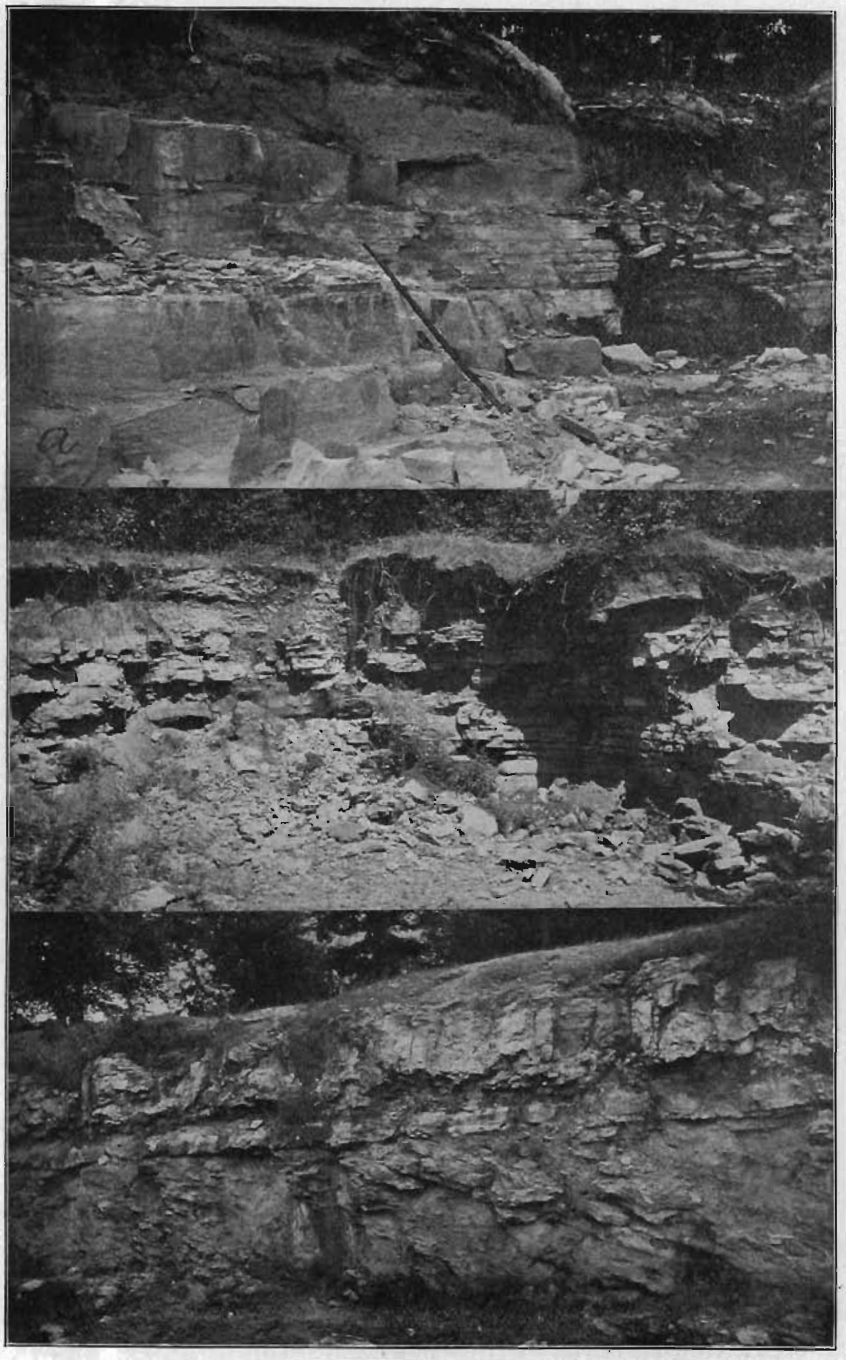


PLATE XXVIII—a. Near view of quarry face, Tracy, Marion county, showing Pella beds.
b. Miller quarry, about two miles north of Sigourney, Keokuk county, showing Pella beds.
c. Local unconformity in Verdi beds, near Showman station, Keokuk county.

		FEET.
4.	Soil and drift almost *nil* at the quarry face, but thickens greatly in the bluff	2+
3.	Limestone, similar to number 1, with arenaceous to argillaceous partings; less evenly bedded than 1 and weathers concretionary; calcite lenses and nests present	3-6
2.	Sandstone, with shaly partings, fine-grained, and but slightly indurated	2
1.	Limestone, hard and compact, gray, evenly bedded, beds ranging from 4 to 12 inches in thickness; numerous pyritic balls present, mostly weathered to limonite	6

The beds dip strongly to the east, and do not appear to be persistent in character. The stone crops of the region appear to rise about forty feet above the creek. The sandstone as a rule is the most conspicuous member, is heavily bedded but imperfectly indurated.

Outcrops in English river are less common than along the Skunk, but are in a general way, repetitions of those already given.

The quarries of the county, while numerous, are small and without exception are of local importance only. The stone available is, as a rule, rather soft for road work, but is fairly satisfactory for most kinds of concrete construction.

KOSSUTH COUNTY.

SAND AND GRAVEL.

Kossuth county lies entirely within the area covered by the Wisconsin glaciers. The sand and gravel deposits are of two kinds, pockets in the drift hills and gravel trains along the streams.

Stream Terraces.—By far the greater part of the streams of Kossuth county are younger than the youngest one of the drift sheets which were responsible for the gravel trains in northern and northwestern Iowa, and are devoid of deposits of this kind. Such gravel terraces as are to be found in this county occur in the Des Moines valley in the few miles between Algona and the Humboldt county line. From a point about two miles south of Algona to where the river leaves the county its channel has been choked with gravel. Just at the south edge of the town of Irvington, the Chicago & North Western Railway has removed enormous quantities of gravel for ballast from the terrace on the east side of the river. This pit is now abandoned, but an open face some forty feet high may still be seen. The gravel here contains much limestone and shale and a large proportion of sand. It is still being used to a considerable extent in a local way, and large quantities of road and concrete materials can still be obtained.

At Irvington the river turns abruptly west for two or three miles, and the north bank is a huge gravel bench. Where the road crosses the edge of it on the west line of section 36, Cresco township, a coarse, somewhat dirty, iron-stained gravel is exposed. This same material may be seen everywhere along the road on the north and west sides of section 36. The terrace is about forty feet above the river, and has an area of one and a half to two square miles.

On the south side of the river in sections 1 and 2 of Riverdale township there is also much gravel. The road here crosses a bench not more than half as high as that on the north side, and gravel has been plowed up in building an approach to a bridge. This bench seems to be continuous practically all the way through section 2 and the east half of section 11, Riverdale township. On top of it the fields are dry, the crops reported as being always poor, and indications would seem to show that practically the whole of it is gravel. Through sections 13, 14, 23 and 24 of the same township gravels occur almost everywhere along the road, and the latter has been surfaced with materials taken largely from shallow excavations.

These gravels have been opened in various places all along the river. In the pasture north of the school house at the southeast corner of section 26, Riverdale township, is a small pit which shows four or five feet of coarse dirty gravel. This pit will doubtless furnish ample supplies for all purposes within several miles.

As has been remarked before, the other streams of the county are devoid of gravel and sand. The source of these streams is almost invariably a swampy or marshy depression, and they seek their way among the drift hills as best they can.

Miscellaneous Deposits.—Kossuth county is covered over its whole area with Wisconsin drift clay. As to the possibility of finding pockets or cappings of gravel in the hills of glacial till, Macbride told the whole story when he said: "Occasionally the typical Wisconsin bowlder clay gives place to piles and beds of sand or gravel, but this is unusual."

LEE COUNTY.

SAND AND GRAVEL.

Lee county is bordered by three large rivers, the Mississippi, the Des Moines and the Skunk. All are in advanced stages of development and capable of handling only the finer materials. As a consequence sands of various grades are abundant while gravels are scarce in and along these streams. Some of the tributary streams have accumulated coarser materials, but the stream gravel beds are in comparatively small units and widely scattered. Sufficient of these materials can usually be obtained for the local demand within reasonable distances, but no deposits large enough to supply gravel by the train load are known in the county. Interglacial gravels are usually too much obscured to be considered commercially available.

STONE.

The Osage limestone comprises a very considerable portion of the country rocks in Lee county and forms the greater part of the vertical extent of the bluffs on all of the streams bordering the county. In the interior it is largely overlain by the Saint Louis and the Coal Measures.

It includes quite a diversity of beds which for convenience in discussion are divided into three groups of limestones which are separated by shales and chert beds. The lowest member is generally known as the Burlington, which many investigators have divided into Upper and Lower Burlington. This is separated by chert beds from the middle member, the Keokuk limestone, which in turn is separated by shales and geode beds from the uppermost member, known as the Warsaw.

The Lower Burlington, while composed in part of heavy beds of subcrystalline limestone, is unimportant in the present connection as it comprises only a narrow strip along the base of the Skunk river bluffs north of Wever and a few miles east of the town of Augusta in the northeastern part of the county.

The Upper Burlington is very similar in character to the Lower Burlington, but usually occurs in thinner beds and carries a greater abundance of chert in irregular nodules and thin bands. The Upper beds are best exposed in the bed of Skunk river at Augusta. The flinty beds of the Upper Burlington are sometimes called the Montrose cherts. They appear along Mississippi river from Montrose to Keokuk. Between these points they constitute the bed of the river and cause the obstruction to navigation known as the Des Moines rapids. While both members of the Burlington afford good material for constructional purposes, neither is sufficiently accessible to merit extended notice.

A quarry has been opened in the Burlington limestone, west of Wever. The beds worked are as follows:

		FEET.
5.	Soil and drift	4
4.	Limestone, brownish, thinly bedded, with some chert, encrinital	1½
3.	Limestone, white, rather soft, somewhat cherty in places	½
2.	Limestone, yellowish	2⅓
1.	Limestone, hard, brown, encrinital, heavily bedded, exposed	2

Other openings have been made in the near vicinity, but while the stone is durable and pleasing in appearance, the aggregate annual output has never been large and is practically *nil* at this time.

The Keokuk beds are typically developed in Lee county, but at the same time their surface area is relatively small. These beds occupy the larger portion of Denmark township and a part of Washington. In addition thin beds are exposed in the bluffs facing all of the larger streams. Along Des Moines river, while the Keokuk is present above the water line, it is largely obscured by heavy talus slopes. In general the formation consists of twenty-five to forty feet of coarse-grained, bluish, often crinoidal limestone, overlain by rather more than thirty feet of shales, generally known as the geode beds. Chert is quite prevalent through the limestone, while some beds are somewhat argillaceous and from these two causes, many of the layers are unfit for dimension stone, but are serviceable for crushed stone purposes. The best layers for dimension stone are known as the "White ledge," which is quarried in Keokuk and vicinity. The heaviest beds and thinnest partings are near the base, while the beds become thinner and more argillaceous in character near the top, grading into the geode beds above. (See plate XV, a, page 227.)

The geode beds are of small importance in the discussion of "quarry products" save as a possible source of shales suitable for use in the manufacture of Portland cement. The lower half is made up largely of more or less indurated calcareous shales with some chert and occasional bands of limestone, graduating downward into the limestone below. The upper half is more argillaceous, sometimes slightly arenaceous and less calcareous and slakes more readily under weathering influence than the lower portion. The siliceous and calcareous concretions give name to the formations and are quite generally, although not universally, present in southeastern Iowa.

The Keokuk limestone has always been a large contributor to the stone output of the county. Numerous quarries have been opened, and it is this horizon which affords the greater portion of the quarry rock in the vicinity of the city of Keokuk. As a rule the formation is compact, rather hard, often subcrystalline rock, of an ashen or bluish gray color. It presents an even to conchoidal fracture.

The Warsaw beds comprise a buff magnesian limestone at the base, in a massive layer often ten to twelve feet in thickness; blue arenaceous shales with intercalated limestones in thin bands, and at the top a buff, sandy limestone locally called "sandstone." These beds are typically developed at Warsaw, a town five miles below Keokuk on the Illinois side of the river.

The quarry rock of the Warsaw is chiefly a magnesian limestone containing some sand and small pebbles. It is generally called sandstone. The principal quarries are located at Sonora on the east side of the river. The rock occurs in a massive layer ranging from six to twelve feet in thickness, is bluish to yellowish in color when first taken out of the quarry, but, on exposure to the weather for some time, it changes to a buff or brown. The stone has been used in the building of the locks and many of the most important structures in the city of Keokuk. It has also been used in pier and bridge work. It is very durable and highly prized for all grades of dimension and cut stone work. The principal quarries in the county are located near the city of Keokuk, within half a mile of the railway bridge crossing Des Moines river, and near Ballinger, above the city along Mississippi river.

Of the numerous sections of Osage available, only sufficient are selected to illustrate the principal features of the beds. There is an almost continuous outcrop of these beds in and about the city of Keokuk and facing the principal streams on the three sides of the county.

The Tigue quarry, a short distance west of the Rand lumber yard, is one of the oldest openings in the vicinity. It has been in operation for more than forty years. The section is as follows:

		FEET.
4.	Soil and drift	8
3.	Limestone, thinly bedded, with considerable calcareous shale	6
2.	Limestone, more massive than 3	9
1.	Limestone, rather sandy, with shaly partings, exposed to railway track	14

In the west part of the city of Keokuk, along Soap creek for a distance of fully one mile, quarries have been opened at a number of points. The section exposed near the mouth of Soap creek is given below:

		FEET.
8.	Soil and drift of variable thickness.	
7.	Shale, cherty	6
6.	Shale, calcareous, with intercalated beds of limestone; some geodes present	8
5.	Limestone, drab, impure, heavily bedded, shaly below	12
4.	Limestone, light colored, with nodular masses of chert; the "white ledge"	3
3.	Limestone, argillaceous and massive, with spheroidal masses of calcite, sometimes carrying millerite	5-6
2.	Limestone, coarse, gray, encrinital, cherty	3
1.	Limestone, with chert in irregular beds, exposed	5

North of the city about one-fourth mile north of Ballinger station on the Chicago, Burlington & Quincy railway, the Tucker and McManus quarry displays the following beds:

		FEET.
7.	Soil, loess and drift	0-10
6.	Limestone, weathered, soft, yellowish above, blue-gray below; yields some rubble where protected; somewhat cherty	10-15
5.	Limestone, shaly	1
4.	Limestone in two heavy beds, the upper about three and the lower 3½ feet in thickness, separated by a one foot shaly parting; fossiliferous and subcrystalline	7½
3.	Limestone, cherty, subcrystalline, similar to 1, somewhat irregularly bedded; where sufficiently free from chert yields good rubble stone	8
2.	Limestone, evenly bedded, gray-blue, subcrystalline	1⅓
1.	Limestone, chert present as bands and nodules, irregularly distributed throughout, exposed	6

In this quarry the beds dip to the northwest. Numbers 2 and 4 furnish the best dimension stone. Only hand methods are used in quarrying, although a steam drill is employed. Power for drilling is supplied by an ordinary traction engine. The waste stone is loaded in cars with removable beds. The car beds are swung up to a Gates crusher by means of the only derrick used in the plant. All of the stone below the weathered zones is utilized. The crushed stone is graded by being passed through a cylindrical screen. Storage bins are provided for the larger sizes. The dust is removed by a belt conveyer and dumped on the ground. In addition to crushed stone, rubble and dimension stone are produced. This is the most important quarry in the county at this time.

The Saint Louis limestone comprises some of the most important rock formations in Lee county, occupying about one-third of its superficial area. Numerous outcrops appear along the streams in West Point and Franklin townships, and in the bluffs below Montrose on the Mississippi and along the Des Moines above Sand Prairie.

According to Keyes and Gordon, the Saint Louis consists of a lower magnesian or somewhat sandy limestone, grading at times into a calcareous blue sandstone and an upper white compact or granular limestone. A brecciated zone often separates the two members. From a study of the field relations of the above beds and those already discussed under the head of the Osage, it would appear that the upper or so-called Warsaw beds of the Osage are the same as the arenaceous member of the Saint Louis of Keyes and Gordon. Whatever the taxonomic relations of these beds may be, both members of the Saint Louis as given above are quarried to some extent, the limestone being the more highly prized, in the numerous outcrops available.

The sections given below give a fair picture of the leading characteristics of the beds.

A mile west of Sand Prairie the Saint Louis appears in several ravines opening into the Des Moines valley, and from these some stone has been produced for local use. One-half mile above Hillsdale, the Santa Fe Railway worked extensively years ago. The section is shown as follows:

	FEET.
6. Soil and drift	6+
5. Limestone, brecciated, with pockets of green clay, sometimes rudely and coarsely stratified	30
4. Limestone, blue, encrinital	3
3. Shale, blue, calcareous	3
2. Sandstone, blue, calcareous, with discontinuous beds of blue shale; the principal quarry rock	8
1. Shale, blue	15

The stone was used largely for bridge work; the rubble and small sizes were put through the crusher.

Just below Belfast some quarrying has been done. The stone was used largely by the Chicago, Rock Island & Pacific Railway for bridge work. The section quite closely resembles the Santa Fe quarry, though the sandstone horizon was more extensively developed. The section which may be seen at the present time is as follows:

BELFAST SECTION.

	FEET.
5. Soil and drift, which thicken considerably back in the bluff, variable at the face.	
4. Limestone, earthy, yellowish, gray to blue-gray, weathers clayey; probably attains much thickness in the bluff, exposed	4
3. Limestone, brecciated and concretionary and shaly, in places. The concretions appear to be compact, brittle, blue, limestone, uniform neither in thickness nor in appearance	4
2. Limestone, arenaceous, especially below, fossiliferous; gray to blue-gray; thinly bedded, although bedding planes are not apparent	8

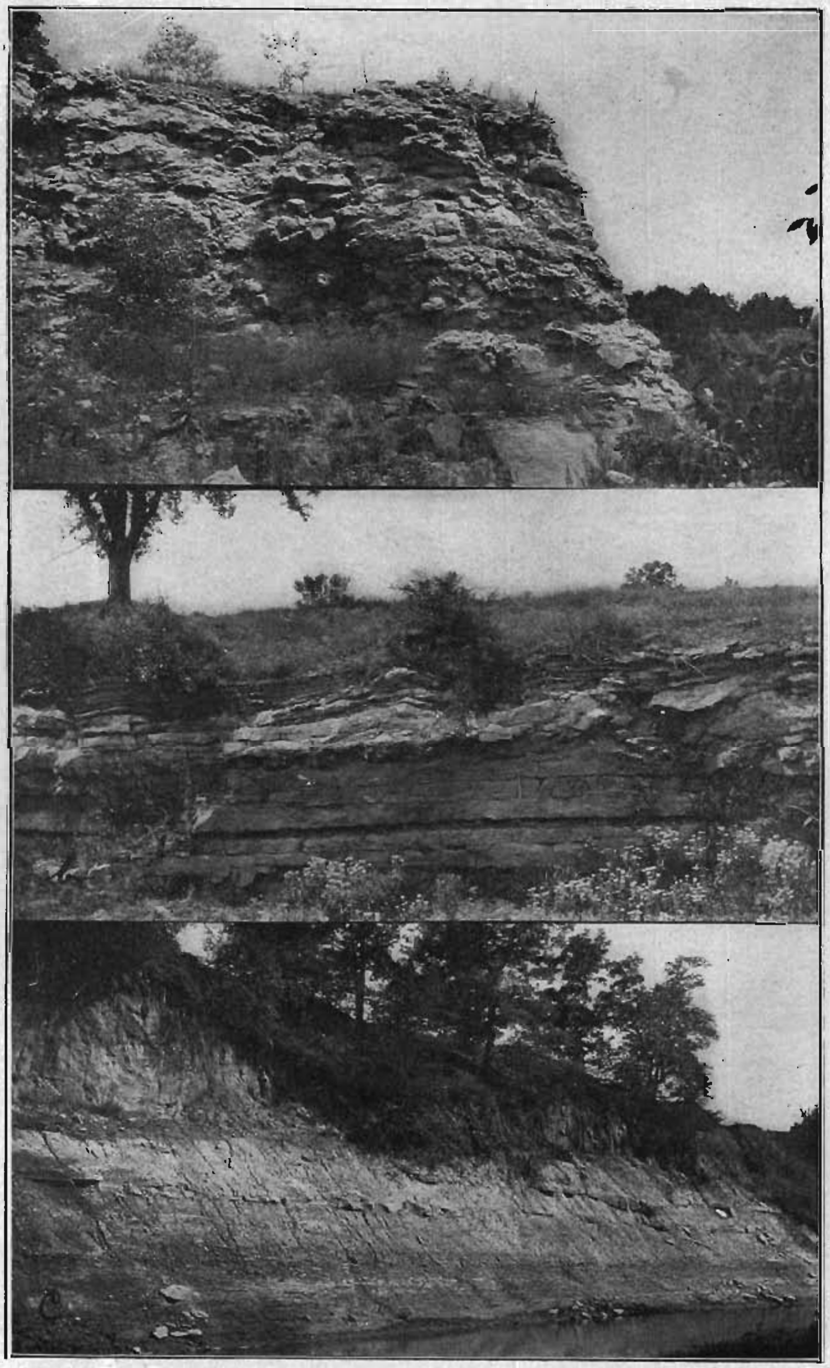


PLATE XXIX—a. Abandoned Santa Fe quarry east of Belfast.
b. Principal quarry section southwest of Mt. Pleasant.
c. Geode bearing shale, west of Farmington, Van Buren county.

		FEET.
1.	Sandstone, calcareous, or limestone, highly arenaceous, in heavy beds up to five feet in fresh exposure; beds rather uneven and show some tendency to wedge; cross-bedding is evident in places, exposed	12

The base of the section is about four feet above the railway track. No quarrying is being done at the present time. About a fourth of a mile below the railway station in Belfast, twenty feet of plastic shales are exposed along a small creek entering the Des Moines from the east. The shale appears to be quite uniform in character throughout and lies clearly below the beds in the above sections. The section continues about one hundred yards up stream, where it is obscured by talus. Near the east end of the outcrop, a weathered caprock appears at just about the level of the Chicago, Rock Island & Pacific railroad track. The depth of the shales below the stream channel is unknown.

Exposures of Saint Louis continue up Des Moines river but almost no quarrying is done at the present time, and no new phases are shown.

One of the best sections exposed in the interior of the county is located along Sugar creek about one and a half miles east of the town of Franklin. The following beds are exposed:

GRANER QUARRY.

		FEET.
10.	Drift	10
9.	Limestone, white, granular, oölitic, even-textured, more or less distinctly cross-bedded	8
8.	Limestone, subcrystalline	2
7.	Limestone, blue, concretionary	1
6.	Shale, blue	½
5.	Limestone, granular, oölitic	6
4.	Limestone, brecciated	10
3.	Limestone, brown, arenaceous	8
2.	Shale, blue	10
1.	Shale, blue, with geodes	20

Beds 5, 7 and 8 dress well and have been used in making tombstones. Number 3 has been used for all kinds of rough masonry and for bases of monuments. All the layers were used formerly for manufacturing lime, but number 7 was the best for this purpose.

LINN COUNTY.

Sand and Gravel.

There are extensive bodies of upland gravels in the neighborhood of Viola and Springville. Several of the hills south and east of Viola are capped with Buchanan gravels and these are said to extend several miles northwest of the town. Three miles to the northwest the county owns an acre of land whence considerable gravel has been removed for road making. A well sunk near the county line about a mile east of Viola is reported to have penetrated thirty-seven feet of gravel. Underlying the bed a brownish hardpan was encountered. The gravels also extend to the southeast as far as Martelle in Jones county.

A large pit has been opened on the west side of the road about one-half mile south of Viola, in the southwest quarter of section 13, Brown township. Part of the pit is owned by the county and part by Mrs. Rosella Corbett, who owns the adjacent land. This pit shows, under one or two feet of black loam, about three feet of coarse gravel with which is mingled considerable clay, enough to give a sticky feel to the moist material. Some of the pebbles in this layer are from two to four inches in diameter, but many of them, especially the granites, are badly decayed. Below the gravel are exposed four to five feet of finer sand, with some clay. This layer is very much reddened and its iron content oxidized. In several places streaks of dirt are shown in the pit. This material must be contemporaneous in its deposition with the sands.

The material from this pit has been used on the streets in Viola and gives excellent satisfaction. The clay serves as a binder and assists in packing the roadbed and keeping it free from dust. The county hauled out about twenty carloads in the summer of 1908, chiefly for use on the boulevard between Cedar Rapids and Marion. The gravel also gives good results in concrete work.

Very little stripping is required to reach these gravels. There is no loess overlying those in the pit just described and the same holds true for a small pit across the road and a few hundred yards eastward. A small exposure on the south edge of town has a little loess covering and some loess is seen along the roadside.

Along the road between sections 15 and 22, Brown township, the gravels are exposed and in the southwest corner of section 16 is a large pit opened in gravels similar to those at Viola. Under a foot of humus are found six to ten feet of irregularly bedded, alternatingly coarse and fine gravels very much reddened and iron-stained, and with the granite pebbles badly decayed. Local seams of clay are present, but there is not so much, apparently, as in the Viola deposit. At the bottom of the pit is a fine red sand, rather incoherent and breaking down quite readily, while the coarser gravel is somewhat indurated and stands up fairly well. There may be some clay as well as iron present. The gravels have been used on the roads near Springville and in most cases with excellent results. The roadway is firm and hard and fairly free from dust and loose sand. Where the cleaner sand was used, however, the roadbed is still soft and dusty.

STONE.

The Niagaran limestone includes an irregular strip which crosses the east end of the county and comprises one-third of its superficial area. Tongue shaped projections extend up all of the more important streams, reaching Cedar Rapids along the Cedar. The Niagaran presents its usual phases, including a lower heavy bedded, coarse, cherty dolomite now referred to the Hopkinton, which is followed by the subcrystalline, hard, brittle, often highly inclined beds of the LeClaire and these in turn, succeeded by the smooth, evenly bedded gray to buff, dolomitic layers of the Anamosa phase of the Gower, which are followed in turn by hard, compact, brittle magnesian limestones, which Norton has designated the Bertram, and which complete the series.

Practically all of the important quarries in the county are operating in the Anamosa beds which are typically developed at Stone City, while the lime producers are developing the LeClaire beds. A wealth of exposures occurs along nearly all of the principal streams. A few only are given by way of illustration.

The sections already given for Stone City and vicinity may be taken as a standard, as the beds are more extensively exposed and developed at that point than at any point in Linn county. At Mount Vernon practically the same beds appear and differ only in being of slightly coarser grain. The quarries are connected by a switch with the main line of the Chicago and North Western Railway and are equipped with a steel derrick, cars, trackage, an inclined plane to a No. 3 Gates crusher and the usual number of elevators, screens and bins. The quarry section shows the following sequence of layers:

MOUNT VERNON SECTION.

		FEET.
4.	Soil, loess and drift	0-10
3.	Limestone, dolomitic, weathered to spalls and chipstone	6-8
2.	Limestone, dolomitic, in layers up to eight inches in thickness	3-5
1.	Dolomite, in layers ranging from six to thirty-six inches in thickness, aggregating, exposed	12

The pit is filled with water at the present time so that number 1 is obscured very largely. The property is in litigation and the quarry has not been operated save in a very small way during the past few years. Stone suitable for bridge work, caps and sills, dimension and cut stone purposes, is available and equal in quality to any produced from the Niagaran in Iowa. Other quarries have been opened in the district, some of which are still operated intermittently.

Splendid sections of the Anamosa stone may be viewed along the Wapsipinicon northwest of Stone City. Several quarries have been opened at Waubeek and vicinity, but owing to the lack of proper transportation facilities, stone is produced to supply the local demand only. The beds available are essentially the same as those exploited at Stone City and are as easily accessible.

The Devonian limestones cover about two-thirds of the superficial area of the county and are quite generally exposed along the principal streamways, but notwithstanding these facts, comparatively little dimension stone is derived from any of the beds. The Anamosa beds of the Niagaran practically have a monopoly

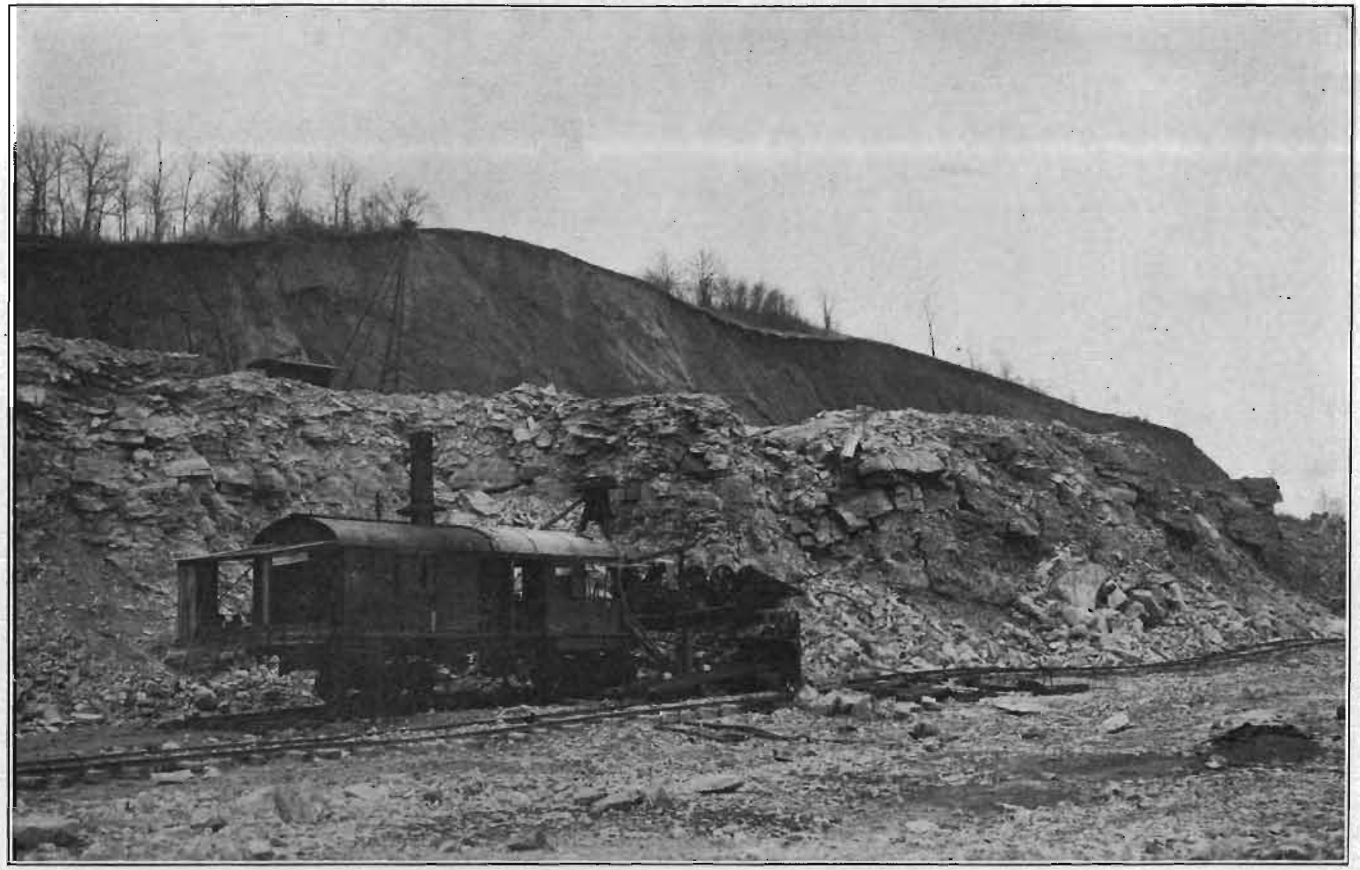


PLATE XXX—Quarry of the Chicago and North Western Railway, Cedar Rapids, showing steam shovel, drill rig and broken stone.

of the commercial building stone trade in this part of the state. All of the members of the Devonian represented in the county furnish some stone suitable for structural purposes, especially crushed stone.

The Coggan beds of Norton, formerly referred to the Niagaran but at present included in the Devonian, are dolomitic, heavy-bedded, destitute of lamination and often porous and highly vesicular. When sufficiently compact, the stone is well adapted for bridge work and other heavy masonry. A quarry near the railway station at Coggan gives a fair idea of the beds and is as follows:

COGGAN SECTION.

		FEET.
4.	Soil, loess and drift of variable thickness.	
3.	Limestone, gray, hard, compact, subcrystalline, magnesian; layers from one to four inches thick, weathering into block-chipstone	2
2.	Limestone, massive, pale buff, magnesian, moderately hard, granular, subcrystalline; porous or vesicular, with a few irregular cavities about an inch in diameter; in layers eighteen to twenty-four inches thick. In places the rock weathers into chipstone, and is a brownish buff, semi-earthy, semicrystalline limestone; exposed to quarry floor	8
1.	Slope to water in river, elsewhere seen to be occupied by massive limestone as above	6

The beds exposed here are quite variable texturally and in color. They vary from a compact subcrystalline limestone to a highly vesicular to earthy material almost pumaceous in character. The full thickness of the Coggan beds is displayed a short distance above the dam at Central City. The sequence is as follows:

CENTRAL CITY SECTION.

		FEET.
6.	Soil, loess and drift, variable thickness.	
5.	Limestone, even-bedded, nonmagnesian above, becoming more and more magnesian below, and so graduating by thin layers into the beds below that the line between them is somewhat arbitrarily drawn (Otis Beds)	12¼
4.	Limestone, magnesian, light buff, compact, granular	$^5/_6$
3.	Limestone as above, darker, also nonfossiliferous excepting some minute vermicular cavities; in three layers	1
2.	Limestone, massive, buff, magnesian; with moulds and casts of fossils, as at Coggan; porous and vesicular; upper layer cherty, with dark nodules forming in places a continuous band. The layers from above downward are respectively one foot, five feet and ten inches, eleven inches, and four feet ten inches in thickness	$12^7/_{12}$
1.	Unexposed to river	10

Numbers 2, 3 and 4 of the above belong to the Coggan beds. These beds maintain their level to a fine exposure on the left bank of the river, two miles northwest of Central City, at Granger's old quarry.

The Otis beds of Norton have been exploited more extensively for crushed stone than any other. Several large crusher plants are located in Cedar Rapids and vicinity and furnish stone for street and road work, concrete and railway ballast. The principal plants are located east and south of town on either side of Cedar river. One of the largest plants running at the present time is operated by J. J. Snouffer, Jr., and is located along the Chicago, Rock Island and Pacific railway in the south part of town. The beds exposed are approximately as follows:

		FEET.
12.	Loess stripping	12-20
11.	Thin-bedded, shelly, weathered limestone, for the most part worthless; portions of lower ledges usable in crusher	11-12
10.	Light brown, saccharoidal limestone, heavy ledge, containing cavities and masses of crystalline calcite, in places, contains numerous fragments of soft yellow limestone, prominent in face of quarry	4
9.	Similar to No. 10 but more distinctly laminated and separates readily along bedding planes	2
8.	Laminated, soft magnesian limestone, sandy to the feel, porous; thin-bedded and breaks well both horizontally and vertically, contains occasional small calcite cavities	4
7.	Limestone, dense brown, noncrystalline ledge	$2\frac{1}{2}$
6.	Ledge, dark brown in color, including in places thin layers of black, carbonaceous clay	$1\frac{1}{3}$
5.	Limestone ledge, light drab in color, has suffered shattering, cut by thin, irregular veins of crystalline calcite; close texture and conchoidal fracture	$1\frac{2}{3}$
4.	Dark brown limestone, in large part coarsely crystalline; hard and breaks very irregularly	$1\frac{1}{6}$
3.	Hard, close-textured limestone, has apparently been shattered and recemented by numerous veinlets of calcite; displays fine wavy laminations	$2\frac{1}{6}$
2.	Shale, black, carbonaceous and contains fragments of limestone, in places soft and plastic	$\frac{1}{6}$-$\frac{1}{2}$
1.	Sugary brown dolomite in layers from two to six inches, alternating laminæ of varying shades; the darker weathering to a residue of dusty sand; breaks irregularly except along planes of stratification	5

This quarry is located in close proximity to the Chicago, Rock Island and Pacific tracks. At present the total output is crushed stone. The crusher is located on the railroad and the stone hauled by horse and cart up a low incline. Four grades of crushed product are put on the market, viz., No. 1 ranging in size from 1 to 2½ inches; No. 2 from ½ to 1 inch; No. 3, ¼ to ¾, and No. 4, below ¼ inch in diameter and termed "rock dust."

The upper beds of the Wapsipinicon are quite generally brecciated and as a consequence have been but little quarried. These beds have been developed in a small way at Marion, and in the vicinity of Cedar Rapids and Flemingville.

The Cedar Valley beds are often too shaly to be of much use for building or crushed stone purposes. As developed in Linn county, they break up readily under the action of frost and are not evenly bedded. The best quarries are in the vicinity of Center Point, Toddville and Troy Mills. At best the stone produced is not recommended for important structures as a coursing stone, but may be used as crushed stone.

LOUISA COUNTY.

Sand and Gravel.

The gravel and sand deposits of Louisa county represent at least three horizons geologically, viz., Aftonian, Buchanan and recent. The benches which occur along Iowa and Cedar rivers may have been formed from the waste from melting Iowan ice.

The Aftonian.—The Nebraskan or lowest glacial till in Louisa county is almost invariably overlain by sand and gravel, varying in thickness from two to ten feet. This is occasionally cemented into a mortar-like rock. The prevailing color of the deposit is yellow. A peculiar relation which it maintains to the till below is that pockets of the sand extend down into the otherwise level surface of the latter. These pockets are from one to several feet in width and of equal depth. Occasionally they form "filled tunnels" in the drift. This stratum is the main water sand in all the deep wells of the upland. Along the level of its outcrops in the bluffs there are a number of springs. These gravels will be described in some detail in the report on Union county.

Buchanan Gravels.—Above that part of the Kansan till which is east of Iowa river, there often lies another sand which has the same relation to the Kansan as the Aftonian has to the Nebraskan. This is seen in several places along the Muscatine North and South railroad, particularly in section 10, Grand View township. In the northeast quarter of the northeast quarter of this section it rests on an almost horizontal plane surface on the Kansan bowlder clay. This plane is sharply marked and can be seen for a quarter of a mile. The sand is evidently a glacial product. It is somewhat gravelly, contains occasional striated pebbles, and is rather imperfectly assorted. Here and there it has a long slanting or curving oblique lamination and is also seen to run into silt. Occasional pockets extend into the underlying drift. In the southwest quarter of section 11, Grand View township, it is ocherous from the infiltration of ferruginous material. In other places it is leached to a gray color. Sometimes its upper part changes into a soil-like stratum, either directly overlain by loess or plainly covered by another till.

Terrace and Alluvium.—The greater part of the higher lowlands along Iowa and Cedar rivers lie from thirty to forty feet above the flood plains. This higher lowland, usually known as the "second bottom," is an ancient terrace which probably was built up, in part at least, at the time of the Iowan ice invasion. It consists of sand and some gravel with a thin veneer of loess. In many places the surface materials have been drifted by the wind into sandy ridges. The depth of the terrace sand is not certainly known, except at a few points along the river. Around Wapello and north of Columbus Junction it is seen to rest on the Nebraskan till and is some thirty or thirty-five feet deep. This same terrace is continued up the valley of Long creek as far as section 13, township 75 N., R. V W. It is also present along the lower courses of some of the other tributaries coming from the uplands. On Long creek the terrace sand is sometimes overlain by a few feet of a fine, laminated, grayish blue silt, above which there is the usual loess capping. Along Otter creek in sections 1 and 2, township 73 north, range IV west, this loess capping with a soil layer on top has been covered over by a few feet of more recent alluvium.

On the bottoms of Mississippi river a similar terrace extends south from Muscatine county in sections 4 and 9, township 75 north, range II west. This is probably a remnant of an extensive terrace built up over these lowlands by the drainage of the Wisconsin ice.

The most recent deposits are represented by the alluvium from the present streams now laid down over their flood plains during high water. This consists in the main of dark sandy silt and gray sand. The most extensive alluvial tracts are along Mississippi river, where only a few vestiges of the earlier terraces remain.

STONE.

The underlying, indurated rocks that are exposed in Louisa county belong almost exclusively to the Kinderhook and Osage stages of the Mississippian. The Kinderhook beds consist chiefly of soft clays and impure limestones, with occasional strata of sandstone. The Osage is represented by the heavier, more durable beds of the Burlington limestone. Exposures are found in the southern and southwestern portions of the county. They appear to best advantage in the bluffs west of the Mississippi and south of Iowa river in Elliott, Wapello and Morning Sun townships. Outcrops are also common along the streams in Columbus and Elm Grove townships.

The best stone comes from the Upper Burlington beds and all of the present working quarries make use of these strata. The lower beds were formerly worked on the property of J. D. Anderson, just south of Elrick Junction, but this rock is usually too much weathered to furnish durable building material. The principal quarries are located near Morning Sun on Honey creek and on Long creek and its tributaries.

The Chas. B. Wilson quarry, one and one-half miles east of Morning Sun in the southwest quarter of section 28, affords a characteristic section of the Upper Burlington. The following details are based in part on data found in the *Geology of Louisa County*.*

*J. A. Udden, Iowa Geol. Survey, Vol. XI, p. 76.

		FEET.
6.	Disintegrated crinoidal limestone, brown to yellow........	3½
5.	Partially weathered crinoidal limestone containing some chert; ledges 4 to 6 inches thick, fair stone.............	$2^2/_3$
4.	White chert, nearly fails in places	½
3.	Yellowish crinoidal limestone with chert above and containing fossils	4
2.	Yellowish fine-grained limestone, containing open pockets often lined with botryoidal calcite or quartz crystals, soft and can usually be crumbled to a powder in the fingers..	1-3
1.	Coarsely crystalline pure limestone, light brown to bluish white; in ledges from one foot above to massive three-foot ledges below; stylolitic jointing very common; free from chert	6

The quarry base is about twenty-five feet above low water in Honey creek. This depth consists largely of cherty limestone in part obscured. A face approximately one-fourth mile in length has been opened on both sides of the stream and a large amount of stone removed. With the exception of the upper few feet, there is little worthless material in the section, and numbers 1 and 3 especially afford a most excellent stone for any of the finer grades of work. A considerable acreage is available at this point, both to the east and west of Honey creek, over which there is no drift and little else to require much dead work in stripping.

A similar succession is found at the W. C. Bryant quarry just south of the Iowa Central track in the southeast corner of section 29. Seven and one-half feet of number 1 are quarried, and the opening has reached such a depth that number 2 is quite firm and unweathered. It is seen to be a coarsely granular and fossiliferous brown limestone similar to number 3, save for the presence of numerous geode cavities. The heavy beds furnish suitable stone for heavy foundations, bridge piers, and other masonry work, besides walls and finishings. The white stone does not, however, split with uniformity in any direction except along well defined lines of stratification.

The stone is handled in this quarry by derrick to wagons and some is shipped from Morning Sun.

Number 1 in these quarries is an unusually pure limestone as shown by the chemical analysis, given herewith, of a sample from the Wilson property.

Insoluble	1.60
Iron oxide and alumina ($Fe_2O_3 + Al_2O_3$)	1.20
Lime carbonate ($CaCO_3$)	97.02
Magnesium carbonate ($MgCO_3$)	.32
Hygroscopic moisture	.34
Total	100.48

The very low magnesia content commends the stone for the manufacture of Portland cement. It would also make, without doubt, an excellent grade of white lime.

Both the Wilson and the Bryant quarries are conveniently located for transportation of the output by rail. The stone is of high quality and limitless quantities are available. The territory to be supplied is principally the counties to the westward of Louisa which are heavily drift laden and possess no building stones of their own.

The Ackenbaum quarry is located in the northwest quarter of section 27, Morning Sun township. The beds here consist of about three feet of overlying disintegrated crinoidal limestone, associated with the lighter colored heavier beds as exposed on Honey creek. The latter are beds coarsely crystalline to saccharoidal in texture. A stylolitic structure is common, but the rock splits irregularly and with no greater facility along such lines of jointing. The stone outcrops for some distance along Gospel run and at the quarry face is covered with but one to three feet of loesslike soil. Immediately back from the streams, however, there is a heavy drift covering.

There are a number of small quarries situated along Long and Buffington creeks in Columbus and Elm Grove townships respectively. The old Wasson, now C. J. Gipple, quarry, in the low terrace along the south bank of the south branch of Long creek in the northwest corner of section 23, Elm Grove, affords the following section:

	FEET.
9. Soil in small amount which does not thicken materially for several rods from quarry face.	
8. Limestone, badly shattered, containing much chert below...	7
7. Disintegrated limestone carrying much chert. Worked back in the hill, becomes a fairly firm rock of bluish color and crystalline texture; separates into ledges of 6 inches to 1 foot	

		FEET.
6.	Yellow, disintegrated limestone, in part solid and coarsely crystalline	3
5.	Blue shale, calcareous	1
4.	Band of chert, fossiliferous, persistent, used for building rock; a maximum of	1
3.	Yellow, badly disintegrated crinoidal limestone with geode cavities, in part a crumbling brown sand	4
2.	Yellowish, partially disintegrated but usable limestone	1½
1.	Crinoidal white limestone, in ledges from 6 to 10 inches.	

Number 1 is not now in sight but has been taken out to a depth of twelve feet as the principal quarry rock. The base of the full quarry face would therefore be somewhat below water level in the creek.

These same beds crop at an indefinite number of points in this vicinity on Long creek and in section 14 of Elm Grove township on Buffington creek.

J. L. Thurston takes out a small amount of stone near the northwest corner of section 14, and J. E. Gray and J. M. Marshall quarry the same "white" beds in the north part of section 3, Columbus township. At the Marshall quarry, considerable stone has been quarried in the past and there is less stripping needed than at other observed points where quarrying is done.

Western Louisa county in general is heavily drift laden and the rocks are exposed only at infrequent intervals along the streams.

LUCAS COUNTY.

Sand and Gravel.

Lucas county is wholly within the loess-covered Kansan area. Chariton river, the principal stream in the county, has a low grade and is characterized by mud flats and bars. Sand and gravel deposits are exceedingly rare. Some of the smaller streams contain meager amounts of sand and gravel in their channels, not sufficient, however, to satisfy the local demand. Practically all of the road and concrete material used is imported. The older gravels are concealed.

Stone.

The country rock of Lucas county belongs entirely to the Coal Measures. The formation consists almost wholly of shales with seams of coal and accompanying beds of fire clay. Occasional thin bands of dark bluish limestone and moderate thicknesses of sandstone are found associated with the heavy beds of shale.

In Pleasant township, near the northeast corner of the county, ten to fifteen feet of a coarse, grayish blue sandstone outcrop along Flint creek. Quarrying to any extent has not been done, but the beds are available at a number of points along this stream and its tributaries. On a branch of the Little Whitebreast in the northeast quarter of section 32, English township, a soft yellow sandstone occurs associated with bituminous shales and has been quarried in years past.

Upper Coal Measure beds may be seen on Long Branch in the northwest quarter of section 3 of English township, where limestone quarries were formerly worked. The beds consist of about four feet of light gray overlain with buff limestone, separated in ledges by calcareous shaly partings. The stone is said to produce a high grade of quick-lime and has been used for this purpose. Limestone has also been quarried and burned for lime on the Little Whitebreast two miles northeast of Chariton.

On the whole, the building stone resources of Lucas county are very limited, the valuable beds being in general so associated with other sedimentary strata as to render their utilization impossible.

LYON COUNTY.

Sand and Gravel.

Lyon county is bountifully supplied with sands and gravels, in the main closely related to the various drift sheets as gravel trains which margin the present streams, as terraces, and as kames which are more or less irregularly distributed over the upland. In addition to these deposits the present streams have classified and deposited large quantities of sands and gravels as bars and banks.

Stream Terraces.—The stream terrace gravels are by far the most important in Lyon county. Enormous quantities are to be found in the terraces of Rock river especially, and in lesser quantities along the smaller streams, such as Little Rock river, Otter, Tom and Plum creeks, etc.

The most extensive openings of the Rock river gravels have been made at Doon. Here there are two pits, one owned by the Great Northern Railway and the other by Miller and Montgomery. In the latter pit there are twenty-five to thirty feet of gravels under a cover of soil and alluvium which varies in depth from three to eight feet. The upper portions contain more coarse material, and pebbles of quartzite and red sandstone up to three inches in diameter run in more or less continuous thin bands. The lower eight to ten feet are chiefly clean white sand interspersed with some very fine-grained, even clayey streaks, and containing occasional rounded clay balls which are sometimes as large as a man's head. The supply here is unlimited, and a most excellent grade of clean sand and gravel for any purpose is obtainable.

In the railroad pit, located in southeast 26 and northeast 35, Doon township, southwest of the town of Doon, practically the same section as described above may be seen.

Enormous quantities of sand and gravel may easily be obtained at Doon and vicinity. The town itself is located upon this gravel terrace, and hundreds of acres south and southwest of town will furnish a supply which is practically inexhaustible. This area is readily accessible as it is an easy task to build a railway spur to almost any portion of it.

From Doon to Rock Rapids gravel deposits do not compare in amount with those just named. The Rock river terrace is not continuous and while the gravels may be seen in many places, and it is practically certain that they are present in others, there is no place where a pit could be opened on anything like the scale possible at Doon or north of Rock Rapids.

There is an exposure north of Doon on the west bank of the river at the bridge just northwest of town. Here is a portion of the same terrace in which the large pits farther south are located, and a small opening shows the same material. Gravel may be seen along the road between Rock and Garfield townships just west of where the railroad crosses it. The same terrace gravel is in evidence beside the road in southeast 15, Rock township, and also in several places along the road through

PLATE XXXI—The Miller-Montgomery pit showing pit methods. Doon, Lyon county.

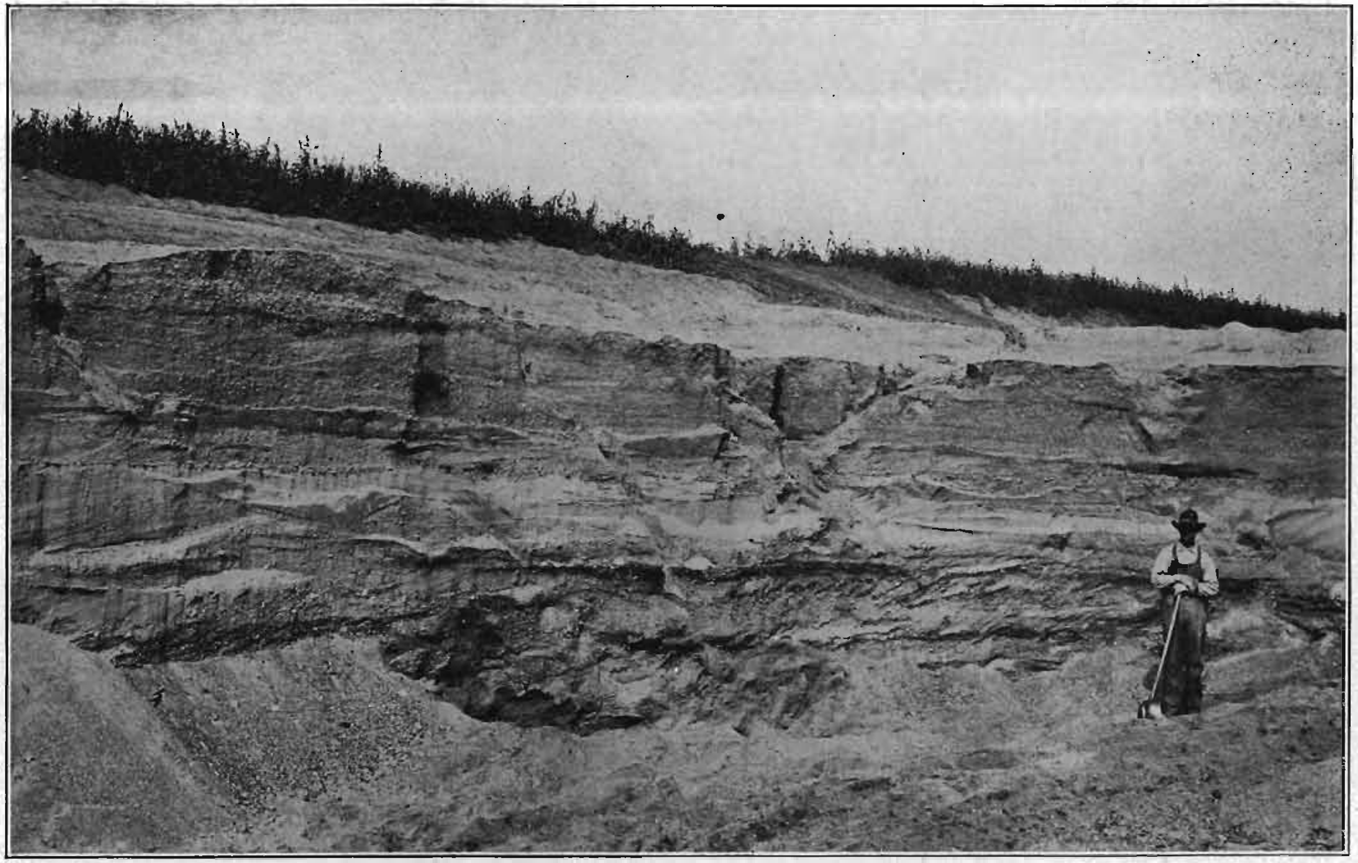


PLATE XXXII—Lehatchka and Pattengill pit which shows great irregularity in bedding. Rock Rapids, Lyon county.

sections 15 and 10. A considerable amount of material could be obtained from pits opened at or near these places, especially from the terrace south of the road in southwest 10. The latter would furnish an abundance of material for use within teaming distance.

Rock Rapids itself is situated, for the most part, upon this terrace, which here is some fifteen feet above the river. Much inconvenience on account of the gravel is experienced in the digging of cellars and ditches, and the covering over it is so thin that in the summer it is difficult to keep sufficient moisture on lawns, gardens, etc. Just in the northeast edge of town, on the east side of the river, Mr. Libbey has a pit from which much of the material used in town is being taken. This pit shows some six or seven feet of moderately coarse gravel on the side of the exposure nearest the river, but reduces down to about three feet on the opposite side. Below the gravel, and separated from it by a narrow band of bowlders up to six inches in diameter, are three feet of clean, fine, cross-bedded sand, in which are streaks of fine gravel. The whole is covered by alluvium to a depth of three to four feet. This gravel has been used on the streets in Rock Rapids for a number of years, and its value as a road material is attested by the excellence of the same.

North of Rock Rapids the terrace is continuous to the Minnesota line and beyond, and will average one-half mile wide all the way to the boundary of Iowa. There are two places close to town from which gravel is beng taken, the city pit at the old pumping station in the edge of town, and the one owned by Lehatchka & Pattengill. The latter, which is perhaps one-half mile from the edge of town, shows the following section:

	FEET.
Stripping	2-4
Gravel, fine and clean, with lenses of sand	3-4
Sand, silty in streaks, and having some fine gravel	1-2
Pebble band	$\frac{1}{4}$-$\frac{1}{3}$
Sand, cross-bedded, and with streaks and lenses of gravel	2-3
Gravel, cross-bedded, iron-stained in part	2
Sand and fine gravel	2
To water line (not exposed)	2

This gravel is being used by the owners for the manufacture of cement tile, blocks, etc.

Records of city and private wells indicate that there are upwards of thirty feet of gravel here, at least within a mile of Rock Rapids. It doubtless is not so deep as this further north, but no authentic records of its depth could be obtained.

The problem of opening these gravels on a commercial scale is a simple one. A railroad spur could be built to any part of this region at a minimum cost, and a large area could be opened with but a small amount of trackage. The soil covering is only moderately heavy and could readily be removed.

Along Tom creek northeastward from Rock Rapids a gravel terrace can be followed for miles. At some places, as in southwest 33, Riverside township, it is not particularly prominent nor are the gravels readily seen; while at others, as in section 34, the gravels are exposed along the creek in many places. This terrace, while hardly of sufficient size to furnish material workable on a large scale, should yield a sufficient amount for use on roads and in concrete work within hauling distance.

Along Little Rock river a terrace can be made out all the way from Little Rock to its union with Rock river at Doon. In the vicinity of Little Rock, notably at the bridge north of town, the terrace has been opened in several places. The material exposed is rudely stratified gravel and sand covered by a varying depth of alluvium.

Practically all the way to Doon terrace gravels are exposed in various places. Through section 9 of Grant township the terrace is more prominent than at any other place. Here it rises sharply above the river plain and the edge is continuous for a half mile or more. Two openings in the terrace, one on the north and one on the west lines of section 9, near the bottom and top of the terrace respectively, indicate that large quantities of gravel might possibly be available at this particular place. Development work is an easy problem.

Below George the terrace is not nearly so well defined as above. In only a few places can a definite bench be recognized, and then the surface slopes back to higher ground very rapidly. There are many openings from which road and concrete materials have been taken, but the supplies seem to be adequate for local consumption only. The large pits at Doon, described previously, are located on the broad flat at the junction of Little Rock and Rock rivers.

Along Big Sioux river entirely across the county there are remnants of what must at one time have been an enormous gravel terrace. By far the greater part of what can be recognized as terrace lies on the Dakota side of the river, the river now cutting under the bluffs on the Iowa side most of the way across the county.

One of the largest openings in this terrace is the pit a mile west of Granite, which is owned by Mr. Iverson and leased by the Rock Island Railway. This pit shows some twenty-two feet of stained, unassorted gravel, overlain by four feet of alluvium and resting upon limy, pebbly drift clay. The pebbles are largely granite and quartzite and range in diameter from six inches down. There is much yellowish clayey matter admixed. In describing it, I. A. Williams says: "Too dirty for cement work, but good for ballast." The terrace is fully half a mile wide and is as flat as a floor for a distance of one and a half or two miles toward the north. Although no actual openings were seen in the northern part of this area, it is highly probable that the whole of it is underlain by this water-deposited material.

Along a small creek in southeast 7, Centennial township, the top of the terrace is opened for several feet. The section shows rotten bowlders and very much iron-stained sand and gravel. No stratification whatever could be made out, the whole being but a heterogeneous mass of rotten bowlders, pebbles and sand. Bowlders a foot and more in diameter crumbled to small bits at a stroke of the hammer, and the sand grains were so deeply stained as to be hardly recognizable. It is hard to believe that this is Wisconsin material, in spite of the fact that it lies at the top of the terrace which has been considered by Wilder and others as a Wisconsin gravel train.

For a mile or so northwest of Klondyke the terrace is about a quarter of a mile wide and broadens to a half or three-quarters in section 17. It is quite probable that it is composed largely of the old gravels noted several times. An exposure of some fifteen feet of these may be seen east of the bridge at Klondyke, and a smaller one west of the school house at the northeast corner of section 21, where Plum creek has cut into the Big Sioux terrace. At Klondyke bridge the top of these gravels is about fifty feet above the water in the Big Sioux.

From Klondyke to Beloit the terrace is mainly on the South Dakota side of the river, and at the latter place it has a maximum width of nearly two miles.

The high bluffs all along the river are a serious obstacle in the way of opening many of the river benches. It is practically impossible to haul gravel and sand by team over most of the hills. The only other outlet is along the river, and there are no open roads on the Iowa side. The roads on the Dakota side are not now available because of the absence of bridges.

Along Blood run and Plum creek, tributaries of the Big Sioux, there are small gravel terraces. The gravels in these are entirely different from those in the main terrace along the Big Sioux, and the amount of available material is not large. Along Plum creek the story is practically the same. The terrace is low and indistinct and at no place has it a very large area. On the south side of the creek near the southwest corner of section 6, Logan township, is an open pit which shows material somewhat similar to that on Blood run. This is a clean fine sand, topped by six to eight inches of gravel and the whole covered by three or four feet of soil and wash. Only two or three feet are exposed, but the depth may run up to ten feet. A few rods south and west of here the creek exposes the whole section. Here are some seven or eight feet of gravel and sand in all; the fine sand as noted above grades downward into fine gravel, which in turn rests directly upon blue clay.

These terrace gravels are being used for concrete and other purposes within a few miles of the open pits. While there is not, economically speaking, a large amount available, yet the supply will probably prove adequate for almost all needs within a reasonable hauling distance. This is not so true of Blood run as of Plum creek, but the former will furnish a large and easily accessible supply.

Outwash Gravels.—An important deposit of gravel in the county is the outwash plain in the northeastern part. A moraine, the age of which is now a disputed question, crossed the very northeastern corner of the county. Waters flowing away from the melting ice deposited an enormous amount of gravel as an outwash plain in front of the glacier. Exposures of this may now be seen in any number of places over an area of several square miles.

Farmers all over this district report finding gravel in wells, ditches, etc., and in some cases even in post holes. The depth of the cover varies considerably, but at almost no place is it more than two or three feet. The material itself is quite variable, as would readily be expected from the manner of its deposition. In places it is clean and sharp, and usable for any purpose; at others so iron-stained and dirty as to be good for almost nothing. Variations between coarse and fine occur within inches.

Within this area are several pits which have furnished gravel for cement and other purposes. On the south side of the creek in southeast 24, Midland township, several hundred feet west of the road, is a pit which supplies gravel for cement work in the neighborhood. This opening shows some six feet of sand and gravel, very much iron-stained, and containing pebbles up to two and three inches in diameter. Fine sand occurs in lenses, and the gravel contains a large percentage of fine material. The covering is a stony soil, about one foot deep at the opening, but increasing in depth toward the upland. Probably fifteen or twenty acres would prove productive here, and the deposit is very easily accessible. Just west of the bridge on the line between sections 23 and 24, Midland township, is an entirely different material. The creek here has exposed clean fine sand overlain by a few inches of coarse gravel, the whole covered by some eighteen inches of soil. There is also a small pit about forty rods north of the southeast corner of Midland township, in which are exposed up to five feet of fine, rudely stratified gravel. Most of the material is below three-quarters or one inch in diameter, but pebbles up to three or four inches are common. Pockets of sand are numerous, and the whole section is somewhat iron-stained. Coarse and dirty gravel is exposed on the north side of the creek some sixty rods west of the bridge on the east line of section 1, Grant township. Probably up to thirty acres or so will yield gravel here.

These are but a few illustrations of the variation in the material which is found in this outwash plain. The openings are found indiscriminately on high land and low, and gravels may be found where almost any kind of excavation goes through the thin covering of soil over the gravel.

Reworked Materials.—The sand and gravel bars in the streams of Lyon county are, from an utilitarian standpoint, practically of no importance. The enormous quantities of other gravels which are so readily at hand and which are so much more dependable in quality and quantity have reduced their use to the veriest minimum. Sand and gravel bars are, however, present in nearly all the streams. Those of the Big Sioux are of course the most prominent, because of the enormous amount of gravel in the river terraces which is easily reworked by the stream. Small amounts of the material in these bars are used occasionally for local purposes and numerous openings have been made from time to time.

The same is true of all the other streams. The bars are not particularly prominent along Rock river. Little Rock river has a few of varying importance which have been used at a few places. Those of the other streams are hardly worth mentioning.

Deposits of Other Kinds.—It has been remarked previously that a moraine crosses the very northeast corner of Lyon county. The area included within this later drift is little more than a dozen square miles. The town of Little Rock is situated just within the edge of the area, and a ridge of morainal hills extends from here northwestward, swinging thence back to the north in a long almost circular curve and passing out of the county near the north center of section 8, Elgin township.

Within the area of this latest drift are to be found low hills and knobs, often composed wholly or in part of gravel, which are characteristic of some glacial deposits. Some of these knobs have been opened and considerable amounts of gravel and sand removed. One of the more prominent of these is situated on the farm of William Anderson in southeast 23, Elgin township. A small opening has been made on the top of this hill and three or four feet of sand and fine gravel are exposed. These materials are much iron-stained, and contain many pebbles up to five and six inches in diameter, but have been used for concrete. Near the center of section 26, Elgin township, is a kame from which a considerable amount of gravel has been removed. This pit shows mostly sand with fine to medium gravel intermixed and plenty of big bowlders, some of them ranging up to six or eight feet in diameter. It is quite dirty where it can be seen. About ten feet have been opened to view.

A high hill, the apex of which is just at the southwest corner of section 27, Elgin township, supplies gravel and sand for cement work in the town of Little Rock. There are about ten feet exposed, the amount decreasing toward the slopes. This is coarse gravel, iron-stained, and stands so firmly at the open face as to require some little force to break it down.

There are many morainal hills and knobs north and northeast of Little Rock that will doubtless yield abundant sand and gravel. Only a few of these have been opened, but there is scarcely any doubt that more of them will prove as productive as those that are now open. Many of these hills are several acres in extent, and it is highly probable that an adequate supply of road and concrete material may be had within short hauling distance of any part of Elgin township.

What is now believed to be the terminal moraine of the South Dakota lobe of the Wisconsin glacier just touches the western boundary of the county near Granite. What has been said of the gravel-bearing hills and knobs in Elgin township is equally true here. A few exposures of gravel may be seen on the hills west and southwest of Granite.

There are a few unimportant exposures of upland gravels other than those in Wisconsin drift hills in various scattered places. Of these, Professor I. A. Williams says, "Outside of the gravel trains, on the uplands, it is likewise not at all rare to find accessible deposits of the older (Buchanan) gravels. These always lie beneath the loess, which is itself usually the obstacle in the way of their development, varying in thickness from inches to great depths. Such deposits, as would be expected, are found and are most apt to be, along the courses of upland streams that have cut their way a greater or lesser distance into the surface materials. Inwood and Larchwood both draw their supplies from beds of this kind and position."

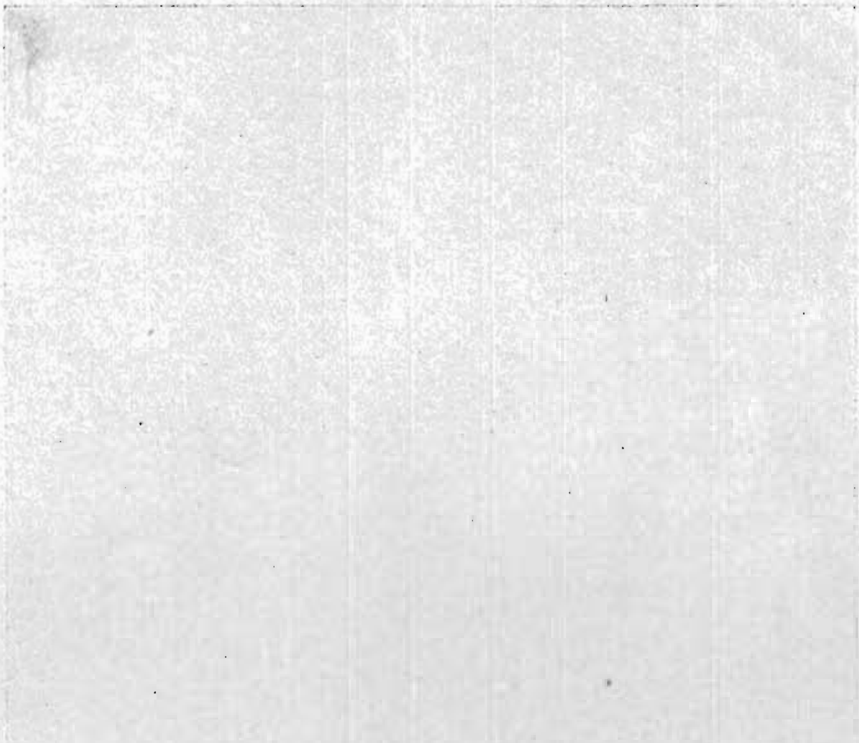
STONE.

The Sioux quartzite appears in the extreme northwest corner of the county. The stone is highly indurated, being a true quartzite, and rises some thirty feet above the level of Big Sioux river which has cut a narrow gorge through it. The quartzite outcrops cover a wedge-shaped area in Iowa of about twenty acres, the Big Sioux serving as the base of the wedge. The beds dip west of north at a low angle and form marked rapids where they cross the river. The twenty acres mentioned have no overburden. About a half mile to the east the quartzite is exposed over a very limited area by a recent gully and the probabilities are that it is not far from the surface over a considerably larger area than indicated above. Extensive outcrops appear beyond the Iowa boundaries in South Dakota and Minnesota.

The stone is highly indurated, hard, strong, and excellently adapted for road and concrete work. It is equal or even superior to granite for service demanding strength and wearing capacity. It is admirably adapted for use in the wearing surface in road and concrete. The amount easily available in Iowa above the water level in the Big Sioux exceeds a million cubic yards. It is probable that the area available is greater than indicated and that quarrying can be carried on much below the water level in the river. In addition to crushed stone, stone suitable for piers, culverts, abutments and paving block can be produced.

PLATE XXXIII—Sioux quartzite escarpment along Big Sioux river in the extreme northwest corner of Iowa; the best material in Iowa for crushed stone products.

PLATE XXXIV—Sioux quartzite ledges outcropping in the channel of Big Sioux river and forming rapids. The river cuts a gorge here within a hundred yards of the extreme northwest corner of Iowa.



MADISON COUNTY.

Sand and Gravel.

Gravel and even good sand are rather scarce in Madison county. Both are found only in the beds of the streams. North river has some sand south of Earlham, but it is rather too fine and dirty for good concrete work. Otherwise this stream has nothing but mud and quicksand. Middle river has the only sand of value and this occurs only intermittently. Near Webster there is quite a bit of good coarse, clean sand with good gravel in places, but both sand and gravel are wanting from here east until Winterset is reached. Some sand is hauled from the river near the latter place, but the quality is so poor that most of the sand and gravel used is shipped in from Commerce, Avon or Des Moines. At Patterson there is a large amount of clean coarse sand and fine gravel, but below this place there is neither sand nor gravel along the river. South river has no sand nor gravel.

Stone.

The Missouri limestones underlie about two-thirds of Madison county, and belong entirely to the Bethany substage. The four limestone members representing this substage are well represented in the county and all may be observed along Middle river in Lincoln township. A composite section, produced by blending the beds exposed along the ravine in section 22 in Lincoln township with the lower beds which may be seen in the locality of the Devil's Backbone, is as follows:

		Feet.
13.	Glacial debris variable in character and thickness.	
12.	Limestone, yellow, earthy; thinly bedded, Fusulina zone....	4
11.	Shale, variable in color and composition, bisected by compact limestone and decidedly calcareous above..............	13
10.	Limestone, coarse, with shaly partings...................	3
9.	Shale, dark, carbonaceous in part and with calcareous, fossiliferous bands......................................	8
8.	Limestone, blue, fossiliferous, with shaly partings..........	3
7.	Shale, dark above; lighter and calcareous to marly below..	5
6.	Limestone, yellowish above, shaly partings below..........	17
5.	Shale, black above; variable, earthy, yellowish, calcareous beds below..	7
4.	Limestone, with shale partings..........................	12

3.	Shale, black above, arenaceous below; the two members separated by a thin band of limestone	18
2.	Limestone, exhibits a nodular structure in weathering; fragmental, with shale parting near the middle	9
1.	Shale, exposed	20

Number 2 in the above section corresponds to the Fragmental phase of the Bethany, typically developed at Bethany, Missouri, and forms the ledge over which the water falls at the Backbone mill. Number 4 represents the Earlham, number 6 the Winterset, and number 12 the Fusulina or DeKalb phase, according to Bain in his Decatur county report. All of the members are comparatively pure, the limestone being essentially non-magnesian and reasonably free from iron pyrite. The associated shales are usually more or less calcareous and often carry considerable of the iron sulphides. The two middle limestone members are the ones most widely distributed in the county, and are the only ones quarried extensively.

The Fragmental limestone apparently occurs in heavy beds in fresh exposures, but where the beds have been exposed some time, they readily show their fragmental character, and are practically worthless for structural purposes, though serviceable as crushed stone.

The Missouri limestones are responsible for a prominent topographic feature producing a well marked escarpment which crosses the county diagonally in a northwest-southeast direction. The principal streams cross the escarpment at right angles and the most important outcrops occur where the streams debouch on the Lower Coal Measures. Quarry opening has been limited to the streamways which have railway facilities, and three centers are worthy of mention. These, named in their order from northwest to southeast, are as follows: Earlham, Winterset, and Peru. Unimportant quarries have been opened and operated from time to time at numerous other points but at present do not merit individual mention.

The Earlham beds have been most extensively quarried and afford a fair grade of stone suitable for dimension stone, rubble, and crushed stone. Near Earlham two quarry companies have operated extensively, and are directly connected with the main

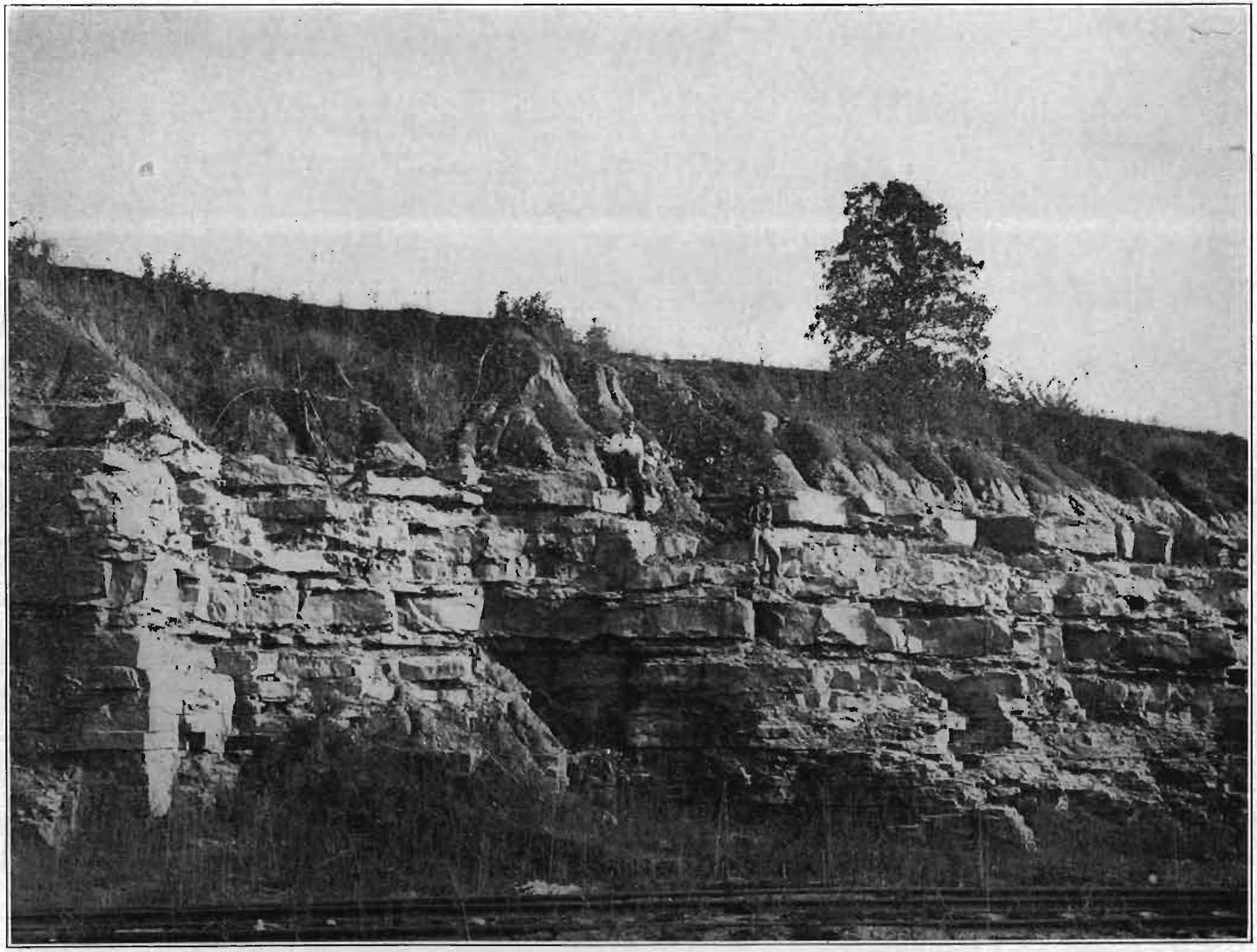


PLATE XXXV—Iowa Portland Cement Company quarry, Earlham, Madison county, showing the principal limestone beds with their characteristic clay partings.

line of the Rock Island Railway. The first is owned and operated by the Earlham Land Company with offices in Des Moines, and is located about one and one-half miles south of the railway station in Earlham, along the north branch of North river. The section exposed is as follows:

EARLHAM LAND COMPANY QUARRY SECTION.

		FEET.
4.	Loess and drift, of variable thickness	10-14
3.	Limestone, in regular beds, with shale parting near the middle	9
2.	Limestone, less evenly bedded than the above, hard and brittle	6
1.	Sandstone, calcareous and shaly, exposed.	

The second is located along the main line of the Chicago, Rock Island and Pacific Railway two miles east of the town of Earlham, on Bear creek, and is owned and operated by the Iowa Portland Cement Company of Des Moines. The sequence of beds is as follows:

IOWA PORTLAND CEMENT COMPANY QUARRY SECTION.

		FEET.
7.	Loess and drift, variable	2-8
6.	Limestone, gray to buff, evenly bedded	2
5.	Limestone, irregularly bedded, with some cherts	3
4.	Limestone, evenly bedded, becoming shaly near the middle	4
3.	Limestone, shattered, unevenly bedded, cherty	1½
2.	Limestone, rather evenly bedded above, and unevenly bedded below. Hard and compact, but in thin ledges	6
1.	Sandstone, calcareous and shaly, exposed.	

A composite sample was selected from the second quarry and analyzed. The result of the analysis is given below:

Insoluble	7.85
Iron oxide and alumina	1.00
Calcium carbonate	91.15
Magnesium carbonate	0.61

L. G. MICHAEL, Analyst.

The beds lie almost in horizontal position, and have little overburden. Quarrying is carried on according to the most approved methods and the entire limestone product is used by the present owners in the manufacture of Portland cement.

The quarry of the Earlham Land Company has been worked only intermittently during the past few years. The amount of overburden is rather greater than at the cement quarry. The equipment and quarry methods employed and products put upon the market are practically the same at both quarries.

The Winterset limestone has been most extensively developed in the vicinity of Winterset. The stone used in the Madison county court house was obtained from the local quarries. The building was erected nearly forty years ago, bearing the date of 1876, and all parts are in an excellent state of preservation save some of the stone steps, and one or two of the large columns, which show signs of failure due to selection of poor materials. One of the porch columns has become roughened owing to the presence of "clay balls" which appear to be one of the most serious defects in the stone but could be avoided by careful selection. Several of the steps have been replaced while others show signs of werkness. The failure in this instance was due to spalling and opening of cracks along bedding planes. Most of the materials used in the court house were obtained from the quarry in the northwest quarter of section 12 and the "Backbone" quarry, both in Lincoln township.

FIG. 46—Winterset quarry located about one-half mile southeast of the court house, Winterset, Madison county.

A good section showing the Winterset beds may be viewed within the city limits about a half mile southeast of court house square. The sequence is as follows:

		FEET.
7.	Drift and soil (thickens greatly in the bluffs)	3
6.	Limestone, disintegrated, uneven on the upper surface and probably thickens toward the bluffs, exposed	3
5.	Limestone, gray, heavy-bedded, somewhat porous and fossiliferous	3
4.	Limestone, fossiliferous and presents a concretionary facies; decidedly argillaceous	1$^1/_3$
3.	Limestone, gray to buff, hard, brittle and fossiliferous; unevenly bedded, top and bottom layers thickest, slightly concretionary	8
2.	Limestone, shaly, gray to yellow, highly fossiliferous	1½
1.	Limestone, buff to gray, somewhat unevenly bedded and slightly clayey; massive in unweathered sections, exposed	4

The base of the above section is about sixteen feet above the roadway, which follows the ravine down to Middle river. A black shale band appears in the bluff about ten feet above number 6 in the section.

FIG. 47—Quarry near top of hill southwest of Winterset, showing limestone above the black shale which appears well up in the ravines south of town.

Analysis of Winterset limestone selected from City quarry.

Insoluble	12.63
Iron and alumina	1.18
Calcium carbonate	84.34
Magnesium carbonate	2.19
Moisture	0.02
Total	100.36

Similar limestone deposits are to be found along the Chicago Great Western railway at Peru. According to T. E. Savage, the beds exposed at this point are as follows:

		FEET.
10.	Yellow colored loess	5-8
9.	Drift, reddish brown above grading down to gray below; containing numerous bowlders in the lower portion	9-15
8.	Gray or yellowish limestone, argillaceous, fine-grained; in three layers respectively 15, 18 and 12 inches in thickness. Much stained in upper part	4¾
7.	Bluish colored shale, with a band of limestone 1 to 5 inches in thickness near the middle portion	1⅚
6.	Dense, gray limestone, in layers 16, 24, 6 and 16 inches in thickness	5
5.	Band of gray shale	⅔
4.	Layer of gray limestone, crinoidal in lower portion	2½
3.	Ledge of gray limestone similar to number 4 above, in two layers respectively 12 and 30 inches in thickness	3½
2.	Band of grayish blue shale	1⅚
1.	Talus slope with occasional outcrops of limestone, to level of flood plain	20

The principal product of the quarry at the present time is crushed stone, which is used extensively in and about Des Moines.

According to Mr. Savage the bluff continues a distance of one-half mile along Clanton creek. A composite sample was selected from the limestone members of the above section and analyzed, and the results of the analysis are given below:

Silica	17.16
Iron oxide and alumina	2.64
Calcium carbonate	72.76
Magnesium carbonate	2.86
Sulphur trioxide	0.95
Moisture	0.30
Combined water	3.12

Analyzed by L. G. MICHAEL.

The Earlham and Winterset limestones are of good quality and satisfactory for crushed stone products.

MAHASKA COUNTY.

SAND AND GRAVEL.

Des Moines river affords an abundant supply of sand and gravel of excellent quality, sufficient to supply the entire county. At the present time this storehouse of road and concrete materials is being extensively exported from but a single point, Eddyville.

The Eddyville Sand Company is operating a plant located on a spur of the Minneapolis and Saint Louis railroad in Eddyville. The plant is equipped with a barge upon which an engine and sand pump are located, sand barges, a shell conveyor and overhead tram to transport the sand from barge to car and a power plant located on the shore to operate the shell and tram and move the cars on the railway as needed. The pump on the barge is an eight inch centrifugal with pipe line to match. The sand and gravel are not screened when loaded on the barge. Driftwood and float material, present in almost insignificant amounts, are removed by hand picking. The clam shell holds about one-half cubic yard. The barges have a capacity of sixty to eighty-five cubic yards. The output is shipped north and east to a distance of fifty miles.

None of the other streams in the county are of importance as sources of sand and gravel and none are producers worthy of mention, although small quantities are obtained at several points from stream channels and used locally. The interglacial gravels are not available.

STONE.

All of the more important streams crossing the county have cut through the drift and overlying Coal Measures to the subjacent limestone, at least throughout the greater portion of their courses. The beds represented are believed to be equivalent to the upper beds in Marion county, which are generally known as the Pella beds. Small quarries have been opened from time to time at a number of points, mainly along the two branches of the Skunk river. Perhaps the most important quarry section may be viewed in the Mayer quarry about two miles north of New Sharon near the North Skunk. The section is as follows:

		INCHES.
9.	Drift and Coal Measures of indefinite thickness.	
8.	Limestone	6
7.	Limestone	5
6.	Limestone	5
5.	Limestone	14
4.	Limestone	20
3.	Limestone	8
2.	Clay-shale	6
1.	Limestone, exposed.	

The stone exposed is fine-grained, compact, ash-colored to gray limestone, brittle and breaking with a conchoidal to uneven fracture. The above divisions represent ledges which are separated by clay partings. Less important exposures occur at Union mill and McBride mill on the North Skunk; near Peoria and near the Oskaloosa water works on the South Skunk; in the vicinity of Bellefontaine on Des Moines river and along Muchakinock creek. The same thin-bedded, compact, brittle limestone characterizes all of the leading quarry exposures and affords excellent material for road and concrete work.

MARION COUNTY.

Sand and Gravel.

The sand and gravel supplies of Marion county are limited to the flats of Des Moines river, and to beds and bars in the channel of the same stream. Sand bars are of frequent occurrence all along its course, and are utilized as sources of local supply in numerous places.

J. A. Wilson is shippiing sand and gravel obtained from the Des Moines river flats. The present pit is located on the Oskaloosa branch of the Chicago, Burlington and Quincy Railroad, and is on leased ground. A clam dipper and steam plant is installed, which has a capacity of from five to ten cars per day. The dipper holds one cubic yard. The pit section is as follows:

		FEET.
4.	Alluvial material	1-3
3.	Sand with gravel seams, cross-bedded	15-20
2.	Sand and gravel much coarser than above	15-20
1.	All resting on shaly limestone.	

Numbers 3 and 4 are above water level in the pit, which corresponds to the water level in the river. Occasional tree trunks and hard ledges are encountered in the lower gravels. Some coarse material is obtained from an extensive gravel bar just below the Chicago, Burlington and Quincy railway bridge. Immense quantities of sand and gravel are obtainable from the river bars and river flood plain in this vicinity.

STONE.

The Saint Louis limestone appears only in the eastern half of the county and there only along South Skunk and Des Moines rivers and their immediate tributaries. Only the two upper substages are exposed, the Verdi beds overlain by the Pella beds. The former beds are not persistent and comprise a rather complicated series of sandstones, cherty limestones, clays and shales. The upper beds are prevailingly limestones, fairly low in magnesia and other impurities. While both formations have been exploited to some extent, quarrying operations have been confined largely to the upper beds.

One of the most extensive sections exposed in the county occurs about two miles southwest of Tracy, on the southeast quarter of section 35 in Clay township. The sequence is as follows:

TRACY SECTION.

		FEET.
7.	Loess and drift of indefinite thickness	2-10
6.	Sandstone, argillaceous, much weathered and iron-stained	6
5.	Shale, arenaceous, variable in color and state of induration	4
4.	Limestone, argillaceous to arenaceous, weathers decidedly shaly	4
3.	Limestone, similar to 1, but harder; in a single heavy ledge	2
2.	Limestone, argillaceous, but hard and brittle, splits into thin layers on exposure; highly fossiliferous above and below	4
1.	Limestone, gray-blue, in heavy beds, finely brecciated, fossiliferous and slightly crystalline; in three ledges	4

Numbers 1 to 4 inclusive are referred to the Pella beds. Numbers 1 to 3 are the principal ledges quarried and appear to be well adapted for dimension stone, rubble and possibly bridge stone. Number 2 yields a fair flagstone. The individual ledges in numbers 1 to 3 are uniform in thickness and appear to be persistent. The layers are fine-grained, oftentimes bluish when first exposed, but turn white when long exposed to the weather. Number 6 appears to be quite compact when fresh, and large blocks may be removed. When exposed to the atmosphere, the blocks disintegrate rapidly to a drab product resembling clay. It is highly fossiliferous throughout.

A switch of the Chicago, Burlington and Quincy Railroad has been laid into the quarries. These have been opened up on the north bank of Cedar creek for a distance of more than half a mile.

In the vicinity of the town of Harvey the limestones belonging to the Pella beds of the Saint Louis and the Lower Coal Measure strata are exposed at many points in the valley of English creek and along the west border of the Des Moines valley. They appear also in the hillsides along the ravines and small streams in sections 10 to 15, Clay township. All of the exposures of the Pella limestones observed in this vicinity are covered with a greater or less thickness of the Des Moines shales and glacial drift. As a rule the amount of these materials is so great as to prohibit the quarrying of the limestone.

Good exposures of the Verdi beds may be viewed along Skunk river in Lake township, especially in sections 23, 24 and 26. A composite section for the district shows the following beds:

		FEET.
6.	Loess and drift, of variable thickness.	
5.	Sandstone, buff, cross-bedded, lower part very soft	5
4.	Limestone, massive, cherty, breaks irregularly	4
3.	Sandstone, gray, soft to quartzitic in places	3
2.	Limestone, cherty	2
1.	Sandstone, massive, yellow, with interbedded arenaceo-calcareous bands one-half inch to four inches in thickness. These bands are very hard, compact, fine-grained, and are more resistant to weathering than the sandstone, so that layers stand out on weathered surfaces. Occasional irregular fragments of this limestone, 1 to 2 inches in diameter, are found in the sandstone; exposed	20

Number 4 is quarried to some extent, the product being used for rough masonry. The heavy overburden and the difficulty of producing regular blocks preclude any possibility of its extensive use as a coursing stone.

The Pella beds have been quite extensively developed at Durham and between Durham and Flagler; southwest of Pella on the Pella-Knoxville road, and north of Tracy. The quarry opened between Durham and Flagler, between the Chicago, Rock Island and Pacific and Chicago, Burlington and Quincy railways, shows the following sequence of beds:

		FEET.
5.	Loess and drift	3'
4.	Limestone, thinly bedded	6
3.	Limestone, in well defined ledges, varying from 6 to 20 inches in thickness	5½
2.	Limestone, soft, granular, of little value for structural purposes	$1^1/_6$
1.	Limestone, very hard, breaks irregularly	3

A twenty inch ledge near the middle of number 3 is the principal layer in the quarry. It is coarse-grained, dark colored, but weathers white. The vertical joint planes are a sufficient distance apart to permit the removal of blocks of large size. Much of the product from this quarry and the old quarry northeast of

FIG. 48—Exposure of Saint Louis limestone, near Harvey, showing Pella beds.

Durham has been shipped to points along the Chicago, Rock Island and Pacific Railroad as far east as Washington, Iowa. Most of the stone used for structural purposes and flagging in Pella has been obtained from two quarries located about one and one-half miles southwest of the town on the Pella-Knoxville road. The beds exposed are very similar to those which are shown in the preceding section, save that an extensive deposit of marl similar to that which occurs in the Tracy quarries overlies the limestone.

The Durham-Flagler section is almost exactly duplicated in a quarry opened on the southeast quarter of section 13, in Clay township, about three miles southeast of Harvey. The beds exposed here are as follows:

		FEET.
5.	Loess and drift, of variable thickness.	
4.	Limestone, thinly bedded, greatly fractured	5
3.	Limestone, in ledges varying from 4 to 20 inches in thickness	5
2.	Shale, black above and gray below, soft	1$^1/_6$
1.	Limestone, thinly bedded, crystalline	1

Here as before a twenty inch ledge just below the middle of number 3 is the principal ledge in the quarry. It is granular in texture, with vertical joint planes from four to ten feet apart.

While the beds which comprise the Pella substage are persistent and uniform in texture, and of convenient and sufficient thickness for building and other structural purposes, they will probably never be extensively developed on account of the small aggregate thickness of the beds which are usable as compared with the amount of overburden and worthless layers which must be handled. Some of the upper beds will not stand alternate freezing and thawing, and should not be used in permanent structures. The principal ledges, however, appear to withstand weathering indefinitely as indicated by their fresh appearance, both in natural quarry sections and in walls which have been exposed to the elements for more than twenty years. (See plate XXVIII, a, page 391.)

The following tests were made by Professors Marston and Weems on specimens secured from the Tracy quarry:

CRUSHING TEST.

Stone	Height in Inches	Cross Section Square Inches	Breaking Stress—Pounds Per Square Inch	
			Spalling	Failure
No. 31, Saint Louis Limestone....	1.95	4.12	7,300	9,500
No. 32, Saint Louis Limestone....	2.00	4.20	5,200	9,900

ABSORPTION TEST.

Stone	Per Cent of Increase		
	24 Hours	Week	Total
No. 31, Saint Louis Limestone..........	2.28	0.99	3.27

CHEMICAL COMPOSITION.

Calcium carbonate ($CaCO_3$)	94.60
Magnesium carbonate ($MgCO_3$)	3.17
Alumina (Al_2O_3)	0.49
Iron oxides ($FeO+Fe_2O_3$)	0.17
Insoluble	1.57

Extensive beds of sandstone occur in the Coal Measures of Marion county. The most important deposits are found in the vicinity of Red Rock along Des Moines river. One-half mile northwest of the town a large quarry has been opened, the main face of which is thirty to forty rods in length. There is a maximum thickness of 100 feet of beds here exposed. The stone was channeled, by which method of quarrying blocks of almost any desired dimensions were obtainable. The sandstone separates in ledges five to six feet in thickness. Quarrying operations were formerly carried on here on an extensive scale. A switch was connected with the Wabash at Cordova and the product was shipped to points along this line from Des Moines to St. Louis. The quarries have been worked only intermittently during the past fifteen years and are now practically abandoned.

The sandstone appears to form an elongated lens about ten miles in length and three miles wide. The longer diameter of the lens extends in a northeast-southwest direction. From the maximum thickness of over 100 feet attained by the beds, they thin rapidly. The higher portions of the sandstone ridge have a light overburden of loess, but this attains considerable thickness on either flank. The rock is massive and the heavy beds are practically free from joint planes. The sandstone is imperfectly indurated, varying in hardness from exceedingly friable to almost quartzitic. The color is also variable, ranging from almost white or pale yellow to deep shades of red and brown. In some of the beds the coloring matter is irregularly distributed, producing a blotchy or mottled effect. The prevailing cements are the oxides of iron and silica, although the upper beds are somewhat calcareous. While predominantly soft, the Red Rock stone resists weathering well and may be rated as fairly durable. It is not suitable for crushed stone products.

MARSHALL COUNTY.

Sand and Gravel.

Sand and gravel deposits in Marshall county are confined to Iowa river, Minerva creek and some of the small tributaries of the latter which issue from the Wisconsin drift. Stream terraces are so poorly developed within the county as to be unimportant, the large part of the gravels occurring as beds and bars in the stream channels.

Excavations of various sorts show the presence of large quantities of sand and gravel in the Iowa river bottoms. Twenty to thirty feet of these materials are known to exist in some places, under an overburden of silt and fine sand ranging from zero to five or six feet in depth. Between Marshalltown and Albion the sand flats along the river furnish an inexhaustible supply of good building sand.

At and near Clemons the Wisconsin valley train gravels of South Minerva creek have been extensively developed both as railway ballast and for structural purposes.

Both the Aftonian and Buchanan gravels are represented in Marshall county, but to hardly such an extent as would warrant consideration from an economic standpoint. At Albion ten feet of stratified sand and gravel referable to the former stage may be observed. Gravels which doubtless are of the Buchanan age are typically developed at Albion. The gravels near Gifford probably belong to the Wisconsin gravel train. At Marshalltown there are five to ten feet of siliceous material at the base of the loess. These sub-loessial gravels are widely distributed over the county and often attain a considerable thickness.

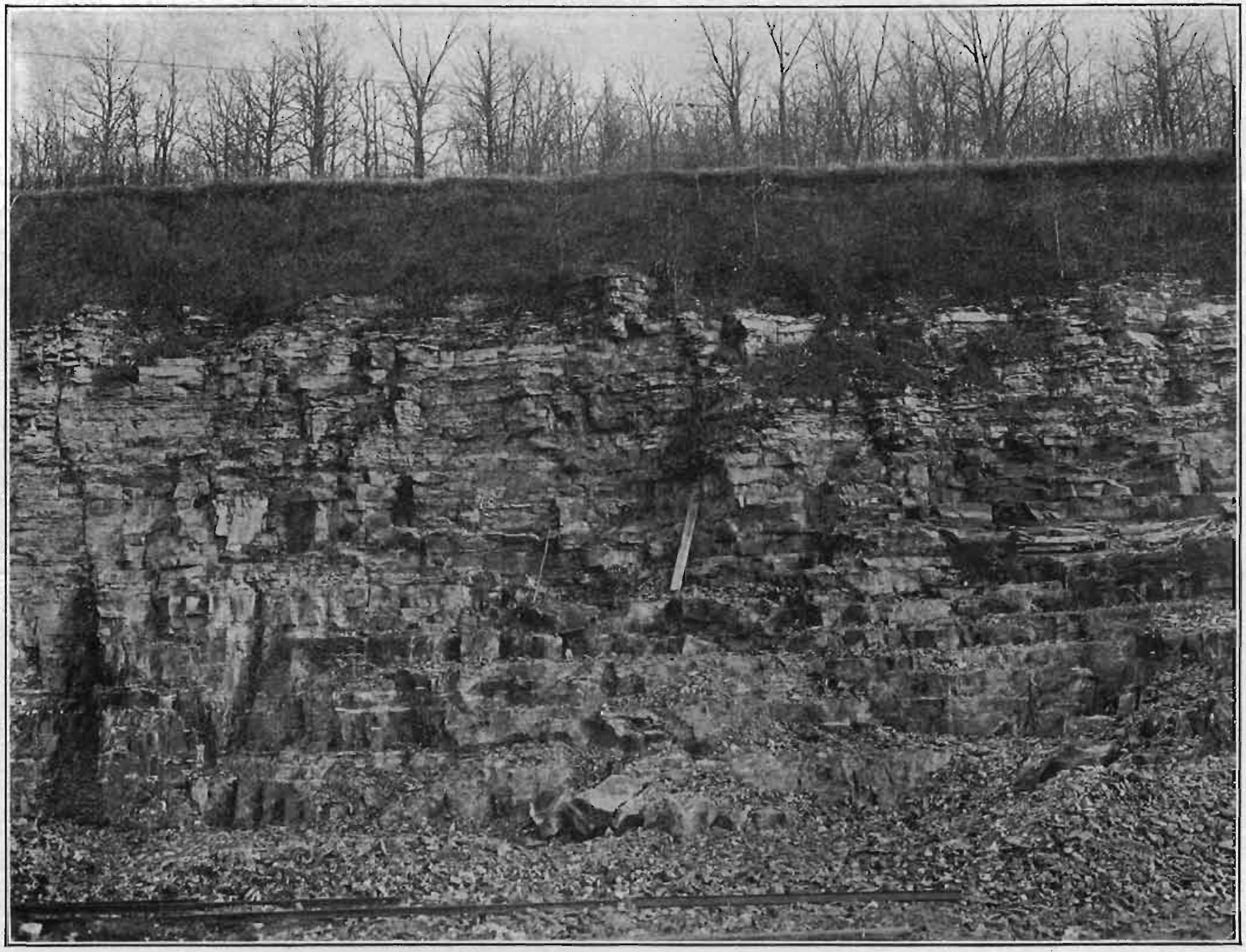


PLATE XXXVI—Typical section in quarry of LeGrand Quarry Company, Quarry, Marshall county. The entire assemblage of beds are suitable for road and concrete materials.

STONE.

The Kinderhook immediately underlies the drift over the northeast one-third of Marshall county, and extensive outcrops may be viewed along the Iowa river in the vicinity of Quarry and LeGrand, along Nicholson creek at Rockton, and on Timber creek, about two and one-half miles southwest of Quarry. All of the leading exposures are near the trunk lines of railway which cross the county, and all are connected by switches extended from these lines.

In the southeastern portion of the state, there are extensive outcrops of the Kinderhook, notably at Burlington, which consist of shale, fine-grained sandstone, and subcrystalline limestones, of which the first and last members are the most important. In Marshall county, the calcareous beds greatly predominate. Five fairly well defined divisions can be recognized readily, the lowest member of which is a shale which resembles the shale member in the pit of the Granite Brick Company, at Burlington. This is overlain by a fine-grained, blue to gray calcareous sandstone which is in turn followed by beds of oölite. Above the oölite, cherty magnesian limestones are present in considerable thickness, and completing the section are the brown to gray subcrystalline limestones.

The Kinderhook shales are not exposed in Marshall county, but are present in well sections which penetrate the indurated rocks. The basal member exposed is the fine-grained sandstone which appears only in the eastern portion of the county. The leading quarries develop the oölite and the magnesian limestone, although all of the members above the shale have been exploited to some extent. The most extensive section in the county is exposed north of LeGrand, near Iowa river. The following sequence of beds may be observed at this point:

		FEET.
18.	Loess, interstratified sands and silts below	16
17.	Bowlder clay oxidized a deep brown and containing bowlders much decayed	5-10
16.	Limestone, subcrystalline, pebbly	3
15.	Oölite, fine-grained, with many brecciated grains	4
14.	Limestone, gray, slightly oölitic	2½
13.	Limestone, gray above and yellow below	2

		FEET.
12.	Limestone, buff, magnesian, rather heavily bedded, bisected by chert band about four feet from the base..........	9
11.	Limestone, mixed gray, blue and buff, breaks very irregularly ("Brindle" of the quarrymen) really an intraformational conglomerate	3½
10.	Chert	⅓
9.	Limestone, soft, yellow, arenaceous; in thin layers; earthy in places	2½
8.	Chert	⅓
7.	Limestone, blue, variegated to yellow-brown...............	6
6.	Chert	¼
5.	Fossil breccia with lenses of crystalline calcite............	1
4.	Limestone, buff, magnesian, fine even texture and massive; cherty concretions scattered promiscuously throughout. One quite persistent band of chert about four feet from the base	12
3.	Limestone, blue, variegated to brown, hard, conchoidal fracture, in heavy layers..................................	3½
2.	Oölite, in layers 14, 12, 8, 9, 6, 36, 26, 24 and 42 inches in thickness	15
1.	Sandstone, fine-grained, blue, calciferous, in part shaly, exposed	10

The beds dip gradually to the southwest, and as the ground rises in that direction, are soon carried below the surface of the river. Near Indian Town in Tama county, the base of the oölite lies more than twenty feet above the water level. At the northeast quarry above LeGrand, it is about ten feet above the water level, while in the west quarries, both the oölite and the sandstone lie below the bed of the river. At the west quarry, the upper members in the above section are better developed. Number 16 shows a thickness of about twelve feet. At Rockton only numbers 14, 15 and 16 are exposed, and the beds are more shattered and weathered than their equivalents in the LeGrand quarries. The section exposed near the Minneapolis and St. Louis railway is second only in importance to the Quarry and LeGrand sections. The beds exposed are as follows:

		FEET.
8.	Loess, sandy below......................................	10
7.	Bowlder clay (Kansan)..................................	6
6.	Limestone, brown, subcrystalline, thinly bedded, and rubbly above, heavier below	8
5.	Limestone, yellow, brittle, with occasional small caverns decorated with concretionary calcite..................	1½
4.	Limestone, blue, hard, brittle...........................	2
3.	Oölite in three layers, 8, 22 and 6 inches respectively......	3

	FEET.
2. Limestone, gray-brown, with layers of blue, subcrystalline limestone interbedded	6
1. Limestone, gray-blue, close-textured, soft when first exposed, weathered portion, yellow; layers vary from 6 to 18 inches, very evenly bedded, magnesian	12

The oölite in the Timber creek section is undoubtedly the equivalent of the oölite exposed at Rockton, and the upper oölite of the LeGrand section. Numbers 1 to 6 in the Timber creek section find their counterparts in 12 to 16 in the LeGrand section, with the possible exception of Number 5, which was not certainly recognized farther north and east.

The differences in physical properties and coloration are largely if not wholly due to differences in the weathering. The Timber creek beds are in large part below the water level, and the prevailing colors of the beds developed are shades of blue and gray, while the tones of yellow and buff which prevail in the east quarries at LeGrand are believed to have been brought about through the action of weathering agencies. The hardness of the Timber creek stone increases materially on exposure.

Kinderhook beds are also exposed northwest of Liscomb, near the center of section 2.

Quarry Industry.

The Kinderhook beds have been exploited mainly in the vicinities of Quarry and LeGrand, and Timber creek. Quarries were operated formerly at Rockton, but have been abandoned for some years. Stone has also been taken out along the river, near Liscomb, for local use only.

LE GRAND QUARRY COMPANY.

The pioneer in the quarry industry, as well as the largest company operating in the county at the present time, is the LeGrand Quarry Company, with its central office in Marshalltown. The company owns and operates quarries at Quarry and Timber creek.

Quarry.—Three quarries are connected with the Chicago and North Western railroad, by branch lines at this point. Active operations were begun as early as 1860, when a limited quantity of building stone and lime was produced. Two years later the railway tracks were extended into the quarries, and the company has operated continuously ever since.

At present only the southeast quarry is being operated.

The quarries are now under lease by the Chicago and North Western Railway Company and are being operated by Dolese Brothers of Chicago. Crushed stone is the only product.

The plant is fully equipped throughout with the most approved machinery for producing crushed stone economically. Hand labor is reduced to a minimum. The quarry rock is first shattered by blasting, then loaded by steam shovel into dump cars which are conveyed to foot of crusher incline by dummy engines, hoisted by cable and dumped directly into a number 11 Gates Gyratory crusher. The product from the large crusher passes into a trommel screen, the oversize being conveyed to two auxiliary crushers. The entire product is elevated to the top of the building, sized and distributed to the appropriate storage bins. This is the most complete crusher plant in the state.

Timber Creek.—The LeGrand Quarry Company has also developed an extensive quarry in Timber creek. A side track is laid in from the Minneapolis and Saint Louis railway and the plant is well equipped with modern machinery. The beds worked are the same as those at Quarry, from the magnesian limestone upwards. As has been mentioned, the magnesian limestone here differs in color from its homologue at Quarry and LeGrand. At the latter places shades of buff prevail, while at the Timber creek quarries the chief beds are a gray-blue with occasional layers in part light yellow. The fact is emphasized that the predominating color in the unaltered LeGrand beds is a gray-blue, which is changed to tones of buff and yellow through weathering agencies. Here as in other places, the magnesian layers succumb less readily to disintegrating forces than

PLATE XXXVII—The LeGrand Quarry Company crusher plant—perhaps the largest crusher plant in Iowa. Quarry, Marshall county.

PLATE XXXVIII—LeGrand quarry showing the results of successful blast. Quarry, Marshall county.

the associated beds, and as a consequence stand out prominently in natural quarry faces.

The upper oölite and brown subcrystalline limestone are of more importance here than at the exposures along Iowa river.

The Coal Measures in Marshall county consist chiefly of shales with occasional beds of sandstone. A heavy bed of sandstone appears in Timber Creek township, and has been developed to a limited extent. Quarries have been opened on sections 8 and 9, and stone suitable for the rougher grades of masonry has been produced. The sandstone is reddish brown in color, and apparently durable. It exhibits a conglomerate facies in part. Well polished grains of sand and gravel are laid in a matrix of ferric oxide. Some of the iron oxide is found in the form of small nodules which frequently are hollow and possess the concentric structure peculiar to concretions. The impressions of trunks and branches of trees which have retained their woody texture in a remarkable degree, although their original organic substance has been entirely replaced by mineral matter, occur throughout the beds. In some instances, a pulverulent ash surrounded by a highly ferruginous shield is all that remains. One case exhibited a central core of very hard material, almost quartzitic, around which was a zone of wood fibre, and surrounding all, a concentric, ferruginous shield. All of the stems are in a recumbent position.

At the present time only the upper layers have been exploited. The lower beds are more regular and afford a stone suitable for building and trimming.

The sandstone here as elsewhere in the Coal Measures is not suitable for crushed stone products.

MILLS COUNTY.

Sand and Gravel.

There are only a few places in Mills county where gravel has been found, and these are along the Missouri river bluffs. Outcrops may be seen in section 4 of Oak township and section 10 of Lyons township. Extensive operation of these pits is not feasible on account of the rapidity with which the loess cover deepens back into the bluff. Local supplies for small work only are taken from these pits, the materials used for work of much importance being shipped from Platte river in Nebraska.

The town of Farragut obtains small amounts of sand for local consumption from the east fork of Nishnabotna river.

STONE.

The constitution of the Missouri in Mills county is almost an exact duplicate of the stage in Fremont county to the south. The shale members greatly predominate, and as before, the exposures of the indurated beds are limited almost wholly to the bluffs facing Missouri river. A few exposures are found elsewhere, especially along Nishnabotna river and its immediate tributaries. While the limestone ledges appear at a considerable number of points, quarrying operations have been carried on at a very few, and the probabilities are that the industry will never attain any importance in the county. The leading sections are given below.

Section in the bluffs in the southeast quarter of section 16, Lyons township:

		FEET.
13.	Loess and drift of indefinite thickness, which reach great depth immediately back from quarry face, average....	18
12.	Limestone, oölitic above and compact below..............	3
11.	Shale, gray, with two calcareous stone layers about 3½ and 4½ feet from the upper surface, fossiliferous throughout	6½
10.	Limestone	1
9.	Shale, gray, calcareous and fossiliferous..................	1
8.	Limestone with a band of chert..........................	1¾
7.	Shale, gray and black, slightly calcareous, with occasional streaks or pockets of coal............................	1½
6.	Limestone, compact, white, breaking preferably along vertical planes	1
5.	Shale, varying from slightly to highly calcareous.........	2
4.	Limestone, gray, fragmental, some of the fragments clean and some covered with oölitic crust, all imbedded in a fine-grained matrix	3½
3.	Limestone, shaly, grading into 4.........................	1
2.	Limestone, yellowish gray, in heavy ledges, showing a tendency to wedge out, shale partings present..............	4
1.	Shale, bluish gray to black, and talus....................	8

The above is the most important section in the county, and continues along the bluff for about half a mile. Extensive quarrying was carried on formerly, but the industry has been practically abandoned. Number 2 appears to have furnished the most important quarry stone. A small quantity of stone is now burned for lime at this place.

Section formerly exposed in the quarry near the Missouri river bluffs, at Mills station:

	FEET.
6. Loess and drift of variable thickness	50-60
5. Disintegrated limestone containing *Fusulina cylindrica*	½
4. Yellow shale or disintegrated limestone containing *Fusulina cylindrica*	2½
3. Limestone, decayed and yellow above, gray and sound below, containing numerous nodules of fossiliferous chert	3
2. Concealed, probably shale	2
1. Bluish, dark gray limestone	1

Only No. 3 is now visible in above section. The same stone appears in the stream channel south of the railroad.

Section in the quarry at Henton:

	FEET.
5. Loess and drift of variable thickness.	
4. Shale, gray, with thin calcareous layers and occasional small calcareous concretions	2
3. Limestone, gray or yellow	1½
2. Limestone, gray to cream-colored, with dark cherty concretions several inches in diameter, somewhat pyritic	1
1. Limestone, light bluish gray, in heavy ledges with some shale partings, and irregular nodules of chert; fossiliferous	3

Several small quarries have been opened in this vicinity. Quarrying operations have, however, been carried on only intermittently, and then in a desultory way. Away from the Missouri bluffs, very few quarries have been opened, although the limestone members are occasionally exposed. The section given below shows more limestone than the average.

Section near the banks of Silver creek, one-third of a mile west of the center of section 5, White Cloud township:

	FEET.
7. Loess and gravelly drift	17+
6. Shale, marly	½
5. Limestone, grayish yellow, in three or four heavy ledges, cherty and cavernous	6
4. Limestone, grayish blue, compact	⅔
3. Talus slope	2
2. Limestone, yellow, fragmental	2
1. Limestone, formerly quarried, but now concealed to water level of Silver creek, about	3

These beds are much obscured, the outcropping edges of No. 5 being the only stone visible in place. Quarries were formerly operated in section 36, Rawls township, the upper ledge being striated. Stone is no longer quarried in the vicinity. While the limestone ledges exposed are of fair quality for crushed stone purposes the large percentage of materials which must be wasted makes quarrying unprofitable.

MITCHELL COUNTY.

Sand and Gravel.

Mitchell county is almost completely covered with Iowan drift except for a few "islands" of Kansan drift overlain by loess. While the Iowan drift is often covered by a gray loess, the thickness of this is measured in inches rather than feet. Buchanan gravels are represented by both the valley phase, appearing now as stream terraces, and the upland phase. (See Buchanan county report.) In addition, reworked materials and Iowan gravel trains are present. The former appear as sand and gravel bars in Little Cedar river east of Osage, and in the Wapsipinicon near Riceville, but as a source of supply are of minor importance.

Stream Terraces.—The valley phase of the Buchanan gravels makes its appearance along Little Cedar and Wapsipinicon rivers. A low terrace rising from ten to fifteen feet above the flood plain of the Little Cedar probably contains sand and gravel, judging from the springs above and the bogs below, yet no pits could be observed.

Terraces of Iowan age may be seen occasionally along the Cedar valley. The city of Osage derives much of its supply of sand and gravel from a pit in a broad terrace fifteen feet above the river flood plain in the northern part of section 34, Cedar township. This pit is operated by the Osage Cement Products Company. The section shows:

	Feet.
Soil, pebbly	½-1
Gravel, fine, some sand and coarse gravel, dark brown	1-2
Gravel, similar to above but lighter colored	1-2
Gravel, fine to coarse, fairly clean, containing limestone slabs and a little clean sharp sand, exposed	5

Several acres of similar materials are known on N. W. Nelson's farm, where pits have been opened. In section 21 of the same township, there is another broad terrace similar in its essentials to the one just described.

Upland Gravels.—The upland phase or outwash aprons of the Buchanan stage are of prime importance in road construction as they are more evenly distributed than any of the other forms in which suitable materials occur. Professor Calvin in his report on this county in volume XIII of the Iowa Geological Survey describes a few pits in the following way, "There is a typical pit of the upland phase of the gravels a short distance southwest of Osage in the northwest quarter of section 35, Cedar

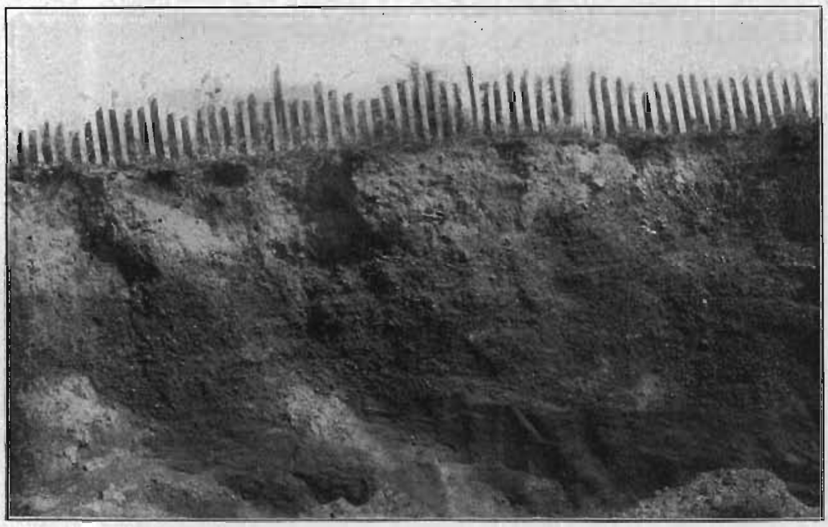


FIG. 49—Buchanan gravels overlain by Iowan loess, in the northwest quarter of section 35, Cedar township, Mitchell county.

township. The deposit is very ferruginous and weather-stained. Most of the crystalline pebbles are profoundly altered and decayed. The section shows four feet of coarse, ferruginous gravel. Along with the northern granites and greenstones are some fragments of the local lithographic limestone, and it is interesting to note that the limestone has suffered less from weathering than most of the crystalline pebbles. Above the gravel is a mantle of fresh Iowan loess. There is no Iowan drift. The pit is located on a knob which rises eighty feet above the level of the river. A short distance west of Mitchell is another pit of rusty Buchanan gravel similarly located in a loess-Kansan area which rises conspicuously above the level of the adjacent Iowan plain."

Gravel is common along the river but it is found on the bluffs and not in the valley. An example of this is an iron-stained gravel occurring on the bluff at the west end of the mill dam in Mitchell. Extensive deposits are also fairly common on the uplands remote from the streams. It seems hardly necessary to mention each deposit but it might be added that Jenkins and Douglas townships have these gravels in greater abundance than other localities.

STONE.

The Cedar Valley limestone of the Devonian forms the country rock over the entire county. Excellent sections may be seen along the principal streams, especially along Cedar river west of Osage. Practically the entire series of beds known to occur in the county appear in a single section aggregating about eighty-five to ninety feet. According to Professor Calvin in his admirable discussion of the Geology of Mitchell county the details of one of these standard sections are as follows:

The Chandler Cliff Section, located on the east side of the river on the southeast quarter of the southeast quarter of section 21, directly west of Osage:

		FEET.
26.	Residual clay in which thin, weathered slabs and flakes of limestone are embedded, part of mantle of waste......	4
25.	Limestone, coarse-grained, rough, weathered, magnesian..	½
24.	Limestone, firm, fine-grained, lithographic ledge, somewhat concretionary and containing imperfectly preserved stromatoporoids	1
23.	Limestone, partly decayed and partly shaly layer........	1
22.	Limestone, fine, light colored, lithographic bed. The bed as usual shows two divisions which are separated by a peculiar suture-like joint due to the interlocking of small prominences from the apposed surfaces. This interlocking joint is seen in all the exposures of this vicinity. The interlocking denticles show stylolitic structure..........	2
21.	Shaly parting	1/12

		FEET.
20.	Limestone, lithographic, in three parts; upper part as usual very fine-grained and homogeneous	2½
19.	Shaly parting	1/6
18.	Limestone, lithographic, fine-grained	1
17.	Limestone, coarse, dolomitic	1
16.	Limestone, fine-grained, laminated	1
15.	Dolomite, coarse, granular, in beds ranging from six inches to a foot in thickness	4
14.	Shaly parting	½
13.	Limestone with lithographic nodules embedded in granular matrix	1 1/6
12.	Limestone, heavy layer which is dolomitic below and partly lithographic above. The lithographic portion is joined to the coarser dolomite by a wavy and irregular line	1 1/6
11.	Shaly band, variable in thickness, averaging about	½
10.	Dolomite, heavy layer, subcrystalline	1½
9.	Shaly parting	1/6
8.	Limestone, thick layer, coarse and granular at the base, upper six inches partly lithographic	1½
7.	Limestone, hard, light gray, lithographic stone	1 1/12
6.	Limestone, shaly, decayed	1
5.	Limestone, light gray, crystalline, good building stone	1 1/6
4.	Dolomite, evenly bedded, yellowish, good quality, quarried for building stone at many points in the county, layers ranging up to a foot or more in thickness, no fossils	9
3.	Dolomite, irregularly and indefinitely bedded, much checked and cut by joints, carries numerous casts of *Athyris vittata* and other species characteristic of the same horizon. This member will be referred to hereafter as the Athyris zone	12
2.	Limestone, two heavy, irregular, nonlaminated, dolomitic beds, containing many shapeless cavities lined with calcite	5
1.	Limestone, magnesian, partly dolomitic, in regular layers	15

For convenience a generalized section may be composed from the above section and one or two others in the immediate neighborhood. The following is believed to closely approximate the truth:

GENERALIZED DEVONIAN SECTION.

		FEET.
8.	Magnesian limestone above the lithographic zone, represented usually by weathered chips	6
7.	Lithographic zone	9
6.	Assemblage of variable beds between the lithographic zone and the evenly bedded quarry stone	15
5.	Quarry stone, No. 4 of the Chandler cliff section	10
4.	Athyris bed	12
3.	Coarse, vesicular bed with calcite-lined cavities	5
2.	Regular bedded dolomite at base of Chandler section	15
1.	Folded and brecciated zone	15

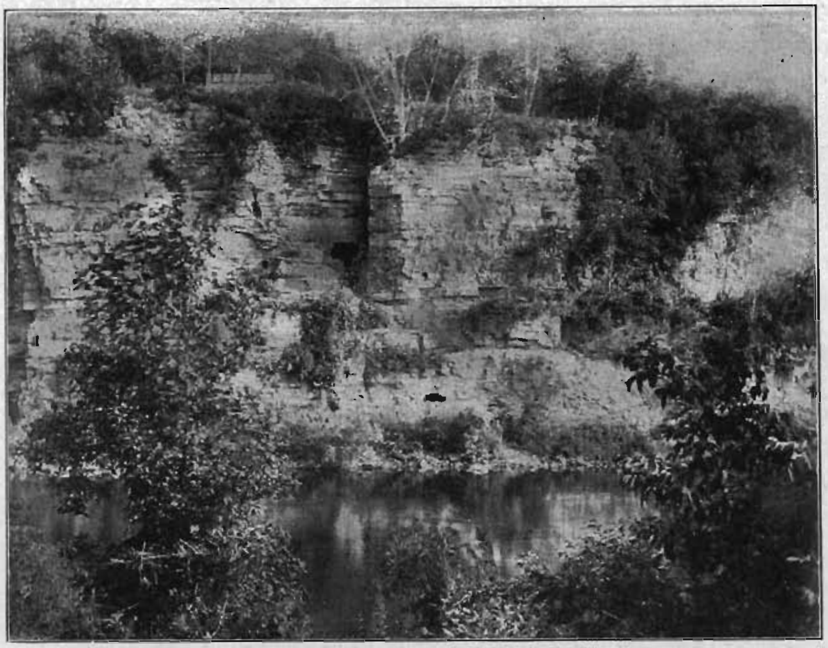


FIG. 50—Cliff below the wagon bridge in the northeast quarter of section 28, Osage township, Mitchell county. There are folded and brecciated beds at the base of the cliff; the lithographic limestone appears at the top.

Number 1 in the general section may be seen one-fourth mile below the electric power plant just below the wagon bridge directly west of Osage. The upper portion of the section closely resembles Chandler's Cliff.

The principal streams in the county are strike streams and the general slope is parallel with the dip south and west. The beds which are quarried at St. Ansgar are essentially the same as those quarried at Orchard, and those being developed in the vicinity of McIntire find their counterparts in the quarries along Rock creek.

In the vicinity of Osage quarrying operations are limited almost wholly to the lithographic beds. Near Mitchell and St. Ansgar, and along the Little Cedar from Stacyville to Brownville, the regularly bedded dolomites, corresponding to number 4 in the Chandler section, are worked. At McIntire and along Rock creek the lithographic zone is the one mainly utilized. At

Otranto the Athyris bed is worked and it would appear that number 1 of the Chandler section ought to be within working distance of the surface. In order that the details may be better understood and the latent resources of the county more fully appreciated, a detailed quarry section from each of the more important districts is given below. A considerable number of quarries have been opened along Sugar creek southwest of Osage. One of the most important of these is known as the Lewis lime quarry. The section is as follows:

FIG. 51—The Lewis lime quarry, in southeast quarter of section 27, Osage township, Mitchell county, one and one-half miles southwest of Osage. The beds exposed are hard and compact and are fairly representative of the vicinity.

LEWIS LIME QUARRY.

		FEET.
10.	Dark brown residual clays with some granular, calcareous, residual material resembling fine sand, and many weathered chips of limestone	4
9.	Limestone, firm, whitish, fine-grained ledge of concretionary lithographic stone containing a number of obscure stromatoporoids	5/6
8.	Limestone, shaly, fossiliferous, fossils mostly in the form of comminuted brachiopod shells	1/4

7.	Limestone, hard, fine-grained, lithographic, with lamination planes well defined in some places, less perfectly defined in others, and with a tendency to split up into individual layers of varying degrees of thickness	1 1/6
6.	Shale, marly	1/4
5.	Limestone, heavy ledge of fine-grained lithographic stone dividing into two parts, the upper ten, the lower seventeen inches in thickness. The lower five inches is very fine and homogeneous in texture and tends in places to separate as a distinct layer	2 1/4
4.	Thin shaly parting	1/12
3.	Limestone, ledge of fine-textured lithographic stone in three parts, eight, seventeen and one-half, and three and one-half inches respectively	2 1/3
2.	Shaly parting	1/12
1.	Limestone, coarser and less perfect lithographic stone, in two parts, eleven and nine inches thick	1 2/3

Beds 3, 5, 7 and 9 are fine-grained and light colored, break with conchoidal fracture, and would all be classed as lithographic limestone. It is the upper eight inches of No. 3 and the lower five or six inches of No. 5 that are fine enough and homogeneous enough to give promise of possessing commercial value as serviceable lithographic stone. All the beds are checked and jointed on an extensive scale, and this renders it difficult to obtain blocks of usable size for lithographic purposes.

The lithographic beds are quarried at an opening on the land of Dr. W. H. Gable in the northwest quarter of the southeast quarter of section 27 about half a mile northwest of the Lewis quarry. The lithographic beds here, as elsewhere, are remarkably durable as evidenced along natural fissures. Detached blocks which bear evidence of long exposure, ring when struck with the hammer and show slight indication of surface softening and disintegration. An average sample was taken from the Gable quarry and analyzed. The results were as follows:

Insoluble	2.21
Iron and alumina	3.82
Calcium carbonate	90.17
Magnesium carbonate	1.03
Moisture and organic matter	2.63
	99.86

A. O. ANDERSON, Analyst.

The sections exposed at St. Ansgar and Mitchell show no new facies. The dolomitic beds are worked the most though the lithographic beds are available at the latter place. At Otranto only the lower beds exposed in the Chandler section are known, while along the Little Cedar the middle to lower beds are available.

Near McIntire the following section exposed near the mill southeast of town may be taken as a fair average. The beds exposed are as follows:

		FEET.
5.	Loess and soil	6
4.	Limestone, decayed, magnesian, granular	2
3.	Limestone, laminated, lithographic stone	3
2.	Limestone, solid, granular and fossiliferous	1¼
1.	Limestone, thin-bedded, partly lithographic stone, variable.	2

In the bed of the small creek between the quarry and the mill, there are firm dolomitic beds below the level of the above section. The entire assemblage of beds in this part of the county are supposed to be the equivalents of those exposed near the top at Osage and Orchard.

Notwithstanding the abundance of excellent structural materials available none of the quarries are of more than local importance.

The Cedar Valley limestones, as a whole, especially as developed in Mitchell county, are thoroughly indurated and are above the average in quality for crushed stone purposes. At the present time transportation facilities are not available at most of the best quarry sites.

MONONA COUNTY.

SAND AND GRAVEL.

The important sand and gravel deposits of Monona county are in the main similar to those of Harrison county; they are the old, loess and drift covered Aftonian gravels. Professor Shimek, in his report on Harrison and Monona counties in 1909, enters into a quite comprehensive discussion of this formation, and the parts of it that have bearing on the substance of this report are reproduced in the discussion of Harrison county. Duplication of that material is hardly necessary here, and the reader is referred to the first few pages of the report on that county for the general facts which relate to both.

As mentioned in the report on Harrison county, the sequence of numbers of the detailed descriptions by Shimek covers both counties. Those which follow here are all within Monona county, and the numbers will be found to supplement those previously reported. It has been convenient to arrange them here by townships.

Belvidere Township.

8. *Elliott Pit.*—This is a sand pit located in the northeast part of Turin. Sand and gravel in this pit are typically Aftonian in the cross-bedding, streaking with iron and MnO_2, the presence of silt and drift nodules or pellets and white, soft calcareous nodules, and the occurrence of mollusks in the sand and mammalian remains in the gravel. The Aftonian is exposed to a depth of about twelve feet. In the greater part of the exposure the fine sand lies above the gravel, though there is some interbedding, but near the south end a layer of coarse ferruginous gravel rests on the sand. A distinct band of bluish or reddish laminated silt was found above the sand and gravel. It is about two feet thick, and grades downward into fine sand.

There are two small pits in section 34; and a gravel pit showing Loveland in Crabb's bluff in northwest 27.

Kennebec Township.

9. *Ordway Pit.*—Located on a bluff on the southwest side of Maple river, opposite Castana. The Aftonian here rises about forty feet above the Maple bottoms and shows the following section:

		FEET.
5.	Loess, abundant on ridge above section.	
4.	Loveland	5-6
3.	Kansan drift	6-18
2.	Aftonian, fine, cross-bedded, with interstratified silt and other characteristics of typical Aftonian	5-8
1.	Aftonian ferruginous gravel, in part forming conglomerate plates	3-4

Both this and the following section are on a sloping Kansan bench with no overlying loess. In the northern part of the same pit a layer of gravel three feet in thickness lies under the sand. Several large bowlders rested on this gravel layer.

10. Ordway Well.—This is excavated on the same terrace-like slope about one-eighth of a mile northeast of the pit. It shows the presence of Aftonian sand, with a little gravel, underlying Kansan till and resting on a deep bed of Nebraskan drift.

16. Weniger Pit.—A sand pit located in the east half of section 18, in the bluffs facing the Missouri valley. It shows eight feet of sand and gravel, on which typical Kansan drift rests unconformably. The Aftonian here rises about forty feet above the Missouri bottoms.

MONROE COUNTY.

Sand and Gravel.

Terrace gravels occur along some of the larger streams in Monroe county, but the deposits are somewhat interrupted. Large quantities of excellent material may be obtained from Des Moines river in the vicinity of Eddyville, both from the present stream channel and from the flood plain. The Chicago, Burlington & Quincy Railroad Company has put down a number of test pits along Whippoorwill creek in Wayne and Guilford townships. The pits show from ten to twelve feet of gravel. The gravels are evidently stratified and in some of the pits show materials fairly free from silt and clay, which are suitable for railway and road work. These gravels form a terrace some twenty to thirty feet higher than the present flood plain. As a rule, the terraces at lower levels are composed of fine gravel with predominating sand and some silt and are not so well suited for road work. The lower terraces are usually covered with alluvium from zero up to four or five feet in thickness.

The older gravels are not available. The principal source of supply is Des Moines river outside the confines of the county.

Stone.

The Saint Louis limestone outcrops along the principal streams in the immediate vicinity of Eddyville. The harder beds afford excellent materials suitable for road and concrete work, but only limited quantities are available on account of the excessive stripping when the beds are followed into the bluffs.

MONTGOMERY COUNTY.

SAND AND GRAVEL.

The only deposits of sand and gravel in Montgomery county which are of any importance are found in East Nishnabotna river. These are very small, however, and are of practical value only from Stennett to a point a short distance below Red Oak. Other streams have some sand and gravel, but in such small amounts as to be of no economic importance.

Sand which is practically uncemented and usable for structural purposes is occasionally found in the Cretaceous beds which underlie the surface deposits. In the upper portion of the Cretaceous between Coburg and Red Oak the conglomerates and loose sandy and pebbly layers are quite accessible and could be made available. At the former place the combined section as given by Lonsdale in his report* on the county, is as follows:

		FEET.
5.	Loess	12
4.	Conglomerate or pudding-stone with hard limonite and clays as matrix; thickness variable	9
3.	Gravel and sand in alternate cross-bedded layers	3
2.	Gravel and sand, very coarse	2
1.	Sand and gravel; light colored; variably cross-bedded	18

On the top of a high knob in section 22, Douglas township, is a large deposit of clean sharp sand. A similar bed has been opened on a slope about a mile east of Villisca. The material from both of these has been used for mortar and plaster.

In section 17 of Grant township the Chicago, Burlington & Quincy Railroad has a pit from which the loose material from the Cretaceous conglomerate is being removed. This conglomerate, or "pudding-stone" lies on the east slopes of the East Nishnabotna almost continuously from Red Oak to the southern boundary of the county, and has an average thickness of some twenty-five feet. In places it is firmly cemented by limonite and again the pebbles and sand are loose.

*Iowa Geological Survey, Vol. IV, p. 419.

In none of the deposits named do the materials occur in any quantity. For work of any importance outside sources of gravel and sand must be relied upon. At present most of the material shipped in comes from Platte river in Nebraska.

The Stennett limestone and the Cretaceous and Coal Measures shales are possible sources of road material. The gumbo clays have been burned in the past for railway ballast, and it would seem that they might be made to serve a useful purpose in road-making.

STONE.

Strata belonging to the Missouri stage of the Upper Carboniferous underlie the whole of Montgomery county. They are covered in part by Cretaceous beds, but are exposed at a large number of places along the principal streams. Carboniferous strata are the country rock of all lowlands, where the drift or alluvial beds rest directly upon them.

The principal exposures of economic importance occur along East Nishnabotna river and Walnut creek in the western half of the county, and on the lower course of Tarkio river and the upper course of the West Nodaway in the eastern part of the county. The quarry industry is not at present in a very flourishing condition, but stone suitable for common building purposes has been taken out at times from a score or more of different places. Many of the quarries that were formerly worked on a scale of some magnitude are now abandoned and good, unobscured sections are somewhat difficult to find.

The town of Stennett in the southern part of Sherman township is the center of what have been the most extensive quarry operations in the county. Lonsdale* records in his report on Montgomery county in 1894, nine working quarries in this district. Some dressed stone was produced and large quantities were shipped. At present stone is being taken from but one opening, the W. Stennett quarry, and this is sold locally. The section here as given by Lonsdale is as follows:

*Iowa Geological Survey, Vol. IV, 1894.

		FEET.
12.	Soil and loess	8
11.	Clay, residuary, red to brown in color	1⅓
10.	Limestone, weathered	2
9.	Shale, argillaceous	½
8.	Limestone, hard	1⅔
7.	Shale, clayey, buff to gray	3½
6.	Limestone, earthy, in part ocherous	2½
5.	Limestone, shaly	3
4.	Limestone, impure, earthy	1
3.	Limestone, hard, subcrystalline	⅔
2.	Limestone, contains much dark chert	½
1.	Limestone, in thin layers	6

Number 8 is persistent in all exposures in the vicinity, and is one of the principal ledges used. It is hard, blue in color, and a very good building stone. As observed in the quarry, the other beds appear less stable under weathering influences. Occasional thin bands of shale separate the limestone ledges in most exposures. An overburden of two to eight feet of soil and loess is usually present, and this, along with an average of five feet of worthless stone, must be stripped.

The principal quarries that have been worked here are located in sections 22, 26 and 27, of Sherman township. There are considerable areas in this vicinity in which the limestone is not far beneath the surface, and where it would be available without an excessive amount of stripping. Near the southeast corner of section 21, and in section 22, along a small tributary, is exposed a thickness of some twenty-six feet of limestone strata, the principal layers of which are lower than the Stennett quarry section given. A maximum depth of twenty feet of loess covering is present a little back from the present face.

Following is the section at the old McCalla quarry, in the southwest quarter of the southeast quarter of section 23, Sherman township:

		FEET.
13.	Soil	1
12.	Limestone, decomposed, Fusulina-bearing	1½
11.	Clay, for the most part residual	1⅓
10.	Limestone, hard, light to dark gray	⅔
9.	Limestone, with black flint, hard in central part; many Fusulina present throughout	6
8.	Limestone, buff to brown in color, Fusulina irregularly distributed	1

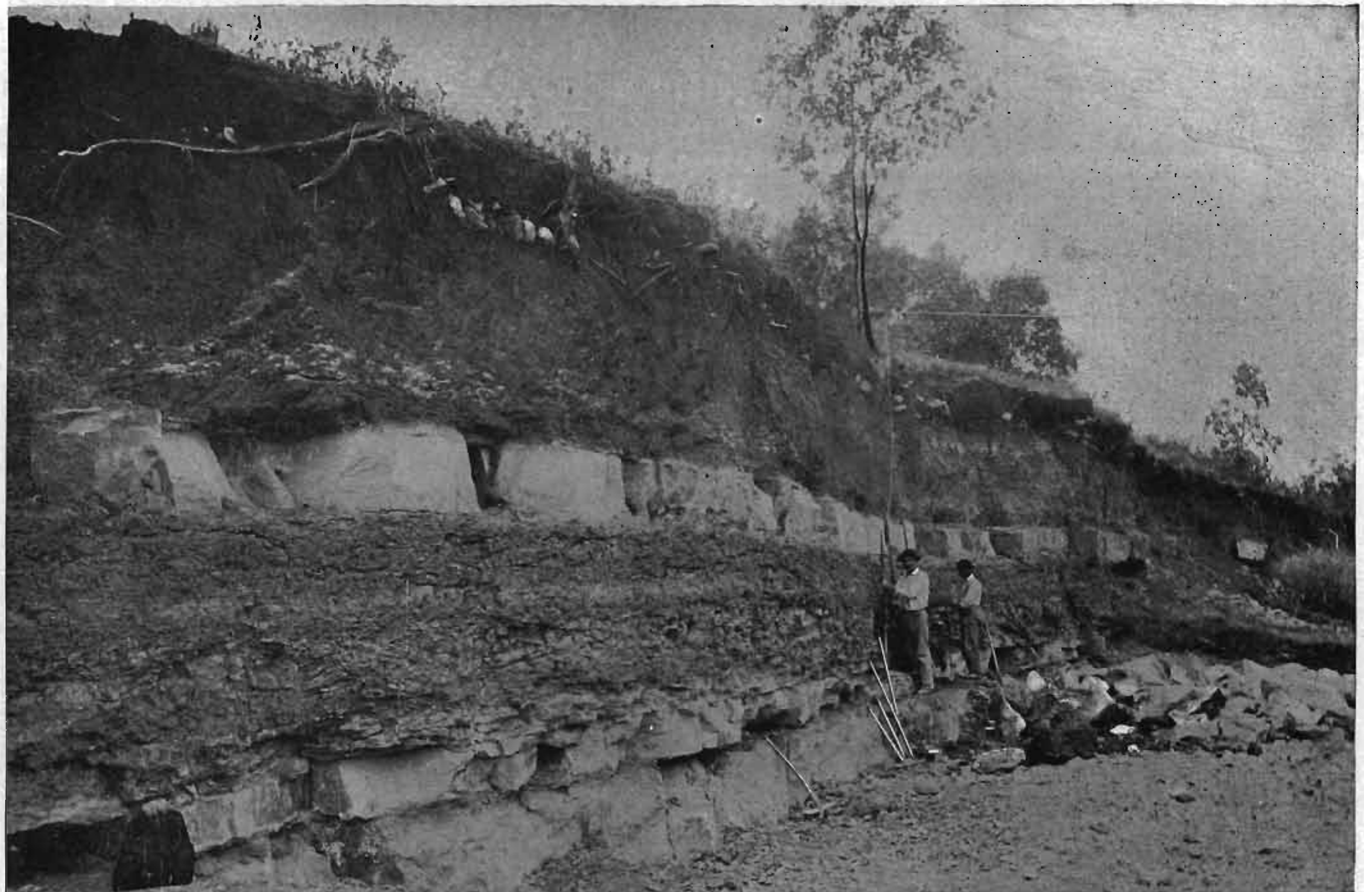


PLATE XXXIX—Typical exposure of the Missouri stage of the Coal Measures. Fate quarry, Stennett, Montgomery county. The stripping and interbedded shales and clays make quarrying unprofitable.

		FEET.
7.	Limestone, light, 12-inch ledges; weathered	1⅔
6.	Unexposed, probably similar to No. 9	4
5.	Limestone, thin layers, shaly partings	5
4.	Limestone, hard, grayish brown; concretions of dark flint disseminated in central portions	1½
3.	Limestone, earthy	⅔
2.	Shaly partings	⅙
1.	Limestone, buff, earthy	1

Several ledges of usable stone are here available, and the covering is not thick.

Limestone has been quarried along Walnut creek, in the east half of section 1, Walnut township. The following section was formerly exposed:

		FEET.
6.	Soil and residual material	5
5.	Shale, buff to gray	⅔
4.	Limestone (decomposed), and shales	5
3.	Limestone, flint-bearing	1⅙
2.	Limestone, hard, grayish, in two ledges; very fossiliferous, dimension stone	1½
1.	Limestone, "blue layer," dimension stone	1⅓

Near Climax in the southeast quarter of section 19, West township, some ten feet of the Missouri strata under a heavy overburden were formerly quarried. They were:

		FEET.
7.	Soil, loess and drift	18
6.	Limestone, hard, drab, fine-textured, not fully exposed	1
5.	Limestone and shale, marly	3
4.	Shale, argillaceous, gray	2
3.	Limestone, bluish, dull, earthy	1
2.	Shale, argillaceous, gray	1
1.	Limestone, light blue, hard; dimension stone	1½

Two or three small quarries have been worked along Middle Tarkio river and its tributaries in section 20 of Scott township, and stone has been taken out at other points northward to Stanton. The stone used came from two ledges, each about one foot thick, and separated by six inches of marly shale. The upper layer is a yellowish gray, earthy limestone; the lower, a hard, grayish blue limestone, containing particles of iron pyrite which are often oxidized to the brown hydroxide or iron rust. Both strata are suited for undressed dimension stone and for foundation work.

A small amount of stone has been removed from an opening one and one-half miles east of Villisca. But one bed of value occurs here, and it is covered with several feet of shales. From this point northward, the Upper Coal Measures can be traced along the West Nodaway to the north county line.

Suitable stone for quarrying is found in the vicinity of Grant (Milford) in Douglas township. Here a number of quarries have been worked, but from only one is stone now being removed. The section is almost entirely limestone, and the ledges vary from a few inches to more than three feet in thickness. The old Fisher quarry, located near the south edge of section 3, and west of the river, is now worked intermittently by Mr. Richard Berry. The strata now exposed are:

		FEET.
6.	Soil, loess, oxidized drift, sand and gravel	5
5.	Shale, plastic, gray to yellow	1½
4.	Shaly limestone, fossiliferous, thinly laminated and of no value	1
3.	Shale, soft, yellow	1-2
2.	Weathered limestone, nodular, yellow, marly texture, flint in lower portion, distinctly separated from No. 1	1⅔
1.	Limestone, filled with Fusulina which stand out on weathered faces. Many small and large flint nodules often including the Fusulina; yellow to gray in color, numerous cavities lined with calcite. One solid ledge and apparently of a fair grade	3¼

The rock is exposed at the mill dam at Grant, and at other points up the river into Cass county. It has been quarried directly across the Nodaway from the Berry opening. No stone has been taken out for some time, but there is an old face some 600 feet in length along the hillside. The covering is not excessive.

It is obvious from a casual inspection of the sections given above that considerable limestone of usable quality is present in Montgomery county, but it is equally obvious that the excessive amount of materials which must be wasted in the form of overburden and interbedded shales and clays make economic quarrying for road and concrete materials unprofitable.

MUSCATINE COUNTY.

SAND AND GRAVEL.

With the exception of the Mississippi river deposits the sand and gravel resources of Muscatine county are extremely limited. Some gravel has been obtained along the railroad in the east bluff of Mad creek, near the northwest corner of section 25, in Muscatine township. It has been used for ballast on the railroad. Other pits have been opened near this place, the most important of which is located on the Sinnett Estate in section 24 of Bloomington township. Here the gravels attain a thickness of forty feet. The material is variable in texture and composition, ranging from sand to coarse gravel carrying some cobblestones and more or less silt and clay throughout. The deposit is overlain by loess and wash from zero to ten feet in thickness. It is well adapted for road work, but carries too much dirt for use in concrete. From the outcrops it appears that four or five acres of these gravels are easily available on the west side of Mad creek. A somewhat more extensive deposit of gravel and sand occurs under the Kansan till in the bluff near the center of section 6 in Fruitland township. This gravel is in part sand. Some years ago it was used in macadamizing the Hershey Avenue road for a distance of three miles west of the city of Muscatine. In the railroad excavation made west of Stockton, gravel was uncovered in the west side of a low flat hill which lies to the south of the road and was used for ballast on the road bed. The deposit was not far from twenty feet in depth at one place. Most of the pebbles consist of Devonian limestone.

River Sands and Gravels.—Mississippi river has deposited enormous quantities of sand and gravel in its channel. The proportion of gravel to sand is, however, small. Local supplies for Muscatine and other towns are obtained from the river, the material being pumped into barges which are towed out into the river.

Practically all of that wide flat plain below Muscatine known as Muscatine Island, and also several square miles to the west and north of Muscatine Slough, which forms its western boundary, is probably underlain by sand and gravel. In the southeast corner of section 16, Fruitland township, these materials are being removed by the Northern Gravel Company of Davenport. The sand is being pumped out. The water level in the pond is about six or eight feet below the general level of the plain. This sand is clean and bright, and is being used in all kinds of construction work.

Stone.

While stratified rocks of Devonian age are believed to form the country rock immediately under the glacial debris over the larger portion of the county, exposures are practically limited to Moscow, Sweetland, and Montpelier townships. Unimportant outcrops are also known to occur in the city of Muscatine. The lowest limestone beds exposed are prevailingly brecciated in character, and carry a high percentage of calcium carbonate, being almost pure limestones, and are nonfossiliferous. The upper limestone beds are rich in organic remains and oftentimes are magnesian to dolomitic in character. Quarrying operations have been carried on only on a small scale, save near Mississippi river where considerable material has been used for Mississippi river improvement work by the Federal Government. A composite section compiled from the outcrops in the vicinity of Moscow is about as follows:

		Feet.
6.	Drift and surface detritus of variable thickness.	
5.	Limestone, hard, gray, in rather irregular ledges, fossiliferous and somewhat brecciated; mixed with the rock below	5
4.	Limestone, softer than above, mostly concealed, with frequent crinoid stems above; blue and fine-grained ledges farther down, slightly crushed or brecciated in the lowest part; fossiliferous	29
3.	Limestone, strong, gray, in moderately heavy and regular ledges, slightly broken or brecciated in a few places, fossiliferous	8
2.	Limestone, coarsely brecciated, emitting a faint, bituminous odor under the hammer	4
1.	Limestone, white, evenly bedded, in thin layers	4

Numbers 1 and 2 are exposed only along Sugar creek northeast of Moscow, while the upper members appear west of the town. Quarries have been operated from time to time at several points.

Numerous outcrops of Devonian limestone somewhat higher in the series than those about Moscow may be viewed along Mississippi river and its immediate tributaries from the eastern border of the county to the city of Muscatine. The best developed and least obscured sections occur in the vicinity of Montpelier and along Pine creek.

Along Sulphur branch, a creek which enters the Mississippi about one mile east of Montpelier, the following beds appear:

		FEET.
7.	Drift and soil, of variable thickness.	
6.	Limestone, weathered ledges, with scattered casts of cup corals	$2\frac{1}{3}$
5.	Limestone, black, carbonaceous, with Stromatopora	$\frac{1}{4}$
4.	Limestone, bluish, dolomitic, thick-bedded, with fossil casts	9
3.	Shale, soft, fossiliferous	1
2.	Limestone, in thin hard ledges, with small, kidney-shaped or cakelike Stromatopora	2
1.	Limestone, dolomitic, bluish, finely granular; fossiliferous, exposed	4

Near town number 1 in the above section is seen to rest on a bluish clay of unknown thickness. The upper beds have been quarried, number 4 having been quarried most extensively. These ledges exhibit some of the characteristics of a "freestone," breaking almost as readily in one direction as in another. The bedding planes are even and well marked. The lowermost ledge of number 4 is two feet in thickness. When subjected to weathering influences, the beds tend to become clayey.

Near the center of section 21 in Montpelier township, large quantities of material have been obtained for the construction of wing-dams farther down the river. The section exposed at this point and near vicinity is as follows:

		FEET.
8.	Drift and soil, variable thickness.	
7.	Limestone, hard, brown, weathered, apparently somewhat brecciated and containing fragments of Stromatopora	4
6.	Concealed	5+
5.	Limestone, weathered, apparently brecciated, with a large Stromatopora above a dark carbonaceous layer near the base, carrying casts of an Amplexus	4

		FEET.
4.	Limestone, dolomitic, almost white, bluish, finely granular and evenly bedded; in heavy ledges, the lowermost nearly four feet thick, rapidly turning darker blue and yellowish on exposure; oblique, curving fracture in some places, fossiliferous	8
3.	Limestone, hard, in thin layers and rough, but straight layers above; fossiliferous	2½
2.	Concealed	3
1.	Limestone, dolomitic, bluish or gray, with Cystodictya	2

Number 1 disappears under the creek and also under the water in the river.

Sections along the lower course of Pine creek are practically the same as the one just given. Higher up the stream beds lower in the series appear. Possibly the most extensive succession may be studied in an old quarry in the south bank of a small tributary of Pine creek in the northeast quarter of the southeast quarter of section 4 in Montpelier township.

CARPENTER QUARRY SECTION.

		FEET.
8.	Drift and soil, of variable thickness.	
7.	Limestone, much decayed and appears to be a yellow clayey material; fossiliferous	7
6.	Limestone, hard, solid ledges, a foot in thickness, in places highly fossiliferous	3
5.	Limestone, fine-grained ledge, cut by a network of vertical plates made up of material like that in the ledge above	¾
4.	Marl, earthy	⅙
3.	Limestone, fine-grained, gray, thin-bedded above, thicker bedded and dolomitic below, Gomphoceras and a reniform Stromatopora in upper part, Cystodictya below	2
2.	Concealed	5
1.	Limestone, gray, in somewhat irregular ledges, fossiliferous, exposed	3

Numbers 3 to 6 are the beds developed in the above quarry and in the immediate vicinity.

From the mouth of Pine creek, crops of Devonian limestone continue to the city of Muscatine, but none are of sufficient importance commercially to merit individual mention.

The upper Devonian beds exposed in the county constitute the Sweetland Creek beds of Udden. They are prevailingly argillaceous in character, although they contain certain hard magnesian to dolomitic layers below. The well indurated beds are neither sufficient in quantity nor sufficiently accessible to be worthy of consideration. Certain of the shale members are highly bituminous while others contain a considerable percentage of lime phosphate.

The Des Moines stage of the Coal Measures occurs in a narrow outlier along Mississippi river about five miles in width and extending from Scott county to a point about three miles west of the city of Muscatine. The beds which represent the Des Moines are largely mechanically deposited sediments, ranging from coarse conglomerates to fine shales and fire clays, with unimportant seams of argillaceous limestone and coal. The sandstones constitute the most important beds and occur in rather thick lenses. They are variable in texture, coloration and state of induration. On account of their inconstancy they are not as highly prized for structural purposes as might otherwise be the case. They have been used quite extensively in the past for foundations, retaining walls, and other structural purposes. At the present time, but little sandstone is being quarried in the county. The principal quarries are located on the West branch of Pine creek in Montpelier township, on section 21 in the river bluff in Sweetland township, and on Lowes river in section 32, Bloomington township. The quarry stone attains a thickness of sixty feet in the first quarry, is in heavy beds up to four feet in thickness, is rather fine-grained, and is characterized by peculiar, wavy, ferruginous bands, probably due to infiltration of iron.

In the second quarry, the beds are a little coarser in texture, but otherwise similar to those in the first, while those quarried on Lowes river are less ferruginous and as a consequence, lighter in color, with occasional darker layers.

O'BRIEN COUNTY.

Sand and Gravel.

The gravels of O'Brien county are very similar to those of Lyon and Sioux counties, being in the main, terraces along the streams and morainic deposits of the Wisconsin drift.

Stream Terraces.—There are gravel deposits of more or less importance along practically all of the streams of the county. Along Floyd river north of Sheldon are several openings which are now being worked. Near the pumping plant in the north edge of town are several pits which afford good material for almost any purpose. One of these, near the center of section 30, Floyd township, shows clean cross-bedded and interbedded sand and gravel under some four feet of alluvium. About twelve feet of these materials are exposed.

T. H. Macbride and I. A. Williams, who have done previous work in this vicinity, differ somewhat on the mode of accumulation. This has been gone into more fully in the report on Sioux county. Suffice it to say here that Macbride has listed all these deposits as morainic, of Wisconsin age, while Williams recognizes in addition a stream terrace which he is prone to call a Wisconsin gravel train. The openings which have been observed might lead to the conclusion that Williams is right in recognizing a gravel train, since several of them are located at a uniform height of twelve or fifteen feet above the water line, and the terrace has quite distinct features in various places.

The opening in section 30, mentioned above, and one in the northwest corner of section 21 of the same township would seem to be of morainic origin. Openings which are located in southwest 21, northeast 16, and northwest 12, Floyd township, and in northeast 7 and northwest 9 of Franklin township appear to be in the gravel train.

Along the Little Floyd southeast of Sheldon, somewhat similar gravels are exposed. A deposit reported by the owner as being twenty feet deep occurs in northwest 31, Franklin township. Near the place where the gravel is exposed fifty or sixty acres may prove productive. Various other gravel exposures may be seen along the Little Floyd. These have been observed in northwest 1, southwest 3, northwest 8, and middle 6 of Carroll township. In all of these places the material is fine gravel and sand, and is quite clean and free from iron stain.

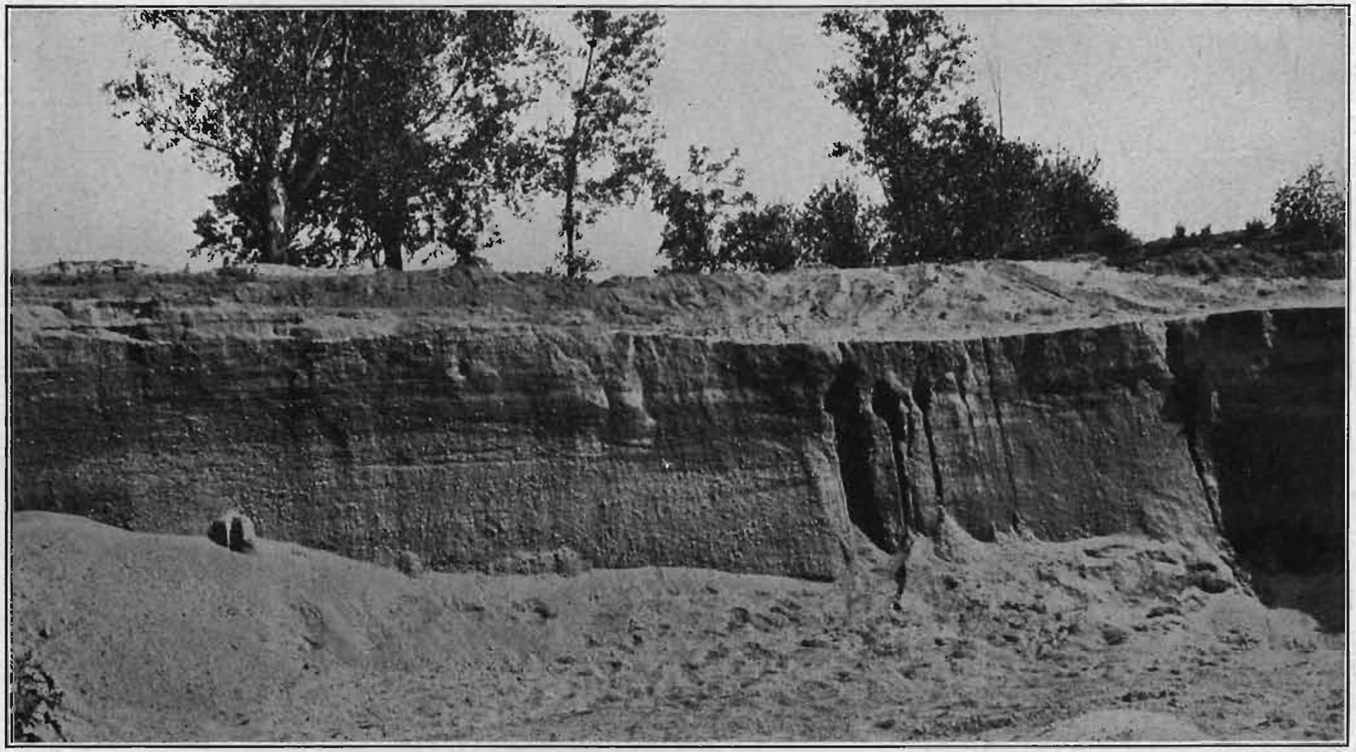


PLATE XL—Griffen pit, Sheldon, O'Brien county.

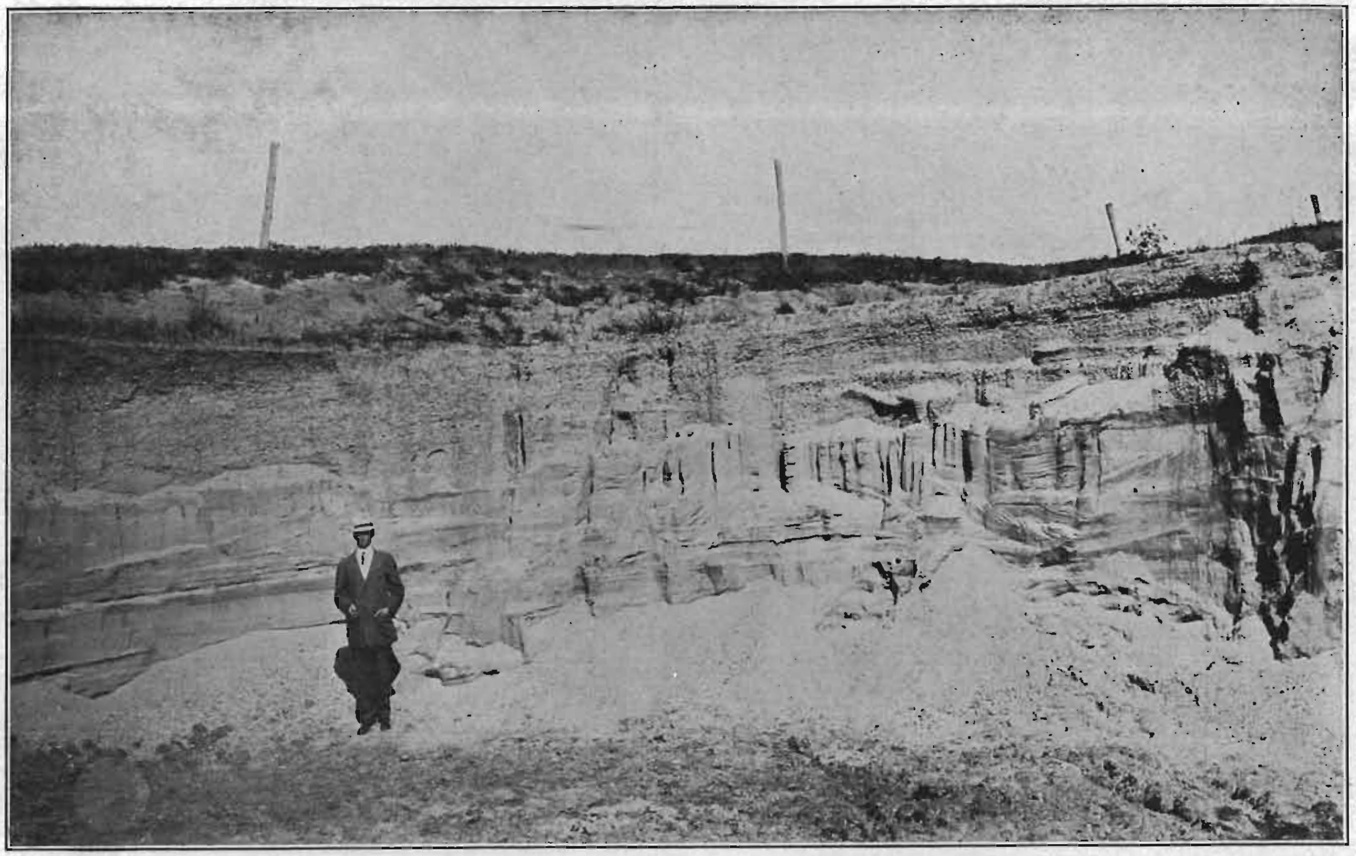


PLATE XLI—McCracken pit, showing gravel above and sand below, Paullina, O'Brien county.

Along Mill creek there is a low terrace ten or twelve feet above water all the way from southeast Summit township to the county line. The width of this bench varies from a hundred to as much as a thousand feet and in one or two places noted the width ran up to a mile or more. As far south as Paullina the openings in the terrace are very superficial, and no good section is visible without digging. In south 22, Dale township, is a good exposure in a bend of Dry river. The top of the terrace here is about twelve feet above water, and doubtless corresponds to that along Mill creek. In section 22, Dry run has gouged into its bank and uncovered about four feet of fine to medium gravel with streaks of sand interbanded. Several minor exposures a foot or so in depth along Mill creek show material very similar to this, and it is probable that the section described above is typical for the whole terrace.

In section 3, Union township, along the road east of Paullina, is an open pit from which the town obtains its supply. The top three feet shows excellent fine gravel, clean and sharp, in which banding is evident, but not prominent. Below this are about eight feet of clean sharp sand, in which stratification and cross-bedding are conspicuous. Along the creek there are several places where virtually the same section may be seen. Two prominent ones are two or three hundred feet north of the pit mentioned, and a short distance southeast of the bridge on the line between sections 3 and 10. In the road on the east line of section 33, Dale township, and just south of the road on the east side of the stream in northwest section 3 of Union township, very similar gravel can be seen.

The largest piece of terrace along the creek is located on the east side of the stream near the middle of section 28, Union township. At this place the bench is about a quarter of a mile wide. The creek has cut into it and exposed the following section:

	FEET.
Loess and soil	10-12
Gravel and fine sand, mixed	10
Coarse sand and some fine gravel	7
Sand, fine and clean	10

There are fifty acres or more in this terrace through section 28, which it seems will run fifteen to twenty feet deep in gravel. The depth of cover varies largely, the upper limit being up to fifteen feet. This terrace could readily be opened on a large scale. A spur track from Paullina would afford a ready means of access and would not be a difficult engineering feat to accomplish.

Through sections 33 and 34 of Union township there are remnants of the terrace all along the river, but they are small and not continuous. It is highly probable that there is gravel and sand in all of these.

A description has been given previously of an opening of gravel along Dry run in section 22 of Dale township. On the south side of the stream here there is another higher terrace rising ten or twelve feet above the one in which the former mentioned exposure occurs. This upper terrace has been opened and sand and gravel from it are being used in the neighborhood. There are exposed here some eight feet of coarse and fine gravel intermixed, the whole being much iron-stained. The cover at the open face is one to two feet of pebbly soil, but this apparently deepens back into the hill. These gravels are not at all the same as the ones in the bend of the creek farther west as described heretofore. They are much older, much coarser, and only roughly stratified. A distinct band about six feet from the top separates the materials into two zones; the lower one coarse and apparently laid down by water having a high velocity, and the upper noticeably finer, as though the velocity had been greatly reduced. This upper terrace can be distinctly made out as far as the northeast corner of section 23, above which point it becomes indistinct and blends with the upland.

At the few places where the lower light colored gravel and sand was found in sections 28, 27, 23 and 13 of Dale township, and at two or three other points along Dry run, they had been gouged into by the stream in its present flood plain and were covered by alluvium up to eight or ten feet in depth. The older iron-stained gravels, as noted principally on the south side of the creek in sections 27 and 26, occur in a conspicuous terrace above these lighter materials. This upper terrace is very prominent on the south side of the creek throughout sections 27, 26 and 24, but is almost indistinguishable on the north side. After passing into section 13 that portion of it on the south side loses its identity, as it also does as it passes into section 28. In the southwest part of the latter section the lower, lighter colored gravels form the terrace, and continue to be the bench materials on down south and east of Paullina.

A few small exposures of gravel and sand may be seen along Mud creek in the northwest portion of Union township, but these are small and not at all important.

Along Nelson and Willow creeks are low terraces which have been opened in a few places. The one along Willow creek is perhaps the most prominent and is quite continuous up the creek to section 20 of Liberty township, in which it loses its identity as a terrace. Above this point the creek flows through a valley with gently sloping sides.

Along Waterman creek the terraces which have been noted along the other streams are absent. The topography of the stream is erosional. Gravels are exposed and used at many points, especially from hilltops bounding the valleys. Likewise toward the head waters of many of its branches extensive beds of sand and gravel overlying the drift and with loess covering are common. Of this stream, Prof. I. A. Williams says, "Along the Waterman a drift terrace appears some twenty feet above the stream. It is usually capped with coarse gravel which is seldom thick enough to be important. The drift itself is often very gravelly and makes good roads. Gravels are, however, distributed often in heavy beds in the flood plains of these streams. All of these streams are vigorous, and local beds may be found in the channels and exposures in convex sides of curves in the stream channel. These beds are often beneath heavy alluvium, but nevertheless are ample and of great value locally." The hilltop gravels mentioned by Williams may be seen in northwest 3, Waterman township, in the road between sections 27 and 34, Grant, and at many other points northward to the pits northwest of Hartley that supply that town.

As Sutherland is approached from the east, gravelly knobs and benches appear along Murray creek in sections 16 and 17, Waterman township. In southwest 8 and in section 7, east and northeast of town, a bed of clean, fine gravel, fit for cement work, underlies considerable areas along the small streams. Pits are open along the road in the east half of section 7 and in the edge of town.

Drift Gravels.—The town of Calumet obtains its supply of sand and gravel from a huge knoll at the northwest corner of section 22, Liberty township. The top of this knoll rises fifty feet or more above the surrounding country, and seems to be practically all gravel. Where it has been opened on the north side there is a foot or so of very dirty gravel, or very gravelly dirt underlain by gravel and sand. The latter is coarse above and grades into finer below. The thickness varies from five to eight feet. Below this is a layer of fine, clayey, iron-stained sand varying in thickness from one up to five or six feet, resting upon four feet of very coarse gravel. This latter is much iron-stained and so firmly cemented as to be almost a conglomerate. Underlying this coarse gravel is a fine gravel which is very markedly cross-bedded, the beds lying at an angle of about 30°. There are perhaps ten feet of this below the coarse gravel. The lower fine gravel has the appearance of being markedly older than the materials lying upon it. Above the upper line of the former there are thin streaks of sand here and there which are absent below. The lower portion is more deeply iron-stained than that above. This knoll is in a ridge which runs in a general northwesterly direction and has all the characteristics of a moraine. To the west the surface is quite flat and rolling for a considerable distance; to the east the country continues hilly for a few miles.

Reworked Materials.—Sand and gravel bars of greater or less extent are present in practically all the streams of O'Brien county. These bars are, however, of little importance from a commercial standpoint. They are utilized in several places as a source of local supply where the terrace materials are not readily available.

OSCEOLA COUNTY.

Sand and Gravel.

The deposits of sand and gravel in Osceola county are from a geological standpoint practically all of one kind, viz., outwash gravels from the Wisconsin glacier. These deposits occur along the present streams, in the channels of ancient streams which are now recognizable as such only to the trained geologist, and as upland deposits laid down by the ice.

Prof. T. H. Macbride, in his report* on this region in 1900, has the following to say in regard to the origin of these gravels:

The terrace or gravel deposits * * * are all laid down with uniformity more or less pronounced, are all stratified, their materials assorted, arranged and re-arranged as by aqueous agency. The materials besides are all water-worn and their peculiar distribution, as we shall presently see, can lead to no conclusion other than that these deposits were laid down as the debris of former streams whose channels even yet may here and there be noticed, and measured by the islands and sand bars they have left behind. These streams were glacial streams; they were coincident with the final retreat of what we have been calling the Wisconsin sheet when it had, in this region at least, been for many years reduced to no more than a series of gigantic glaciers lying in the constructional valleys of which mention has been made. As every one knows who has watched the behavior of even the smallest streamlet, the finer materials are always swept away, deposited far down the stream, while sands and gravels are piled up in regular order wherever the valley widens or the current becomes in any locality for any reason less efficient. The streams that accumulated Milford sands (a deposit in Dickinson county analogous to those in Osceola) seem to me to have been possibly, in part at least, superglacial streams; they passed along on top of the ice. No streams in volume adequate to the effect could have passed down the valley of the "outlet" without showing more characteristic signs of erosion than now appear. But the deposits in question begin near the mouth of the outlet as if at the time of their deposition a glacier lay in all the valley occupied by the present lakes, extending even far down the outlet. Over this icy mass swept down the stream or streams that brought in part at least the debris that fills the Milford valley. It may be remembered in this connection that glacial ice, especially morainic or marginal ice, is seldom pure; it is often covered with morainic materials filled

*Iowa Geological Survey, Vol. X, p. 221.

with sand bowlders and the gathered accumulations derived from the surface of its transit. It is difficult on any other theory to account for the distribution of the deposits which seem in other places to represent the formation now considered—for they are scattered over our entire area, often, generally, far above the course of any present drainage system, entirely out of reach of any recent waters. Yet they are all water-laid, stratified, cross-bedded even, in unmistakable fashion. In Osceola we have the great Ocheyedan mound, not to speak of others, the upper part of which, 150 to 170 feet above the present stream, is made up of stratified sands and gravel. More remarkable still is the great pile of such debris which forms the famous Sibley gravel pit. Here is a deposit twenty or thirty feet in thickness far away from any present water channel, but plainly of water-laid materials, resting unmistakably upon the uneven surface of the Wisconsin drift, * * * the only explanation of the gravel pit is to be found in the carrying power of some broad drainage current flowing across the Allendorf moraine to find its outlet in the broader valley of Otter creek as it widens a mile or two southeast of Sibley.

Of the outwash gravels mentioned by Macbride, several exposures may be seen in the vicinity of Sibley. Just at the eastern edge of that town are two open pits, one being worked by the city and the other by the railroad. In the city pit about fifteen feet of gravel are exposed under two feet of cover. The top is coarse, very much iron-stained gravel, varying in depth from three to six feet. Below this is interbanded gravel and sand. The gravel is mostly fine, with here and there a streak of pebbles up to four or five inches in diameter. Stratification is quite distinct, but there is no cross-bedding. Up to ten feet of this latter are exposed. This material is on the whole clean and sharp, but there is a slight iron-stain noticeable throughout. The bottom four feet exposed is coarse, iron-stained gravel, having pebbles up to three and four inches in diameter. Perhaps fifteen acres of the city's property will still yield the full depth of gravel as exposed, and to the west several acres more, which are plotted as city lots, would doubtless yield the same material.

In the railroad pit, south of that owned by the city, the same section is exposed, the cover here being perhaps a little deeper. In the "forty" in which this is located, perhaps fifteen acres

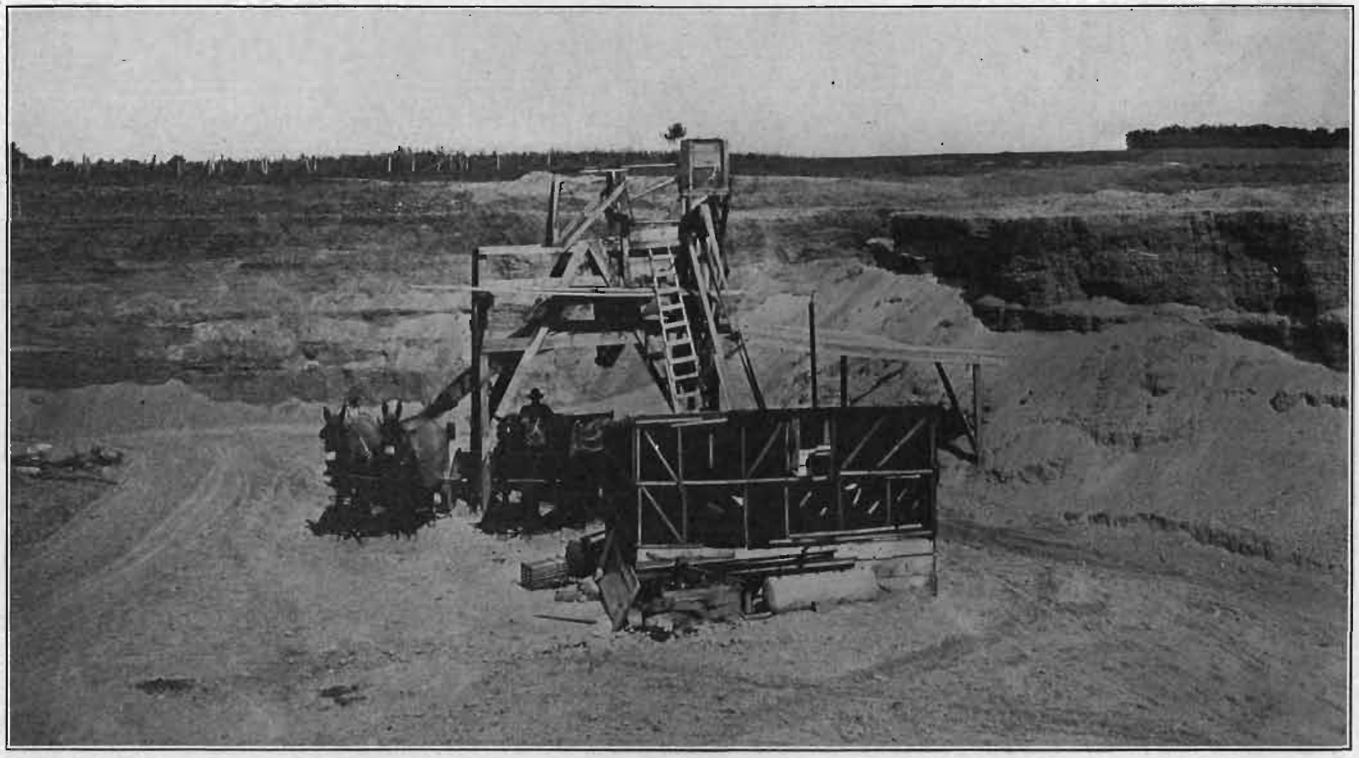


PLATE XLII—City gravel pit showing elevator and loading chute. Sibley, Osceola county.

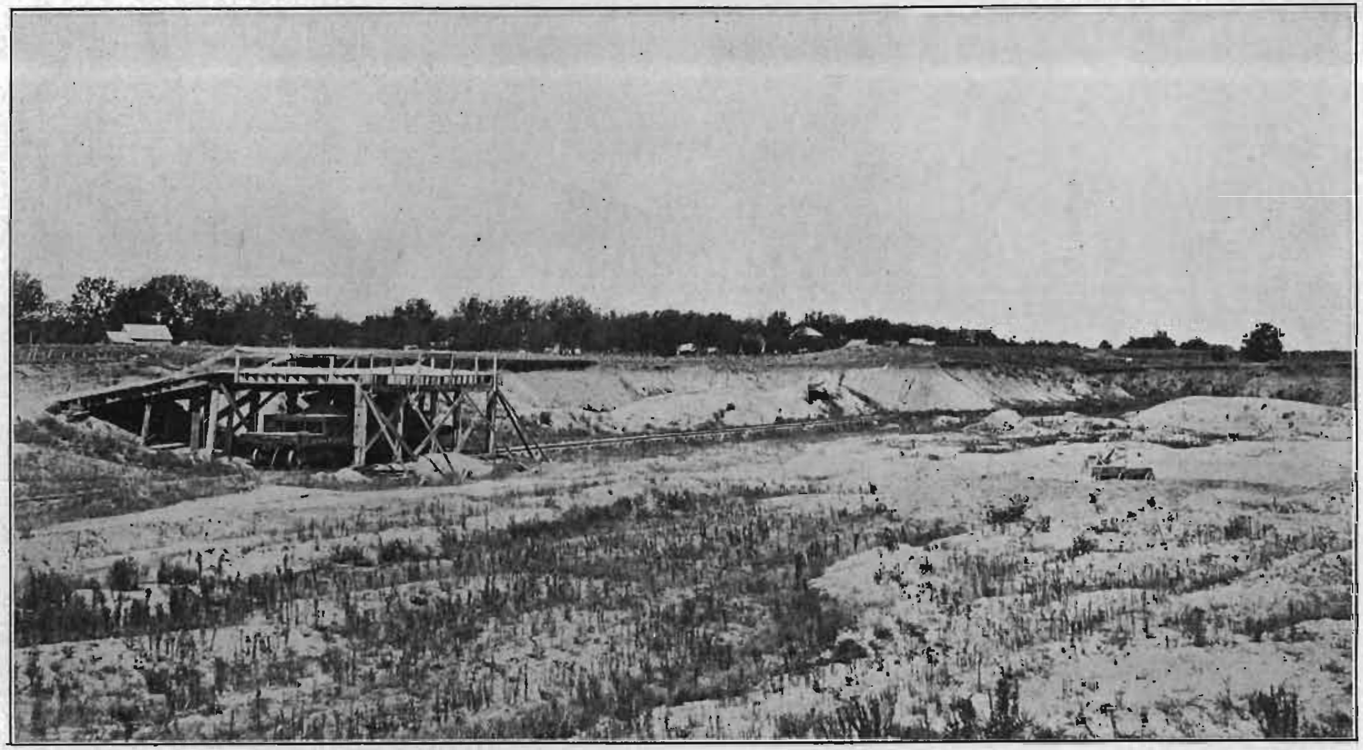


PLATE XLIII—Chicago, Rock Island and Pacific Railway pit showing loading trap. Sibley, Osceola county.

more are available. On the west and south of these property lines a total of twenty-five or thirty acres are probably underlain by the same gravels, some eight or ten acres of which are now plotted in town lots.

The Rock Island Railway has a pit near the northeast corner of section 30, East Holman township. About twenty feet are open to view here under five or six feet of cover. This is practically the same material as shown in the city pit at Sibley. South and west of this opening is a flat area some sixty acres or more in extent, all of which is probably underlain by gravel.

Other minor exposures are reported in various places over the territory between Sibley, Allendorf and Gopher. These seem to bear out the truth of the theory of Macbride stated previously. It is highly probable that gravel under varying amounts of cover might be found over an area of fifty or sixty square miles east and southeast of Sibley. Sufficient material for road surfacing and concrete work in this area are apt to be found within a short distance of where it is needed if a little careful prospecting is done.

Along Otter creek in the southwest portion of the county many evidences of the gravel bench formed by the flood waters from the melting glacier may be seen. Between Ashton and Ritter the terrace is especially prominent, and several openings show the quality of the materials. In southeast 21 of Gilman township is a small open pit. This shows a face of seven or eight feet consisting of fairly coarse gravel at the top and grading into finer materials below. There is practically no stripping, and the whole is slightly iron-stained. This material has nearly all the characteristics of the sections exposed at Sibley. Through sections 21, 28 and 29 of Gilman township the portions of the terrace which give promise of yielding gravel will aggregate in the neighborhood of 150 acres. There are some promising opportunities for commercial development here, as this section is easily accessible by railroad. This same bench seems to continue on down the creek and into O'Brien and Sioux counties. Several small openings in shallow road cuts and in the stream show the presence of gravel all the way. Detailed prospecting would probably demonstrate the accessibility of enormous quantities.

There is no doubt that Ocheyedan river was an outlet for large quantities of water flowing away from the Wisconsin glacier. It flows through a broad flat plain which in places exceeds a mile in width, and is bordered on both sides by morainal hills. At many places there are slight elevations above the general level, evidently islands and sand bars in the old channel. In many places where the roads cross these old bars, notably on the lines between sections 14 and 15, and 14 and 23, Ocheyedan township, the slight veneer of alluvium has been dissected and a gravel surface is exposed. On many of these bars the cover is very slight, and gravel and sand in amounts sufficient for use on roads and in concrete work within a few miles can be obtained with but little trouble and expense.

In the channel proper of the old stream the gravels are more deeply buried. This covering is largely alluvium, probably deposited for the most part by the old stream when its original flood had subsided and the velocity of its waters had become greatly reduced. It was ascertained, largely through inquiry, that practically every well in the whole river bottom throughout the county south of Ocheyedan is in gravel. Ditches and excavations of all sorts strike the gravel horizon at depths varying from two or three up to eight or ten feet. Six to seven feet seems to be a good average depth for the river plain proper. Natural openings of these gravels are rare, but in a few instances they may be seen in bends in the stream. Where the present river channel has been straightened in sections 26 and 35, Ocheyedan township, the material removed from the channel shows unmistakable evidence of the presence of gravel.

Little Ocheyedan river is skirted by a low terrace which furnishes a good supply of road material after the removal of two feet or so of alluvium. This may be seen on the west and south sides of section 33, Ocheyedan township, and at occasional other points up and down the stream. The most important source of gravel along this stream is a bed exposed in its lower course twenty to twenty-five feet above the water. Gravels occur on the tops of low flat hills bordering the valley and often, as in north section 10, south section 13 and also in sections 23 and 24, Baker township, as a marked flat terrace. The gravels rest on yellow bowlder clay and vary in the outcrops seen from a very gravelly till to well-sorted material. The gravels are prevailingly dirty, but make good road materials when the larger bowlders are excluded or crushed. Pits are opened in southeast section 15, Baker township. The gravels continue to the Ocheyedan valley, where they are conspicuous in sections 20, 28 and 29 of Harrison township.

Kame Gravels.—In the vicinity of Ocheyedan are several mounds or knobs which stand out prominently above the general level of the country. By far the largest and highest of these is Ocheyedan Mound, located at the southwest corner of section 12, Ocheyedan township. This mound rises some 150 feet or more above the river to the west, and is a conspicuous landmark for miles around. There are two openings for gravel on this mound, one at the crest and the other on the north side some fifty feet lower. These openings show well-sorted material, varying all the way from six-inch cobbles to fine sand. These gravels are so variable in a short space that predictions as to depth can not be made with any degree of confidence.

The town of Ocheyedan obtains its supply of gravel and sand from pits in similar, but much smaller mounds in sections 3, 4 and 5 west of town. On one of these, beside the road between sections 4 and 5, is an open pit from which a considerable amount of material has been removed. There are some fifteen feet of dirty, iron-stained unassorted gravels here.

Northeast of town near Rush lake are similar hillocks. One of these at the southwest corner of the lake shows interbedded sand and gravel under two feet or so of soil. The bedding is parallel to the surface of the mound.

PAGE COUNTY.

Sand and Gravel.

Only stream gravel and sand are available in Page county, and the materials found here are suitable for only low grade work. The largest pits are located on the south bank of the East Nishnabotna in sections 7 and 8, Grant township. Similar materials are also obtained from a small stream in section 12, Harlan township. Platte river sand and gravel are generally used for all work of any importance.

Burnt clay is mentioned as a possible road material, and this county could furnish an abundance of gumbo clay suitable for the purpose.

Stone.

The strata belonging to the Missouri stage in Page county are composed very largely of argillaceous beds, varying from typical shale to marly clays, and clayey limestones. Relatively thin beds of limestone are found in most exposures, alternating with much thicker beds of shale to such an extent as to make economical quarrying of the limestone impossible.

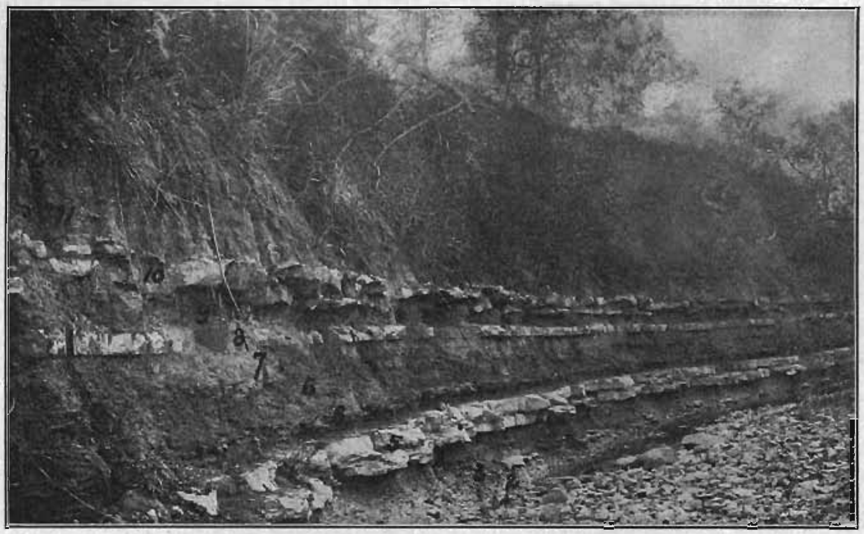


Fig. 52—Exposure of the Forbes limestone near Hawleyville, Page county.

Two distinct horizons of Missouri limestone strata are exposed in the county, one along the East and West Nodaways, and the other principally along Middle Tarkio river. Stratigraphically the latter come above the beds exposed on the Nodaway rivers, and are considered by Calvin to be the equivalents of the limestones quarried at Stennett in Montgomery and near Macedonia in Pottawattamie counties.

Limestone has been quarried at Coin in the southern part of Lincoln township, and the same strata have been worked at intervals along the Middle Tarkio to the north line of the county. In most places the outcropping ledges are displaced and weathered, and a section of any considerable thickness is seldom seen.

A new quarry opening on the farm of Mr. Burns near the southeast corner of the southwest quarter of section 22, Tarkio township, affords the following section:

		FEET.
5.	Drift	10
4.	Fusulina limestone	1
3.	Yellow shale	4
2.	Limestone, soft, yellow	⅔
1.	Blue, fine-grained, hard limestone, breaking at right angles to bedding planes into excellent blocks for building purposes. Fossiliferous, and contains occasional sphalerite grains	1⅓

Professor Calvin* gives a composite section from a number of openings in this same region and in section 27, which includes the following members, coming below those just given:

		FEET.
4.	Shale	12
3.	Limestone, soft, but of fair quality	1½
2.	Shale	3½
1.	Limestone	2

Number 1 is an excellent stone for a variety of purposes and is the ledge chiefly sought in all of the quarries. It is durable and the most important building stone in the county.

The next good exposure is to be seen in section 18, Douglas township, on a small tributary to the Tarkio:

*Geology of Page county, Iowa Geological Survey, Vol. XI, p. 430.

		FEET.
5.	Drift, maximum of	20
4.	Fusulina limestone cap above quarry ledge	2/3
3.	"Blue ledge" limestone, No. 1 of Burns' quarry section	1+
2.	Calcareous and fossiliferous bluish shale	7
1.	Yellow, marly clay, apparently weathered limestone	1¼

As stated, the "blue ledge" is the one sought at all of the numerous small quarries along the Tarkio, the associated strata being almost universally of too incoherent a nature to be of value for building purposes. This ledge lies about eight feet above the water in the Douglas township exposures while in Tarkio and Lincoln townships it appears twenty to thirty feet above the stream. Although it crops out in both sides of the valley at intervals for miles, the heavy drift covering and its association with worthless argillaceous beds that require removal, render very limited in extent the quarrying possible at any one point. From the natural outcrop it is seldom possible, with the present hand methods of quarrying, to work back over twenty feet before the overburden becomes too heavy. Locally, however, this stone has been and will continue to be a very valuable resource to the county.

On a small branch of the East Nodaway, three-quarters of a mile above Hawleyville in Nebraska township, there is an exposure of some magnitude, composed of strata which lie, geologically, below the Tarkio beds. The section comprises alternating bands of calcareous and argillaceous material. The individual members are seldom more than a foot in thickness, and it is not probable that any of them will ever possess more than a very limited local value for building purposes. Similar beds are exposed below the mill at Braddyville in section 31, Buchanan township. At both localities the Missouri beds are overlain by heavy deposits of loess and drift.

PALO ALTO COUNTY.

Sand and Gravel.

The sand and gravel deposits of Palo Alto county seem to belong to two horizons, geologically speaking, viz., the outwash materials from the Wisconsin glacier, and those derived from the Kansan drift, known in Iowa as Buchanan.

The discussion by Mr. T. H. Macbride in Volume XV of the reports of the Iowa Geological Survey, sheds a considerable amount of light on these deposits, and is worthy of at least partial quotation here. The part of his report which deals with the origin of these sands and gravels is quoted almost verbatim.

Wisconsin Gravels.—Stream Terraces.—The deposits so named are the immediate effect of the outpouring of the waters accompanying the melting and retreat of the Wisconsin ice. As the face of the ice cliff moved northward the floods of water seem to have covered the country and the gravel and sand with which the streams were charged were deposited everywhere; especially, of course, in the forming valleys and channels of drainage. Sometimes these channels were no doubt on or in the ice itself so that gravel deposits may, and often do, now appear far out of the way of any present drainage system of any sort whatever; in isolated mounds, on the flanks of hills, in low ridges athwart what were otherwise a level plain. The valley-plain of West Des Moines river is a gravel plain, all gravel of varying depth and width, from the Minnesota line or near it south to Humboldt county. The present stream is as nothing when compared to that earlier river. Des Moines river in the year of 1903 is described as high beyond the previous experience of observers, and yet it by no means covers this gravel plain. The present stream has its own flood plain which in times of freshet it may cover or erode, but this old-time valley owns no relationship to the present river. One might suppose that the action of the earlier, larger current continued not very long, but we must reflect that the erosion force in this, its upper channel, was limited by the work that must be done farther south and east, where the indurated Paleozoic formations were encountered and set bars to the agents of erosion as at this day. The result is that the gravels of that older river lie in these upper stretches largely undisturbed, slow-mouldering with the lapse of centuries.

When we come to investigate the composition of the gravel trains we discover, first of all, the evidence of the mode of their deposition. No better sections need be wished of the entire deposit than those encountered at Estherville, in Emmet county. Here one may easily see the sorting and cross-bedding resultant from the water-currents that once swept the stony debris on and down. But the materials themselves are of every imaginable source, i. e., one may find samples of rock of almost every description and of all sizes from merest pebbles to stones weighing hundreds of pounds. Some of these pebbles are of great age as such and have long been buried, subject to the slow action of waters, filtering, bearing all sorts of solvents in solution. Such pebbles no longer hold together as rock at all, but crumble no sooner exposed to light and dryness, and may be picked from the bank and crushed in the fingers. Through large gray bowlders the steam shovel passes as through sand. Such sections may be commonly observed. These were doubtless, some of them already long constituent parts of the older Buchanan gravels which the Wisconsin ice in these latitudes so generally swept away. Possibly the larger part of these vast recent deposits consists of but a resorting of those older piles and trains laid down by the waters of the Kansan so long ago.

Buchanan Gravels.—Perhaps some of the earlier gravel, even in these river valleys still lies in place here on the blue clay that stretches everywhere beneath all surface deposits in these regions. Thus if anyone will closely scan the exposed wall of the gravel in the excavations south of Estherville, he will easily discover that the lower portions of the exposure are different, strikingly different, from the upper overlying part. Above, the gravel is more loose, fresher and evidently more recent, judging from appearance; below, the material is imperfectly stratified, often stained with iron, deep brown sometimes, the pebbles and bowlders more or less cemented together and associated with concretionary nodules of impure hematite (Fe_2O_3). The line of demarcation is not well defined, but is sometimes quite evident. One is inevitably led to conclude that the lower gravels are here older than the upper.

However we may name these lower gravel strata, the wide distribution of the Wisconsin subwash and overwash is indisputable. Not only by the river, but far away from streams now flowing or even the possibility of streams, piles of water-laid sand and gravel surprise the traveler. In many cases these gravel deposits rest unmistakably on the country drift, so that there can be no question as to their relative age. Indeed it seems as if it (Buchanan) may be looked for almost anywhere as a bottom deposit of what has been here denominated the gravel plain.

Observations which seem to verify the statements of Macbride regarding the origin of the sands and gravels may be made almost anywhere along West Des Moines river in Palo

Alto county. North of Emmetsburg the river plain is between one and two miles in width all the way to the Emmet county line and beyond. The whole valley between the sharp hills which border it on both sides and rise some thirty feet above the plain, is filled with sands and gravels deposited by the rushing waters from the melting ice. Some two miles north of Graettinger, just over the line in Emmet county, the Rock Island Railway is removing large quanties of the material for ballast. About twenty feet of gravel are exposed here, the top being fairly coarse and grading into finer below. The open face exhibits iron stain throughout its entire depth. A large proportion of the pebbles are limestone, with granites next in importance. Many of the latter pebbles are badly weathered and crumble readily in the fingers. (See also figure 28, page 252.)

Several minor openings between Graettinger and Emmetsburg exhibit the same characteristics. A small pit along the Chicago, Milwaukee and St. Paul railway on the east side of the river in section 26 of Emmetsburg township, reveals coarse, iron-stained, water-laid gravels very similar in appearance to the top layers at the Graettinger pit. In the southwest edge of the city of Emmetsburg, almost at the edge of the gravel plain, the Shadbolt Lumber Company has a pit from which gravel and sand for cement products is being taken. This pit is about fifteen feet deep, but the bottom ten feet are under water and the sands are pumped out. The product of this pit is much finer than that of any of the openings previously noted, which observation is in keeping with what would be expected when we reflect that the current here at the edge of the stream was in all probability much slower than that farther out in the channel.

South of Emmetsburg the general relations of the stream, gravel plain, and bounding hills remain unchanged except that through West Bend township the width of the stream "bottoms" is not more than half as wide as throughout the remainder of the county. South of the Des Moines river bridge on the road between sections 1, Great Oak, and 6, Nevada townships, gravel very similar in character to the top layers at Graettinger may be seen under two feet of alluvium.

In many places where the river has gouged its bank the sands and gravels which underlie its whole plain may be seen. As might readily be expected, the cover of alluvium over the gravel is deepest near the stream, thinning out back toward the hills. Wells and other excavations all over the river plain show the presence of gravel and sand, although there are but few open pits.

As previously noted, deposits of sand and gravel derived from the Wisconsin ice may be seen in places entirely removed from any of the present lines of drainage. At Ruthven there is an abundance of this material in the lowland west of the city, nor less on the top of the hill in the city itself near the Minneapolis and St. Louis station. East of Cylinder, in Fairfield township, is also a broad gravel plain some three or four miles in length and of the outwash type.

Reworked Materials.—Sand and gravel bars occur in the streams of Palo Alto county the same as in other counties where stream terraces and other deposits are prominent. West Fork of Des Moines river, by far the most important stream of the county, has a sluggish current, and sand bars are by no means a prominent feature along it. The same is true of the other streams. Cylinder and Prairie creeks are typical prairie streams, such as are common on the Wisconsin drift plain. Willow creek serves as an outlet to Silver lake, and is not important from a sand and gravel standpoint.

Miscellaneous Deposits.—Palo Alto county lies wholly within the area covered by the Des Moines lobe of the Wisconsin glacier, and its whole topography is characteristic of this formation. Sand and gravel may be found in many of the mounds and hillocks over its surface, especially in the western portion where the Altamont moraine lies within the borders of the county. Perhaps at no one place are these deposits of particular importance, yet they serve a useful purpose in supplying gravel and sand for local use on the roads and for concrete construction. Careful prospecting will in all probability reveal to the engineer or road and bridge contractor quantities sufficient for use within easy hauling distance.

PLYMOUTH COUNTY.

SAND AND GRAVEL.

The gravel and sand deposits of Plymouth county are of two kinds, viz., a gravel train along Big Sioux river, and beds underlying the loess and found quite generally over the county.

Wisconsin Gravel Train.—Along the Big Sioux there are evidences of a gravel train composed of materials derived from the Wisconsin ice. This is, however, so deeply covered as to be seen only in a few places. When compared to the loess-covered gravels of the county it is not a really important source of supply.

Loess-covered Gravels.—Over the whole of Plymouth county gravels underlie the loess. No one in need of sand or gravel seems to have serious difficulty in finding it with little search. The depth of the loess cover varies between quite wide limits. The cover is sometimes so deep that the gravels have not been exposed where there is every reason to believe that they are present.

Just east of Millinerville, on the east side of Broken Kettle creek, a good gravelly sand is obtained beneath the loess perhaps seventy-five or eighty feet above the stream. Gravel is also obtained along the creek flowing into Broken Kettle at this point.

In northeast section 9, Sioux township, is an opening showing some ten feet of gravel above the water level. The cover here consists of twelve to fifteen feet of loess and silty sand. The upper three feet or so of sand has interbanded silt, then fine gravel to water. A pit in northeast section 10 shows virtually the same material, with possibly a little less cover. In both of these places the gravel seems to underlie large areas.

Along Floyd river clear across the county gravels can be found with little search, yet they are seldom if ever exposed. The slopes to the river are very gentle, and only black alluvial material is seen in the channel. At Seney a low bench at the north edge of town furnishes a good supply of coarse gravel.

Sand with gravel bowlders is also seen in the road east of the river on the north side of section 34, Elgin township. This is covered with a thin veneer of loess.

The gravel used for sidewalks in LeMars is taken from beneath the clay on the river at the clay plant in the northwest corner of the city. The top three and one-half feet are clean fine gravel with little sand. The largest pebbles seldom exceed one inch in diameter. Below, as deep as can be seen, is a bed of fine white sand which is said to continue for an indefinite depth. Perhaps six feet of gravel and sand may be had above water. Laterally the material varies rapidly between clean and dirty streaks in the upper gravel especially. At the west end of the pit streaks and lenses of plastic sandy blue clay interbanded with the gravel make care necessary in order to get clean material.

At the LeMars Brick and Tile plant are five to eight feet of loess resting upon three and a half feet of stratified gravels. Cross-bedding is common. Up to five feet of sharp white sand underlie the gravel.

The west fork of the Floyd flows in a broad depression with ill-defined boundaries, the loess slopes leading gently down to a very narrow flood plain. The benches are loess-covered, but no sand or gravel is to be seen, even where these benches are dissected to considerable depths. It is possible that sand is present quite generally beneath the loess but the latter is so deep that it is seldom uncovered. From LeMars south to Sioux City gravel is not seen along the river, but there is a possibility of its presence.

Willow creek is of no more importance in Plymouth than in O'Brien county, and yet gravels are apt to be found exposed or available along it as is the case with the other streams. No doubt a continuation of the bed used northwest of LeMars is tapped along both the Chicago, Saint Paul, Minneapolis and Omaha, and Illinois Central railways northeast of town, the former in northeast section 9 and the latter in northeast 10, America township, south of Willow creek. As at LeMars, little of the gravel is above water, so it is dredged with clam-

PLATE XLIV—Dalton pit showing aerial clam shell and loading chutes, LeMars, Plymouth county.

PLATE XLV—Chalk cliff on Sioux river, Plymouth county. The beds in general are not sufficiently indurated for road materials and are not used extensively for concrete.

shell dippers dropping from a cable. Each railway has such an equipment. The amount of stripping here is heavy. The sand is shipped in considerable quantity as well as used locally, and this seems to be the source of supply for considerable territory. It is used for cement blocks in LeMars.

Along Deep creek from near LeMars to Remsen gravels appear and are used at intervals. They are always beneath loess, Good sand is taken from beneath the loess in section 1, west of Remsen, for use in that town.

Stratified beds may be seen near the Remsen city dump in section 6 of Remsen township. The exposure shows about six feet of rudely stratified coarse gravel in which the bowlders are fresh and unweathered. There is also some clean white sand.

At Kingsley the cement works use sand which is taken from beneath a considerable depth of loess along a branch of the west fork of Little Sioux river southwest of town.

Reworked Materials.—Sand bars occur occasionally along the course of the Big Sioux. At Akron there is a bar perhaps one-half acre in extent, although all of it is not above water. The size of the pebbles varies from three inches down. Several bars are reported a few miles to the south. The lower fifteen miles of the Sioux within the county resemble the Missouri in that the banks are muddy and sand bars are not prominent.

STONE.

The Cretaceous beds in Plymouth and Woodbury counties comprise an extensive and somewhat complicated series of sandstones, shales and limestones. The limestones often present a marly facies and are practically confined to the upper portion, the Benton substage, of the Cretaceous. The principal calcareous member of the Cretaceous in this locality was named *The Inoceramus Beds* by White.* Later, the beds were referred to the Niobrara division of Meek and Hayden, but more recent studies show that they are to be correlated with *The Green Horn Limestone,* the middle division of the Benton group

*Report on the Geol. Surv. of the State of Iowa, by Charles A. White, M. D., Vol. I, p. 293; Des Moines, 1870.

as it is developed in the Edgemont quadrangle, South Dakota. In the vicinity of Sioux City, the arenaceous beds are highly indurated in places and become quartzitic in character. They have been quarried to a limited extent, but the excessive overburden renders any extensive development of the beds commercially impossible. The calcareous beds are best exposed in Cedar Bluff and vicinity, near Westfield, and near LeMars. At all of the above places they are interbedded with shales and arenaceous deposits and usually overlain with a thick deposit of loess and glacial debris. They attain a maximum thickness of about thirty feet and are sufficiently pure to be used in the manufacture of lime and Portland cement. The following partial analyses were made for the Survey:

	I.	II.
Calcium carbonate ($CaCO_3$)	83.70	94.39
Magnesium carbonate ($MgCO_3$)	2.48	0.70

I. Chalk rock from old quarries on Big Sioux river south of Westfield, Plymouth county.

II. Chalk rock from Deep creek northeast of LeMars, southwest quarter of section 2, America township, Plymouth county.

While the beds were formerly used in the manufacture of lime, the introduction of cheap limes of better grade from other localities has caused the abandonment of the industry. The great amount of stripping which must be done in order to develop the beds renders them unavailable under present conditions for the manufacture of Portland cement.

POCAHONTAS COUNTY.

Sand and Gravel.

Pocahontas county is entirely within the limits of the Wisconsin drift. Its surface exhibits the typical flat, marshy topography which is so characteristic of the regions covered by the latest ice sheet. All the streams with the exception of one, the Des Moines, are younger than the drift, and the only deposits along them are small sand and gravel bars.

Stream Terraces.—West Fork of Des Moines river cuts across the northeast corner of Pocahontas county, having a total length within its borders of not to exceed eight miles. It flows through a low flat plain very similar, though narrower, to that which it follows through Emmet and Palo Alto counties. In those counties, however, evidence of gravel in the river plain is everywhere abundant; here it is conspicuously lacking. It seems hardly likely, however, that the river plain is entirely devoid of material suitable for road and concrete work.

A patch of what seems to be an old terrace appears on the west side of the river in sections 14 and 23, Des Moines township. In northwest 24 the river has cut some six feet into blue clay and shows resting immediately upon the clay a bed of fine sand four feet deep. The sand is covered by a heavy mantle of alluvium which is fully ten feet deep at the river bank.

The top of the alluvium is the surface of the terrace just mentioned. It is flat on top, with perhaps a slight rise to the west away from the river, and has an area of some fifty or sixty acres. In all probability the sand exposed in the river bank continues back if not to the extreme edge of the terrace, at least under a considerable portion of it. However, the thickness of the entire formation above the blue clay can hardly exceed fifteen feet, and the upper two-thirds of this is alluvium.

Another and much larger remnant of what seems to be the same terrace may be seen along the west side of the river through section 1 of Garfield township. There is a small open pit on the edge of this beside the road through the center of section 1. This opening shows only a foot or so of sand under a cover not to exceed three or four feet in depth. Back from the edge of the bench here the surface of the ground is perfectly level for over a mile, but it is rather a far call to assert that the sand would be found under all of it. The indications are sufficient however to warrant thorough test-pitting.

Along the east side of the river the bench is entirely absent. Residents of the neighborhood disclaim any knowledge whatever of gravel and sand deposits save those in the river channel.

Reworked Materials.—Sand bars in Des Moines river furnish a large part of the sand and gravel used in the northeast part of the county. Gravel is very scarce, most of the material being sand, with occasionally a pocket or small bar of fine gravel. These bars are quite common on the concave side of bends in the stream, and in many places deposits have formed up against the bank on the convex side.

Sand and gravel bars occur to a greater or less extent along many of the smaller streams. These streams are all younger than the drift, and do not have terrace gravels along them. The sands in the bars are materials which are derived from the drift and concentrated in the bed of the stream. The town of Rolfe obtains its supply of building sand from bars in Pilot creek.

Drift Hill Deposits.—All that can be said concerning the possibility of gravel in the hills and knobs of the Wisconsin drift area has been said in various places elsewhere. The reader is referred to the reports on Emmet, Palo Alto, Buena Vista, Osceola and other counties.

There are quite a number of openings of various sizes in the drift hills of Pocahontas county. In the northeastern part there are now open pits in northeast 14 and center 35, Des Moines township, west center of 2, Garfield township, etc. These are but examples of deposits which have been and may be found in the drift hills. In a region so devoid of gravel as is Pocahontas county, these pockets in and cappings on drift hills become of prime importance, and although small amounts only are available in any one place a diligent search is warranted and may prove profitable.

Buchanan Gravels.—A deposit of gravel older than the Wisconsin, the Buchanan, overlies the stone in the quarry at Gilmore City. A discussion of these gravels in detail so far as observed will be found in the reports on Emmet, Palo Alto, and Buchanan counties. They are not of commercial importance in Pocahontas county.

STONE.

But a single exposure of the indurated rocks is known in this county. The Saint Louis has been quarried for a number

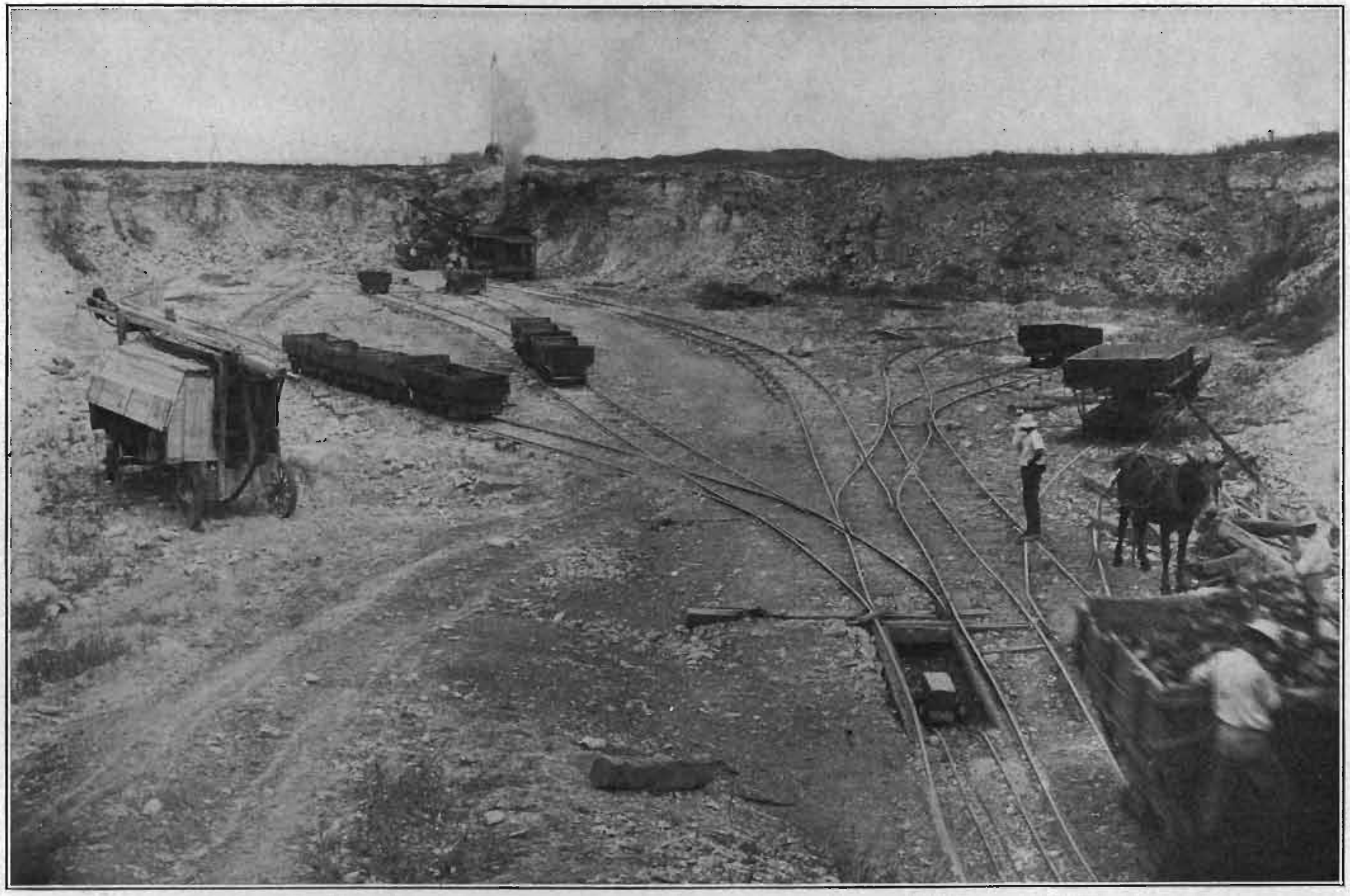


PLATE XLVI—Fort Dodge Portland Cement Company quarry showing steam shovel, drill rigs and track arrangement. This quarry supplies one of the largest crusher plants in the state. Gilmore City, Pocahontas county.

of years two miles north and one mile east of Gilmore. The quarry is now owned and operated by the Fort Dodge Portland Cement Company. The following beds may be observed:

		FEET.
11.	Soil, sand and gravel	5
10.	Crystalline limestone, light brown in color, cavernous due to weathering, much shattered and of little value	4
9.	Limestone, light brown, coarse in texture and subcrystalline, splits well with bedding planes, but in an irregular manner vertically, heavy bed	3
8.	Ledge, as above, underlain with two inches plastic, variegated red and greenish clay	1⅓
7.	White to pinkish brown limestone, in part fossiliferous; beds broken by vertical joint planes along which water has formed many small caverns and on which small pyrite nodules and fossils stand in relief. Ledges running two inches up to three feet in thickness	10

T. H. Macbride in *Geology of Humboldt County** gives the following additional strata then visible below the above section:

		FEET.
6.	Blue shales, limestone and clay; very fossiliferous	2
5.	Lithographic limestone, much inclined to angular fracture	1½
4.	Heavy-bedded, fine-grained limestone, no fossils	3
3.	Shaly, thin-bedded limestones, with few fossils	1
2.	Coarse-grained, fossiliferous limestone, containing fragments of No. 1, but separated from it by a parting of shale	1
1.	Lithographic limestone, fine-grained and very hard	2

This author regards the lowest beds as equivalent to those quarried at Humboldt in the adjoining county to the east.

Numbers 7, 8 and 9 constitute the principal quarry rock. An analysis made of a sample from these members is given herewith:

Silica (SiO_2)	0.32
Calcium carbonate ($CaCO_3$)	99.62
Water and undetermined	0.06

J. B. WEEMS, analyst.

A casual inspection of this analysis shows the limestone to be almost absolutely pure and it appears to be of high quality.

The old quarry is located in the lowest portion of a broad depression which appears to be the site of a former pond or sinkhole. It is a local center of drainage and some trouble with water has been encountered.

*Iowa Geol. Survey, Vol. IX, p. 132.

The present company have opened a new quarry to the northwest of the old quarries and have installed a modern crusher plant of large capacity. They have also built in a spur from the Chicago, Rock Island and Pacific railway with sufficient trackage to permit an economic distribution of their output. Crushed stone is the only product at present. A considerable area of limestone is available under light stripping. The quality is excellent for crushed stone purposes.

POLK COUNTY.

Sand and Gravel.

Polk county is generously supplied with gravel and sand, and is one of the largest exporters of these materials among the counties of Iowa. Enormous quantities are to be found in Des Moines and Raccoon rivers. Water-laid materials also occur quite commonly in the drift hills, but are not so largely developed as the former deposits.

Terraces.—Remnants of a greatly eroded and dissected terrace about sixty feet above Des Moines river appear in sections 29 and 30, Madison, and 3, Jefferson townships. Thorough prospecting done by the Chicago, Milwaukee and Saint Paul Railway showed from fifteen to eighteen feet of gravel under one to three feet of alluvium. The material is in general fairly coarse, and in places is quite badly iron-stained. A remnant of a higher terrace may be seen on the north side of the river and near the Polk-Dallas county line. In Greene county a terrace corresponding to this is gravel-bearing.

There is a terrace along a small creek in section 18, Madison township, that may contain a large supply of gravel. The terrace is 500 to 1,000 feet wide and perhaps half a mile long. The gravel is fine and rather dirty where it can be seen, but good exposures are wanting. The alluvial covering is perhaps two feet thick.

Along Big creek in sections 10 and 22 of Madison township there is a terrace some eighteen feet above the creek. The terrace consists of two feet of alluvium underlain by six to seven feet of fine gravel.

PLATE XLVII—Pump scow and pipe line of Coon River Sand Company, Des Moines, Polk county.

Below Des Moines terraces are occasionally to be seen, but these are almost always composed only of drift.

H. F. Bain reports that all the larger creeks, such as Four Mile, Camp and Mud, have gravel terraces, but these are not at present being exploited. An exception to this is the terrace deposit at Avon.

Reworked Materials.—Enormous quantities of sand and gravel are to be found as beds and bars in Des Moines and Raccoon rivers. These have been and are being developed on a large scale in the vicinity of Des Moines, and materials taken from here are shipped over a wide territory. Depths of gravel up to thirty feet are common in the stream beds. The usual method of working these deposits is by a centrifugal pump mounted upon a barge, but scraper buckets and other devices are occasionally used.

Quite large quantities of clean coarse sand and fine gravel are to be found along Four Mile creek from Alleman south. Similar materials occur on Mud creek between Altoona and Des Moines river. Skunk river is destitute of even sand.

Miscellaneous Deposits.—The northern part of Polk county lies within the area of the Wisconsin drift. Capitol Hill in Des Moines marks the extreme advance of the Des Moines lobe. Kames are common over the northern portion of the county, but do not furnish a large supply of sand and gravel. Even where kame gravels and sand are available the farmers prefer to haul their supplies rather than spoil parts of their fields. In a few instances sand and gravel have been removed and the land smoothed out again. Farmers report that such land is more easily tilled than formerly.

In section 31 of Madison township is a large kame whose surface shows gravel in places, but which has not been opened.

STONE.

The Coal Measures as developed in Polk county comprise shales, argillaceous limestone, sandstone and occasional coal seams. The argillaceous deposits greatly predominate. The sandstones are usually imperfectly indurated, while the limestones occur only in thin beds or as "Caprock," and neither affords any considerable amount of material suitable for structural purposes. The sandstones have been quarried to some extent but are not used in important structures. The sandstone beds exposed at the foot of Capitol Hill have probably been more extensively developed than any other in the county and are said to have supplied material for the walls of old Fort Des Moines. The beds are exceedingly variable in color, texture and hardness and are easily accessible. The county must depend upon other sources for road and concrete materials.

POTTAWATTAMIE COUNTY.

SAND AND GRAVEL.

Sand and gravel are really scarce articles in Pottawattamie county. Missouri river has and does in places show evidence of an old gravel train, but these materials are so deeply buried as to be practically negligible. In speaking of these gravels, J. A. Udden, in his report* on the geology of the county published in 1901 says, "The valley of the Missouri river has a filling about seventy feet deep under the present flood plain, and there is a similar filling in the upper part of the West Nishnabotna valley. The lower part of this filling usually consists of sand and gravel, and the upper part is mostly stream sand and silt." The depth of the covering varies from a few feet to upwards of thirty feet.

Opposite Oakland there is a terrace on the west side of West Nishnabotna river, and some second bottom lands are also seen south of Avoca on the east side. These are remnants of an old flood plain which must have been some thirty feet higher than the present bottoms. This terrace is covered with at least twenty feet of loesslike silt. A similar but higher terrace is seen occasionally along Mosquito creek, as below Neola. At the latter place loess, which forms the upper twenty feet of the material of the terrace, rests on stream sand and gravel, into which some wells have been sunk. Traces of a ter-

*Iowa Geological Survey, Volume XI, p. 201.

race are also seen on the East Nishnabotna, on Keg and Silver creeks, in the bluffs of Missouri river, and along the lower courses of some of its tributaries.

Nishnabotna river is terraced between Harlan (Shelby county) and Oakland. The principal terrace ranges from twenty-five to thirty feet above the flood plain and is composed of the following:

	FEET.
Loess and alluvial wash	6-10
Sands, interbedded with thin clay seams	10-12
Sands, coarser and cleaner than the above, clam shells and occasionally bones are reported to occur in the lower sand	10

The old glacial gravels which occur capping the till and under the loess form an important source of supply. The report by Udden cited above seems to contain all the available information on these deposits, and consequently is reproduced verbatim.

Valley Drift Gravel.—"In the bluffs bordering the larger stream valleys the till is often capped by more or less gravel and sand. Nearly all of the sand and gravel pits which have been worked in the county belong to this class. These deposits are evidently of glacial origin, for in some places they are seen to be interbedded with lentils and layers of bowlder clay, or overlain by the same. The greatest development of glacial gravel and sand is under the loess along the bluffs of the Missouri river, especially north of Kane township. They frequently reach a thickness of twenty to thirty feet, and have in many places been cemented into a solid mortar rock by percolating calcareous water which drains through this open stratum from the uplands back of the river. Along the West Nishnabotna these gravels have a much smaller development, but present the same characters. Some are seen about fifty or sixty feet above the flood plain in the west bluff three miles south of Avoca.

"Without wishing to express it as a mature conclusion, the author is inclined to the view that these deposits represent the work of the present streams at a time when their course was first marked out on the stagnant ice field which brought the underlying bowlder clay. These streams may then have followed open valleys or extensive tunnels in the ice. In either case there would be opportunity for the ice to float out and deposit some till with the stream gravel. Another feature of these deposits not mentioned above is the presence in some places of sharply and clearly cut joints and faults that follow numerous straight and intersecting planes in the gravel and sand. Such faulting could hardly have taken place in this unconsolidated and heterogeneous material unless it was frozen at the time. A conspicuous instance of complex faulting of this kind was observed in a gravel pit just south of Loveland station."

In the vicinity of Loveland are two or three pits which doubtless belong to this class. These may be seen both north and south of town. In southwest section 14 of Rockford township and again a little farther south similar exposures may be seen. Another which probably belongs in the same category is located in section 11 of Lewis township. Bank sand has been and is being used at several points near the foot of the bluff both above and below the city of Council Bluffs. In the vicinity of Avoca bank sand, apparently subloessial, is obtained at several points south of town and is used for mortar and plaster.

Sand and gravel are scarce in Council Bluffs and vicinity. The Missouri river sand is used to some extent, but carries a high percentage of silt. Most of the sand and gravel used for street purposes is imported from Nebraska. The most extensive local deposits occur near Henton's, across the line in Mills county. Outcrops of limestone occur in the same neighborhood. Neither stone nor gravel has been used to any extent in road work in the west end of Pottawattamie county. River sand is used to some extent. Sand for concrete is shipped in from Platte river or Des Moines river. At Oakland sand is obtained from Nishnabotna river by means of centrifugal pumps mounted on scows. Two of these are in operation at the present time. The sand ranges from fine to medium and carries a comparatively small percentage of aggregates up to one and a half to two inches in diameter.

STONE.

With the exception of small areas near the eastern edge of the county, the underlying indurated rocks belong to the Missouri stage of the Upper Carboniferous. These are limestones and shales. In general they lie deeply buried beneath the glacial deposits and where exposed along some of the larger streams, are usually overlain with great depths of drift and loess.

There are but two districts where Missouri strata are exposed. In Carson and Macedonia townships, in the vicinity of the towns of Carson and Macedonia, several small quarries have been operated. No stone is, however, being taken out at the present time, and all exposures are greatly obscured.

At the John Marten quarry near the northwest corner of section 23, Macedonia township, the main quarry beds are covered with fifteen feet of marly shales and weathered fossiliferous limestone, above which are eight to ten feet of drift and loess. The layers quarried consist of three ledges of gray, compact limestone, each about a foot thick and separated by seams of marly material. The upper layer contains nodules of dark chert. Below the gray stone are three feet of a soft, yellow limestone filled with *Fusulina cylindrica*. Similar strata were formerly worked near the northeast corner of section 27 in the Tompkins quarry. West of the river and opposite the town of Carson in section 3 of Carson township, rock has been quarried at several points along the edge of the valley. The following section was formerly exposed on the land of Mr. David Snapp:

		FEET.
7.	Drift and loess	20
6.	Limestone, gray, hard, strong, highly fossiliferous	6
5.	Shale, gray, indurated	.7
4.	Limestone, dark, soft, of fine and uniform texture, gray to black, fossiliferous	1
3.	Shale	.5
2.	Limestone, dark, impure, fine-grained, soft	.5
1.	Shale, greenish gray, exposed	2

All of the rock ledges open to view in this district are much weathered, and of a poor grade for building purposes. These conditions, along with the heavy stripping that would be required, the thinness of the individual usable ledges, and their being interbedded with such large proportions of worthless materials, are all unfavorable to the development of the quarry business.

The Missouri limestones have been quarried at two other points in the county in past years; below the town of Crescent in sections 27 and 34, and on Mosquito creek, section 21, Garner township. At the former locality, the following strata outcrop almost continuously for three-fourths of a mile at the base of the Missouri river bluff.

	FEET.
6. Loess and drift up to	100
5. Limestone, yellowish to gray, in ledges six inches to one foot in thickness, occasionally brecciated and in places having a finely oölitic texture	5
4. Shale, yellow	2
3. Limestone, yellowish gray, compact, occasionally oölitic, fossiliferous	2
2. Shale, gypseous, highly fossiliferous	5
1. Limestone, massive ledge, fine-grained, oölitic, fossiliferous, exposed	3

These strata afford a good quality of building material, and lime was burned here many years ago. But the enormous quantity of stripping necessary to render any considerable amount of the stone available, is a barrier to further development at this point.

The Mosquito creek quarry has long since been abandoned and the strata are very meagerly exposed. Here also the extremely heavy overburden renders the further working of the quarry practically impossible.

Strata belonging to the Cretaceous system underlie portions of Pottawattamie county east of West Nishnabotna river. They consist of beds of clay and soft, friable sandstone, the latter varying in color from white to gray and brown. The entire county is deeply covered with Pleistocene deposits and the only evidence of the presence of the Cretaceous comes from deep wells and a few scattering exposures near the extreme southeast corner of the county.

J. A. Udden* records a maximum thickness of forty-two feet of Cretaceous sandstone occurring in the northeast quarter of section 36, Wright township, as an escarpment over a quarter of a mile in length, facing the river. It is again seen near the southeast corner of section 1 of this same township, also in section 28 of Grove township. In all instances, the rock is of uniform fine texture, but the grains of sand are poorly cemented so that it will usually crumble in the hand. Bedding is not conspicuous, great thicknesses appearing as one continuous ledge. All the exposures noted are heavily covered with glacial deposits. Aside from being the source of local supplies of good sand, the Cretaceous sandstones of this county are of little economic value.

POWESHIEK COUNTY.

Sand and Gravel.

The loess-veneered Kansan drift covers practically the entire surface of the county. No large streams cross the county and none of the smaller streams head back in the Wisconsin drift territory. As a consequence sand and gravel deposits on a commercial scale are not believed to be present. The sub-loessial sands, sometimes more or less gravelly, are quite generally present and important as a water-bearing horizon, but are of little importance as a source of road and concrete materials. Most of these materials used in the county are shipped in from Polk and Mahaska counties.

RINGGOLD COUNTY.

Sand and Gravel.

All of the sand available in Ringgold county is obtained from the beds of the streams. Grand river, which is the largest stream, deposits but little sand or gravel in the vicinity of Knowlton, Diagonal or Benton. A small tributary of this river, entering about a mile south of Diagonal, supplies the local community with sand, and small amounts of the same mate-

*Geology of Pottawattamie county, Iowa Geol. Survey, Vol. XI, p. 237.

rial are reported from some of the streams between Diagonal and the Missouri line.

The northern half of the county is practically destitute of sand and gravel deposits. Most of the sand used at Mount Ayr is shipped from Davis City or Blockley, but some has been hauled from Waterson, ten miles south. The pit from which this is taken is in the bed of a small creek about one and a half mile southeast of town. The annual output is perhaps thirty cars. There is but little sand in Grand river between Mount Ayr and Kellerton. The same is true of Platte river in the vicinity of Benton and Diagonal.

SAC COUNTY.

Sand and Gravel.

The important sand and gravel deposits of Sac county may be classified under two main heads; gravel trains along the streams which were without doubt deposited by flood waters from the melting Wisconsin ice, and water-laid materials in or upon the Wisconsin drift hills themselves. In a few isolated places the Buchanan gravels, which in the northwestern part of the state so generally underlie the loess, and the Aftonian gravels, older than the Kansan series and underlying it, have been exposed by erosion. These latter, however, are of no importance from a practical standpoint, and discussion of them must be brief in a report of this nature.

Stream Terraces.—Marked terraces occur in places along the course of Raccoon river throughout the county. Crossing the line from Buena Vista county almost exactly at the northeast corner of Delaware township, the Raccoon meanders in a wide flood plain to section 1 of that township, in the south half of which it cuts through a range of drift and gravel hills. Below this point, and to within a mile of the corporate limits of the town of Sac City, it finds its way through and around heaps of glacial debris of undoubted morainal origin. To the southward the river has distributed some gravel, but in only a few places is any now seen. In sections 24, Delaware, and 30, Douglass townships, the gravels appear as a terrace some forty

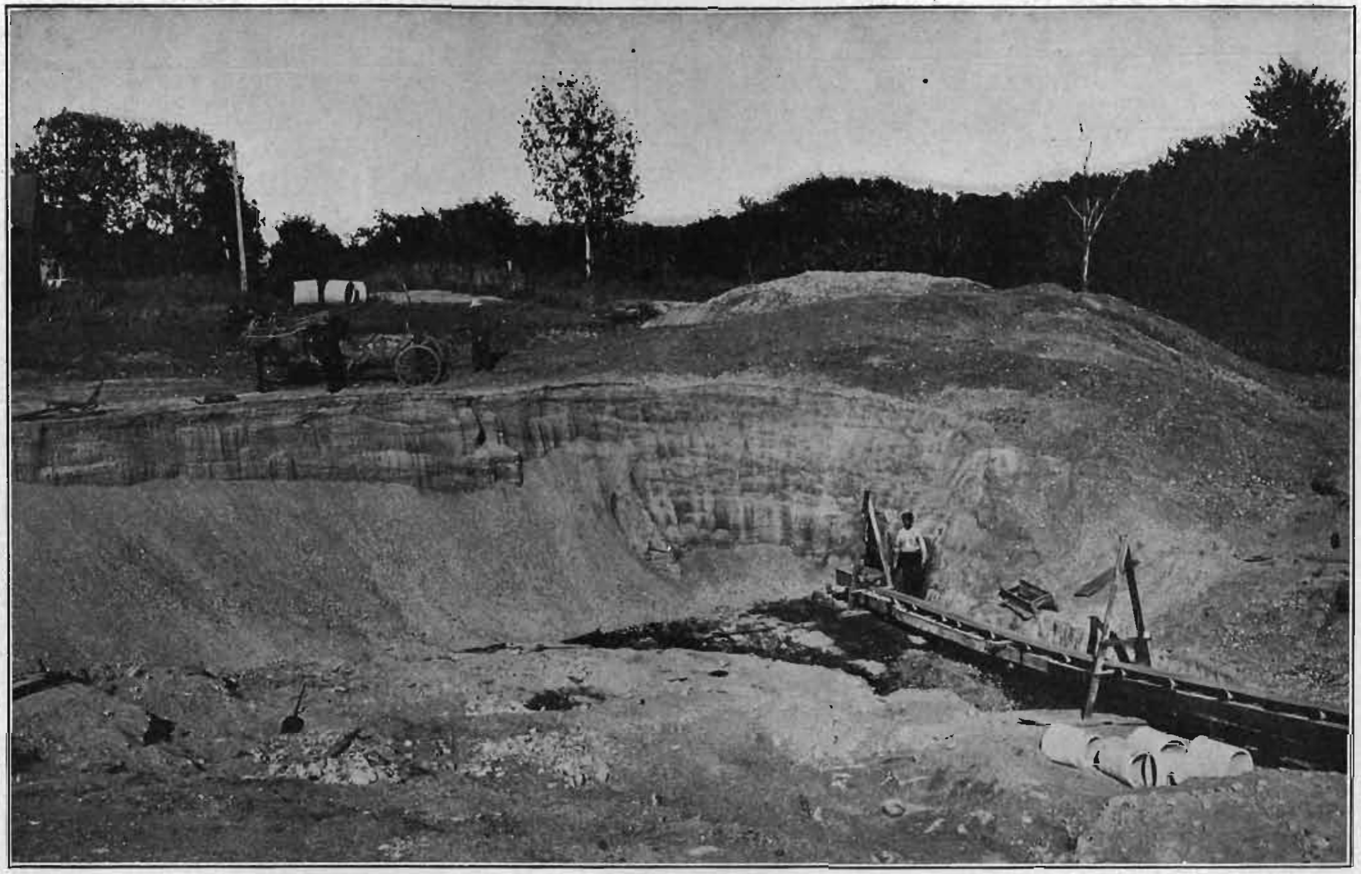


PLATE XLVIII—Hammen pit showing pit end of conveyor and rear view of pit, Sac City Cement Pipe Company, Sac City, Sac county.

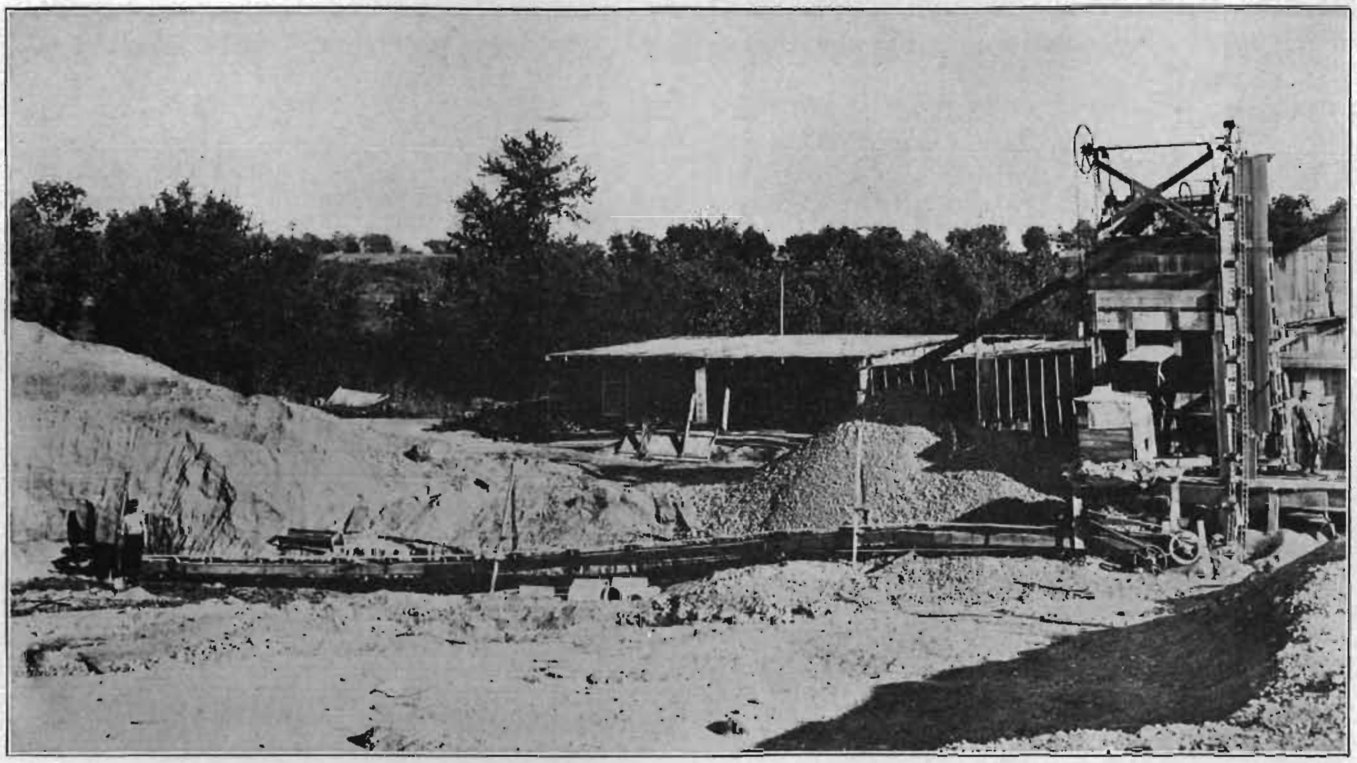


PLATE XLIX—Hammen pit showing belt conveyor, elevator and screen, Sac City Cement Pipe Company, Sac City, Sac county.

feet above water, and are seen at a few places to the east. After the numerous windings of the river here there is nothing in sight but drift, until the northern part of section 14 of Jackson township is reached where a conspicuous terrace appears. This terrace is some twenty-five or thirty feet above the waterline, seems to be nearly all gravel, and is more or less continuous through Sac City. The railway has removed large quantities of gravel where it cuts through this terrace in the north part of section 14.

At Sac City these gravels are used by the Sac City Cement Pipe Company and by Phil Shaller for cement work. The former company has located a pit close to the river, and a twelve to fifteen foot section is open. The total section exposed in the two pits named shows some three and a half feet of wash covering, below which are seven to eight feet of uniform, rather fine sand with streaks of fine gravel. Underlying this are ten to twelve feet of medium fine, well-proportioned gravel resting upon clay some three feet above water. At the Cement Pipe Company's pit there are only five or six inches to be stripped, then good clean gravel, finer below, the whole face averaging well for concrete work.

The Raccoon valley is narrow below Sac City to northeast Wall Lake township, where it widens out and continues so into Coon Valley township. The flood plain itself is usually practically nil, and the bottoms are largely gravel trains. The gravels are exposed at many points and are frequently used; e. g., in south section 12 of Coon Valley township, where an unnamed stream from the east has exposed fifteen to twenty feet of them. A similar opening may be seen in northwest section 32 of the same township.

The river valley narrows again in south Coon Valley township. In section 28 the gravel plain is nearly a mile wide. The valley narrows in section 33 and on into Sac township where it is still bordered by a terrace which here seems to be largely drift, not even gravel covered throughout. At Grant City the terrace is about forty feet above water.

Cedar creek is nearly the size of the Raccoon, and flows through an alluvial valley which becomes somewhat steepwalled as the Raccoon is approached. In section 20 of Cedar township a well-defined gravel terrace appears on the west, and suggestions of it may be seen on the east of the creek, some thirty feet above the stream. This terrace has been opened in the middle of the section where the road crosses it. There is no terrace in Sac county above this point, but it continues below to the confluence of Cedar creek and the Raccoon. The gravels are not prominent but appear in a few places.

Indian creek and its branches are important waterways, but geologically are uninteresting except in the vicinity of Wall Lake. The upper water courses are meandering swamp streams. In southwest Wall Lake township the creek whittles its way through the drift at the west morainal front until, at the town of Lake View, it turns abruptly east and northeast through a maze of morainal hills. The gravels at Lake View and around the west end of the lake are terrace materials and appear to extend southward, continuing in the direction of Indian creek.

A prominent terrace some thirty-five feet high begins just northwest of Lake View, and extends two miles south of town around an arm of the lake. A pit is worked in town by Messrs. B. Kennedy and Molder. The section shows soil two feet; coarse rusty bowlders one to two and one-half feet; good gravel and sand, 10 to 12 feet. A two- to four- or six-inch clay streak comes in three to four feet from the base of the present pit, below which are perhaps twenty feet of good material down to water level of the lake. In the K. & M. bank a band of drift clay apparently a foot or so in thickness contains irregularly arranged pebbles up to the size of one's fist. This is covered by four or five feet of coarse gravel and is underlain by sand or gravel. The boundaries of the layer of till are definite. About ten feet of gravel and sand are now exposed below the till, but not much is being taken out.

Below the town the terrace has been worked on a large scale by the railroad company, and enormous quantities of gravel removed.

There are also considerable amounts of sand and gravel about the town of Early, called Wisconsin outwash by Macbride. The school house is on a gravel mound, and the ceme-

PLATE L—Pit of the Lake View Sand and Gravel Company, Lake View, Sac county.

tery east of town occupies a similar position. The town water supply is reported to be from gravel at a depth of twelve feet.

There is a small opening on the McCormick farm in the northeast quarter of section 10, Boyer Valley township, and a large one in the southwest quarter. The latter pit furnishes suitable gravel for all purposes. The upper eight to nine feet are rusty and somewhat impure but furnish fair material for road work. Below comes apparently clean and fresh gravel, which Williams thinks belongs to the Wisconsin gravel train.

Morainal Deposits.—The east half of Sac county lies within the Wisconsin drift area. The topography of this portion of the county is typically morainal. Many of the gravel-bearing hills have been and are being developed, and they afford a useful and valuable supply of materials suitable for road and concrete work.

All through west Wall Lake township, from section 32 of Jackson, in sections 5, 8, 17, 21, 28 and 29 occur sharp morainal knobs, always gravelly, and sometimes affording gravel and sand, as at north 17, northeast 29, and so on.

In section 28 of Wall Lake township is a series of elongated hills having a general north and south direction. These hills have been opened on the farm of Erie W. Scott, and much gravel has been removed from a pit near the middle of this section. The Scott pit is in a ridge or esker, which has been opened for a distance of forty rods or so. The cover varies in depth from zero to several feet on both sides of the ridge. There is usually fine sand at the top, grading downward into gravel. The gravel overlies a band of eight to sixteen inches in thickness of very silty and worthless sand, which latter does not run regularly, but pinches out, only to appear again higher or lower. Below this clay band are four to five feet of clean cross-bedded sand above gravel, although this sequence is often reversed. The clean gravel rests upon a yellow-brown-black base of partially cemented gravel and sand that is very irregular. It is broken through in places, and a usable iron-stained coarse gravel is then found. As a rule this iron-stained gravel is at the bottom of the pit. A maximum depth of about twenty feet is worked, and several cars a day are being shipped. The gravel contains a marked quantity of shale, which is especially noticeable in the sand as it caves and runs down.

Throughout sections 27, 22 and 23 of Wall Lake township kames are abundant. To the north of Indian creek these sometimes resemble drift hills, level, with gravel caps. They have been opened in many places, notably in south section 22.

Buchanan Gravels.—The western half of Sac county lies outside the Wisconsin drift area, and the surface materials are Kansan drift covered by loess. In many places Buchanan gravels, the water-laid materials from the older drift sheet, may be seen. These impure subloessial gravels appear in places in road cuts, as on the township line between sections 25 and 30 and 13 and 18, Eden and Delaware townships respectively. They are always highly iron-stained, and an abundance of limestone is always noticeable. They do, however, usually afford good and needed road ballast.

The same subloessial, iron-stained gravels appear at rare intervals along the edges of the upper Boyer valley, as in northeast section 11 and southwest 22. There are no signs of terraces anywhere on this part of the Boyer, but in the broad flats of the stream in Eden township there seems to have been a small amount of gravel distributed, which now occurs at intervals underneath low alluvial benches, perhaps eight to ten feet above water. These are seldom uncovered or made use of, and are indeed unimportant, although much needed. The only exposure of these gravels noted is in the road between sections 21 and 22, Eden township, north of a stream from the west. The same low flats are seen at points to the north and northeast, but none have been opened.

In section 10 of Boyer Valley township, just southeast of Early, is a ridge running diagonally northeast to southwest which appears to be gravel capped if not entirely composed of gravel. The relation between loess, drift and gravel here is the usual one, and these seem to be only a more prominent development of what may be seen in a loess-covered country, comparable to the Sibley, Sheldon, LeMars and Correctionville pits. They bear no definite relation to any present stream, but are fifty feet above the Boyer, and remind one of a similar occurrence south of Alta (Buena Vista county) along the Little Maple and again on the same stream just over the line in Cherokee county.

Reworked Materials.—Sand and gravel bars are variously distributed in the streams of Sac county, but are of practically no importance as sources of supply. They are utilized occasionally, however, to satisfy small local needs.

STONE.

Stratified rocks outcrop at but a single point within the confines of the county so far as known at this time. At Grant City Raccoon river impinges strongly against its south bank and uncovers a series of coarse-grained sandstones, clay shales and chalk deposits, the assemblage aggregating forty or fifty feet in thickness and belonging to the Cretaceous system. Where exposed the sandstone is not sufficiently indurated to be useful as a structural material. The clay shales are of good quality and are used in a small way in the manufacture of brick. The chalk was used formerly for the manufacture of lime, an industry which long since was abandoned. The clay shales and chalk blended in the proper proportions would probably produce a mixture suitable for the manufacture of Portland cement. The smallness of the section and the inaccessibility of the beds make such use impossible.

SCOTT COUNTY.

SAND AND GRAVEL.

The absence of sand and gravel over the larger part of Scott county is a striking fact, and one in strong contrast with the abundance of these coarser deposits in the counties a little north and northwest. Beyond a short distance south of the Iowan frontier which follows roughly the course of Wapsipini-

FIG. 53—Sand hills of Iowan frontier, Princeton township, Scott county.

con river and is two or three miles south of it, there were no agencies during Pleistocene times capable of carrying heavier sediment than the fine silts and sands of the loess. North of that frontier, however, sand is plenty, and in the great belt of hills in Princeton township, which overlooks the flood plain of the Wapsipinicon, heavy beds of sand are superior and peripheral to the loess. In many road cuts in this district typical loess is seen to pass outward into sands by gradations which show that the two deposits were contemporaneous. The loess is often seen also to pass downward into beds of sand by intercalation in tortuous, irregular, discontinuous layers, showing conclusively the genetic indentity of the two deposits.

So far as now known the Buchanan gravels, the heavy deposits laid down in the swift glacial streams from the melting Kansan ice, do not exist in Scott county. They are, however, found in force a few miles north of the county line, near DeWitt, and it is from pits in the paha-like hills which they there form that the gravel is obtained which is being largely used for road making in Scott county. Just south of the county line the Durant cut of the Chicago, Rock Island and Pacific railway discloses a gravel, almost wholly made up of local materials, overlying Kansan till and covered with a ferretto; and similar gravels no doubt exist in the adjacent hills across the line.

STONE.

The Silurian rocks in Scott county belong to the Niagaran series and form the country rock over the northern two-thirds of the county. The lowest stage of the Niagaran, the Hopkinton, has not been recognized in the county and all of the Silurian limestones are referred to the upper stage, the Gower of Norton. Exposures of the Gower occur in all the townships north of a line extending from Valley City slightly northwest to about five miles north of Durant, save in Sheridan and Lincoln townships where the drift completely conceals the country rocks.

The two distinct lithological phases of the Gower are well shown in the county. The pure, hard, subcrystalline dolomite, free from chert and especially adapted to the manufacture of lime, is known as the LeClaire from its occurrence at the village of that name. The upper beds, comprising light buff, vesicular, evenly bedded dolomite, are generally known as the Anamosa stone.

A distinguishing characteristic of the LeClaire rocks is the absence or abnormal disposition of its bedding planes. It often apparently occurs in large mounds in which scarcely a trace of stratification is visible. Such an example may be seen at Schmidt's lime quarry south of Dixon. The LeClaire often exhibits false bedding on gigantic scale; the beds being inclined from zero to 40 degrees. The dip is exceedingly inconstant, varying both in inclination and direction in short distances.

The Anamosa beds are intimately associated with the LeClaire, and usually lie in even and horizontal or slightly undulating layers. Chemically the Anamosa stone is a dolomite, differing in its constituents from the LeClaire in the larger per cent of impurities present. In Scott county the stone runs in even parallel courses, whose thickness depends largely upon weathering. Layers from eight to twelve inches are the most common and blocks can be taken out of almost any dimensions. The Anamosa beds are generally laminated, but grade downward insensibly into the LeClaire by the lamination planes becoming obscure, and the stone becoming subcrystalline. By another type of lithological variation the rock becomes hard and compact with a subconchoidal fracture, resembling the lithographic phase of the Devonian. These layers are often termed "flint" by the quarrymen, although destitute of silica.

Outcrops of both the LeClaire and Anamosa are generally distributed along all of the principal waterways. Numerous quarries have been opened, but with a few exceptions they are of local importance only. A few typical exposures are given below. The LeClaire beds are exposed and have been quarried on sections 13, 14, 15, 18 and 22, Liberty township, and section 5 in Cleona township, in the west end of the county. The beds range from twelve to thirty feet in thickness and show the usual LeClaire characteristics. The LeClaire also occurs in section 7, Allen Grove township, where it has been burned for lime for more than a half century, and at a number of points near Big Rock. It occurs and has been quarried near Princeton and LeClaire.

The Anamosa beds have been developed extensively in the vicinity of Princeton and LeClaire. North of the latter place the LeClaire Stone Company has opened and is operating the largest quarry in the county. The quarry is connected with the Iowa and Illinois railway.

The beds exposed are as follows:

LE CLAIRE SECTION.

		FEET.
8.	Loess and drift, thickness variable	0-10
7.	Limestone, buff, dolomitic, much weathered, thinly bedded and often almost clayey in appearance	10-30
6.	Dolomite, cavernous, most vesicular layer in the quarry, hard and brittle, subcrystalline; some of the cavities contain crystals	5-6
5.	Dolomite, thinly bedded and much weathered in places; often hard and brittle and bluish when fresh	4
4.	Dolomite, heavy-bedded, somewhat vesicular and irregularly indurated Spring line here.	2
3.	Dolomite in remarkably even beds and very soft when first quarried. The best dimension stone in the quarry; in six layers	6
2.	Dolomite, in heavy beds, upper portion shows a tendency to split irregularly; brittle	6
1.	Dolomite, thinly bedded, cavernous in places, exposed	4

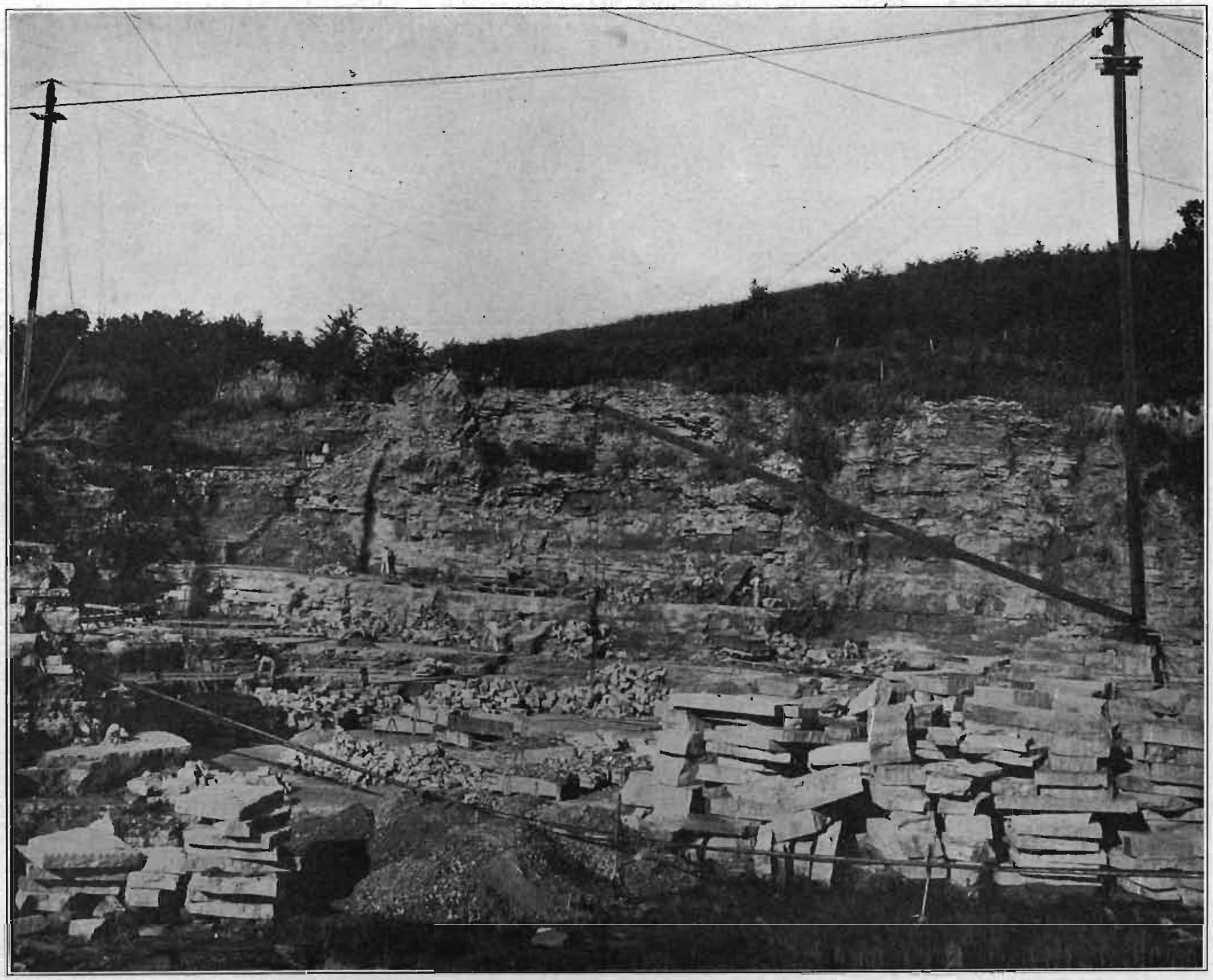


PLATE LI—General view of LeClaire Stone Company quarry, near LeClaire, Scott county. The handling of material is done by derricks alone.

The quarry is equipped with steam drills and derricks and an Austin crusher plant. The stone is carried from quarry to cars and crusher by means of derricks, and very little trackage is required. Three sizes of crushed stone, in addition to the dust, are put upon the market. The quarry also supplies rubble and riprap and all sorts of dimension stone.

The Anamosa beds here dip toward the northwest at a low angle.

Other quarries have been opened near LeClaire but show no new features. The beds developed are usually less regular than those just described. Of the large number of quarries which have been worked from time to time in the vicinity of Princeton, only one is given here. Several quarries have been opened at the base of the high bluffs which skirt the valley of the Wapsipinicon, northwest of the town of Princeton; one of the most extensive is located on the northwest quarter of section 34, Princeton township. The succession of beds is as follows:

		FEET.
5.	Superficial deposits resting on unpitted rock surface......	2
4.	Limestone in thin layers, mostly 2 to 4 inches thick, a few reaching 8 inches, and some consisting of thin calcareous plates	12
3.	Limestone, close, granular, slightly harder and more brittle than typical Anamosa stone, in even, horizontal courses from 6 to 20 and 24 inches in thickness, buff in color, with few cavities and smooth surfaced, including a foot or so of thinly laminated "flinty" limestone..........	14
2.	Limestone in layers from 2 inches to 18 inches, semicrystalline	7
1.	Limestone in thin, gray, crystalline, calcareous plates....	5

Beds intermediate in character between the Anamosa and LeClaire beds, supply an abundance of quarry stone. Small quarries have been opened in Liberty, Cleona, Butler, LeClaire and Pleasant Valley townships.

These intermediate beds are buff, nonlaminated, regular and heavy. They are generally highly vesicular, and often subcrystalline. A representative section may be seen in a small quarry on the northeast quarter of section 1, in Liberty township. Natural ledges, aggregating twenty or thirty feet, appear along the gorge of the Wapsipinicon and show an earthy dolomite in massive beds up to three feet or more in thickness.

The stone is nonlaminated and is subcrystalline in places. The bedding planes are rough and cavities of considerable size are present. In Cleona township a quarry located on the northwest quarter of section 7 shows the following succession:

	FEET.
4. Limestone, magnesian, horizontally bedded, brown, semicrystalline, weathering into small chipstone, with one or two 6-inch layers more resistant	9
3. Limestone, magnesian, light gray, laminated, earthy, in places vesicular, more thinly bedded than above, passing in places into thin beds. This includes a distinct layer of buff magnesian limestone 1 foot thick	6
2. Limestone, magnesian, gray, irregularly bedded, thin-layered, weathering to small, sharp-angled chipstones	6
1. Limestone, magnesian, brown, earthy, ocherous, in thicker beds than above, partly cemented	3

Similar but less extensive sections may be viewed at numerous points in the northeastern townships.

Devonian limestones have been quarried extensively from Pleasant Valley to Buffalo along Mississippi river. The most extensive quarries are located at Bettendorf east of Davenport and at Linwood near Buffalo. Several companies are operating near Bettendorf, crushed stone being the chief product. The Grommoll quarry is located east of Bettendorf and south of the electric railway tracks. The pit section aggregates ten to twelve feet. The upper six to eight feet is composed of a thinly bedded, brittle, white limestone while the lower four feet developed comprises heavier beds of gray to buff limestone. The upper beds in their entirety along with the spalls from the lower beds, are put through the crusher, while the lower beds supply some rubble stone. The stone is hoisted by derricks and dropped directly into a Brennan crusher (Blake type, jaws in three parts working separately). The crushed product is elevated to a cylindrical screen and sized, the screened product falling directly into storage bins from which it is loaded into cars. The output is used to a large extent locally.

The LeClaire Stone Company has a plant just west of the Grommoll quarry. The pit has been opened to a depth of about twenty feet. The section is the same as the preceding, save that the lower beds are more important and furnish a

PLATE LII—Clark quarry, near Buffalo, Scott county; upper view showing trackage arrangements leading to incline, lower view showing irregular beds and large amount of shaly talus.

[illegible] 13. — [illegible] showing [illegible] lower view showing [illegible] beds and [illegible] good grade of rubble and some range stone. The beds are gray-blue in color and range from eight to sixteen inches in thickness. The bedding planes are not very apparent. The plant is equipped with steam drills, steam hoists, and two Gates crushers. Both plants produce a superior grade of crushed stone, and practically no stripping is required at either plant.

At Linwood, east of Buffalo and north of the railroad tracks, the Linwood Quarry Company installed a crusher plant a few years ago and is producing crushed stone only. The pit shows much shattered beds of white to shaly limestone. In places the color of the stone is somewhat variegated. The plant is equipped with a Blake crusher and a number 5 Austin crusher, and the necessary trackage and derricks. A small amount of rubble is produced.

A crusher plant was opened some years ago just west of Buffalo on the Clark farm. The stone developed is similar to that at Linwood but appears to be less shaly. The plant is one of the largest in the state, having a capacity of 100 yards per hour, and is equipped with a number 7½ and a number 5 Austin crusher. The plant is well housed and is supplied with a full complement of up-to-date machinery. The stone is loosened by drilling and heavy charges of dynamite. Compressed air is used in drilling. The stone is loaded into cars having a capacity of two yards and drawn by a rope up an incline to the crusher. Most of the output is taken by the Chicago, Rock Island and Pacific Railway for ballast.

The Wapsipinicon stage of the Devonian has produced and is capable of producing some very good dimension stone and dressed stone, especially rock-faced ashlar. Trinity church, Davenport, is an example of the stone obtained from the upper Davenport beds, while the cathedral of the Protestant Episcopal church was built from stone obtained from the Lower Davenport beds.

The Middle Devonian beds as represented by the Cedar Valley limestone, are for the most part too argillaceous to afford building stone of good quality. Several of the lower layers furnish stone of fair quality and several quarries have been opened to develop them, the most important of which are located near Buffalo. One of the most extensive quarries is located on the southwest quarter of section 13, Buffalo township. The beds worked are as follows:

	FEET.
2. Limestone, hard, gray, subcrystalline, fossiliferous, in horizontal layers ranging from four to nine inches in thickness	7
1. Limestone, argillaceous, blue weathering buff, upper nine feet highly encrinal, main joints run north, 35 degrees east and do not continue upward into number 2	14

The other quarries of the township present very similar sections. Most of the stone quarried was used for river improvement work by the government. Some has been used for road work and rough masonry.

SHELBY COUNTY.

Sand and Gravel.

Shelby county is wholly within the loess-covered Kansan drift area. The Nishnabotna is the most important stream and flows in a wide valley across the county from north to south. This stream is in its meander stage and has done but little work in sand and gravel accumulation. The subloessial sands have been exploited from time to time in the vicinity of Harlan on the east bluff of the river. The sands are of the usual character, are fine-grained and carry considerable clay, and are all highly iron-stained. Formerly some coarser material was obtained from a pit on Elk creek two miles north of Kirkman along the Harlan branch of the Chicago and North Western Railway. Small quantities of sand are obtained from some of the creek channels, but the bulk of the sand and all of the gravel is shipped in from the Platte river in Nebraska, Raccoon river in Des Moines and vicinity, and from near Lanesboro in Carroll county.

Nishnabotna river has remnants of a terrace from Harlan to Oakland, in Pottawattamie county. A brief description of this, together with a generalized section, is included in the report on that county.

SIOUX COUNTY.

Sand and Gravel.

Sioux county is well supplied with gravel and sand deposits. There is an almost continuous terrace along Big Sioux river entirely across the county, which affords enormous quantities of water-deposited materials. Rock and Floyd rivers and other smaller streams also have gravel terraces.

Some of the streams have cut through the veneer of loess, which covers the whole county, and have in many places exposed gravel and sand which are of much importance locally. Sand and gravel bars in the streams also furnish large amounts of road and concrete materials.

Terrace Gravels.—So far as terrace gravels are concerned, the Big Sioux is the important stream of Sioux county. There is an almost continuous terrace along it entirely across the county.

Beside the road at the southwest corner of section 9, Settlers township, is an exposure of old iron-stained gravel underlain by sand. The pebbles are very much decayed, and the whole is deeply iron-stained and firmly cemented throughout. This is some forty feet or so above the river. Two or three hundred yards southwest of the schoolhouse a gully some ten feet deep has exposed practically the same material. In the latter place the top of the gravel is perhaps fifteen or twenty feet above water. This gravel is in every respect the same as that seen along the Big Sioux throughout its course in Lyon county except that here there seems to be a larger proportion of sand and that the classification is more complete. The river has cut down through the old gravels and left a bench, on the edge of which the exposure in the road noted above is located. The latter exposure is right in the present flood plain, and the gravels are covered by three to four feet of alluvium. A short stretch of road north of the schoolhouse has been surfaced with this gravel, and is in excellent condition.

From Beloit to Elm Springs the terrace is almost continuous and will average a quarter of a mile or more wide. Other than the exposure at the southwest corner of section 9, there are several localities between that point and Elm Springs which show the same material. In the upper bench the gravel is covered to a depth of two or three feet, and in the flood plain of the river the covering over the gravels is on the whole perhaps a little deeper.

On the east bank of the river just south of the southwest corner of section 25, Settlers township, the Big Sioux has cut back into the high terrace, here forty feet above water, and has exposed the full depth of the terrace gravels. The lower limit is marked by a spring line twenty-two feet above water level, leaving eighteen feet as the depth of the gravels. The section shows all sorts and sizes of material from coarse sand up to bowlders more than a foot in diameter dumped in helter-skelter. The whole is deeply iron-stained and the large granite bowlders are in an advanced stage of decay and fall to pieces with a light stroke of the hammer. This material corresponds in every respect to the gravels which are exposed so often along the river in Lyon county and thus far in Sioux.

Practically all of section 36 and half or more of section 25 are on the bench in which these gravels occur. But near the middle of the west side of section 25 a gully some eight or ten feet deep has failed to expose gravel. Its walls exhibit nothing but a loess-like substance which grades downward into a rusty material which is half clay and half sand, and rests upon blue clay. This is in the same bench in which the gravels occur farther south.

East of Hudson, South Dakota, on the Iowa side, is a wide plain at the junction of Big Sioux and Rock rivers. This plain has an area of nine or ten square miles and is perfectly level between the flood plains of the two rivers. The Chicago, Milwaukee and Saint Paul Railway has a pit on this terrace in the southwest corner of section 8, Garfield township. This opening shows:

	FEET.
Soil and alluvium	1-2
Gravel, medium; few pebbles over 1 inch diameter; very clayey above and iron-stained below; sand layers of varying thickness interbedded; horizontally stratified	4
Gravel, very coarse, pebbles ranging up to 1 foot or more in diameter, exposed	5

This gravel is being removed by a steam shovel and is used for ballast, as much as a hundred cars per day having been taken out. Water is reached at the bottom of the present opening. These same gravels may be seen in a shallow road cut in the center of section 17, Garfield township, just on the edge of the terrace where it has been cut down by Rock river.

It is highly probable that the whole of this area is underlain by these gravels. Except for a hill a quarter section or so in extent in the middle of section 8 the surface is perfectly flat and the problem of opening the gravels is an easy one. These are not the same gravels as are found in the Big Sioux terrace as seen so far, but correspond more closely to the deposits along Rock river.

At Fairview, on the Dakota side of the river between Hudson and Elm Springs, is a pit which has been worked by the railroad. It is not now being operated, but large quantities of surfacing material have been removed in the past.

Between Hudson and Hawarden the river terrace is not at all prominent. In only a few places is the gravel visible, and then the exposures are far from being satisfactory. Three miles north of Hawarden, where the bench can be observed most closely, it is covered with several feet of alluvium.

In and about Hawarden the terrace gravel has been opened in many places. Two pits in the northwest part of town exhibit a section as follows:

	FEET.
Soil, sandy	2-3
Gravel, fine, interbedded with coarse sand; roughly stratified and somewhat cross-bedded	3
Gravel, fine above, grading into coarser below; pebbles up to 2 or 3 inches in diameter; somewhat iron-stained	2-3
Coarse sand and fine gravel intermixed and cross-bedded	3
Coarse gravel to bottom.	

This detailed section was taken in the Briggs pit. The railroad pit just adjoining, which is worked occasionally, shows the same materials. Except for some iron stain which occurs practically all through the section, the gravel is clean and bright. The pebbles are principally greenstone, quartzite and granite, and are hard and fresh. Road material has been taken from here, and gravel is now being used for concrete.

Some of the material stripped from the top of these gravels has been used on the streets in Hawarden, and a more abominable road stock could hardly be conceived. Many of the streets are so dusty in summer as to be hardly passable, and the surface is very soft. Some of the streets have been surfaced with gravel and are in good condition.

Along Rock river in Sioux county the same terrace as noted in Lyon county continues. A small abandoned sand pit near the northwest corner of section 15, Garfield township, shows about three feet of fine, clean sand and gravel, covered by two feet of alluvium. There are perhaps a hundred acres in this portion of the bench. Along the river in the northwest corner of section 10, Garfield township, some two or three hundred yards south of the railroad bridge, fine gravel and sand may be seen in the river bank. Fully two feet, and probably more, are exposed here under two feet of alluvium. The top of the bank is some twelve feet above the water level.

Fine gravel and dirty sand are to be seen on the north side of a small creek at the northwest corner of section 2, Garfield township. A litle farther north, along the road between sections 34 and 35, Sioux township, is an opening in the bench showing:

	FEET.
Gravelly soil	2
Gravel and sand, becoming finer below	3-4

This portion of the terrace probably corresponds to the one of much larger extent just east of Hudson, and has an area here of some two hundred acres or so.

The terrace continues very much the same on to Rock Valley, which town is situated almost wholly upon it. An exposure in the southwest part of the town at the edge of the creek and north of the main line of the railroad shows some six or eight feet of very fine gravel grading into sand below and covered by two feet of black soil. Practically this same material is found in excavations for cellars, etc., in Rock Valley. The depth of the alluvial covering is as high as five feet in places.

Between Rock Valley and Doon in Lyon county the same fine gravels are exposed in many places. The cover of alluvium varies in depth, which is as high as ten feet in places. The gravels grow coarser up the river, as might be expected from their manner of deposition.

Floyd river affords gravel for road and concrete purposes throughout all of its course in Sioux county. A more or less continuous terrace some twenty feet above water level in the Floyd can be followed most of the way, and is particularly prominent between Hosper and Alton. The largest opening in this terrace is at the former place, where sand and gravel are being used for cement products. The section here shows clean, fine gravel and sand, stratified horizontally, lying beneath a cover which varies in depth from zero to three feet. The top of the terrace is fifteen to eighteen feet above the Floyd, and there are twenty to twenty-five acres in the bench in which the pit is located.

Both north and south of Hosper along the river exposures of this same bench gravel may be seen. A few places at which openings have been made are in the middle of the west side of section 23, near the northeast corner of section 27, and where the river crosses the north line of section 34, all in Lyon township; in the southwest corner of section 9, the middle of the east side of section 17, at the intersection of the river and the north line of section 29, and near the southwest corner of section 30, all in Floyd township. At the bridge on the east line of section 35, Floyd township, is a small open pit which furnishes gravel and sand for the neighborhood. This exposure shows intermixed and interbedded sand and gravel which correspond quite closely to the beds exposed at Hosper, described above. Another very similar section may be seen just east of the bridge in the north edge of Alton.

South of Alton to the county line the pronounced terrace which is so much in evidence northward toward Hosper is not at all conspicuous. There are several openings of gravel in this vicinity that will be discussed under another head.

Other Stream Gravels.—Along some of the streams in Sioux county may be found exposures of gravel which quite certainly are not of Wisconsin age, yet whose exact location stratigraphically is a disputed question. Mention has been made of certain deposits in northwestern O'Brien county called morainic by Macbride. Gravels that may correspond to these have been opened in several places in the vicinity of Alton. Excellent sections of these gravels may be seen in two pits in southwest 1 and southeast 2 of Nassua township, half a mile southeast of Alton. In the former place are exposed ten to eleven feet of usable gravel and sand, well interbedded, but not cross-bedded. The sand element is predominant. The cover is loess or wash and varies in depth from two to six or eight feet. There is a considerable amount of clay in the upper beds, but the lower appear to be composed of clean and sharp sand and gravel. The beds as a whole maintain a vertical face with but little sliding, being in places quite firmly cemented with calcite. So stable are the beds that swallows have built nests in burrowings in the upper portion. Large bowlders, even up to one and a half and two feet, not in great numbers, but plentiful, are sprinkled here and there throughout. Quartzite is common among these.

Very similar material may be seen in a bend of the river in southeast 15, Nassua township. At this place the loess covering is as much as ten feet deep in places.

Gravels occurring along the West Floyd and the upper reaches of Six Mile creek, north of Ireton, seem to come under this category. They possess the same general characteristics as those mentioned above. In almost every case the deposits show fine gravel and sand of varying degrees of purity grading into more or less clean, sharp sand below. Deposits of this kind may be seen in southwest 17, west 20 and southwest 19 of Center township, and in several places along the West Floyd west of Maurice.

In relation to these latter gravels, Prof. I. A. Williams remarks, "The gravels certainly bear no relation to any recent stage of the streams, except as the latter have gratuitously and fortuitously called attention to their location, and in places

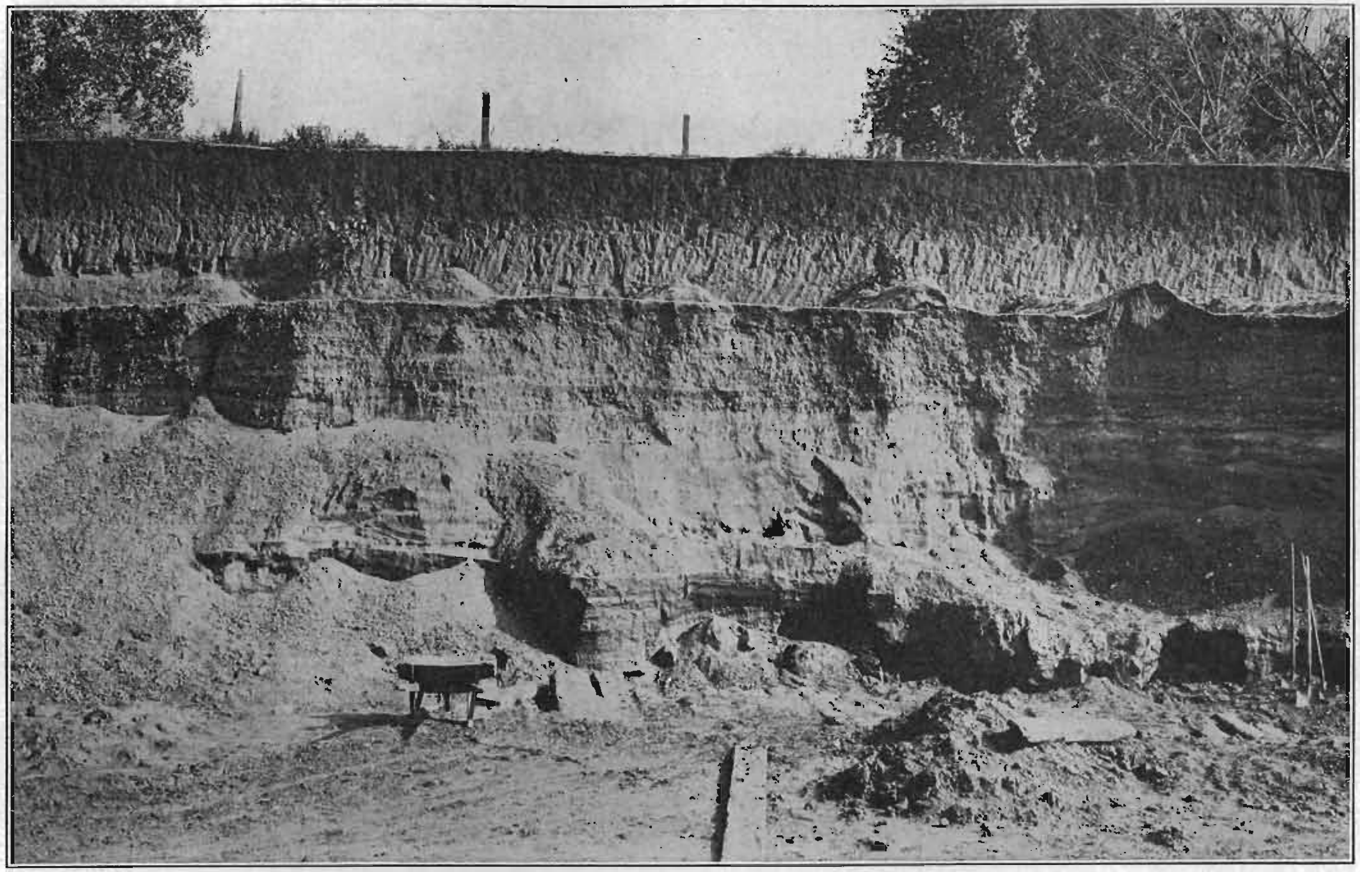


PLATE LIII—Hyink pit showing rather heavy stripping. Alton, Sioux county.

partly uncovered them, in their meanderings. They seem to be well developed portions of the beds that quite universally underlie the loess in Lyon and Sioux counties into which the streams have cut."

Reworked Materials.—Along the Big Sioux are many sand and gravel bars much the same as mentioned in Lyon county. Perhaps the one of prime importance is that at the union of Dry creek with the Big Sioux at Hawarden, now being worked by the Hawarden Sand and Gravel Company. This company has a lease from the Government on a big bar, in which perhaps eight or ten acres are still workable. The sand and gravel, which will average about eighteen feet deep, are removed by means of a centrifugal pump.

The waste product obtained by screening and washing the "pump run" would make an excellent road material.

There are also bars of various sizes along Rock river and some other streams, but none of these are really important.

STORY COUNTY.

Sand and Gravel.

The sand and gravel deposits of Story county are of the two classes found so generally in those counties covered by the Wisconsin drift, viz., stream terraces and pockets in the drift hills. The former appear along Skunk river, its leading tributary, Squaw creek, and Indian creek. Gravel-bearing knobs are most common in the vicinity of the Altamont and Gary moraines.

Stream Terraces.—"Contemporaneous with the heaping up of glacial debris at the end of the ice were certain streams issuing from the melting ice. These surcharged streams were competent to carry coarse sand, gravel and even bowlders of small size, which were redeposited over the flood plains of the then existent streams in their lower courses. These gravel beds and bars have been removed in part since the retreat of the ice, and broad benches or terraces are the result. A system of terraces has its beginning at the Walnut creek moraine (a series of morainal hills marking a temporary halt in the retreat of the ice). Cambridge, on Skunk river, and Maxwell, on Indian creek, are built on terraces belonging to this system and attaining heights of twenty-five and twenty feet above the flood plains of the respective streams.

"Terraces continue northward on East Indian creek to the three forks in sections 13 and 14 in Nevada township, where they have a height of twenty-five feet above the flood plain and are composed of very coarse materials; much coarser than at Maxwell. The equivalent terrace was not recognized on the west fork of the Indian.

"Along the Skunk the Walnut creek terrace may be traced northward to the creek of the same name, where it is superseded by a younger terrace, the contemporary of the Gary mo-

FIG. 54—Gravel pit, Skunk river terrace near Soper's Mill, Story county.

raine. (The Gary moraine represents a similar halt to that which formed the Walnut creek moraine, and is younger than the latter.) The gravel train produced by the Gary reaches its maximum development, both areally and vertically, in the vicinity of Ames along both Skunk river and Squaw creek. At Soper's mills the Gary terrace rises twenty feet above the flood

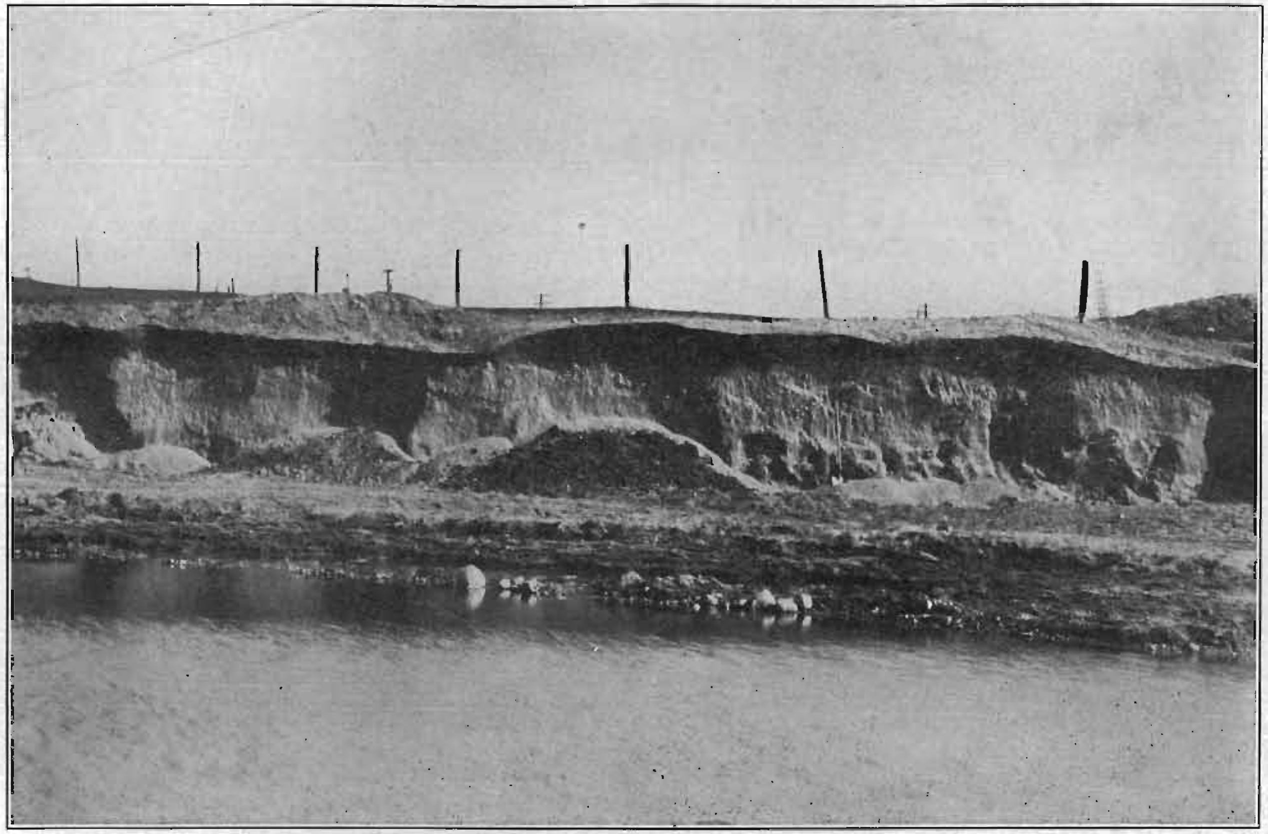


PLATE LIV—Iowa State College gravel pit located on the Squaw creek terrace, Ames, Story county.

plain; at Ames it rises thirty feet, after which it grades down gradually to ten feet in southern Grant township, and finally merges into the Walnut creek bench.

"The towns of Ames and Cambridge are built on gravel bars located at the confluences of Squaw and Ballard creeks respectively with Skunk river. Records of wells put down at these points show a series of sands and gravels separated by heavy beds of clays and silts."

At Maxwell and at Ames the terrace gravels were formerly developed by the railroads, but these pits are now abandoned.

Stream Channel Deposits.—Sand in every way suitable for building purposes and for plaster is found in nearly all of the stream channels. The extensive sand flats along the Skunk furnish unlimited quantities of sand adapted to the rougher grades of masonry.

Morainal Gravels.—Away from the streams numerous knobs and kamelike aggregations furnish great quantities of material suitable for road making. Sand usable for building purposes may also be found in these knobs, which are often prominent in the morainal regions of the Wisconsin.

Stone.

Story county is poorly supplied with stone suitable for structural purposes. The Saint Louis limestone affords a limited quantity of stone adapted to foundation work and use in the rougher grades of masonry. The rock is, as a rule, highly absorbent and does not stand frost well. Its earthy buff to gray-buff color gives it a dull, somber appearance which increases rapidly on exposure on account of the readiness with which it takes up foreign matter. Some quarrying has been done at nearly every one of the outcrops in the county, though in no instance does the annual output of any single quarry exceed a few dozen cords of rough stone. The ledges developed are practically the same at all points and are confined to Skunk river between Bloomington and Soper's mill, and to Onion creek, a

FIG. 55—Representative section of Saint Louis limestone, as it appears along Onion creek, about four miles northwest of Ames, Story county.

tributary of Squaw creek, northeast of Ontario. The section exposed north of Hannom's mill may be considered a fair average for the Skunk river district, and is as follows:

	FEET.
6. Till, pale yellow; unoxidized and unleached	0-6
5. Till, oxidized to a deep reddish brown and thoroughly leached; much weathered limestone and many decayed granite bowlders, and numerous, tolerably fresh greenstones present	1-3
4. Limestone, residual; reduced to an iron-stained, cavernous chert	1
3. Limestone, arenaceous, where unaltered, a bluish gray, but weathering stains it a yellowish brown; not thoroughly indurated, though when unweathered presents a massive appearance	5
2. Sandstone, bluish gray; shaly, presents a fissile character after being exposed to the weather, and forms a marked reëntrant in the quarry face	3
1. Limestone, impure, buff to earthy yellow, gray-buff when unweathered, heavy-bedded, compact; lithographic in part, chief quarry stone; exposed	8

At the Bloomington quarries more of number 1 is exposed.

Several outcrops of the Saint Louis may be observed along Onion creek in section 32, Franklin township. The beds exposed attain a maximum thickness of nearly thirty feet, but are less constant in character than their equivalents along Skunk river. A composite section representing the district is as follows:

		FEET.
7.	Drift and soil of variable thickness, in places reduced almost to zero, but thickens greatly in the bluffs	1-70
6.	Limestone, thinly bedded and much weathered, stratification planes almost entirely eliminated; in places grading upward into a residual clay	4
5.	Limestone, impure, yellowish brown or gray-brown, compact to earthy, heavy-bedded	7
4.	Limestone, finely arenaceous and marly, contains beautifully preserved mud cracks and ripple marks in places	2
3.	Sandstone, white to bluish gray, friable; obliquely laminated and fissile; readily undermined by the creek; not persistent	1½
2.	Limestone, cherty and concretionary; contains much limonitic iron	2
1.	Sandstone, argillaceous; becoming shaly below, exposed	3

Number 5 is the principal bed quarried, and the rock is similar to that in the Hannom's mill and Bloomington quarries. All of the stone exposed in Story county is too soft for road work and is of rather poor quality for concrete. The outcrops are not numerous and the overburden thickens rapidly from the face of the crops. The outlook for the county as a crushed stone producer is not encouraging.

TAMA COUNTY.

SAND AND GRAVEL.

In sharp contrast with the counties which border it, Tama county is practically devoid of gravel. Even the Buchanan gravels, which have a more or less prominent development in some of the neighboring counties, are not known to occur in Tama. On the hill slopes in a few places there are thin sheets of bowldery gravels overlying the Kansan till which simulate the Buchanan gravels, but these in no place are of sufficient importance to constitute workable deposits. Beds of this kind may be seen along the roadside between sections 13 and 14, Highland, and between 19 and 20, Howard townships.

The channels of all the larger streams of the county are bordered by a wide belt of alluvium. Excavations in the flood plain of Iowa river reveal about four feet of dark colored, fine-grained soil at the top resting upon a bed from twenty to upwards of thirty feet in thickness composed of yellow clay, sand and gravel. This bed rests upon the bowlder clay of the Kansan drift. The bottom lands of Iowa river in Tama county have a total area of almost a hundred square miles. Large quantities of sand suitable for building purposes are taken annually from the sand flats in and along the channel of this stream.

There are a few small patches of gravel, but they are of no economic importance. Gravel two or three feet deep and covering an area of perhaps forty square rods is present on the farm of Frank Lewis, three-quarters of a mile northwest of Butlerville. About five miles east of Clutier, in southeast 13 of Oneida township, there is about an acre of land uncultivated because of gravel. There are no deep pits here, but the soil is gravelly to a depth of one or two feet. A quarter of a mile east of this there are terrace gravels in small quantities, and there is also some terrace gravel in the east part of section 24 of the same township. On the farm of Benjamin Lorenzen in the latter section there are some fifty square rods unfit for cultivation because of the presence of gravel. Similar water-laid material is reported three and one-half miles south of Traer, in Perry township.

Stone.

While the Kinderhook beds are believed to lie immediately beneath the drift over practically the entire county, outcrops are limited to a comparatively small area along the middle western border.

Essentially the same members which have been noted in the better sections at Quarry and LeGrand in Marshall county are exposed in Tama county, but in Tama they are more weathered. The Stevens quarry near the southwest corner of section 8 of Indian Village township, about one and one-fourth miles west of Butlerville, may be taken as fairly typical. The section is as follows:

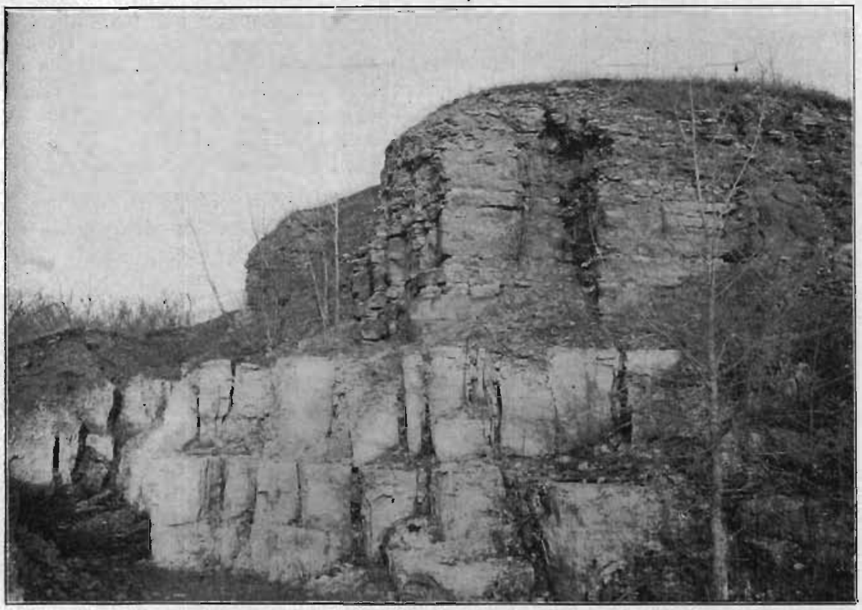


FIG. 56—View in the Stevens quarry in section 8, Indian Village township, Tama county. The thin layers at the very top are limestone and admirably adapted for road and concrete work. The white, massive beds below comprise the oolite.

STEVENS QUARRY SECTION, BUTLERVILLE.

		FEET.
15.	Gray crinoidal limestone which weathers into thin pieces..	1
14.	Crinoidal limestone, gray in color, with numerous fossil fragments	$\frac{2}{3}$
13.	Fissile limestone in thin layers, few fossils	4
12.	Brown magnesian limestone with layer of chert nodules two inches in thickness at the top	$\frac{3}{4}$
11.	Bed of rather soft, friable sandstone, much water-seamed and containing numerous chert nodules, fossils few	7
10.	Arenaceo-magnesian limestone, fine-grained and quite hard, brown in color, layers 8 to 12 inches in thickness; containing casts of a species of Chonetes, Productus, Rhynchonella and Spirifer	4
9.	Bed of incoherent, brown, fine-grained sand	$1\frac{1}{6}$
8.	Band made up of chert nodules	$\frac{1}{3}$
7.	Impure arenaceo-magnesian limestone, few fossils	$1\frac{1}{12}$
6.	Bed composed largely of nodules of chert carrying a layer of sand, 3 inches in thickness	1
5.	Magnesian limestone containing some fine-grained yellow sand	$1\frac{2}{3}$
4.	Bed similar to number 5 above	$1\frac{1}{2}$

		FEET.
3.	Layer of massive oölite weathering into small bits and bearing numerous fossils among which appear *Orthothetes crenistra*, *Spirifer biplicatus*, *Spirifer cf. extenuatus* and *Straparollus latus*	7
2.	Layer similar to number 3 above in lithological characters and fossil contents	4½
1.	Layer of light gray oölite similar to numbers 2 and 3 above	3

The oölite rests on the argillaceous sandstone exposed in other sections in the vicinity and at the base of the northeast quarry at LeGrand. The beds here exposed correspond to the coarse- and fine-grained oölite and the magnesian limestone beds of the Marshall county sections.

West of Montour in the southwest corner of section 21, Indian Village township, there are exposed in a small ravine:

		FEET.
3.	Reddish brown clay, pebbly	4
2.	Oölite, light gray, fossiliferous	6
1.	Oölite, similar in every respect to number 2 above	3½

This is the abandoned quarry of the Oxford Lime Company. The oölite was formerly used in the manufacture of lime and considerable quantities were made at this place.

Other sections appear along Iowa river toward LeGrand, and along Sugar creek in Carlton township and Deer creek in Spring Creek township. No new facies are presented.

The upper limestones wherever exposed furnish good material for road and concrete work. The oölites, on the other hand, are not satisfactory for crushed stone products.

TAYLOR COUNTY.

Sand and Gravel.

Taylor county lies wholly within the loess-veneered Kansan drift area and contains no large streams, nor streams of sufficient length to head back into the Wisconsin drift. As a consequence, the county contains but little sand and gravel. A small quantity of sand occurs in the stream channels but not enough to merit specific mention. The interglacial gravels are as a rule completely concealed by the loess and are of no consequence for road and concrete work.

Stone.

There seems little likelihood that the quarry interests of Taylor county will attain any important development. The county is universally covered with glacial materials, and the underlying strata, where they do appear, consist largely of shales and shaly limestones. Stone has been quarried at but one known point in the county, viz., at Bedford. It is twenty years since this quarry was worked and the ledge is almost entirely hidden from view. The stone was taken from about water level in East Hundred and Two creek at a point 100 yards north from the railroad station. The main ledge is about ten inches thick and contains abundant Fusulinæ. It splits very easily and is said to go to pieces in the weather. These qualities, along with the thick overburden, which runs twenty to thirty feet, have prevented its use.

Thin beds of limestone have been exposed in the banks of the Nodaway in the northwest corner of Dallas township, where they occur interstratified with much greater thicknesses of argillaceous strata. A detailed section may be found in *Geology of Page County.** The factors just enumerated would prevent the utilization of these beds for structural purposes. The drift covering is more than ten feet in thickness, and the calcareous strata are of poor quality.

UNION COUNTY.

Sand and Gravel.

Union county has sand and gravel deposits of two classes, viz., the Aftonian gravels, which underlie the Kansan drift and are numbered among the oldest of the Pleistocene deposits, and the recent accumulations of sand as banks and bars in the streams.

Aftonian Gravels.—The Aftonian gravels, so named because they were first recognized and studied at Afton Junction, constitute the most important resource of road materials within the county. This deposit lies immediately beneath the Kansan

*Samuel Calvin, Iowa Geol. Survey, Vol. XI, p. 423.

drift and, in one place at least, rests upon the limestone of the Missouri stage. There are three prominent exposures of this gravel-bearing horizon in Union county: one at Afton Junction, where it was first studied, one at Thayer, and one at the ford in section 36 of Pleasant township.

The exposure at Afton Junction is a pit opened by the Chicago Great Western Railway and long since abandoned. The gravel is deeply iron-stained and badly disintegrated, and shows all the signs of advanced age. Granite bowlders as large as a man's head may easily be crushed in the hands, and the quartz pebbles are stained a deep red-brown. All sorts and kinds of pebbles may be found, granite, greenstone, limestone, quartz, gneiss, and these are in all stages of preservation. In many places the pebbles are so firmly cemented together as to form a conglomerate which may be broken with a hammer only with difficulty. Pebbles larger than three inches in diameter are common, but not numerous. Upwards of thirty feet are exposed, covered by twenty feet or so of bowlder clay, the open face being perhaps 100 yards long. Large quantities of this material may still be obtained without further stripping, which latter operation would seem to be quite out of the question. These gravels are unfit for cement or concrete work, but will probably prove satisfactory for road surfacing.

The opening at Thayer is also an abandoned railroad pit, and the materials have all the characteristics mentioned above. Here, however, the cover is deeper, reaching as much as forty and fifty feet in places, and not so much material is still available. There is a sufficient amount for quite extensive local use, and it will doubtless constitute a valuable asset in highway improvement.

The third exposure mentioned is not so large as either of the others. The maximum thickness is not to exceed twenty feet, and the lateral extent is but a few rods. The gravel rests on a gray-blue limestone, into which the river has cut its way, and is covered by at least fifteen feet of drift. A short distance upstream from the ford two small streamlets empty into Twelve Mile creek. Between these is a flat bench perhaps twenty or thirty acres in extent, along the west edge of which these old gravels appear for some distance. Their position is marked by a definite spring line, and the gravels appear to be quite persistent. The cover seems hardly so deep here as at the other places mentioned. At this place the gravel contains a large percentage of clay, so much that if a little wet it can easily be packed into balls in the hands.

Reworked Materials.—In many of the streams of Union county sand and gravel bars are quite common, and, for local purposes at least, constitute a readily accessible source of supply. Along Four Mile creek from Thayer to its union with Grand river beds of sand in the stream channel are common. This sand is, for the most part, somewhat dirty, but in places is clean and bright. It is quite generally used for cement work by residents of the neighborhood.

In Grand river, particularly in its lower course in the county, sand bars occur frequently. Beside the road near the middle of section 2, Pleasant township, is a large bar which is used by the owner and his neighbors for cement work, but which has, however, been rejected as material for concrete bridges in the neighborhood. Farther up the river the bars contain increasing amounts of mud and silt.

These sand and gravel bars are not at all important as sources of material for bridge and highway purposes, and practically all of these materials are shipped in.

VAN BUREN COUNTY.

Sand and Gravel.

All of the sand and gravel deposits of Van Buren county are confined to Des Moines river and a few of its tributaries. These occur both as terraces and as beds and bars in the river channel and bottoms, the latter being of considerable more importance than the former.

Stream Terraces.—The most marked development of terraces in the county is in the Keosauqua "ox-bow" in Des Moines river. In this area eight well-marked terraces have been determined, reaching up to an elevation of 145 feet above the level of the river. These are composed of sands, gravels and silts deposited by the river, and mark the several phases in the development of the river valley as it now exists.

Stream Channel Deposits.—Sand may be had in abundance along all of the larger streams of the county. A short distance east of Farmington there is a gravel pit from which large amounts of ballast have been removed by the Burlington Railroad. The greatest depth worked is about eighteen feet. Of this, the top eight feet are coarse gravel and the remainder a coarse beautifully cross-bedded sand containing some pebbles. Directly south of here is a second pit worked by the Rock Island Railway. The latter, which is twelve feet deep, was opened in 1878 and has furnished ballast for some twenty-five miles of track.

STONE.

Both the Upper and Lower Carboniferous series are represented in the rocks of Van Buren county; the former by the Lower Coal Measures or the Des Moines stage and the latter by the limestones of the Saint Louis, the shales and limestones of the Keokuk and the Montrose cherts of the Burlington substage. Exposures occur chiefly along Des Moines river and its tributaries, although a few outcrops of the Saint Louis are to be seen along Cedar creek and branches, near the northeast corner of the county.

The beds belonging to the several stages and formations bear the customary relations to each other. Between the Des Moines and the Saint Louis is a major unconformity and evidences are to be observed of a break in sedimentation between the Saint Louis and the Keokuk beds. A marked anticlinal with its crest at Bentonsport brings the Burlington cherts into view in the channel of Des Moines river between Bentonsport and Bonaparte. A maximum of forty feet of these beds is exposed, but they disappear both to the north and south within narrow limits. The Burlington consists of beds of chert with occasional bands of limestone or calcareous shale but affords in this county no quarry products.

Keokuk Beds.—This member is exposed along the Des Moines from the mouth of Rock creek in Washington township to the southeast corner of the county. It is found exposed in only a narrow belt along the river, where it is usually overlain by the limestones of the Saint Louis. The formations belonging to the Keokuk substage in Van Buren county consist of the Keokuk limestone below, the Geode shales and, at the top, the Warsaw shales. C. H. Gordon writes as follows regarding the Keokuk limestone, its distribution and character:

The Keokuk limestone makes its first appearance in the extreme southeastern part of the county on a small branch on the south side of the river. About six or eight feet are exposed, and quarried to a limited extent. The next appearance is at the mouth of Reed creek, where about ten feet of bluish gray limestone, coarse, subcrystalline and mostly thin-bedded, are exposed. As the strata rise toward the west, lower beds come into view, and are seen well up in the bluff below Bonaparte, with nearly thirty feet of the Burlington chert beds below. The limestone has been quarried at several places here, but it contains large quantities of chert. Much of the rock is also shaly and the bedding of the better quality of rock is quite variable. At Bentonsport at one time, quarrying was carried on quite extensively. The principal quarry bed is from five to eight feet above the base of the division and perhaps represents the same ledge as that quarried at Keokuk and there termed the "white ledge." The upper layers at the quarry are thinner. The horizon between the thicker and thinner beds is marked by a series of undulations of one of the beds remarkable for their regularity. The vertical interval of the undulations does not exceed ten inches, while the horizontal interval does not vary much from fifteen feet throughout the whole extent of the quarry. On the opposite side of the river the rocks are well exposed for some distance up Bear creek, and show essentially the same characters as elsewhere in southeastern Iowa.*

The limestone has been quarried at a number of points in the vicinity of both Bonaparte and Bentonsport but most ex-

*Geology of Van Buren County, Iowa, Iowa Geological Survey, Vol. IV, p. 211.

tensively at the latter place, where the following is the approximate section:

		FEET.
7.	Geode shales, at quarry face	10+
6.	Argillaceous limestone, carrying much chert and some geodes	2
5.	Blue-gray limestone in thin ledges with interbanded black shale and numerous chert bands	8
4.	Persistent bed, blue, crystalline, fossiliferous limestone with usually a band of chert	1⅙
3.	Calcareous, dark gray shale	1
2.	Heavy bed, clean, blue-gray, coarsely crystalline	1½
1.	Calcareous shale.	

The quarry face is intermittently open in the bluff above the town for one-fourth of a mile. The base of the quarry is about forty feet above water in the river and twenty feet higher than the railway track which runs at the foot of the bluffs. Numbers 2 and 4 only have been used, and these have furnished stone for bridge piers and riprap. The stone has not proved very durable in exposed positions. It is believed, however, that all the beds might be used for crushed stone and the situation is suitable for such an industry. The exposures are in general covered with the geode-bearing shales and heavy deposits of drift.

Equivalent beds have been worked by the Chicago, Rock Island and Pacific Railway Company, three-fourths of a mile east of the town, but they are no longer used.

In the vicinity of Bonaparte the Keokuk limestone is occasionally quarried for local use. The following layers are to be seen in the southeast quarter of the southwest quarter of section 9, Bonaparte township:

		FEET.
3.	Drift	3-10
2.	Limestone, blue, irregular, thin-bedded; intermixed with layers of shale; fossiliferous, cherty	7½
1.	Limestone, blue, hard, cherty, thick-bedded, main quarry rock; exposed	6

Farther up Mack creek the fine-grained yellow limestone appears and has been quarried at a few points.

Gordon thus described the beds of the Saint Louis stage as they occur in Van Buren county:*

*Iowa Geological Survey, Vol. IV, p. 214.

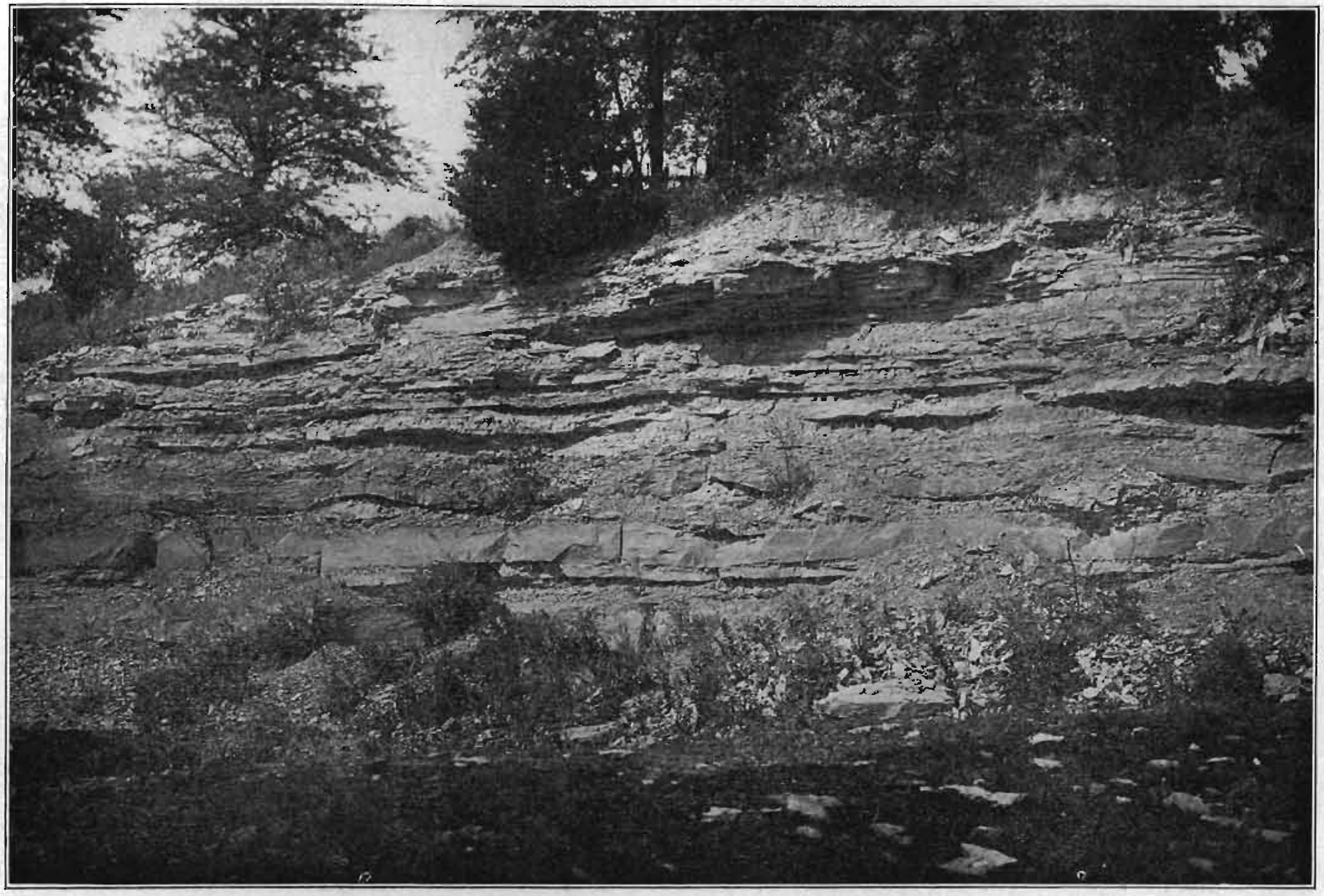


PLATE LV—Old quarry opening in Bentonsport, Van Buren county.

The Saint Louis limestone constitutes the uppermost division of the Mississippian, . . . and has the greatest superficial extent of any of these members in Van Buren county. It is generally overlain by the rocks of the Des Moines stage of the Upper Carboniferous. . . . The maximum thickness in Van Buren county probably does not exceed ninety feet.

In lithological characters the rocks composing the formation show great variation. In general they present a three-fold division consisting of (1) brown arenaceous and magnesian limestone, (2) brecciated limestone, and (3) gray, compact, and granular limestone.

Arenaceo-magnesian Beds.—The first of these is exposed at many places along the Des Moines and is especially well developed in the vicinity of Kilbourn and in the bluffs below Keosauqua. It consists of fine-grained or vesicular magnesian limestone in rather heavy ledges, which grade horizontally into a more or less clearly marked arenaceous rock characterized in places as a sandstone. A large percentage of the rock, however, is made up of calcareous matter, and hence it is more properly designated as an arenaceous limestone. It is well developed on Price and Bear creeks where it furnishes a very good quality of stone for building purposes, and has been quarried quite extensively for plates and sills. This bed represents that quarried at Belfast and Keokuk. It constitutes the upper member of the Warsaw as originally defined. The arenaceous character is confined generally to the lower part of the beds, but on Bear creek as well as elsewhere, sand forms the larger part of the formation. The magnesian limestone constitutes the most generally recognized phase of the division in the county. When first removed from the bed, the rock is of a blue or drab color, but it soon changes to a rusty brown by the oxidation of the iron which it contains. . . . The magnesian rock occurs in thick, gently undulating beds, and is distinguished by a more or less concretionary structure. . . . In places these beds are interrupted by the brecciated phase which in these instances is in direct continuity with that of the overlying bed. The thickness of the arenaceo-magnesian beds varies from ten to twenty-five feet.

Brecciated Limestone is a widely recognized phase of the formation in Iowa. The bed is made up generally of compact and granular, gray limestones, in sharp angular fragments of various sizes cemented together by similar calcareous material.

Near the mouth of Reed creek, the whole of an exposure seventy-five to eighty feet in height shows brecciation. The lower portion represents the arenaceo-magnesian bed and is composed of large fragments of this limestone with clay filling the interstices, while the upper part is made up of the compact and granular limestone more completely cemented. In the vicinity of Keosauqua, the upper portion of the bed contains more or less arenaceous material. This is well marked on the south side of the Des Moines above the town, where a brown sandstone ten to twenty feet thick replaces nearly the whole brecciated division and is overlain by limestone. Two or three miles below, the sandstone varies from five to twenty-five feet in thickness and rests upon the brecciated bed, while it is overlain by the compact limestones as shown in the bluffs opposite Keosauqua.

Quoting again from Gordon:

The sandstone at Keosauqua is decidedly calcareous in places, and sometimes includes irregular ledges and fragments of limestone. . . . The thickness of the brecciated division varies from nothing to seventy-five feet. In general, however, it may be said to be from ten to twenty feet thick.

Compact and Granular Limestone.—Overlying the brecciated limestone in places, and the Keosauqua sandstone where that formation occurs, is a compact, fine-grained, gray limestone characterized by having a conchoidal fracture, concretions, and a considerable number of fossils. . . . In some places the compact limestone is replaced by a thin-bedded limerock with a marked granular structure often cross-bedded. . . . The limestone of this upper division is well developed along Indian creek where the compact variety is quarried quite extensively. The thickness of the bed does not exceed fifteen feet. It is also quarried at Keosauqua on both sides of the river.

As pointed out, the Saint Louis beds have been more extensively quarried than the other formations of the county. Near Des Moines river in the northwest quarter of section 31, Lick Creek township, the Saint Louis beds were formerly opened up for quarrying. A few feet of the upper arenaceous limestone has been quarried at Kilbourn and at other points on Lick creek but all these openings have been long since abandoned.

The white limestone has been quarried on Thatcher's creek on the southeast quarter of section 2, also on the southeast quarter of section 1, Des Moines township. Just east of the town of Keosauqua near the north edge of section 31, twelve to fifteen feet of limestone has long been worked for foundation and rough building stone.

The Saint Louis beds have been opened up for local use at many places along Rock creek in Washington township. Gordon (page 220) gives the following section at the mouth of Rock creek:

ROCK CREEK SECTION.

		FEET.
6.	Concealed	5
5.	Limestone, compact, gray; breaking with conchoidal fracture; contains abundant brachiopod remains	6
4.	Sandstone, brown, quartzose	4
3.	Limestone, brecciated, well cemented	20
2.	Limestone, hard, blue, weathering brown; heavily bedded and concretionary; sandy at top, at base bluish and dolomitic in appearance	14
1.	Concealed to river level	35
	Total	84

Number 2 has been quite extensively quarried here for the early river improvements.

Northeast of Bonaparte on Mack creek and farther south on Reed and Potter creeks, the sandstone and brown magnesian strata have been quarried for use in locks and dams in river improvement work. The beds worked on Reed creek afford a stone which dresses well and has been used also for caps, sills and for well and cellar walls. It is said to be much more durable than the white limestone under the same conditions. Unlimited quantities of these strata are available along Potter and Reed creeks, where little stripping would be necessary and the quarries would be conveniently accessible to the railroad.

The blue sandstone has been quarried for many years on Bear creek in section 11, and a more recent opening has been made by Perry and Isaac Davis in the northwest corner of section 31, Henry township. The section at the latter place is given herewith:

FIG. 57—Davis quarry, west of Bentonsport, Van Buren county. Heavy beds of magnesian sandstone (Warsaw Sandstone).

		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, "sandstone", solid ledge which splits readily with chisel parallel to bedding; some chert near base	5
3.	Irregularly bedded gray to blue, coarse-grained limestone, fossiliferous (bryozoan abundant)	5+
2.	"Soapstone," containing chert, to water in creek	1½
1.	White limestone reported to unknown depth	1½

Number 6 is plastic and appears free from concretionary matter. The maximum amount of stripping, about fifteen feet, is indicated in the section. Stone is shipped from this quarry but must be hauled to the railroad at Bentonsport. The sandstone gives good satisfaction in walls, and dresses well for use in more conspicuous and exposed parts of buildings. John Gaston has a small opening in the same beds one-fifth of a mile south on the opposite side of Bear creek.

A good development of the "sandstone" occurs also in the Price quarry on a tributary of Chequest creek in the southwest quarter of section 20, Van Buren township.

Section six miles northwest of Keosauqua along a small tributary of Chequest which enters the larger stream from the southwest:

		FEET.
7.	Drift and loess of variable thickness.	
6.	Limestone, much weathered and siliceous, certain layers weather shaly and are stained red to yellowish brown....	2-4
5.	Limestone, blue-gray, evenly bedded and of uniform texture; very hard and tough, beds up to thirty inches in thickness	4
4.	Talus slope.	
3.	Limestone, gray, vesicular, coarser textured than number 5 and fossiliferous, partially obscured by talus slope; thickness not determined.	
2.	Sandstone in heavy ledges, evenly bedded though beds are somewhat undulating; layers smooth enough to be used for dimension stone without tooling....................	10-12
1.	Shale, calcareous to arenaceous, blue-gray, yellow where weathered; said to become more shaly below the bed of the stream; exposed..................................	3

The sandstone beds range up to three feet in thickness, although blocks more than two feet thick were not seen in any of the sections exposed. It has been used extensively for bridge work and other heavy masonry. This stone was used for the piers which support the wagon bridge across Des Moines river. It yields to any kind of stone dressing, is strong and withstands weathering influences well. Blocks put in walls or piers more than a half century ago still retain the tool marks, which appear to be as fresh as when the blocks were laid. On account of lack of transportation facilities almost no stone is quarried at the present time.

The Saint Louis limestone is well exposed all along Chequest creek from the middle of Chequest township to Pittsburgh. As indicated in the above two sections the lower portion of the magnesian limestone grades locally into a sandstone.

The large proportion of the stone used in the southern part of the county has come from the Indian creek quarries west of Farmington. Outcrops occur along this stream from near its mouth to the quarries on the line between sections 5 and 32 of Farmington township. The quarry in section 5 is now

FIG. 58—Saint Louis limestone exposed along creek about three miles west of Farmington, Van Buren county.

worked by Cyrus Falker and Mark Hornbaker. Lime burning was formerly done here. The strata now visible are given:

		FEET.
8.	Loess and drift	10+
7.	Limestone, gray, coarsely subcrystalline, weathering to a friable condition; thin shaly layer at base	2½
6.	Limestone, homogeneous and fine-grained, with conchoidal fracture above; coarser and more impure below; separated into heavy ledges, the upper one 18 inches thick; stone traversed by seams of crystalline calcite which in general run vertically	5⅚
5.	Obscured	3½
4.	Soft shale, gray	4
3.	Limestone, heavy ledge; gray, compact, fracture conchoidal, irregularly shattered by weathering	2½
2.	Alternating bands of light blue to brown limestone and slaty shale	2
1.	Thin-bedded limestone, to water	3⅚

Only the members above No. 5 have been used. The upper three feet of No. 6 make a fair building rock. It is hard and weathers slowly. There is a considerable area on both sides of the creek where the stone is available without an excessive amount of stripping. The beds would afford a good product if crushed. The Chicago, Burlington and Quincy railroad follows Indian creek and would afford good transportation facilities.

Section one and a half miles west of Farmington, south of coal chute of Chicago, Burlington and Quincy Railroad:

		FEET.
6.	Loess and wash, rather sandy and iron-stained and mottled throughout	5-20
5.	Shale, clayey, blue-gray	3
4.	Shale, arenaceous, hard, projecting ledge; variable	1-2
3.	Shale as above	3
2.	Shale, arenaceous, forms a projecting ledge similar to 4, variable	1-2
1.	Shale, somewhat variable in texture, varying from plastic and gritless to slightly arenaceous; as a rule becomes highly plastic on weathering; evidently fissile, blue-gray to dark blue; occasional concretions and geodes present. Exposed above creek channel about	8

About one-half mile farther west a massive sandstone appears in a cut along the railroad and below the railroad bridge the heavy-bedded sandstone may be seen resting on the shales. The undercutting of the creek has produced and is maintaining an escarpment. The bedding planes in the sandstone are not apparent and the beds in the railway cut appear to be disturbed. The sandstone and shales appear to be the equivalents of those exposed along Des Moines river below Belfast. (See plate XXIX, c, page 401.)

Van Buren county is unusually rich in hard, compact limestone suitable for crushed stone products. The county is not, however, very well equipped with transportation facilities, especially near the important stone crops.

WAPELLO COUNTY.

Sand and Gravel.

The gravel and sand deposits of Wapello county are of two kinds, viz., the Aftonian gravels which underlie the Kansan drift, and bars and beds of sand in the channels of the principal streams.

Aftonian Gravels.—A few exposures of Aftonian gravels are present in the county. As a source of gravel supply this formation is not commercially important, but it will doubtless furnish limited amounts for local use. This ferruginous and much weathered gravel, often partially cemented into a conglomerate (described in some detail in the report on Union county), occurs at the base of the drift of the district and rests directly upon the Coal Measures. It is well shown near the northwest corner of section 6, Cass township, along a tributary of South Avery creek. Here the black shales are overlain by a very ferruginous gravel and coarse, cross-bedded sand. In places the iron is sufficiently abundant to serve as a cementing material, and a firm conglomerate or coarse sandstone is formed. The pebbles are mostly quartz and sandstone, but some are igneous in character, such as greenstone and granite. On North Avery creek in the southwest quarter 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 Des Moines river just above Eldon. The gravel and sand at this place have a thickness of ten feet. They rest upon the Coal Measure shales and are overlain by fifty feet of drift.

Sand and some gravel is taken from Des Moines river in Ottumwa and vicinity. The sand plants are located from one-fourth mile south of the Milwaukee railway bridge to the principal pit just below the west end of the Vine street bridge. The gravel is fine-grained, mostly sand, and the supply is renewed by the river.

The Ottumwa Sand Company is operating a pumping plant one-third of a mile below the Milwaukee railway bridge. A 75 H. P. motor is placed on a dredge in the river. The capacity of the plant is about 500 tons per day. The sand bed varies from three to five feet in depth. The quality is not quite so good as at the Vine street bridge. About one-fourth of a mile below the pumping plant considerable gravel is obtained for local use.

Large amounts of sand and gravel are being accumulated near Chillicothe and considerable quantities of sand have been accumulated by the river between Chillicothe and Eldon but these deposits are of less importance below Cliffland. At Eldon there is a large sand and gravel bar.

There is a sand pit on the flood plain of the river in section 14, Keokuk township. The small creeks emptying into Des Moines river between Chillicothe and Eldon deposit sand only in small amounts. The sand is considered too fine-grained for commercial purposes though it is used to some extent by the county. Village creek is accumulating some sand in section 9, Keokuk township. Soap creek, which enters Des Moines river at Eldon, deposits a considerable amount of good sand, though mostly in Davis county. This sand bar is about 75 to 100 feet in width and one-half mile in length. The quality is probably inferior to that at Ottumwa.

STONE.

In Wapello county the representatives of the Saint Louis stage that are of economic importance belong to the Pella beds, the upper division of the formation. Exposures are practically confined to the northwestern part of the county where the beds outcrop along the Des Moines valley from Eddyville to Ottumwa, and on North and South Avery creeks in the vicinity of Dudley.

Limestone was formerly quarried at a number of openings south of Eddyville, near the mouth of Miller creek. The John Lafferty quarry is the only one now in operation. It is located on Miller creek in the southwest quarter of section 7, Columbia township. The section exposed here for a distance of eight to ten rods, is as follows:

		FEET.
7.	Loess and river silt	5
6.	Residual clay, deep red, plastic	3½
5.	Residual clay, greenish, calcareous, grading into argillaceous limestone	3
4.	Compact limestone of lithographic texture and separated by marly partings; on exposure it becomes badly shattered by weathering of partings and vertical jointing	2⅓
3.	Heavy limestone bed, highly fossiliferous, upper portion contains cavities lined with calcite and abundant iron pyrite concretions; two ledges, respectively 14 and 22 inches	3
2.	Shell marl, a few inches.	
1.	Close-textured bluish limestone in 4 to 6 inch layers, to base of quarry	2½

Number 3 shapes readily and affords excellent stone for building purposes and for heavy masonry.

This quarry supplies stone which is used in bridge abutments in this and adjoining counties. The stone is handled by derrick and loaded on wagons. Considerable quantities have been shipped from Eddyville. There is a triangular terrace area here of considerable extent lying between Des Moines river and Miller creek around the borders of which the stone outcrops. The overburden is probably not more than ten or twelve feet at any place, and an unlimited supply is thus available.

At Dudley large quantities of rock have been removed just west of the Chicago, Burlington and Quincy station, both north and south of the tracks. Stone is now quarried by Andrew Lames on the south side of the railroad. The following strata are shown in the quarry face:

		FEET.
5.	Loesslike silt, underlain with a thin bed of iron-stained gravel	18
4.	Bluish shale in places.	
3.	Limestone, compact but shatters readily on exposure, separates in 2- to 3-inch laminæ	2½
2.	Limestone, compact, light brown to blue, fossiliferous in upper portion, and contains much iron pyrites	9½
1.	Blue limestone in thin layers	18-20

Only number 2 is used for building purposes and it furnishes good dimension stone, although not so heavy as the corresponding layer in the Eddyville section. Much crushed stone is produced, the railroad company using the major portion of the output. All work in the quarry is by hand. Stone for the crusher is loaded on small flat cars and drawn by one horse. Stripping is done by means of scrapers.

The T. L. Stevens opening is located on Middle Avery creek one-half mile south of Dudley. The same strata are to be seen as given in the section above. They are covered with loess and gravel. The iron sulphide concretions are more conspicuous and numerous than in the Lames section.

The Saint Louis beds in this vicinity afford a fair grade of crushed stone for ballast. The presence of iron pyrite, which rapidly weathers and leaves blotches, streaks of iron rust,

PLATE LVI—Andrew Lames quarry, Dudley, Wapello county. The section shows the hard, compact beds of the Saint Louis limestone under the usual heavy stripping of the district.

and small cavities in the stone, is a drawback to the extensive use of number 2, which is otherwise suitable for building purposes. Without question there is more and better stone available in the vicinity of Eddyville than at Dudley, but it is in a less accessible location at present for railroad transportation.

Limestone has been quarried at several points in Ottumwa and vicinity. It has for many years been taken from the bed of the river at Ottumwa during low water. A new place is opened up and worked out each season. That portion of the bed of the stream which is to be quarried during the summer is enclosed by an embankment to keep out the water. This is constructed of barrels filled with clay against which are piled broken stone, gravel and sand, until a substantial barrier is built up. About six feet of limestone are removed, the upper layers being thin-bedded and the lower ledges three to eight inches thick. All of the Saint Louis beds exposed here and at other places in the county are suitable for crushed stone products.

WARREN COUNTY.

Sand and Gravel.

Warren county as a whole presents an unbroken loess-Kansan drift surface. Des Moines river forms the northeastern boundary for some half dozen miles and the river here as elsewhere in central Iowa is margined with sand flats and contains sand and gravel bars of sufficient volume to supply a large portion of the county. These natural resources have not been developed to any extent in Warren county. The interior streams, while important as drainage lines, are of little importance as sources of sand and gravel. The interglacial sands and gravels are of no importance in the county. At the present time Des Moines and vicinity is the chief source of supply.

WASHINGTON COUNTY.

Sand and Gravel.

The usual interglacial sand and gravel terraces are poorly developed or almost wholly concealed in Washington county. Deposits occur in varying quantity here and there throughout the drift, but at only a few points is there a sufficient quantity of the right quality easily available. These points are, in general, along the larger streams. At Coppock, just over the line in Henry county, there is a gravel terrace margining Skunk river from which considerable amounts of material have been taken by the Chicago, Burlington and Quincy Railroad. The gravel is fine and is mixed with sand.

South of Riverside, on Goose creek, the following section was observed by Bain:*

		FEET.
3.	Sand, coarse, yellow, alternating with fine gravel	25
2.	Clay, yellow, with pebbles	½
1.	Clay, blue, plastic, few small pebbles	12

Sand and gravel in small quantities and of rather inferior quality occur in the present streams. These as well as the drift pockets are of local interest only.

Clay of good quality, such as has been burned elsewhere for ballast and road materials, is everywhere present.

STONE.

The upper magnesian layers of the Kinderhook outcrop along South English river and its immediate tributaries, but they have little to commend them for structural purposes. They have been developed, however, to a limited extent near Riverside and Wassonville, and have been used for rough foundation work, well curbing and even for bridge stone, ordinary dimension stone and caps and sills. The stone is rather soft and not pleasing in appearance.

Limestone beds referable to the Osage outcrop at numerous points in a belt which crosses the middle portion of the county in an east and west direction. Quarries have been opened northwest of Washington and north of Wellman. The Eckels quarry, located on the southwest quarter of section 2, Franklin township, presents one of the best sections between Washington and West Chester and is given below.

*Iowa Geological Survey, Vol. V, p. 153.

ECKELS QUARRY.

		FEET.
3.	Loess	12
2.	Drift	6
1.	Limestone, coarsely subcrystalline, blue, gray and white in color, running in ledges from 3 to 20 inches in thickness	20

Other quarries in the neighborhood display less extensive sections and present no new features of importance. Chert bands are quite common in all of the quarries and in one of the quarries an earthy to arenaceous bed carrying calcareous geodes may be viewed. North of Wellman, near Dayton, an old quarry shows the following indurated beds:

		FEET.
3.	Limestone, buff, arenaceous	5
2.	Limestone, brown, coarse, subcrystalline, fossiliferous	½
1.	Limestone, blue to gray, finely subcrystalline, fossiliferous	4

The stone very closely resembles that quarried in the Washington district. Openings have been made at other points, but are of local interest only.

The Saint Louis limestone occurs over a large area in the southern portion of the county, comprising a strip ranging from about five miles in width, on the east boundary, to eleven miles on the west. The most important exposures occur along Skunk river and near vicinity, in Brighton and Clay townships. The principal quarries are located in the immediate vicinity of the town of Brighton. The most valuable ledges quarried here, as well as at other points, belong to the upper member or Pella beds. The overburden is usually heavy, ranging from a few feet at the face in natural outcrops to fifteen or twenty feet a short distance toward the bluffs. There are two main ledges especially suitable for bridge stone which range from sixteen inches to two feet in thickness and rest upon two layers of flagstone. The flagstone layers are in turn underlain by heavy beds which were at one time worked by the Chicago, Rock Island and Pacific Railway Company near Brighton. These lower ledges are more or less water-coursed, and the quarry has been abandoned. On the west side of the Rock Island tracks, immediately north of town, the following layers were formerly exposed and quarried:

		FEET.
7.	Soil and drift, variable, thickening rapidly in the bluff	5-15
6.	Marl	2-4
5.	Limestone, in thin layers	2/3
4.	Limestone ledge, bridge stone	1¾
3.	Limestone ledge, bridge stone	1 11/12
2.	Limestone, flagging and rubble	¼
1.	Limestone, flagging and rubble	¼

Other quarries opened in the immediate neighborhood show essentially the same beds but in slightly different thicknesses.

About two miles northwest of Brighton, a quarry is being operated on the Whitmore place. The beds developed are as follows:

		FEET.
2.	Loess and drift up to	20
1.	Limestone, gray-blue, compact, tough, somewhat fossiliferous; in ledges as follows: Top ledge, 8 inches; Bridge stone, 20 inches; Bridge stone, 20 inches; Flagstone, 6 inches; Flagstone, 6 inches	5

The upper ledges are very much weathered along the joint planes, and in places the blocks are reduced to rounded cores practically valueless though they appear to be as tough and of the same color as the unweathered blocks. The ledges work readily by the feather and wedge method. The flags are somewhat rough but appear to be durable.

The Chicago, Rock Island and Pacific Railway has used much of the stone of the district for bridge purposes. The stone has been generally used in the town and county and has been shipped in large quantities to adjoining counties.

The stone quarried in this region is fine-grained, compact, breaks with an even to conchoidal fracture, and is of a pleasing ash-gray color. It is of good quality, but limited in quantity, as only a few ledges are workable, and can be obtained only at great expense on account of the excessive overburden. Below are the disturbed beds of the Verdi which are of little value for quarry purposes. Small quarries have been opened in these beds near Verdi, but have long since been abandoned.

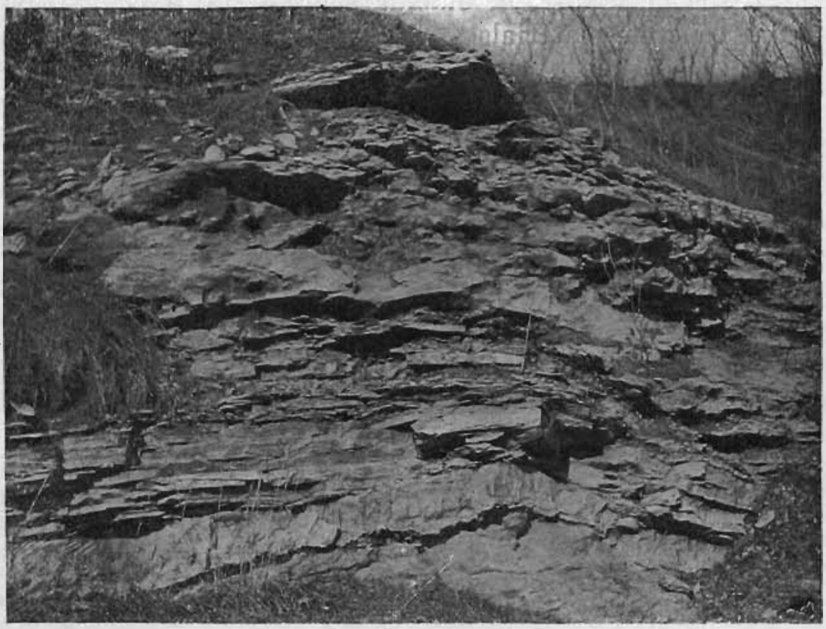


FIG. 59—Irregular beds of limestone in the Saint Louis, Verdi quarry, Washington county.

About three miles south of Washington on Crooked creek, a small quarry has developed the lower magnesian portion of the Saint Louis, but it is of local importance only.

With the exception of layers in the Kinderhook, all of the limestones available in the county are well adapted for road and concrete materials.

WAYNE COUNTY.

SAND AND GRAVEL.

Wayne county lies wholly within the loess-Kansan area and contains no large streams. The northern portion of the county is drained by Chariton river and its tributaries, but none of these have accumulated any considerable deposits of sand and practically no gravel. Some sand and gravel is obtained from the vicinity of Morgan in Decatur county for use in and about Lineville. The interglacial gravels, while probably present in the county, are not known to be available. The county is dependent almost wholly on outside sources for its supply of road and concrete materials.

STONE.

Exposures of the underlying rocks are very scarce in Wayne county. The Des Moines stage of the Coal Measures occupies the major portion of its area. Stone suitable for quarrying is known to occur only along the south fork of Chariton river near the east edge of the county. A small amount of rock has been taken out on the farm of Mr. Talkington in the northeast quarter of the southwest quarter of section 36, Wright township. Four feet of gray fossiliferous limestone are exposed, overlain with fifteen to twenty feet of drift. The stone is traversed by veinlets of calcite and separates into thin laminæ on exposure. The same bed has been worked at a few points farther up the river and over the line in Appanoose county. It can be of little importance even locally.

WEBSTER COUNTY.

SAND AND GRAVEL.

The chief source of sand and gravel is Des Moines river and its immediate tributaries. Lesser quantities are found in the knoblike hillocks of the drift.

Des Moines river has cut a deep trench from north to east of south across the entire county. The sands and gravels occur in two well-marked terraces about twenty to seventy feet respectively above the level of the water in the river. Fragments of higher terraces appear occasionally and are gravel-bearing. Sand bars and flats in the present stream are of some importance. Remnants of the terraces may be viewed in and near Fort Dodge; e. g., on Soldier creek at Miller's quarry; near the stone bridge in Fort Dodge; back of the city hospital and on the bank of the river in west Fort Dodge; and on section 30, Cooper township.

Near the north line of Douglass township the terraces are especially well marked and are separated by a drift terrace about fifty feet above water level. Similar terraces, not so well developed, are found along some of the leading tributaries.

Kame and esker gravels are somewhat erratically distributed over the Wisconsin upland drift plain. One of the most prominent of these occurs on section 9, Lost Grove township, and is locally known as Coon Mound. The mound is an esker which rises to a height of some fifty feet above the level country surrounding it, and is composed of more or less classified material—largely sand and gravel. Similar hillocks occur in other parts of the county. A sample of gravel was taken from a pit located in a knob near the middle of section 10 in Cedar Creek township.

STONE.

In Webster county the outcrops of the Saint Louis limestone worthy of mention are confined to Des Moines river and immediate tributaries, from the north line of the county to Fort Dodge. A few detached areas are known south of this point along the river, and one or two small patches occur in the interior of the county. The beds comprising the Saint Louis are decidedly heterogeneous in character, varying from a hard, compact limestone in well developed ledges to a structureless, clayey marl, and from a pure calcium carbonate to a highly magnesian limestone. In places a calcareous sandstone appears. The beds are usually too deeply buried under the Coal Measures and glacial debris to be of interest economically, but in the vicinity of Fort Dodge and northward along the river and along Soldier creek, considerable areas have been partially stripped of their overburden and quarrying has been thus made possible. On account of the lack of persistence and rather indifferent quality of the beds, quarrying has not been, and is not likely to become, an important industry in the county. The stone has been developed at a number of points, and a considerable quantity has been used for foundations and retaining walls in and about Fort Dodge. A few representative sections are given herewith.

Section at Miller's quarry, near the stone bridge over Soldier creek in Fort Dodge:

		FEET.
7.	Soil	2
6.	Gravel, fresh, cross-bedded	10
5.	Clay, yellow, not jointed, unleached, many limestone pebbles	15
4.	Soil and clay mingled, both unleached, soil dark and containing many wood fragments	15
3.	Sand, uncemented, containing lumps of coal and large pieces of wood, in layers varying greatly in color from white to gray	8
2.	Calcareous sandstone, a single layer, very firm	1½
1.	Limestone, layers coarse, often two feet thick, stone of fine, even texture, no fossils	25

In the creek bed at the foot of this exposure the limestone gives place again to calcareous sandstone, the thickness of which could not be determined.

Number 1 in the above section is variable, the beds ranging from limestone more or less pure, to limestone more or less magnesian. The texture also lacks constancy. The terrace on the west side of the river from the mouth of Lizard creek northward for about two miles is supported by the Saint Louis limestone. South of the center of section 7 in Cooper township, a good section may be viewed. The beds are as follows:

		FEET.
5.	Sand and silt	5
4.	Limestone, rather heavy-bedded, variable, with persistent chert band near the top	12
3.	Sandstone, cherty in places	½
2.	Limestone ledge	1½
1.	Sandstone, to water level	1½

While the limestones continue to the county line, they are as a rule too deeply covered and too far removed from transportation lines, to merit consideration. Below Fort Dodge, limestone outcrops are unimportant.

Des Moines river and its immediate tributaries have exposed heavy beds of sandstone at several points in the county. As a rule these beds are composed of massive, friable sandstone oftentimes strongly pyritic or marcasitic. The presence of these ingredients causes the stone to disintegrate rapidly on exposure while their presence in small quantity in a finely divided state produces discoloration of the exposed surface.

Several quarries have been opened and operated at various times. The most important one is located in the northwest quarter of the northeast quarter of section 14, Pleasant Valley township. The quarry is located in a small ravine where the rock is naturally exposed. An average section through the quarry face shows the following beds:

		FEET.
3.	Soil and drift	10-15
2.	Shale	2-3
1.	Sandstone	15

The sandstone is probably much thicker, but it has not been quarried below the bottom of the ravine. It is ferruginous and contains many selenite scales which look like mica. Even in a given layer the stone varies often in color and hardness. The colors are various shades of red. Some layers are practically useless for building purposes because they contain many small iron concretions. At certain points in the quarry the rock attains a fair degree of hardness. The layers are of a desirable thickness, varying from six inches to two feet. Jointing is imperfect, but sufficiently well developed to render quarrying easy. Some years ago the quarry was well equipped with steam derricks, and a side track gave good shipping facilities, but at present it is not operated. The product is known commercially as the Albee sandstone, and at one time this was the most extensive sandstone quarry in the state.

Sandstone quarries have been opened at other points in the county. In Fort Dodge some stone of fair quality has been taken out. North of the city the sandstone layers appear to be better cemented but have not been developed to any extent. Neither the Coal Measures sandstones nor the Saint Louis limestones as developed in Webster county are promising sources of supply for crushed stone products.

WINNEBAGO COUNTY.

SAND AND GRAVEL.

Winnebago county lies wholly within the Wisconsin drift area. While this youngest ice sheet extends well into Worth and Cerro Gordo counties, the morainal belt which marks the rather unstable ice front continues back over the eastern one-half of Winnebago county. The "knobby drift" of Owen, now known as the Altamont moraine, contains occasional sand and gravel domes and ridges, and these are the chief sources of road and concrete materials in the county. While the sand and gravel hillocks are more common in the morainal belt they are generally, though not numerously, distributed over the Wisconsin drift plain. The kame sands and gravels are as usual poorly classified and generally carry considerable percentages of undersize (clay and silt) and oversize (cobbles and bowlders) materials.

Unlike many another county within the Wisconsin area, the streams of Winnebago exhibit practically no traces of gravel trains. What streams may have transported glacial debris in their flood waters carried it out beyond the limits of the county.

WINNESHIEK COUNTY.

SAND AND GRAVEL.

The valley of Oneota or Upper Iowa river is plentifully strewn with beds and banks of sand and gravel of various ages and characteristics. These comprise fine, fresh, clean sands, beds of coarse pebbles and old, rusty, weathered gravels. The character of these deposits serves in many instances as a fair index of their relative ages, although the evidence is not conclusive for some of them. Thus there are at intervals from the county line westward to a point a short distance beyond Decorah banks composed chiefly of pebbles of limestone with some chert, foreign pebbles and sand. Such a deposit is described by Calvin from section 36, Pleasant township; and in section 35 of the same township test holes sunk by the Upper Iowa Power Company at the site of their dam showed:

	FEET.
Black dirt (alluvium)	2-10
Gravel	1-6
Sand, clean, fresh, in streaks and pockets	7+
Clay in streaks.	
Bowlders and gravel mixed.	
Bed rock.	

The materials form a broad flat terrace reaching as high as thirty feet above the stream. The coarser elements are largely limestone, with some foreign pebbles. They were used in making the concrete dam and other structures of the company's power plant.

Again in section 3, Glenwood township, is a similar terrace which shows about thirty feet of alternating sands and coarse gravel below eight feet of yellow Iowan loess. This latter is weathered above but fresh below, and at the contact the gravels are iron-stained. One exposure shows two feet of ferruginous

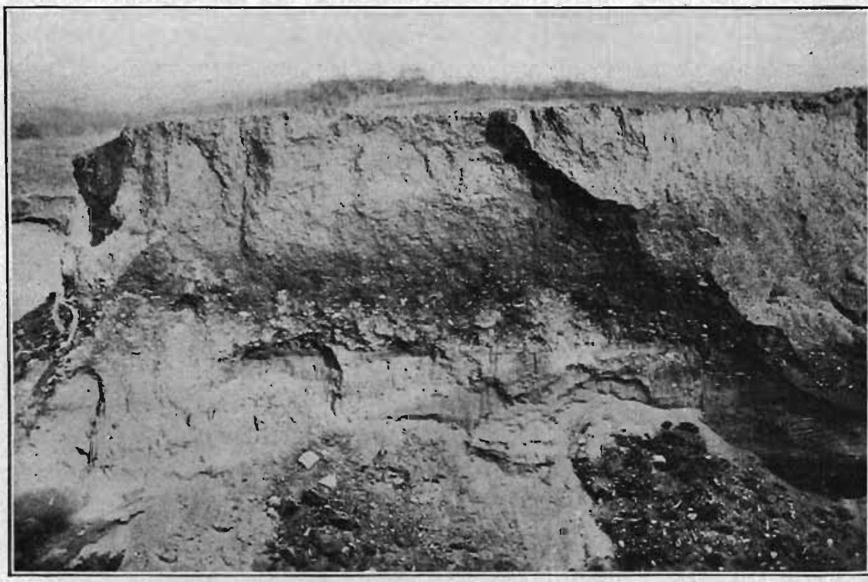


FIG. 60—Old weathered gravels over fresher sand, section 9, Glenwood township, Winneshiek county.

gravel immediately below the yellow soil. Other terraces of like nature are also seen in sections 4 and 9 of the same township, and on the north bank of the river opposite Decorah similar deposits are bound into a firm conglomerate by a calcareous cement. This conglomerate is discussed by Calvin in his report on Winneshiek county* where the probable origin of the materials here mentioned is treated.

*Iowa Geological Survey, Vol. XVI, p. 37.

Above Decorah there are no terraces, but in the river banks there are exposed beds of gravel and sand at a few localities. In the southwest quarter of section 8, Decorah township, about two miles above the town, the river impinges upon its left bank and has cut into a bed of coarse gravel, chiefly local, with some fresh sand intermingled. This bed is similar to those below Freeport. Six feet of this material are exposed and overlain by finer, much more weathered sand with some coarse material, about equally divided between local and foreign pebbles. The material from this bank has been used on the roads in the immediate vicinity with excellent results, as it cements well and forms a firm roadbed. Other deposits in similar situations and doubtless laid down under like conditions are exposed at the bridge near the north line of section 6, Decorah township, and in the northeast quarter of section 10, Bluffton township.

The beds at these different localities may be classified as of undetermined, but probably Kansan age. Their character does not in all cases permit of an accurate determination of their geologic position. But there are other deposits about which there is not such uncertainty. A notable instance is in section 7 of Glenwood and section 13 of Decorah townships, where a broad sheet of gravels is spread over the bottom lands in the vicinity of Freeport. These gravels bear unmistakable evidence of their relationships with the Buchanan gravels in their weathered and rusty condition. They are rather fine, like the typical valley phase of the Buchanan gravels, and are overlain by fresh, clean Iowan sand. The road leading northeast from Freeport is cut through these beds and exposes a good section. Similar beds occur for some miles up and down the river. They are of excellent character for use on the roads and should be used where the newer incoherent sands make the roads of the neighborhood very heavy.

In the northwest quarter of section 30, Canoe township, is an extensive deposit of dark red, weathered sand somewhat indurated, bearing very little coarse material. It extends 200 yards back from the flood plain in the form of a sloping terrace, and grades up to a sandy soil twenty to forty feet above the plain.

Sands of Iowan age also occur at various points in the Oneota valley. In sections 7 and 8 of Glenwood and 13 of Decorah townships are large bodies of fresh sand. About the middle of the section last mentioned, on the east side of the road, is an immense bed of clean, white sand with darker layers beneath. These latter are in some cases quite hard, are for the most part quite fine, and may be Buchanan in age. In section 23 of Decorah township is another bank of similar clean fresh sand of Iowan age.

In sections 11 and 14 of Bluffton township is an extensive area which lies comparatively level, with the exception of several hills of circumdenudation. Considerable amounts of fresh sand, apparently of Iowan age, are exposed here along the plain and covering the hills. In places, however, the rocky core of these latter is exposed.

Aside from the main drainage course of the county, there are numerous bodies of Buchanan gravels. Calvin has mentioned several of these; as in section 22, Hesper township, section 36, Madison, and section 15, Decorah township, all of which are related to the upland phase.

The valley phase of these gravels is represented by beds seen in the southwest quarter of section 35, in the northeast quarter of section 28, and in the northwest quarter of section 20, all in Washington township. All of these beds consist for the most part of rather fine, rusty gravels and sands with some associated coarser layers. At the last locality mentioned there is quite a large bench which seems to be underlain by the gravels.

A considerable part of the town of Fort Atkinson is built upon a bench of coarse, rusty Buchanan gravels. These extend from the margin of the flood plain of Goddard creek northward beyond the railroad tracks where they are probably banked against the hills of Fort Atkinson dolomite. Where they have been exposed by street grading in the southern edge of the village a thickness of four feet is exposed. The basement of the Catholic school was sunk into them to a depth of five feet and the railroad pit opposite the depot, whence large quan-

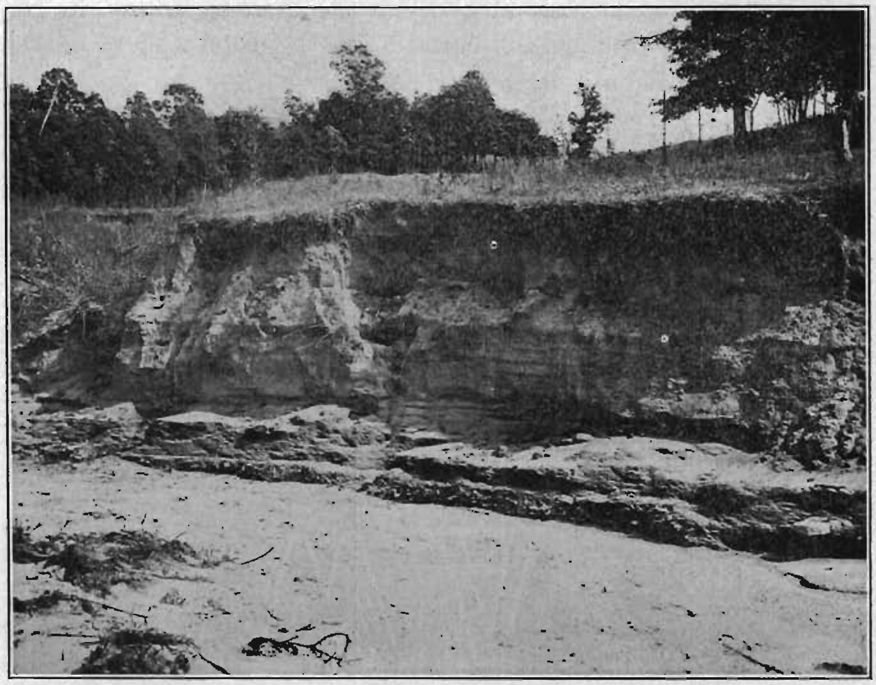


FIG. 61—Buchanan gravels overlain by fresher sands, southwest quarter of section 35, Washington township, Winneshiek county.

tities have been removed, shows a section ten feet in depth, above which are ten feet of Iowan loess. These gravels have been used on the roads with good results except that they are a little soft.

Another quite extensive deposit is cut into by a small creek in the northeast quarter of section 1, Jackson township, and the northwest quarter of section 6, Washington township. Where the road crosses the creek about six feet of hard, ferruginous gravels are exposed and the bench extends to the river plain 200 yards or more distant. About one-half mile farther north, along the same road, eight feet of fine, ferruginous, red to yellow sands, alternating with fine gravel and coarser material of mingled native and foreign derivation, are exposed. A few rods south of the bridge crossing the creek on the south edge of Spillville is a bank of gravel which has been opened up to some extent. This bank shows a section as follows:

	FEET.
Soil, sandy, fine, gray	1
Soil, with coarse red sand	1
Gravel, hard, oxidized, breaks up with difficulty	1
Sand, fine, yellowish, incoherent	½
Gravel, hard, red, with some layers of fine sand	1½
Gravel and sand in alternating layers, coarse material both local and foreign; all fairly fresh and incoherent	3

One-half mile east of here the fine phase of the Buchanan gravels is shown by the roadside at the top of a flat bench which extends from the steep bluffs on the north side of the river to the lower level of the flood plain.

STONE.

Good quarry stone is available at a number of horizons in the Ordovician as developed in Winneshiek county. The lowest beds eminently suitable for structural purposes occur near the base of the Oneota limestone in Highland and Pleasant townships. The lower thirty or forty feet, resting directly on the Jordan sandstone, is a light buff, evenly bedded dolomite, fairly uniform in texture and obtainable in blocks of almost any dimensions up to thirty inches in thickness and easily dressed. The outcrops are practically limited to the bluffs facing Bear creek from Highlandville to the county line, and limited outcrops on sections 23, 24, 25 and 26 in Pleasant township. These beds are almost wholly undeveloped in the county on account of the absence of transportation facilities. The upper beds of the Oneota are less desirable for structural purposes on account of their more drusy character, absence of regular bedding planes and general lack of uniformity in texture, structure and composition. At the present time none of the beds belonging to the Oneota are quarried in Winneshiek county.

The Galena-Platteville limestone, as in adjoining counties, affords several well-defined quarry horizons. The three divisions recognized by the Minnesota and Wisconsin geologists are very marked here. The lowest division or Platteville limestone is again divisible in three parts, "Lower Buff Beds," "Thin, Brittle Beds," and "Thicker Quarry Beds" in ascending order.

As a whole the Platteville thickens southward and as a consequence is much thicker in Dubuque than in Winneshiek county. The Lower Buff Beds do not exceed five or six feet in the latter county, with eight inch layers, and have been developed at but few points and then in a small way. The heaviest ledges of the Lower Buff Beds occur in the valley of the Upper Iowa in the vicinity of Freeport and east. The Thin, Brittle Beds were quarried formerly to a limited extent, and while apparently in heavy beds where protected, they break down when exposed to weathering influences and are of little economic importance. The uppermost member or Thicker Quarry Bed attains a thickness of from four to eight feet and is evenly bedded. The stone is hard and compact, fine-grained, nondolomitic limestone, and is of a bluish color. The individual layers range from six to eight inches in thickness, are remarkably uniform and can be obtained in sheets or tablets of almost any desired dimensions. This horizon has been quarried extensively in the vicinity of Decorah and Hesper. The beds are composed chiefly of finely comminuted and firmly cemented brachiopod shells. From one of the quarries north of the river at Decorah attempts were made to produce an ornamental stone by sawing into thin slabs and polishing by machinery. The product possessed a rather pleasing appearance and was used to a limited extent for table tops and interior decoration.

A number of quarries have been opened in the Galena limestone, above the level of the Decorah shale. Many are small and were operated only temporarily to supply some immediate local need. At no point does quarrying in the Galena assume commercial importance. The upper quarry of Mr. Halloran is worked at the level of the lower Receptaculites zone, about fifty feet above the Decorah shales. The quality of the stone is not as good as that from the upper part of the Platteville. The bedding is not so regular; the texture is less uniform; much of the stone is liable to split into small chips on long exposure to the weather.

Several quarries have been opened in the blue ledges of the Platteville on the north valley wall of the river, opposite Decorah. One between the Ice Cave and Mill Spring ravine shows about fifteen feet of these beds. There are also great quantities of rock washed out from the Galena beds in the ravine through which the road enters Decorah from the northwest. These have been used on this road, as has similar material from the river bed in section 8, Decorah township, and all these give excellent results. The road leading southeast from Decorah across section 22 to Trout run has also been macadamized with limestone as well as with gravels from the river terraces. This road is firm and smooth, an excellent example of what may be accomplished with the materials so abundantly at hand.

In the neighborhood of Nasset, in the southwest quarter of the southwest quarter of section 22, Glenwood, is a small quarry opened in the hillside in the blue ledges of the Platteville, just below the Decorah shales. The rock is hard and firm and the location is favorable for getting out road material. Along the east-west road across section 26, Glenwood, are several exposures of geest, dark rust-red, with much chert. While this is not present in great quantity it would make excellent material for road work as far as it goes. There is a large quarry at Nordness which is opened in the upper beds of the Galena. The Maquoketa begins only a few feet above the exposure. The upper beds are badly checked and weathered, but below these there are some quite firm ledges varying from ten to fourteen inches in thickness, with which there is associated a ten inch band of shale. About the middle of the quarry face there is a belt of irregularly bedded concretionary limestone, three feet in thickness, altogether lacking in the homogeneity requisite for good quarry stone. Below this belt there are six feet of more regular and more homogeneous beds, with some of the individual courses fully ten inches in thickness. Another quarry at the same horizon as that at Nordness is opened on the south side of Yellow river in the north half of the northeast quarter of section 13, Bloomfield township, on land belonging to the estate of Mr. Melvin Green. The characteristics are the same as at Nordness except that there are several bands of shale, ranging from two or three to ten inches in thickness, interstratified with the limestone. Another quarry which includes the uppermost beds of the Galena is located on the south side of the diagonal road in the southwest quarter of section 17, Bluffton township. There are other small quarries, worked temporarily or intermittently to supply the purely local demands, near Kendallville, Plymouth Rock and Burr Oak. In the southeast quarter of section 7, Fremont township, are some small quarries opened in beds of dolomitized Galena, a phase of the formation resembling that at Dubuque. Dolomitization here is local, being restricted to an area of three or four square miles. The many other small openings in the Galena limestone are too numerous to be individually noted.

Much of the Galena limestone is very unreliable. When quarrying has been carried into the hillside beyond the zone of weathering, the ledges may appear to be thick, firm, durable, suitable for any kind of construction; but after being placed in

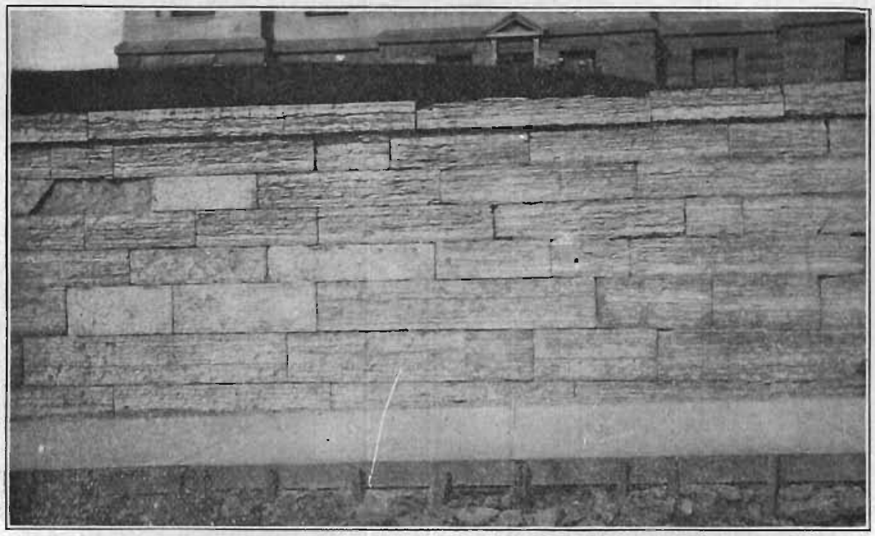


FIG. 62—Portion of retaining wall around Court House Square in Decorah, Winneshiek county, showing unreliable character of Galena limestone.

walls and exposed to alternations of temperature and the chemical effects of air and moisture they split into thin laminæ and eventually break up into small, irregular chips. The effect is well shown in the portions of the old retaining wall still standing around the court house square at Decorah.

Quite an amount of quarrying has been done in the Maquoketa formation. The Isotelus zone is very regularly and evenly bedded, and in a few instances it is firm enough to serve for building stone. One quarry at this horizon, located in the northwest quarter of section 18, Springfield township, is noted by Calvin in connection with the general discussion of the Maquoketa beds of this county.* In some cases the strata lying between the Isotelus zone and the Clermont shale are capable of furnishing a fair grade of building material for rough walls and foundations; but the principal quarry horizon in the Maquoketa is that of the Fort Atkinson limestone. This, not infrequently, is a hard, granular, crystalline dolomite, comparable to some phases of the Galena limestone in Dubuque county. At Fort Atkinson quarries have been worked in this formation for many years, and one of these, located a few yards west of the

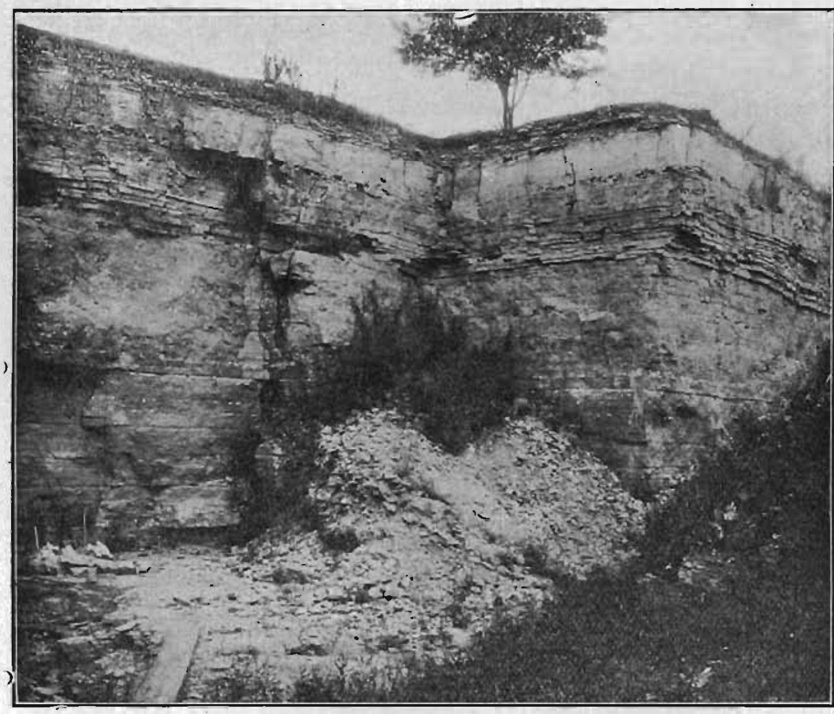


FIG. 63—Fort Atkinson limestone as seen in quarry a few rods west of the old fort, Fort Atkinson, Winneshiek county.

*Iowa Geological Survey, Vol. XVI, p. 101.

old fort (Fig. 63), is capable of yielding blocks of any desired dimensions up to three feet in thickness. Another quarry in the same limestone, on the east side of the fort, has been operated intermittently for some time and has furnished quite an amount of fairly good material. In the southwest part of Military township there are many quarries and natural exposures in the Fort Atkinson beds. The small quarry near the center of the southwest quarter of section 33, and that near Ossian in the northwest quarter of section 15, will be found noted with some detail in the part of the report on Winneshiek county which treats of the Fort Atkinson limestone.*

About a mile south of Calmar, in the southeast quarter of section 35, Calmar township, is a quarry of Mr. Gallaman. This is opened in the Fort Atkinson beds and shows eight to ten feet of yellow, flinty, thin-bedded layers overlying yellow beds free from chert, the beds two to eight inches thick. Of these lower beds four feet are exposed. On top is one to two feet of waste rock, then one foot of soil. The quarry has been well opened and is easy of access from the road. The beds shown here are also exposed on both sides of the ravine which runs past the quarry and a considerable amount of rock is available. Similar beds are exposed in the ravines and road-cuts just north of Festina.

On the north side of the Cresco-Calmar ridge the Fort Atkinson formation comes to the surface and is quarried near the center of the southwest quarter of section 27, Springfield township, and about sixty rods south of the northwest corner of section 5, Bloomfield. At the point last named the rock is yellower, softer, less crystalline than at Fort Atkinson. The rocks of this horizon become more earthy or shaly toward the northeast, and gradually lose the qualities of a pure dolomite which distinguish them at the type localities in Fort Atkinson and Clermont.

Several small outliers of the Niagaran limestone appear in Washington township and are believed to be the northernmost outcrops of that formation in the state. The stone commonly representing the Niagaran here is a yellow-buff, dolomitic lime-

*Iowa Geological Survey, Vol. XVI, p. 101.

stone. Some of the layers exposed in an old quarry west of Festina comprise a hard, buff, subcrystalline dolomite comparable with typical Niagaran dolomites exposed farther south. The beds are of small importance and have been but little developed in Winneshiek county.

The Chicago, Rock Island and Pacific Railway has a large quarry near the station at Nordness. This shows at the base fifteen feet of heavy blue-gray ledges of fine texture which weather to gray or buff. The ledges are six inches to a foot in thickness. The upper ones show a conchoidal fracture. Above these heavy beds is a layer of slaty shale, drab or slate color, eight to ten inches thick, which breaks into very thin spalls. Overlying this layer is a heavy ten-inch ledge, then thinner ledges for fifteen feet. These are separated by thin shale bands of one to two inches thickness and are nodular and of uneven thickness. They are capped by a five-foot bed of yellowish gray calcareous shale which breaks up into small angular bits. At the top of the section are five feet or more of gray iron-stained loess with the lower part strongly impregnated with iron. There is no drift present here.

A sample was collected from the heavy beds below the shale band, also from the thinner beds above. Several quarries are opened in this vicinity in the heavy beds below the shaly layers of the Galena. The yellow shale beds are the basal layers of the Elgin Shaly Limestones, the lowermost division of the Maquoketa stage. Forty feet of these are exposed in the roadside one-half mile east of Nordness. Below the quarry beds are exposed layers which appear hard and solid, as if suitable for road work.

At the time samples were being collected the quarry of E. H. Weber, one-fourth mile south of Hesper, was not being used. Considerable quantities of stone have been removed, however. The beds used are the blue layers of the Platteville. Only a few feet are removed and these are just below the Decorah shales. On the northeast edge of town is a smaller quarry which is opened in the same ledges as the Weber quarry, but the location is not so advantageous as is that of the latter.

A little rock is taken out near Locust from these same blue layers.

On the south slopes of the hills in section 35 of Washington township the Niagaran is exposed in steep scarps and in the road bed. It is fine-grained, subcrystalline and responds readily to the acid. On the top of the hill where the road descends to the river plain some rock has been taken out and this pit reveals thin shelly layers on top of thicker ones. The heavy massive beds seen in the scarps are not here exposed.

The type exposure of the Fort Atkinson dolomite is the quarry west of the old fort at the town of Fort Atkinson. This is well described by Calvin. The flinty beds of this formation are also exposed in the road in the northwest quarter of section 7, Washington. These and also the quarry are convenient for obtaining road metal of which they should furnish an excellent quality in abundance. Numerous exposures occur on the road from Fort Atkinson to Spillville and also on the road from the latter village to Calmar. Considerable rock waste is uncovered here and this would yield a supply very easily obtained.

In the town of Ossian a little macadamizing has been done, the cherty layers of the Fort Atkinson beds being the material used. So far as noted the stone gives good results except that as insufficient fine material was used the surfacing was not good. The stone was taken from a quarry in the northern part of section 15, Military. This is described in some detail by Calvin in his report on Winneshiek county.

WOODBURY COUNTY.

Sand and Gravel.

The terraces along Little Sioux river and its tributaries furnish the principal supplies of sand and gravel for Woodbury county. Gravels which occur under the loess are opened in a few places along Missouri river, but these are of minor importance.

Stream Terraces.—The benches along Little Sioux river which are so prominent in Cherokee county continue southward, the lower one being conspicuous across the corner of Ida and on into Woodbury county. It is sometimes as much as a mile in width, and it seems to be composed almost entirely of gravel. It has been opened by the Illinois Central Railway in section 23 of Union township, and from a pit in the northeastern part of section 35, same township, much is being hauled to Correctionville. In the latter place there is only a small amount of cover. The usable material is coarse, rusty, impure gravel at the top, but becomes cleaner and more evenly bedded toward the bottom.

As a rule the higher terrace seen in Cherokee county is not prominent, but appears at many points as jutting headlands which are often capped with gravel. Such occurrences may be seen in sections 14 and 23, Union township, and also in section 27 west of the river. These headlands stand sixty to eighty feet above the river. In Ida county they appear east of the river in the northwest sections and also on Ashton creek.

The high terraces increase in importance as they are traced up Pierson creek and its tributaries. They appear as a low bench in northeast section 17, Union township, where a pit is open along the creek, and continue southward along Pierson creek all the way to Correctionville. This terrace is always prominent—sometimes drift, sometimes merely capped with gravel, again all gravel—but always capped with or leading back beneath the loess which covers all the hills. On the creek at the middle of the south side of section 17, Union township, is a most excellent erosion exposure which shows some twenty-five feet of clean gravel under ten feet of loess. Gravels show in the roads at many places, *e. g.*, southwest 21, southeast 28, south 27 and north 34, Union township. The outcrop last mentioned is owned by John Fleming, is the largest opening and contains the best and most accessible materials. The sand and gravel are usually clean and moderately fine, with few bowlders, but contain streaks of almost quicksand, and lenses of very fine sand with clay are not uncommon. These latter are, however, easily wasted. There are not over three feet of stripping at the most, resting on fully thirty feet of usable gravel followed by a very ferruginous red coarse gravel which grades downward into an unusually clayey material. Apparently there is an unlimited quantity available, and it is readily accessible to the Chicago and North Western railroad.

Along Pierson creek there is also a lower bench noticeable south of the stream in section 28, Union township, where its exact relation to the Little Sioux benches is not clear. It seems, however, to be composed almost entirely of gravel and sand. In southwest Union township there are enormous quantities of gravel and sand along the creek. Far up on the hillside near the northeast corner of section 14 is a large pit which shows a few feet of sand over clean stratified gravel.

Above Correctionville, and especially to the west of the Sioux and north of Pierson creek the gravels form a conspicuous platform fully fifty feet above both streams. There is practically no covering over the gravel, which crops out in prominent escarpments and is so near the surface that there is scarcely sufficient soil for tillage.

Two pits, those of Welch Bros., in southeast 28, and of Moran and Hempel in northeast 20, Union township, have been opened quite recently. The first is a clean exposure with very light stripping on the valley end of a ridge. Fifteen to eighteen feet of gravel are open, finer and with more sand and cross-bedding at top, but coarser below. Moran and Hempel have a large opening, but except at the very point of the hill the depth of cover runs up to six or eight feet. They have confined their development work to the edge of the hill where the cover is thin. As a rule, the gravel seems coarser here, running coarse at top and fine below. There are about eighteen feet of gravel resting upon blue till with an iron-stained band at the top.

South of Correctionville the lower terrace is of wide expanse, at the town east of the river and on the concave sides of curves all the way to section 8, Miller township, south of Anthon. The latter town is on a terrace which seems to be not over fifteen to eighteen feet above water.

At Anthon, in west section 33 of Kedron township, there are three feet of black alluvium to strip. Below this are three and a half feet of coarse iron-stained clayey gravel with little sand,

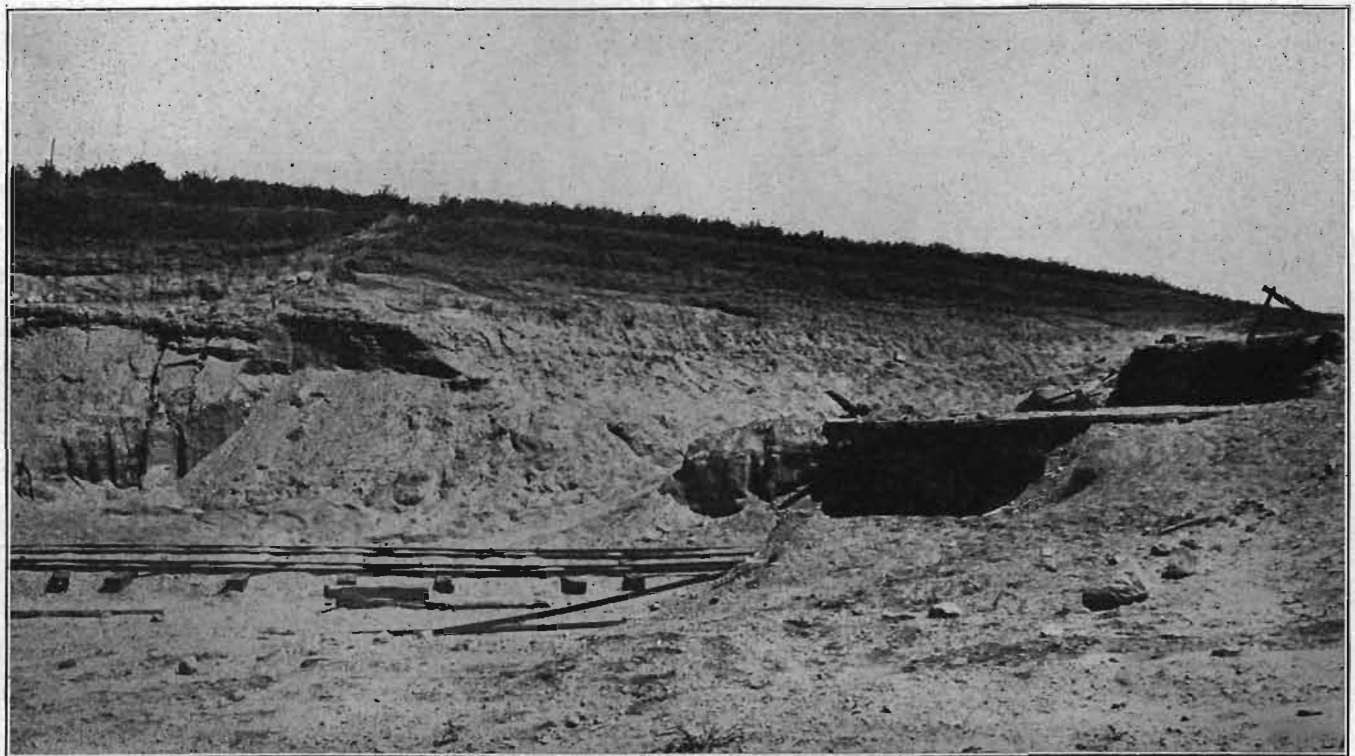


PLATE LVII—Moran and Hempel pit showing loading trap, Correctionville, Woodbury county.

and then four feet of cross-bedded, nicely banded clean gravel with coarse sand, the largest pebbles being not over an inch or so in diameter. Underlying this are five feet of clean gravel down to talus and perhaps to six or eight feet above water. At the Gilleas opening on the railway in southwest 15, Kedron township, there are fully twenty feet of good material available under but little cover.

Farther south than this the lower gravels do not appear conspicuously, but the bench blends gradually into the flood plain of the river. It is likely, however, that fragments of this bench occur to the south county line or farther although not noticeable.

The upper (sixty to seventy-foot) terrace is evident as jutting promontories at many places on both sides of the stream. These are particularly noticeable in sections 21, 28 and 34 of Kedron township and in section 4, Miller township, on Wright creek. These benches are sometimes gravelly, but not invariably so.

Reworked Materials.—Missouri river has immense beds and bars of sand (mostly quicksand) in its channel the whole way across the county. Although there are enormous quantities of material in these beds they are unimportant from a practical standpoint, as there are many conditions which prevent their economical removal.

Sand bars also occur along Little Sioux in varying quantities, but the presence of so much more reliable deposits in the terraces renders them of little importance.

Miscellaneous Deposits.—It is not uncommon in parts of the county where erosion forms are abrupt, as near the mouths of all streams coming into Little Sioux, to find outcropping at the base of the loess a very coarse quartzitic bowlder bed, sometimes resting on drift and again on top of beds of red gravel or sand. Such may be noted in section 17 of Union township, and at other points along branches of Pierson creek. They are also seen in the lower courses of Bacon, Wright and Plumb creeks and at many points along the west side of the valley. These are different from the high terrace gravels. At many points along the bluffs on the east side of Missouri river gravel and sand are to be seen outcropping from under the loess. As a rule, this material is available in only small quantities, if at all. Where attempts are made to recover it a sort of crude mining system is used. The gravel is removed from under the loess, which varies in depth up to forty or fifty feet in places, and work usually stops when the loess caves down. Sometimes timbering is done, but this is not commonly the case.

In the vicinity of Sioux City the upland is covered with a thick veneer of loess. The loess here, as in adjoining counties, seems to be quite generally underlain by sand, which is rarely exposed except artificially and is not worked to any extent because of the great expense of stripping. This is the only local source of sand, so most of what is used is shipped from Correctionville. In speaking of the subloessial sands and gravels, Mr. H. F. Bain, in his report* on Woodbury county in 1896, says, "At some time in the period between the retreat of the Cretaceous sea and the advent of glacial conditions, at least a part of Woodbury county was covered by a shallow lake. The deposits made at this time are shown under the later glacial deposits in the pits at Riverside:

	FEET.
Loess, usual character, variable thickness	30
Clay, plastic, brown, weathering yellow along joints, usually free from grit; pebbles rarely found	6
Gravel, erratic drift pebbles	½
Sand, fine, white and even-grained, with small granitic pebbles; no distinctly northern gravel	12

"The lake deposits consist of fine to coarse white sand containing occasional small pebbles, in the main granitic with chips of wood and a few fossils. The pebbles found are of small size, water-worn, and of such type that they might readily come from either the west or the north. There are, as far as careful search reveals, no distinctively northern rocks present, and certainly no rocks showing ice action. The general character of the sand is much like that of the Miocene or Pliocene beds found a few miles west in Nebraska and South Dakota." In the beds, of

*Iowa Geological Survey, Vol. V, p. 243.

which the section given by Bain is typical, the sand and gravel are usually mixed together so that neither can be used without screening.

Along the loess escarpment stretching southeast from Sargent Bluff there are occasional exposures of gravelly drift cropping out from beneath the loess. Gravel was once taken from the bluff at this latter place, but the pit was abandoned when the loess cover reached a thickness of twenty feet. East of Hornick the beds have been opened up at one or two places and sand and gravel for local consumption are being removed.

A very old and quite coarse gravel appears about 150 feet above the Missouri bottoms in sections 24 and 25, Orange township. The gravel is much iron-stained, and some of the pebbles can be crushed in the hand. A lower and finer gravel outcrops in section 31, Westfork township. This material has a newer appearance and is entirely different from the high gravel mentioned above. There may possibly be as much as twenty-five feet of the gravel under two feet of loess at the outcrop, but the cover rapidly becomes much deeper. It would seem, however, that several hundred yards of gravel suitable for roads could be removed before the cost for stripping would become prohibitive.

STONE.

(For notes on stone see Plymouth County.)

WORTH COUNTY.

SAND AND GRAVEL.

The Wisconsin drift covers the northwest two-fifths of Worth county. The Altamont moraine, with its knobs and hillocks, stretches diagonally from Fertile to Northwood township. Sands and gravels in abundance occur along Lime creek and its immediate tributaries, Willow and Winans creeks. The gravel terrace rises from ten to twenty feet above the bottom land, reaches about a mile in width, and rests on a limestone bench, which rises a few feet above the water level in the creeks.

The terrace appears only in the north bank of Lime creek and continues up Winans and Willow creeks a distance of one and a half to two miles. These terraces are composed of fairly coarse materials. The granitoid bowlders are more or less weathered and break down readily on exposure. Pits have been opened at numerous points for road and concrete materials, but none are being worked on a large scale at present. The gravel varies from ten to twenty feet in thickness and covers most of sections 29, 30, 32 and 33 in Danville township and considerable portions of sections 25, 26, 35 and 36 in Fertile township. The alluvial wash covering over the gravel varies from almost nothing on the breaks to three to five feet on the bench some distance back from the escarpment.

Terrace gravels are also found along Elk creek outside the Wisconsin drift area. Here, as in the case of Lime creek, the terrace is most prominent on the north bank.

Occasional sand banks are found along Shell Rock river, but well-marked gravel terraces are unimportant, if not absent.

Sand flats and bars are present occasionally in nearly all of the streams in the county, but are of interest only locally.

In the morainal tract kame and esker sands and gravels are available as usual and have been developed to meet the local demand, especially for road work. Occasional sand knobs are found in the upland Wisconsin plain.

STONE.

Limestones of the Mason City substage of the Cedar Valley stage outcrop in the banks of both Shell Rock river and Lime creek and their chief tributaries. The strata are similar in every way to their equivalents in the Mason City sections in Cerro Gordo county.

On the Shell Rock a maximum thickness of twenty feet of the limestone beds may be observed at the railroad bridge in section 1 of Lincoln township.

The following section at Foster's mill in the northeast corner of section 30, Union township, is typical for the Cedar Valley beds:

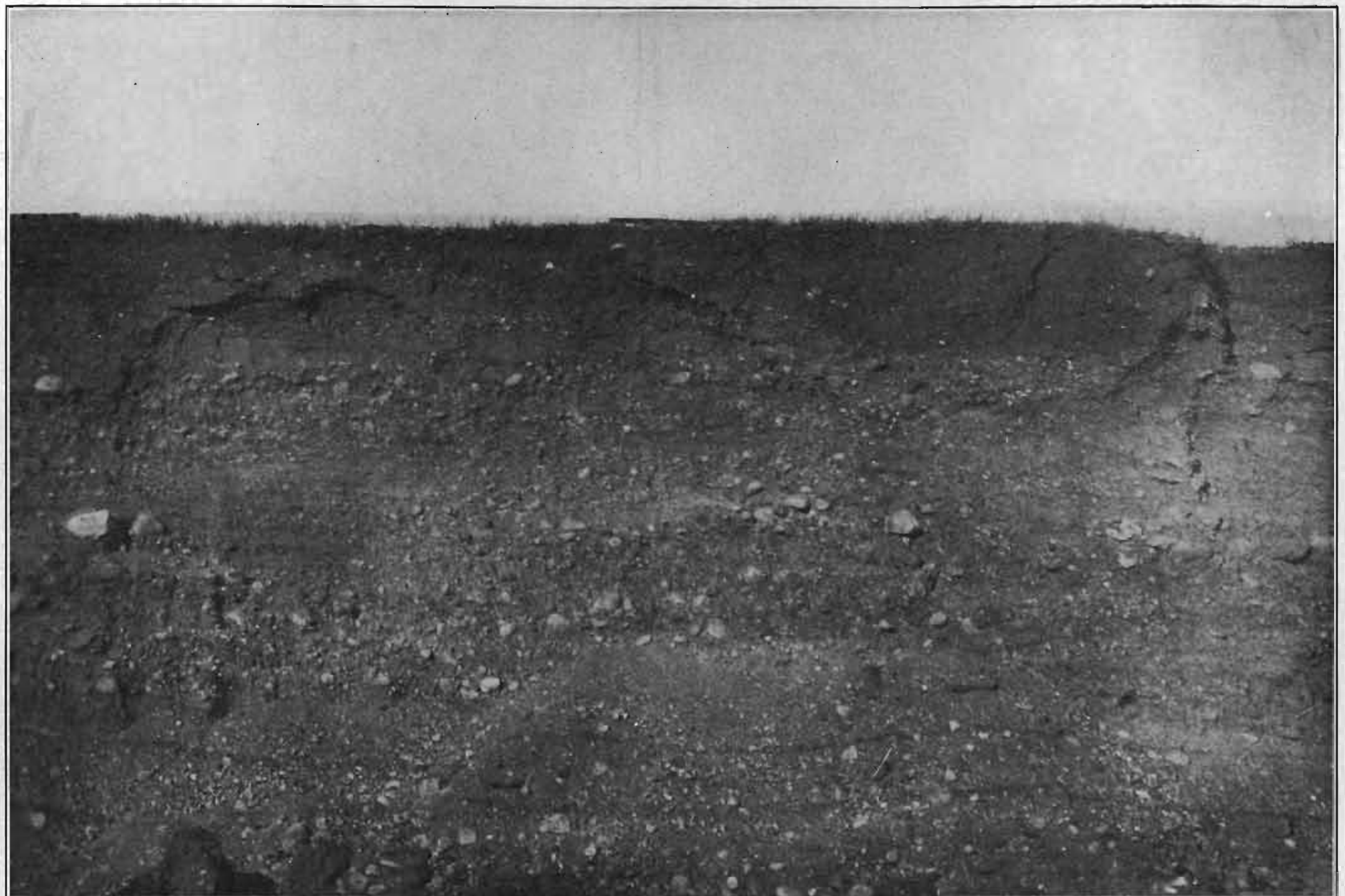


PLATE LVIII—Lime creek terrace gravels, one and a fourth miles east of Hanlontown, Worth county.

		FEET.
4.	Weathered limestone, crystalline, and containing numerous calcite cavities	10
3.	Compact, light colored, dolomitic limestone, heavy-bedded..	4
2.	Very close textured limestone, lithographic in appearance, hard and breaking with conchoidal fracture. Has a very characteristic ring when struck with the hammer	3
1.	Argillaceous, bluish dolomite layer, exposed to water below dam	1

No. 4 is the Stromatopora zone which characterizes this stage at nearly every exposure. It is the equivalent of the beds that are employed for the manufacture of Portland cement at the Mason City plant, in the adjoining county to the south.

Near the south edge of section 12, Lincoln township, is a small quarry from which crushed stone has been taken for road material. The middle layer of the Foster mill section is the one used.

FIG. 64—Quarry in northern Lincoln township, Worth county, showing excellent material for road and concrete work.

Beginning in the northwest quarter of section 1, Lincoln township, is a continuous outcrop for about one-third of a mile where Shell Rock river flows close to the west edge of its valley and at the foot of the exposure. From a short distance below the railroad bridge it extends northward across the line into Kensett township. The following is the somewhat generalized section:

		FEET.
5.	Bowldery drift	2
4.	Badly weathered limestone, rusty red in color, no fossils, nodular in appearance, bedding obscure on account of disintegration	6
3.	Fine-textured limestone of light color, nonfossiliferous and containing much interstitial crystalline calcite, heavy-bedded	3
2.	Slightly argillaceous magnesian limestone, grading downward into the darker variety, breaks with earthy fracture, but is very hard, bedding 8 to 12 inches	2-3
1.	Argillaceous dolomite, that portion not adjacent to joint or bedding planes a dark blue, good building stone, to water	6

No. 4 of this section is the equivalent of the upper member in the Foster mill section. Below the railroad bridge a layer of calcareous sandstone eight inches thick appears between Nos. 3 and 2. This is very susceptible to the weathering agencies, and its breaking down forms a reëntrant in the quarry face.

A small quarry has been opened in the northern part of section 14, Kensett township, and some stone removed to supply a local demand for the purpose of rough masonry. The argillaceous dolomite has here been quarried to a depth of six feet. A thin layer of sandy, shaly and weathered limestone occurs between strata of the dolomite. All the layers shown at this exposure have suffered more or less from weathering and are of little value as building material.

At Fertile an outcrop in the south bank of the stream, below the wagon bridge, gives the following section:

		FEET.
3.	Hard limestone, badly shattered into small blocks by weathering	4½
2.	Arenaceous shaly limestone, very slight effervescence with dilute HCl	8
1.	Heavy-bedded, subcrystalline, dolomitic limestone, to water level	5

Bed No. 2 gives way much more readily to weathering than the other members and is conspicuous as a reëntrant along the face of the exposure. A small amount of stone has been quarried at the east edge of the town in a low terrace to the north of Lime creek.

Limestone outcrops along Willow creek along the roadway between sections 29 and 30, Danville township. A considerable area is available here under light stripping. Both the white and the brown limestone are of excellent quality for crushed stone products.

The quarry industry of Worth county has been developed only to the extent of supplying a local demand in the immediate vicinities of the exposures of the limestone beds. Practically all that has been used for building purposes has been from the compact, light colored stratum and the underlying dark magnesian layer given in the sections along the Shell Rock. The former is well suited for road material and concrete work, while the latter, which is the equivalent of the Mason City dolomite, is considered one of the best and most durable building stones taken from the several quarries in Cerro Gordo county. This stone is well exposed to a thickness of ten to twelve feet in the northern part of Lincoln township, where the Chicago Great Western crosses Shell Rock river, and in a location where conditions are favorable for development.

FIG. 65—Iowan bowlder field in northwestern Lincoln township, Worth county.

WRIGHT COUNTY.

SAND AND GRAVEL.

Wright county lies wholly within the Wisconsin drift area. Two drainage systems are represented in the county: Iowa river in the eastern portion, and Boone river, the most important tributary of Des Moines river, which drains the western two-thirds of the county. The former stream is the more important as a source of sand and gravel. Iowa river and its largest tributary in the county, West Branch, have well marked terraces almost throughout their courses within the confines of the county. The terraces are best developed in the vicinity of Belmond, where extensive pits have been opened by all of the railways entering the town. The principal terrace varies from fifteen to thirty feet above the water in the river. The terrace rises up stream. At Belmond it is about twenty feet above the river level. The usual terrace section is:

	FEET.
Alluvium	1- 3
Sand and gravel	12-15
Bowlder clay, exposed at, or about 3 to 5 feet above water level.	

Pebbles above two inches in diameter are relatively rare, although occasional cobbles up to six inches in diameter are present. Limestone pebbles are conspicuous. Sand as a rule predominates. Cross-bedding is common and prevails below, while more or less horizontal bedding is the rule above. The terrace attains a width up to three-fourths of a mile or more, and is persistent on one or both sides of the river. The grade of the present river is low and the terrace rises up stream, the materials becoming coarser. The town of Belmond is in large part built on the terrace. While the terrace rises relatively up stream when compared with the present grade of the river, the gravels do not thicken appreciably as the bog line below the gravels also rises.

The terrace on West Branch is almost identical with the Iowa river terrace but rises more rapidly up stream and is not so well developed. In section 12, Belmond township, the terrace rises some forty feet on the west side of the branch, while the bog line is about fifteen feet above the water level. Between the top of the bog line and the stream channel large bowlders are strewn over the surface in some abundance. Near the channel the bowlders are less conspicuous on account of

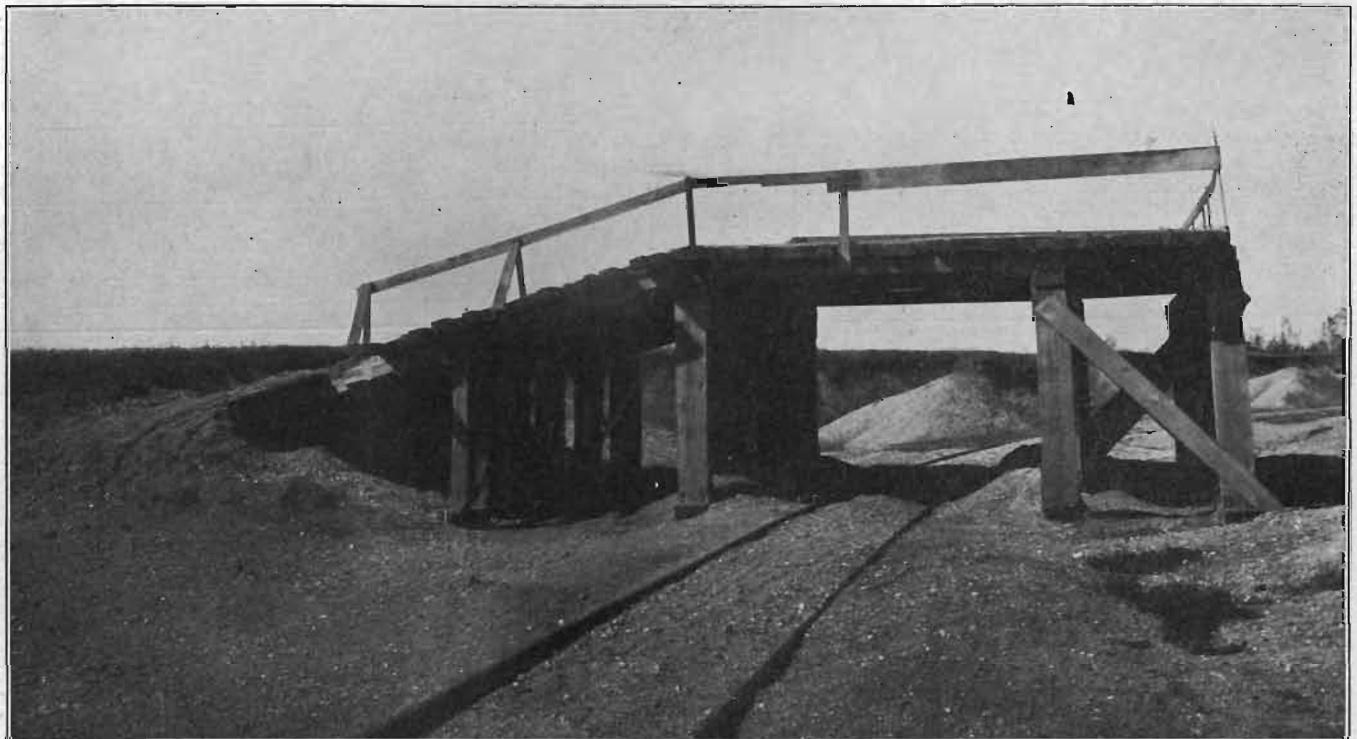


PLATE LIX—Pit of the Chicago, Rock Island & Pacific Railway showing loading trap. Belmond, Wright county.

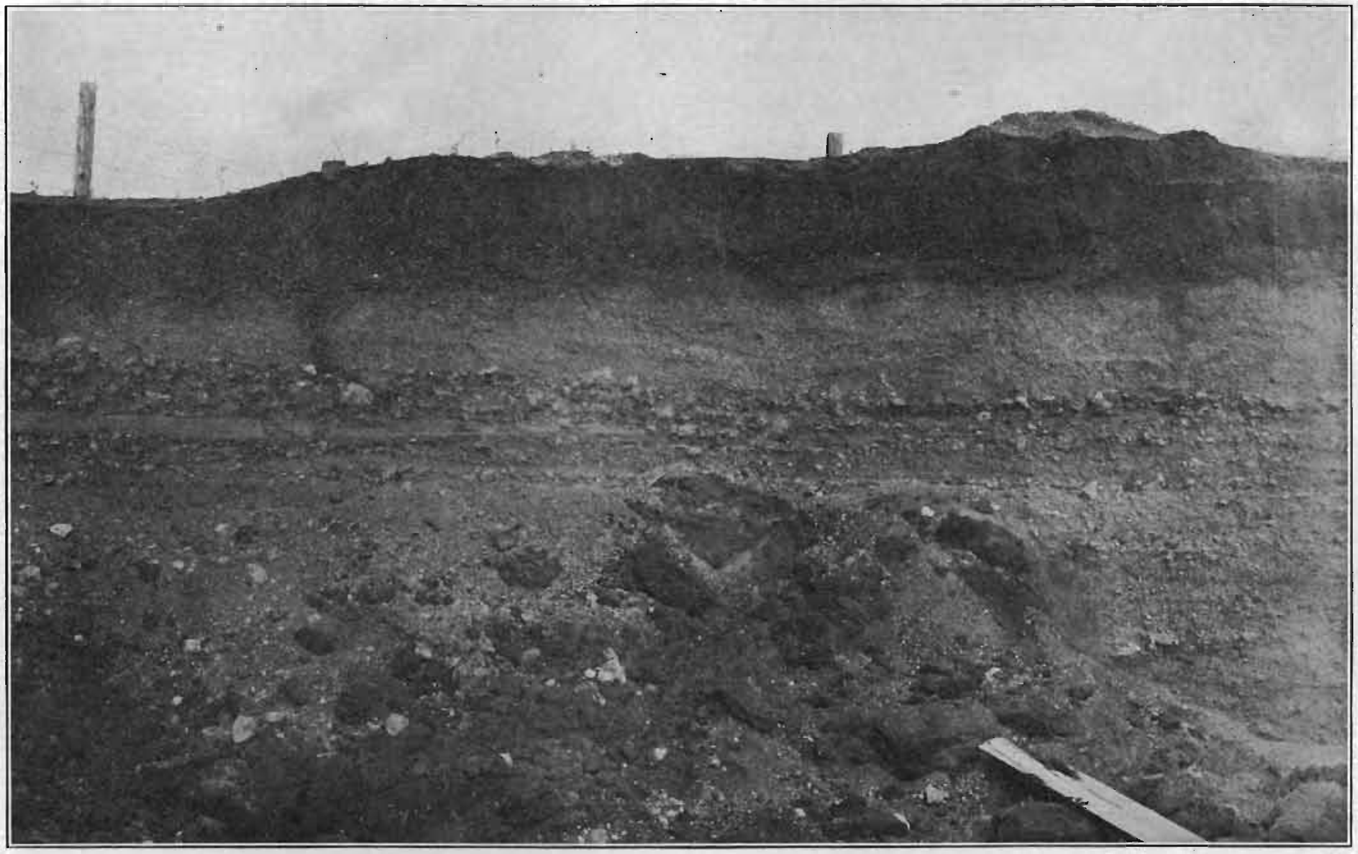


PLATE LX—Country pit about two and a half miles northwest of Belmond, Wright county.

natural levees of alluvium. West Branch has a steep grade—much steeper than the river itself. There is a pit opened in the extreme northwest corner of Belmond township. The gravel is coarser here than in the pits farther down stream. The section exposed is about as follows:

		FEET.
4.	Alluvium	1-3
3.	Gravel and sand, more or less evenly bedded	2-4
2.	Gravel, coarse cobbles up to four or five inches in diameter	2-3
1.	Gravel and sand, variable in texture and bedding	6

Cross-bedding is evident in number 1 of the above section. The section as a whole affords material excellently adapted for road work and all save the alluvium may be used for concrete.

The leading railway pits are at present located in sections 19 and 30, Pleasant township, and 12 in Belmond township.

Crude methods are used for loading the material, the commonest of which are the team and scraper with the incline and platform with trap.

Boone river is also terraced but the terraces are less well developed than those along Iowa river. Pits have been opened in section 32, Eagle Grove township. The material is sand and some gravel and occasional cobbles, and contains considerable clayey and silty material. The terrace here is from twenty-five to thirty feet above the river. Seven to ten feet of sand and gravel under from two to three feet of stripping are available. Much coarser material appears along the roadway in sections 18 and 19 in the same township, but little development work has been done. The most extensive pit in this neighborhood is located in the northeast quarter of section 7 on a small tributary just above its junction with Boone river. The gravel runs from five to seven feet in depth on a terrace some fifteen feet above the river level. The gravel is fairly coarse and much iron-stained. Limestone pebbles prevail. A few bowlders are present but few of the pebbles are over an inch in diameter. Similar deposits are available both north and south of Eagle Grove township. Occasional bars and sand flats occur in the channel of the river, but so far as known gravel is scarce or wanting in such deposits.

The Boone river terraces afford a sufficient supply of material suitable for road work to meet the local demand. The deposits as a rule are not being utilized extensively. The local supply is not so well suited for concrete work on account of high percentage of silt, clay and fine sand. Most of the gravel used for city work in Eagle Grove is shipped in from Mason City and Belmond.

In addition to terrace and stream sand and gravel, some material for road work may be obtained from kame deposits in the morainal tracts. Such tracts are best developed near Dows, through Vernon and Blaine townships, a belt east of Cornelia in Grant and Belmond townships and a less important belt northwest of Wall lake in Wall Lake township. The kame gravels are much more variable in every way than are the stream and terrace materials.

Wright county has enough sand and gravel not only for home use but for export to less favored counties. Pits could be opened in the Iowa river terrace near Belmond where road and concrete material could be produced by the train load at small cost.

TESTS AND ANALYSES OF IOWA LIMESTONES, SANDS AND GRAVELS.

Among the various properties of stone or gravel that is to be used for road construction, three are of such importance as to determine, in most cases, the value of the materials for the purpose. These three are: cementing value, toughness, and hardness.

In order to determine the relative value of various materials for road construction, numerous tests have been proposed for these three properties and finally standard methods of testing have been adopted. The tests in themselves determine the degree of the various properties possessed by a certain stone, yet the value of the determination, so far as the suitability of the material for road construction is concerned, is that it forms a basis for comparing the material with other materials that have been satisfactory in service. That is to say, by a careful study of the records of tests that have been made upon materials which have been used for road purposes, approximate limits may be determined for the various properties of the stone.

Cementing Value.—By "cementing value" is meant that quality in finely broken stone which will cause it to cement together when mixed with water. If broken stone or gravel possesses sufficient cementing value, a road surface made with it will compact readily under rolling, or when subjected to traffic, and the individual stones will be held in the surface by the cementing action of the fine dust which surrounds them. If the stone possesses insufficient cementing value, the pieces which make up the surface will be loosened by traffic and will finally be dislodged. When this happens to a great number of pieces in the surface, a serious deterioration results.

The cementing value of a stone is determined as follows: One-half kilogram of the stone to be tested is broken to a size ranging from one-half inch down, and placed in a ball mill along with about 90 cubic centimeters of water. The ball mill is rotated for 2½ hours at 2,000 revolutions per hour. During this time the stone and water will be ground into a stiff paste. The paste is molded under pressure into cylindrical briquettes 25 centimeters in diameter and 25 cm. high. The pressure used is the same for each briquet, and is usually 132 kg. per square cm. cross section from the briquet. The briquets are cured in a uniform manner, and then subjected to repeated blows from a hammer weighing 1 kg. which drops a distance of 1 cm. at each blow. The number of blows required to break the briquet is taken as a measure of the cementing value, and for any sample of stone the average value of five briquets is taken as the cementing value of the stone. The determination is not an exact one and the conditions under which the test is made may affect the results very materially. The test should always be skillfully made in a laboratory so equipped as to enable the operator to duplicate conditions for each test. A cementing value below 10 is low; from 10 to 25, fair; from 26 to 75, good; from 76 to 100, very good; and above 100, excellent. In general, satisfactory results with macadam roads are not obtained if the cementing value of the stone is below 50 and a value of 75 or more is preferable.

Toughness.—The toughness of a stone is its ability to resist the shock of the pounding of horses' hoofs or the jar of heavy vehicles coming upon the stone when it is firmly bedded in the surface of a road.

Hardness.—Hardness is the property of a stone which enables it to resist the abrasive action of the steel tires on heavily loaded vehicles passing over the stone when it is firmly bedded in the surface of the road.

A test was devised by the Department of Bridges and Highways of France, which has been in use for many years for determining both hardness and toughness. It is known as

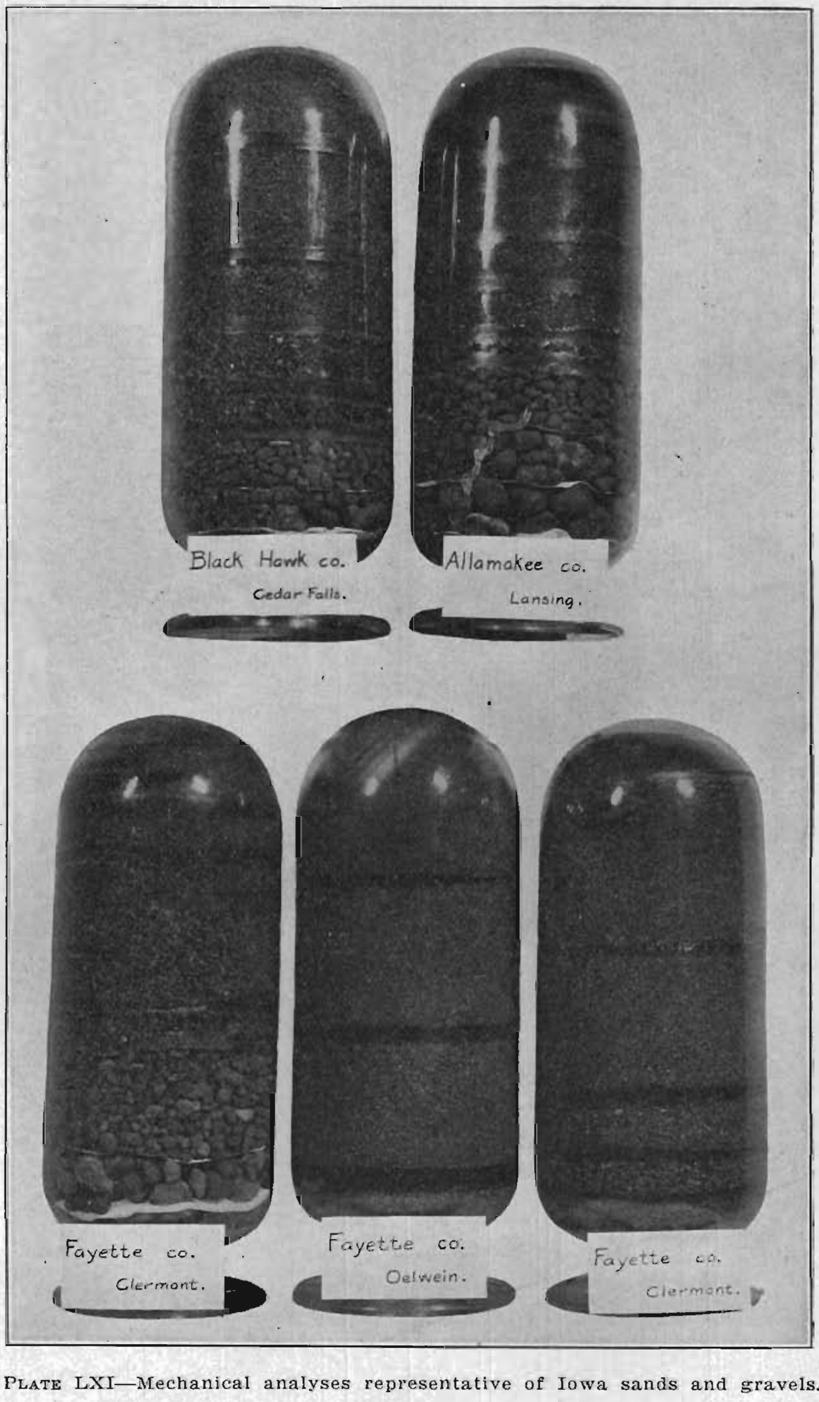


PLATE LXI—Mechanical analyses representative of Iowa sands and gravels.

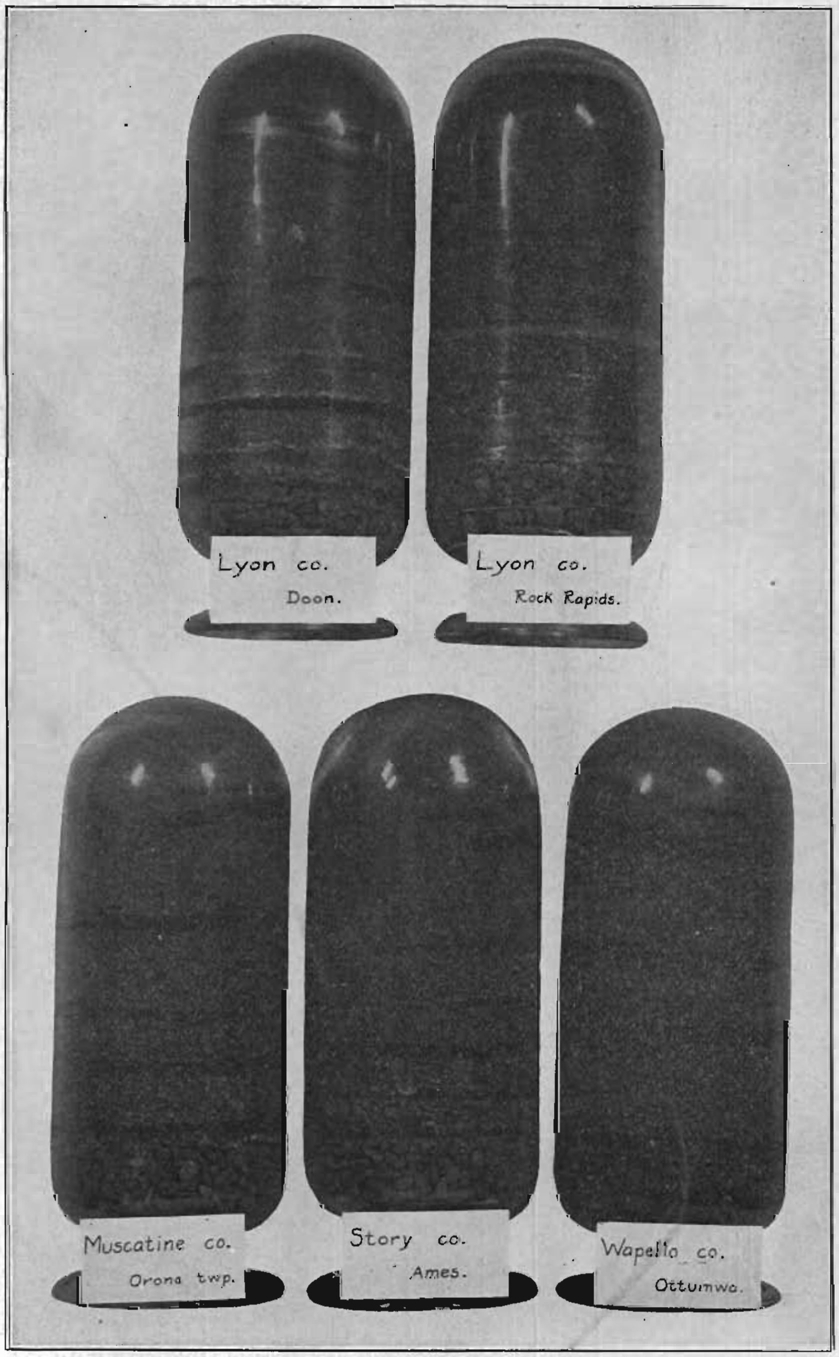


PLATE LXII—Mechanical analyses representative of Iowa sands and gravels.

the "Deval Test," and the results may be expressed as a percentage, or in terms of the French Coefficient of Wear.

The Deval Test.—The machine used for the Deval test is known as the Deval Machine, and consists of two or more hollow cast iron cylinders 20 cm. in inside diameter and 34 cm. long, one end of each being provided with a cover that can be fastened on sufficiently tight to retain all dust resulting from the operation of the machine. The cylinders are attached to a shaft with their axes at an angle of 30° with the shaft. The stone to be tested is placed in one of the cylinders and as it revolves the stone is thrown from one end of the cylinder to the other, thus being subjected to abrasion because of the contact of the pieces with each other, and also being subjected to a mild blow when it strikes the ends of the cylinder. Approximately five kilograms of the stone are used for test, and when possible the charge should consist of 50 pieces as nearly uniform in size as may be selected. The cylinders are rotated for 10,000 revolutions at the rate of 30 to 33 revolutions per minute. When the required number of revolutions has been made the material is taken from the cylinders and screened over a 1-16th inch screen and that which passes through is the amount of loss during the test. If the result is to be expressed in terms of per cent of wear, the per cent would be obtained by dividing the weight of the material which passed the 1-16th inch screen, by the weight of the original sample. If the result is to be expressed in terms of the French Coefficient of Wear:

$$\text{French Coefficient of Wear} = \frac{400}{W}$$

Where W=the loss by abrasion per kg. of the original sample. When expressed in terms of the French Coefficient of Wear a value below 8 is low; 8 to 13 is medium; 14 to 20 is high; and above 20 is very high.

The results of a number of tests for the cementing value of Iowa materials are given in Table III, and it will be noted that there are very few samples having a cementing value less than 50, while a great many of the samples have a cementing value greater than 100. In the column marked "Maximum" is recorded the cementing value of the particular briquet which showed up best and in the column marked "Minimum" is given the cementing value of the briquet which was poorest. It will be noted that in many cases there is a wide difference between these two values. This is due to the fact that the test itself is, in general, inexact, and to variations in the conditions under which the tests are made, such as variations in room temperature, and variation in wetness of the original briquet. In general, however, the test is sufficiently accurate for the purpose for which it is intended, and is a reliable measure of the cementing value of the stone tested.

The results of the Deval test on a number of Iowa limestones are given in Table II, and are tabulated both as per cent of wear and in terms of the French Coefficient of Wear. It will be noted that for a great many of the samples the French Coefficient of Wear is less than 8. That is to say, that while the cementing properties of many of these materials are excellent, the wearing properties are poor. A road constructed with these poorer materials will be apt to be quite dusty due to rapid wear and will require close attention and continual maintenance.

If gravels are to be used for concrete purposes the cementing value, hardness and toughness are relatively of little importance so long as the gravel is not a partially disintegrated material. The gradation of the gravel, the amount of clay or loam present, and the amount of voids in the pebbles are important, however.

In Table IV are given the results of a number of tests of Iowa gravels, in which the above properties were determined. A close study of this table will indicate some significant facts.

First, that the pit-run gravels are exceedingly variable in composition, and for the most part contain a much larger percentage of sand than is necessary for properly proportioned concrete. Concrete made of a fixed proportion of cement and the different pit-run gravels, such as 1 to 4, would therefore

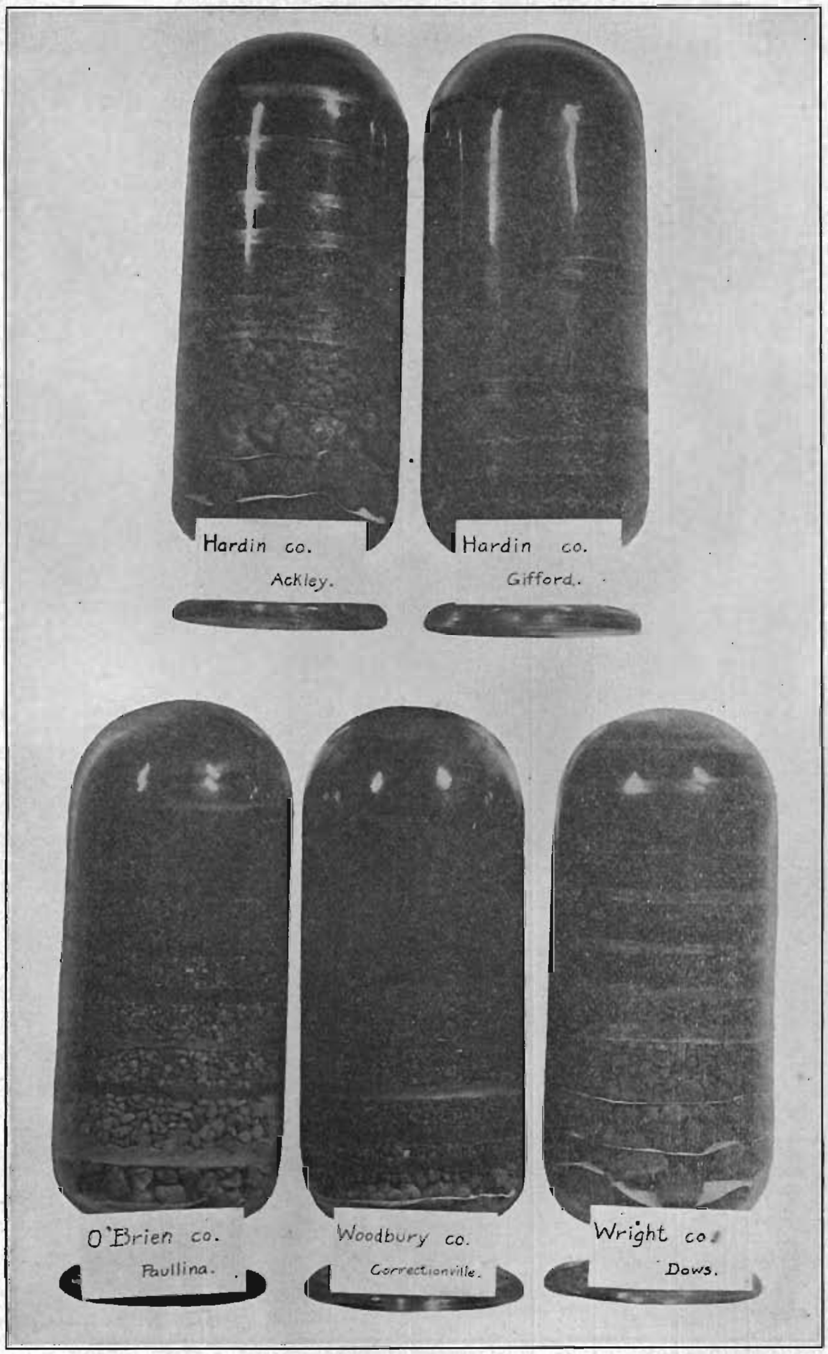


PLATE LXIII—Mechanical analyses representative of Iowa sands and gravels.

vary greatly in strength. It is probable that in most cases it would pay to screen out and throw away the excess sand before making concrete of the gravel. The saving in cement by so doing would be more than enough, in most cases, to pay for the cost of screening.

Second, that the percentage of voids in the pebbles exceeds 40% in only a few cases. Since it is common to proportion concrete on a basis of 40% voids in the pebbles ("coarse aggregate") it would seem that with Iowa gravels this assumption as to percentage of voids may safely be made.

Third, the percentage of clay in a great many of the samples is high, and since clay in excess of about 5% materially decreases the strength of concrete made from the materials, many of the gravels shown in this table would be unsuited for concrete purposes unless the clay or loam were removed by washing.

The percentage of voids in the sand has no particular influence on the proportioning of the concrete, but the fact that the voids in all but a few of the sands shown in the table are about the same is an indication that the sands are fairly uniform in quality and gradation.

ACKNOWLEDGMENTS.

The writers desire to express their appreciation of the courteous co-operation of pit and quarry owners and operators in all parts of the state. Many of the data contained in this report could have been obtained in no other way.

The county reports previously published were used freely in the preparation of this report and references are not always given. The report on Quarry Products was drawn upon extensively, especially the chapter on the Geology of Quarry Products, without any references.

The State Geologist and Assistant State Geologist have facilitated the work in every possible way. The writers take this occasion to make full acknowledgment to all who have aided in any way.

TABLE NO. I.

MECHANICAL ANALYSES OF CRUSHED STONE.

No.	County	Town	Per Cent Retained on 1¼ in. Screen	Per Cent Retained on ¾ in. Screen	Per Cent Passed ¾ in. Screen
20	Allamakee	Lansing	73.063	17.750	9.187
7	Appanoose	Centerville	82.50	15.50	2.00
87	Black Hawk	Cedar Falls	86.0	7.4	6.6
88	Black Hawk	Laporte City	84.4	8.	7.6
73	Black Hawk	Waterloo	81.7	9.4	8.9
74	Black Hawk	Waterloo	84.5	6.9	8.6
78	Benton	Vinton	81.4	9.3	9.3
80	Benton	Garrison	79.1	10.	10.9
82	Benton	Mt. Auburn	84.0	8.5	7.5
83	Benton	Shellsburg	83.	8.	9.
85	Benton	Shellsburg	84.4	6.7	8.9
72	Benton	Vinton	83.6	8.8	7.6
79	Bremer	Waverly	84.4	7.7	7.9
48	Buchanan	Independence	78.74	16.37	4.62
89	Butler	Dumont	81.8	9.6	8.6
81	Butler	Greene	83.75	8.5	7.75
75	Cedar	Lowden	81.3	8.2	10.5
63	Cedar	Cedar Valley	80.93	9.31	9.76
64	Cedar	Tipton	81.4	9.5	9.1
6	Cedar	Tipton	89.562	9.407	1.031
3	Cedar	Lowden	69.50	14.30	16.20
66	Cerro Gordo	Mason City	15.5	47.0	41.5
92	Chickasaw	Chickasaw	84.	9.06	6.94
41	Clayton	Luana	85.12	9.86	4.87
42	Clayton	North McGregor	94.07	3.3	2.5
43	Clayton	Elkader	88.12	5.8	5.6
24	Clayton	Guttenberg	75.500	15.656	8.844
76	Clinton	Clinton	81.0	8.4	10.6
21	Clinton	Lyons	67.312	21.781	10.907
62	Clinton	Charlotte	82.	8.9	9.1
44	Decatur	Davis City	84.26	8.9	6.65
60	Des Moines	Cascade	71.60	16.62	11.78
58	Des Moines	Cascade	73.48	12.64	13.84
28	Fayette	Fayette	65.813	24.250	9.937
26	Fayette	Clermont	60.562	25.938	13.500
94	Floyd	Charles City	90.7	6.15	3.15
95	Franklin	Hampton	74.6	11.4	14.0
77	Franklin	Hampton	84.	6.1	9.9
86	Grundy	Conrad	84.	4.	12.
9	Hardin	Iowa Falls	86.8	7.5	5.0
97	Howard	Cresco	74.9	13.3	11.8
23	Jackson	Maquoketa	68.312	17.250	14.438
11	Jackson	Maquoketa	69.469	17.750	12.781
2	Jackson	Monmouth	43.00	24.00	33.00
93	Johnson	Iowa City	84.8	8.6	6.6
91	Johnson	Iowa City	------	------	------
34	Jones	Stone City	61.563	24.250	14.187
25	Jones	Stone City	77.00	15.875	7.125
22	Jones	Olin	65.594	21.469	12.937
10	Jones	Hale	71.906	18.125	9.969
8	Jones	Stone City	65.063	17.687	17.250
5	Jones	Monticello	84.344	10.063	5.594

TABLE NO. I—CONTINUED

No.	County	Town	Per Cent Retained on 1¼ in. Screen	Per Cent Retained on ¾ in. Screen	Per Cent Passed ¾ in. Screen
4	Jones	Monticello	78.80	13.30	7.90
61	Lee	Keokuk	93.80	3.30	2.90
59	Lee	Ft. Madison	76.67	11.25	11.10
54	Lee	Keokuk	81.86	10.00	8.12
55	Lee	Franklin	61.50	27.50	11.00
56	Lee	Keokuk	74.74	14.62	10.62
57	Lee	Keokuk	69.44	20.3	10.2
49	Lee	Keokuk	77.6	15.1	6.1
50	Lee	Keokuk	79.74	11.11	9.10
46	Lee	Montrose	39.0	37.0	24.0
47	Lee	Keokuk	44.7	42.74	2.5
14	Linn	Cedar Rapids	73.25	16.375	10.375
12	Linn	Cedar Rapids	69.156	22.187	8.657
90	Louisa	Morning Sun	84.94	7.06	8.
39	Madison	Winterset	83.38	15.36	.65
36	Madison	Earlham	100.0	----------	----------
37	Madison	Peru	100.00	----------	----------
96	Mitchell	Osage	80.1	10.6	9.3
67	Muscatine	Fairport	78.	6.25	15.75
98	Pocahontas	Gilmore City	84.50	8.50	7.00
35	Scott	Buffalo	81.0	19.0	----------
19	Scott	Le Claire	76.00	17.094	6.906
68	Tama	Montour	89.75	5.75	4.5
69	Tama	Montour	84.1	10.8	4.1
70	Tama	Montour	83.6	9.5	6.9
71	Tama	Montour	87.1	7.1	5.8
51	Van Buren	Keosauqua	79.0	10.8	10.2
52	Van Buren	Keosauqua	76.12	15.86	7.74
53	Van Buren	Farmington	82.32	10.17	6.88
29	Van Buren	Farmington	58.344	32.687	8.969
30	Van Buren	Keosauqua	74.00	17.00	9.00
31	Van Buren	Keosauqua	64.00	25.812	10.187
32	Van Buren	Keosauqua	65.688	23.812	10.500
33	Van Buren	Van Buren	65.500	24.313	10.187
13	Wapello	Cliffland	74.344	9.469	16.187
18	Wapello	Ottumwa	68.938	19.563	11.500
17	Wapello	Ottumwa	63.906	23.906	12.188
16	Wapello	Ottumwa	73.906	16.563	9.531
15	Wapello	Ottumwa	74.750	15.281	9.969
45	Winneshiek	Decorah	75.48	12.52	12.00
40	Winneshiek	Decorah	87.12	7.46	5.12
27	Winneshiek	Ft. Atkinson	68.812	20.500	10.688
1	Winneshiek	Decorah	81.24	9.76	9.00
38	New Ulm	Minnesota	82.96	16.00	.5

TABLE NO. II.

ABRASION AND IMPACT TESTS

No.	County	Size of Specimens		Per Cent of Wear			Mean Coefficient (French)
		Screen Passed	Retained on	Max.	Min.	Mean	
20	Allamakee	2½ in.	1¼ in.	5.4	5.0	5.2	7.70
20	Allamakee	1¼ in.	¾ in.	4.3	4.22	4.26	9.38
7	Appanoose	2½ in.	1¼ in.	4.6	4.5	4.55	8.80
7	Appanoose	1¼ in.	¾ in.	12.6	13.2	12.9	3.12
87	Black Hawk	2½ in.	1¼ in.	6.2	6.	6.1	6.56
87	Black Hawk	1¼ in.	¾ in.	3.	2.4	2.7	11.11
88	Black Hawk	2½ in.	1¼ in.	10.4	10.	10.2	3.92
88	Black Hawk	1¼ in.	¾ in.	8.	6.	7.	5.62
73	Black Hawk	2½ in.	1¼ in.	11.4	11.	11.2	3.57
73	Black Hawk	1¼ in.	¾ in.	4.2	4.	4.1	9.75
74	Black Hawk	2½ in.	1¼ in.	10.4	10.	10.2	3.82
74	Black Hawk	1¼ in.	¾ in.	4.4	4.	4.2	9.58
78	Benton	2½ in.	1¼ in.	6.5	6.5	6.5	6.16
78	Benton	1¼ in.	¾ in.	2.6	2.5	2.55	15.68
80	Benton	2½ in.	1¼ in.	6.6	5.6	6.1	6.55
80	Benton	1¼ in.	¾ in.	3.4	3.	3.2	12.5
82	Benton	2½ in.	1¼ in.	4.	4.	4.	10.
82	Benton	1¼ in.	¾ in.	6.2	6.	6.1	6.55
83	Benton	2½ in.	1¼ in.	8.6	8.2	8.4	4.76
83	Benton	1¼ in.	¾ in.	5.2	4.6	4.9	8.17
85	Benton	2½ in.	1¼ in.	7.4	6.6	7.	5.71
85	Benton	1¼ in.	¾ in.	4.	3.	3.5	11.42
72	Benton	2½ in.	1¼ in.	6.4	6.2	6.3	6.35
72	Benton	1¼ in.	¾ in.	3.8	3.6	3.7	10.8
79	Bremer	2½ in.	1¼ in.	5.4	5.	5.2	7.68
79	Bremer	1¼ in.	¾ in.	3.	2.4	2.7	11.11
48	Buchanan	2½ in.	1¼ in.	7.0	7.0	7.0	5.71
48	Buchanan	1¼ in.	¾ in.	4.6	4.0	4.3	9.3
89	Butler	2½ in.	1¼ in.	5.	4.2	4.6	8.69
89	Butler	1¼ in.	¾ in.	3.	2.6	2.8	14.28
81	Butler	2½ in.	1¼ in.	6.2	6.	6.1	6.55
81	Butler	1¼ in.	¾ in.	2.4	2.2	2.3	17.39
75	Cedar	2½ in.	1¼ in.	17.2	15.6	16.7	2.33
75	Cedar	1¼ in.	¾ in.	9.4	8.4	8.9	4.49
63	Cedar	2½ in.	1¼ in.	16.2	16.	16.1	2.48
63	Cedar	1¼ in.	¾ in.	9.8	9.2	9.5	4.21
64	Cedar	2½ in.	1¼ in.	6.4	6.4	6.4	6.25
64	Cedar	1¼ in.	¾ in.	4.	3.4	3.7	10.81
6	Cedar	2½ in.	1¼ in.	9.6	9.5	9.55	4.18
6	Cedar	1¼ in.	¾ in.	6.2	5.8	6.0	6.67
3	Cedar	2½ in.	1¼ in.	--------	--------	17.5	2.28
3	Cedar	1¼ in.	¾ in.	--------	--------	12.1	3.31
66	Cerro Gordo	2½ in.	1¼ in.	--------	--------	4.4	9.09
66	Cerro Gordo	1¼ in.	¾ in.	2.1	.18	1.14	34.2
92	Chickasaw	2½ in.	1¼ in.	10.2	9.8	10.	4.
92	Chickasaw	1¼ in.	¾ in.	4.	3.8	3.9	10.25
41	Clayton	2½ in.	1¼ in.	8.4	8.2	8.3	4.82
41	Clayton	1¼ in.	¾ in.	6.4	5.6	6.0	6.6
42	Clayton	2½ in.	1¼ in.	9.5	8.5	9.0	4.4
42	Clayton	1¼ in.	¾ in.	--------	--------	4.8	8.3
43	Clayton	2½ in.	1¼ in.	11.0	9.4	10.2	3.9

TABLE NO. II—CONTINUED

No.	County	Size of Specimens		Per Cent of Wear			Mean Coefficient (French)
		Screen Passed	Retained on	Max.	Min.	Mean	
43	Clayton	1¼ in.	¾ in.	5.0	4.6	4.8	8.3
24	Clayton	2½ in.	1¼ in.	5.8	5.5	5.65	7.08
24	Clayton	1¼ in.	¾ in.	5.0	4.8	4.9	8.17
76	Clinton	2½ in.	1¼ in.	13.	11.	12.	3.33
76	Clinton	1¼ in.	¾ in.	6.	5.	5.5	7.27
21	Clinton	2½ in.	1¼ in.	10.60	8.50	9.55	4.18
21	Clinton	1¼ in.	¾ in.	9.10	9.00	9.05	4.42
62	Clinton	2½ in.	1¼ in.	10.	9.4	9.7	4.12
62	Clinton	1¼ in.	¾ in.	17.2	17.	17.1	2.34
44	Decatur	2½ in.	1¼ in.	4.8	2.6	3.7	10.8
44	Decatur	1¼ in.	¾ in.	3.2	2.4	2.8	14.3
60	Des Moines	2½ in.	1¼ in.	8.0	7.0	7.5	5.33
60	Des Moines	1¼ in.	¾ in.	5.8	5.0	5.4	7.4
58	Des Moines	2½ in.	1¼ in.			12.4	3.22
58	Des Moines	1¼ in.	¾ in.			8.4	4.76
28	Fayette	2½ in.	1¼ in.	6.5	5.8	6.15	6.51
28	Fayette	1¼ in.	¾ in.	7.1	6.7	6.9	5.80
26	Fayette	2½ in.	1¼ in.	20.1	16.4	18.25	2.195
26	Fayette	1¼ in.	¾ in.	15.52	14.82	15.17	2.64
94	Floyd	2½ in.	1¼ in.	8.4	7.8	8.1	4.94
94	Floyd	1¼ in.	¾ in.	5.4	3.4	4.4	9.1
95	Franklin	2½ in.	1¼ in.	12.2	10.6	11.4	3.5
95	Franklin	1¼ in.	¾ in.	5.6	4.6	5.1	7.34
77	Franklin	2½ in.	1¼ in.	11.4	10.	10.7	3.73
77	Franklin	1¼ in.	¾ in.	5.2	5.	5.1	7.84
86	Grundy	2½ in.	1¼ in.	10.4	10.	10.2	3.92
86	Grundy	1¼ in.	¾ in.	5.	4.6	4.8	8.33
9	Hardin	2½ in.	1¼ in.			5.1	7.8
9	Hardin	1¼ in.	¾ in.			3.2	12.2
97	Howard	2½ in.	1¼ in.	7.8	7.6	7.7	5.19
97	Howard	1¼ in.	¾ in.	13.4	8.	10.7	3.74
23	Jackson	2½ in.	1¼ in.	10.3	10.1	10.2	3.92
23	Jackson	1¼ in.	¾ in.	7.1	6.8	6.95	5.76
11	Jackson	2½ in.	1¼ in.	12.5	11.5	12.0	3.33
11	Jackson	1¼ in.	¾ in.	13.2	13.2	13.2	3.04
2	Jackson	2½ in.	1¼ in.			10.2	3.9
2	Jackson	1¼ in.	¾ in.			6.45	6.2
93	Johnson	2½ in.	1¼ in.	8.4	8.2	8.3	4.82
93	Johnson	1¼ in	¾ in.			5.0	8.
91	Johnson	2½ in.	1¼ in.			4.2	9.76
91	Johnson	1¼ in.	¾ in.	3.4	3.	3.2	12.5
34	Jones	2½ in.	1¼ in.	7.0	6.6	6.8	5.88
34	Jones	1¼ in.	¾ in.	5.0	4.0	4.5	8.78
25	Jones	2½ in.	1¼ in.	4.2	4.1	4.15	9.64
25	Jones	1¼ in.	¾ in.	3.5	3.46	3.48	11.50
22	Jones	2½ in.	1¼ in.	17.62	17.42	17.52	2.28
22	Jones	1¼ in.	¾ in.	13.2	12.8	13.0	3.08
10	Jones	2½ in.	1¼ in.	7.0	6.6	6.8	5.88
10	Jones	1¼ in.	¾ in.	7.2	6.8	7.0	5.71
8	Jones	2½ in.	1¼ in.	12.44	9.56	10.00	4.00
8	Jones	1¼ in.	¾ in.	11.9	11.8	11.85	3.38
5	Jones	2½ in.	1¼ in.	10.72	10.50	10.61	3.77
5	Jones	1¼ in.	¾ in.	7.16	6.10	6.63	6.04
4	Jones	2½ in.	1¼ in.			7.9	5.07

TABLE NO. II—CONTINUED

No.	County	Size of Specimens		Per Cent of Wear			Mean Coefficient (French)
		Screen Passed	Retained on	Max.	Min.	Mean	
4	Jones	1¼ in.	¾ in.			6.1	6.56
61	Lee	2½ in.	1¼ in.	7.4	7.0	7.2	5.5
61	Lee	1¼ in.	¾ in.	4.0	3.8	3.9	10.2
59	Lee	2½ in.	1¼ in.			8.2	4.87
59	Lee	1¼ in.	¾ in.			6.6	6.06
54	Lee	2½ in.	1¼ in.			4.0	10.00
54	Lee	1¼ in.	¾ in.			2.5	16.00
55	Lee	2½ in.	1¼ in.	3.2	3.0	3.1	12.1
55	Lee	1¼ in.	¾ in.	2.4	2.2	2.1	19.0
56	Lee	2½ in.	1¼ in.	6.2	6.2	6.2	6.4
56	Lee	1¼ in.	¾ in.	4.8	4.4	4.6	8.7
57	Lee	2½ in.	1¼ in.			4.6	8.7
57	Lee	1¼ in.	¾ in.			3.4	11.7
49	Lee	2½ in.	1¼ in.	4.8	4.8	4.8	8.23
49	Lee	1¼ in.	¾ in.	4.0	3.8	3.9	10.2
50	Lee	2½ in.	1¼ in.	7.8	7.6	7.7	5.2
50	Lee	1¼ in.	¾ in.	5.6	4.8	5.2	7.7
46	Lee	2½ in.	1¼ in.	5.0	4.8	4.9	8.01
46	Lee	1¼ in.	¾ in.	4.0	3.2	3.6	11.1
47	Lee	2½ in.	1¼ in.	4.8	4.6	4.7	8.5
47	Lee	1¼ in.	¾ in.	3.6	3.4	3.5	11.4
14	Linn	2½ in.	1¼ in.	9.44	5.56	7.50	5.34
14	Linn	1¼ in.	¾ in.	8.42	4.76	6.59	6.07
12	Linn	2½ in.	1¼ in.	4.40	2.64	3.52	11.37
12	Linn	1¼ in.	¾ in.	7.6	7.6	7.6	5.27
90	Louisa	2½ in.	1¼ in.	7.	6.4	6.7	5.95
90	Louisa	1¼ in.	¾ in.	3.4	3.	3.2	12.5
39	Madison	2½ in.	1¼ in.	4.0	3.6	3.8	10.5
39	Madison	1¼ in.	¾ in.	2.3	2.2	2.25	18.0
36	Madison	2½ in.	1¼ in.	4.8	4.0	4.4	9.1
37	Madison	2½ in.	1¼ in.	4.0	3.6	3.8	10.5
96	Mitchell	2½ in.	1¼ in.	7.2	6.8	7.0	5.72
96	Mitchell	1¼ in.	¾ in.	4.8	4.6	4.7	8.51
67	Muscatine	2½ in.	1¼ in.	53.	47.8	50.4	.79
67	Muscatine	1¼ in.	¾ in.	55.	53.6	54.3	.73
98	Pocahontas	2½ in.	1¼ in.	4.4	4.1	4.25	0.975
98	Pocahontas	1¼ in.	¾ in.	2.8	2.6	2.7	1.54
35	Scott	2½ in.	1¼ in.	4.3	4.0	4.15	9.65
35	Scott	1¼ in.	¾ in.	2.9	2.6	2.75	14.52
19	Scott	2½ in.	1¼ in.	3.6	2.9	3.25	12.30
19	Scott	1¼ in.	¾ in.	4.00	3.80	3.90	10.25
68	Tama	2½ in.	1¼ in.	5.6	5.4	5.5	7.27
68	Tama	1¼ in.	¾ in.	2.4	2.	2.2	18.18
69	Tama	2½ in.	1¼ in.	8.4	8.	8.2	4.87
69	Tama	1¼ in.	¾ in.	4.	3.	3.5	11.42
70	Tama	2½ in.	1¼ in.	15.4	14.	14.7	2.72
70	Tama	1¼ in.	¾ in.	10.2	6.4	8.3	4.81
71	Tama	2½ in.	1¼ in.	6.6	6.	6.3	6.34
71	Tama	1¼ in.	¾ in.	4.	3.6	3.8	10.5
51	Van Buren	2½ in.	1¼ in.	9.0	8.4	8.7	4.6
51	Van Buren	1¼ in.	¾ in.	3.6	3.0	3.3	12.1
52	Van Buren	2½ in.	1¼ in.	5.6	5.4	5.5	7.27
52	Van Buren	1¼ in.	¾ in.	5.2	5.2	5.2	7.7
53	Van Buren	2½ in.	1¼ in.			6.0	6.6

TABLE NO. II—CONTINUED

No.	County	Size of Specimens		Per Cent of Wear			Mean Coeffi-cient (French)
		Screen Passed	Retained on	Max.	Min.	Mean	
53	Van Buren	1¼ in.	¾ in.			3.6	11.1
29	Van Buren	2½ in.	1¼ in.	4.2	4.0	4.1	9.98
29	Van Buren	1¼ in.	¾ in.	3.36	3.36	3.36	11.80
30	Van Buren	2½ in.	1¼ in.	3.4	3.2	3.3	12.12
30	Van Buren	1¼ in	¾ in.	2.9	2.0	2.45	16.32
31	Van Buren	2½ in.	1¼ in.	4.60	4.30	4.45	8.99
31	Van Buren	1¼ in.	¾ in.	3.66	3.5	3.58	11.30
32	Van Buren	2½ in.	1¼ in.	7.16	6.76	6.96	5.82
32	Van Buren	1¼ in.	¾ in.	6.36	5.80	6.08	6.67
33	Van Buren	2½ in.	1¼ in.	3.06	3.36	3.51	11.40
33	Van Buren	1¼ in.	¾ in.	2.86	2.40	2.63	15.22
13	Wapello	2½ in.	1¼ in.	70.18	44.00	57.09	.702
13	Wapello	1¼ in.	¾ in.	43.66	43.40	43.53	.918
18	Wapello	2½ in.	1¼ in.	4.10	3.24	3.67	10.89
18	Wapello	1¼ in.	¾ in.	3.0	2.80	2.90	13.80
17	Wapello	2½ in.	1¼ in.	3.60	3.50	3.55	11.28
17	Wapello	1¼ in.	¾ in.	3.30	2.40	2.85	14.03
16	Wapello	2½ in.	1¼ in.	3.20	2.84	3.02	13.25
16	Wapello	1¼ in.	¾ in.	2.44	2.00	2.22	18.02
15	Wapello	2½ in.	1¼ in.	4.44	3.3	3.87	10.63
15	Wapello	1¼ in.	¾ in.	2.5	2.0	2.25	17.78
45	Winneshiek	2½ in.	1¼ in.			6.00	6.6
45	Winneshiek	1¼ in.	¾ in.			3.5	11.4
40	Winneshiek	2½ in.	1¼ in.	5.6	5.4	5.5	7.45
40	Winneshiek	1¼ in.	¾ in.	4.0	4.0	4.0	8.00
27	Winneshiek	2½ in.	1¼ in.	5.45	5.10	5.27	7.58
27	Winneshiek	1¼ in.	¾ in.	4.3	3.9	4.1	9.98
1	Winneshiek	2½ in.	1¼ in.			13.	3.08
1	Winneshiek	1¼ in.	¾ in.			8.3	4.81
38	New Ulm, Minn.	2½ in.	1¼ in.	1.4	1.2	1.3	30.7
38	New Ulm, Minn.	1¼ in.	¾ in.	1.0	0.7	0.85	49.0

TABLE NO. III.

CEMENTATION TESTS.

o.	County	Town	Cementing Value		
			Maximum	Minimum	Mean
20	Allamakee	Lansing	109	65	82
7	Appanoose	Centerville	75	56	65
87	Black Hawk	Cedar Falls	600	300	450
88	Black Hawk	Laporte City	30	10	20
73	Black Hawk	Waterloo	900	510	754
74	Black Hawk	Waterloo	600	310	470
78	Benton	Vinton	256	114	185
80	Benton	Garrison	552	405	492
82	Benton	Mt. Auburn	1290	908	1099
83	Benton	Shellsburg	460	304	362
85	Benton	Shellsburg	470	200	335
72	Benton	Vinton	300	98	182
79	Bremer	Waverly	894	402	670
48	Buchanan	Independence	180	80	130
89	Butler	Dumont	90	10	50
81	Butler	Greene	514	448	467
75	Cedar	Lowden	103	74	86
63	Cedar	Cedar Valley	96	25	59
64	Cedar	Tipton	325	112	233
6	Cedar	Tipton	360	200	295
3	Cedar	Lowden			N. G.
66	Cerro Gordo	Mason City	*		
92	Chickasaw	Chickasaw	30	12	21
41	Clayton	Luana	162	112	146
42	Clayton	North McGregor	66	50	58
43	Clayton	Elkader	400	100	292
24	Clayton	Guttenberg	198	60	105
76	Clinton	Clinton	430	240	329
21	Clinton	Lyons	25	15	20
62	Clinton	Charlotte	110	39	67
44	Decatur	Davis City	125	75	100
60	Des Moines	Cascade	87	31	65
58	Des Moines	Cascade	20	11	15
28	Fayette	Fayette	220	180	200
26	Fayette	Clermont	19	8	14
94	Floyd	Charles City	†		
95	Franklin	Hampton	‡		
77	Franklin	Hampton	308	245	273
86	Grundy	Conrad	220	40	130
9	Hardin	Iowa Falls	200	125	168
97	Howard	Cresco	40	20	30
23	Jackson	Maquoketa	70	26	43
11	Jackson	Maquoketa			N. G.
2	Jackson	Monmouth	31	25	28
93	Johnson	Iowa City	468	300	384
91	Johnson	Iowa City	230	160	195
34	Jones	Stone City	140	30	87
25	Jones	Stone City	280	91	173
22	Jones	Olin	10	5	7
10	Jones	Hale	20	15	17
8	Jones	Stone City	25	12	16

TABLE NO. III—CONTINUED

No.	County	Town	Cementing Value		
			Maximum	Minimum	Mean
5	Jones	Monticello	112	88	98
4	Jones	Monticello	18	15	16
61	Lee	Keokuk	112	50	79
59	Lee	Ft. Madison	237	100	162
54	Lee	Keokuk	180	50	102
55	Lee	Franklin	85	60	72
56	Lee	Keokuk	160	70	118
57	Lee	Keokuk	245	75	155
49	Lee	Keokuk	300	110	205
50	Lee	Keokuk	75	50	59
46	Lee	Montrose	325	62	147
47	Lee	Keokuk	600	150	350
14	Linn	Cedar Rapids	185	65	112
12	Linn	Cedar Rapids	250	51	123
90	Louisa	Morning Sun	225	175	200
39	Madison	Winterset	100	50	59
36	Madison	Earlham	72	14	40
37	Madison	Peru	152	25	73
96	Mitchell	Osage	274	200	237
67	Muscatine	Fairport	*		
98	Pocahontas	Gilmore City	375	325	350
35	Scott	Buffalo	127	26	78
19	Scott	LeClaire	160	80	120
68	Tama	Montour	285	124	219
69	Tama	Montour	425	236	366
70	Tama	Montour	168	54	117
71	Tama	Montour	334	70	206
51	Van Buren	Keosauqua	50	20	33
52	Van Buren	Keosauqua	200	50	111
53	Van Buren	Farmington	110	50	72
29	Van Buren	Farmington	150	30	75
30	Van Buren	Keosauqua	219	42	91
31	Van Buren	Keosauqua	300	69	208
32	Van Buren	Keosauqua	61	30	46
33	Van Buren	Van Buren	271	20	83
13	Wapello	Cliffland			N. G.
18	Wapello	Ottumwa	290	70	136
17	Wapello	Ottumwa	134	25	93
16	Wapello	Ottumwa	125	63	87
15	Wapello	Ottumwa	42	15	26
45	Winneshiek	Decorah	187	100	150
40	Winneshiek	Decorah	250	125	158
27	Winneshiek	Ft. Atkinson	286	87	190
1	Winneshiek	Decorah	18	18	18
38	New Ulm	Minnesota	100	50	85

*No record—no detritus left.
†Would not make briquets.
‡Briquets crumbled at first blow of hammer.

TABLE NO. IV.

PERCENTAGES OF PEBBLES, SAND AND VOIDS IN REPRESENTATIVE IOWA GRAVELS.

No.	Locality		Mech. Anal. Per Cent			Per Cent Voids		
	County	Town	Pebbles	Sand	Clay	Pebbles	Sand	Mixture
15	Allamakee	Lansing	38.0	60.8	1.2	35.0	36.0	-----
65	Benton	Vinton	21.0	76.0	3.0	38.0	36.0	-----
66	Benton	Vinton	42.9	51.8	5.3	43.0	36.0	-----
67	Benton	Vinton	13.9	74.6	11.5	41.0	28.0	-----
70	Black Hawk	Cedar Falls	24.9	72.5	2.6	40.0	36.0	-----
56	Boone	Frazer	5.5	81.2	13.3	40.2	38.0	-----
63	Boone	Pilot Mound	31.5	65.1	3.4	25.9	25.2	-----
68	Bremer	Waverly	45.6	49.7	4.7	40.0	32.0	-----
36	Buchanan	Independence	18.4	58.9	22.7	42.0	42.5	-----
23	Buena Vista	Sioux Rapids	33.6	62.3	4.1	34.0	35.0	-----
78	Buena Vista	Storm Lake	30.5	58.2	11.3	40.0	34.0	-----
76	Butler	Dumont	41.9	51.3	6.8	41.0	32.0	-----
105	Butler	Shell Rock	-----	95.6	4.4	-----	32.0	-----
61	Calhoun	Lake City	46.0	49.3	4.7	34.7	35.0	-----
116	Cherokee	Cherokee	25.8	72.3	1.9	40.6	34.0	-----
79	Chickasaw	Ionia	32.8	57.9	9.3	42.0	33.0	-----
125	Clay	Spencer	31.6	60.1	8.3	-----	-----	35.2
14	Clayton	McGregor	-----	99.0	1.0	-----	36.0	-----
13	Clayton	Elkader	37.8	60.8	1.4	46.0	39.0	-----
2	Clinton	DeWitt	56.4	38.6	5.0	42.0	33.0	-----
120	Clinton	DeWitt	54.9	42.5	2.6	-----	-----	32.9
48	Clinton	DeWitt	55.9	32.7	11.4	37.0	36.0	-----
44	Clinton	Wheatland	2.7	94.6	2.7	38.0	39.0	-----
42	Clinton	Clinton	-----	99.9	.1	38.0	37.5	-----
41	Clinton	Albany	53.9	45.0	1.1	28.0	27.5	-----
37	Clinton	Clinton	84.3	15.1	0.6	32.5	32.5	-----
49	Crawford	Denison	37.0	60.4	2.6	33.0	38.0	-----
12	Decatur	Leon	5.8	91.2	3.0	41.0	37.0	-----
11	Decatur	DeKalb	4.3	91.7	4.0	38.0	39.0	-----
10	Decatur	Leon	8.6	89.6	1.8	42.0	40.0	-----
33	Delaware	Manchester	13.4	81.1	5.5	28.0	30.0	-----
35	Des Moines	Flint River Twp.	35.1	62.9	2.0	35.0	36.0	-----
16	Dubuque	Dubuque	0.7	97.8	1.5	38.0	34.0	-----
106	Emmet	Armstrong	-----	91.0	9.0	-----	-----	-----
3	Fayette	Clermont	25.8	66.4	7.8	40.0	37.0	-----
5	Fayette	Clermont	33.1	56.7	10.2	46.0	42.0	-----
7	Fayette	Clermont	66.1	26.7	7.2	40.0	36.5	-----
17	Fayette	Clermont	48.7	50.8	0.5	38.0	36.0	-----
18	Fayette	Clermont	4.4	95.1	0.5	36.0	34.0	-----
34	Fayette	Oelwein	1.4	92.3	6.3	33.5	37.5	-----
81	Floyd	Charles City	32.6	60.7	6.7	39.0	28.0	-----
73	Floyd	Marble Rock	52.4	45.9	1.7	40.0	35.0	-----
92	Franklin	Hampton	40.1	55.4	4.5	45.0	31.0	-----
84	Franklin	Sheffield	22.3	72.7	5.0	40.0	33.0	-----
51	Greene	Grand Junction	30.9	65.1	4.0	32.5	32.2	-----
101	Greene	Grand Junction	24.8	72.0	3.2	-----	-----	37.0
102	Greene	Grand Junction	44.3	46.4	9.3	-----	-----	46.6
103	Greene	Grand Junction	30.7	67.1	2.2	-----	-----	34.0

TABLE NO. IV—CONTINUED

No.	Locality		Mech. Anal. Per Cent			Per Cent Voids		
	County	Town	Pebbles	Sand	Clay	Pebbles	Sand	Mixture
104	Greene	Grand Junction	37.6	59.2	3.2	-----	-----	32.0
50	Greene	Jefferson	17.6	81.0	1.4	34.0	37.0	-----
108	Greene	Jefferson	37.5	60.3	2.2	-----	-----	29.6
109	Greene	Jefferson	41.9	54.8	3.3	-----	-----	29.1
126	Greene	Jefferson	14.5	85.2	0.3	-----	-----	30.0
89	Grundy	Grundy Center	43.9	52.9	3.2	41.0	27.0	-----
71	Grundy	Wellsburg	42.1	45.4	12.5	43.0	30.0	-----
87	Hamilton	Kamrar	46.6	41.1	12.3	40.0	33.0	-----
88	Hamilton	Webster City	59.3	39.2	1.5	40.0	35.0	-----
90	Hamilton	Webster City	15.0	77.8	7.2	40.0	33.0	-----
93	Hardin	Ackley	44.6	50.9	4.5	41.0	34.0	-----
40	Hardin	Gifford	18.5	78.5	3.0	35.0	35.0	-----
94	Harrison	Pisgah	28.1	69.4	2.5	36.0	34.0	-----
80	Harrison	Missouri Valley	48.4	42.1	9.5	37.0	26.0	-----
115	Humboldt	Humboldt	-----	98.4	1.6	-----	35.0	-----
117	Humboldt	Humboldt	27.2	69.8	3.0	-----	-----	30.7
118	Humboldt	Humboldt	35.4	61.3	3.3	-----	-----	33.5
127	Humboldt	Humboldt	5.8	92.6	1.6	-----	-----	33.4
128	Humboldt	Humboldt	9.2	89.0	1.8	-----	-----	31.5
25	Ida	Ida Grove	10.1	87.6	2.3	42.0	30.0	-----
69	Iowa	South Amana	10.2	86.5	3.3	42.0	37.0	-----
1	Jackson	Maquoketa	15.8	82.5	1.7	38.0	35.0	-----
129	Jones	Oxford Junction	25.0	73.2	1.8	-----	-----	30.0
130	Jones	Oxford Junction	17.8	79.0	3.2	-----	-----	32.3
107	Kossuth	Algona	31.2	67.0	1.8	-----	34.5	-----
82	Lyon	Rock Rapids	25.4	65.1	9.5	37.0	31.0	-----
27	Lyon	Doon	23.8	74.3	1.9	38.0	32.0	-----
132	Madison	Sec. 19, Monroe Twp.	27.1	61.9	11.0	-----	-----	-----
38	Mahaska	Eddyville	23.9	74.7	1.4	34.0	35.0	-----
123	Mahaska	White City	-----	98.0	2.0	-----	33.0	-----
39	Marion	Tracy	10.8	84.9	4.3	33.0	33.0	-----
53	Marshall	Clemons	43.4	53.5	3.1	34.5	33.0	-----
95	Marshall	St. Anthony	46.6	53.4	-----	-----	-----	-----
119	Marshall	St. Anthony	54.7	42.8	2.5	-----	-----	28.8
8	Mills	Pacific Junction	11.8	86.5	1.7	34.0	34.0	-----
75	Mitchell	Osage	38.1	57.1	4.8	45.0	37.0	-----
91	Monona	Mapleton	9.0	85.3	5.7	43.0	30.0	-----
121	Monona	Blencoe	8.3	88.9	2.8	-----	-----	32.0
122	Monona	Rodney	14.8	84.0	1.2	-----	-----	36.0
6	Montgomery	Red Oak	7.5	88.9	3.6	41.0	40.0	-----
113	Muscatine	Muscatine	34.6	64.4	1.0	-----	-----	26.8
114	Muscatine	Muscatine	39.9	58.7	1.4	-----	-----	29.0
55	Muscatine	Muscatine	-----	94.0	6.0	38.0	39.0	-----
59	Muscatine	Nichols	8.4	84.8	6.8	37.0	35.0	-----
54	Muscatine	Orono Twp.	24.4	73.8	1.8	36.0	35.5	-----
74	O'Brien	Paullina	33.7	62.6	3.7	41.0	33.0	-----
20	Osceola	Sibley	21.7	70.5	7.8	42.0	29.0	-----
9	Page	Clarinda	4.6	93.5	1.9	44.0	37.0	-----
4	Plymouth	Le Mars	8.0	89.7	2.3	38.0	33.0	-----
110	Polk	Des Moines	7.4	90.8	1.8	-----	-----	31.1
22	Sac	Early	19.7	79.0	1.3	39.0	35.0	-----

TABLE NO. IV—CONTINUED

No.	Locality		Mech. Anal. Per Cent.			Per Cent Voids		
	County	Town	Pebbles	Sand	Clay	Pebbles	Sand	Mixture
52	Scott	Davenport	1.9	97.5	0.6	38.0	36.0	-----
62	Story	Ames	36.6	59.9	3.5	25.8	25.4	-----
86	Tama	Clutier	39.8	55.2	5.0	42.0	35.0	-----
64	Tama	Montour	23.7	73.0	3.3	40.0	33.0	-----
32	Van Buren	Farmington	24.2	73.8	2.0	37.0	36.0	-----
31	Van Buren	Farmington	12.8	86.6	0.6	37.0	34.0	-----
29	Wapello	Ottumwa	27.6	72.2	0.2	35.0	35.0	-----
131	Wapello	Ottumwa	90.1	9.9	-----	-----	-----	-----
58	Webster	Badger	33.0	56.6	10.4	33.0	32.0	-----
57	Webster	Fort Dodge	32.0	64.7	3.3	30.0	28.0	-----
19	Woodbury	Correctionville	21.3	75.6	3.1	41.0	36.0	-----
28	Woodbury	Correctionville	44.5	54.9	0.6	39.0	30.0	-----
72	Woodbury	Correctionville	23.7	73.8	2.5	39.0	34.0	-----
124	Woodbury	Sioux City	30.6	61.4	8.0	-----	-----	32.1
43	Worth	Hanlontown	42.6	52.3	5.1	35.0	34.2	-----
47	Worth	Hanlontown	38.6	57.6	3.8	27.0	26.0	-----
85	Wright	Dows	47.9	48.8	3.3	42.0	32.0	-----
83	Wright	Dows	24.7	70.0	5.3	38.0	30.0	-----
46	Wright	Eagle Grove	20.9	76.5	2.6	35.0	33.0	-----
45	Wright	Belmond	35.8	59.1	5.1	36.0	34.0	-----

TABLE NO. V.

ANALYSES OF LIMESTONES.

Location	Horizon	Composition: Insoluble	Iron and alumina	Calcium carbonate	Magnesium carbonate	Sulphur trioxide	Moisture and organic matter	Authority
Appanoose County—								
Rathbun	Des Moines	9.90	6.40	83.37	Trace	-------	-------	Lundteigen
Black Hawk County—								
Waterloo	Cedar Valley	1.92	4.20	63.59	30.92	-------	-------	C. E. Ellis
Bremer County—								
Waverly	Devonian	46.34	19.90	18.33	4.20	0.01	3.82	Lundteigen
Waverly	Devonian	2.25	1.32	88.65	6.70	-------	0.35	Lundteigen
Waverly	Devonian	7.74	1.67	86.80	2.35	0.86	1.08	C. E. Ellis
Section 36—Douglas township	Niagaran	1.53	0.48	54.32	43.41	-------	0.26	N. Knight
Quarter Section run	Wapsipinicon	0.71	-------	96.57	1.80	-------	0.51	N. Knight
Section 8—Polk township	Cedar Valley	3.28	2.12	55.23	39.03	-------	0.39	N. Knight
Buchanan County—								
Independence	Wapsipinicon	8.14	1.20	87.36	3.56	-------	0.02	A. O. Anderson
Cedar County—								
Cedar county	Otis	1.52	0.58	93.61	4.20	-------	-------	N. Knight
Rochester	Lower Davenport	0.86	0.30	96.91	1.93	-------	-------	N. Knight
Rochester	Lower Davenport	0.40	0.10	78.75	20.16	-------	-------	N. Knight
Rock Creek	Gower	0.12	0.26	55.76	43.85	-------	-------	N. Knight
Cedar Valley	Gower	0.40	0.70	56.40	42.60	-------	-------	N. Knight
Lime burning rock {Lime City	Gower	0.60	1.40	55.30	43.00	-------	-------	N. Knight
Lime burning rock {Cedar Valley	Gower	0.23	0.35	51.27	48.09	-------	-------	N. Knight

TABLE NO. V—CONTINUED

Location	Horizon	Composition: Insoluble	Iron and alumina	Calcium carbonate	Magnesium carbonate	Sulphur trioxide	Moisture and organic matter	Authority
Cedar Valley	Coggan	1.20	0.90	58.20	39.50	--------	--------	N. Knight
Cedar county	Otis	0.24	0.34	96.73	2.94	--------	--------	N. Knight
Cedar county	Wapsipinicon	18.66	2.00	58.21	21.00	--------	--------	N. Knight
Cerro Gordo County—								
Mason City	Cedar Valley	0.72	0.91	94.22	1.32	0.98	2.51	L. G. Michael
Mason City	Cedar Valley	0.63	0.71	97.48	0.99	--------	0.51	A. O. Anderson
Clarke County—								
Carpenter Quarry, Osceola	Missouri	8.64	1.54	88.92	0.62	--------	--------	A. O. Anderson
Carpenter Quarry, Osceola	Missouri	8.90	1.20	89.30	0.06	--------	0.28	A. O. Anderson
Carpenter Quarry, Osceola	Missouri	13.72	1.26	82.50	2.05	--------	0.59	A. O. Anderson
Des Moines County—								
Burlington	Osage	5.18	0.87	93.11	0.84	--------	--------	Geo. Steiger
Dubuque County—								
Cascade	Niagaran	11.34	0.81	48.53	37.34	--------	0.26	
Eagle Point—Lime burning rock	Galena	2.15	0.82	54.84	41.79	--------	0.02	L. G. Michael
Eagle Point—Nonlime burning rock	Galena	8.63	0.85	51.52	39.52	--------	0.04	L. G. Michael
Spechts Ferry—General sample	Platteville	5.00	2.07	89.64	1.72	0.85	--------	Lundteigen
Spechts Ferry	Platteville	8.98	2.58	73.65	12.18	--------	--------	Lundteigen
Spechts Ferry	Platteville	7.28	1.27	83.77	5.42	0.39	--------	Lundteigen
Spechts Ferry	Platteville	2.25	1.32	88.64	6.80	--------	--------	Lundteigen
Spechts Ferry	Platteville	7.50	6.17	79.50	3.97	1.48	0.15	L. G. Michael

Dubuque County—Con.								
Spechts Ferry	Platteville	7.94	12.05	73.38	3.52	1.69	0.10	L. G. Michael
Spechts Ferry	Platteville	10.71	6.69	78.67	0.28	1.51	0.15	L. G. Michael
Spechts Ferry	Platteville	11.24	6.31	78.51	0.24	1.58	0.10	L. G. Michael
Spechts Ferry	Platteville	5.74	6.69	83.56	0.25	1.77	0.10	L. G. Michael
Near Zollicoffer lake, north of Dubuque	Platteville	8.28	4.67	80.14	2.37	2.60	0.13	L. G. Michael
Near Zollicoffer lake, north of Dubuque	Platteville	8.02	5.78	77.93	4.43	0.22	0.16	L. G. Michael
Near Zollicoffer lake, north of Dubuque	Platteville	6.79	4.61	78.24	5.12	1.74	0.04	L. G. Michael
Near Zollicoffer lake, north of Dubuque	Platteville	3.85	6.03	84.16	1.93	0.64	1.71	L. G. Michael
Near Zollicoffer lake, north of Dubuque	Platteville	4.54	2.54	86.33	3.54	0.22	0.08	L. G. Michael
Near Zollicoffer lake, north of Dubuque	Platteville	3.26	0.83	90.20	2.65	1.64	0.06	L. G. Michael
Fayette County—								
Clermont	Maquoketa	11.95	2.80	84.80	0.45	----	----	L. G. Michael
Wilkes Williams' quarry, six miles south of Postville	Hopkinton	8.65	0.66	58.13	32.18	----	----	A. O. Anderson
Wilkes Williams' quarry, six miles south of Postville	Hopkinton	8.50	5.37	41.16	45.18	----	----	A. O. Anderson
Wilkes Williams' quarry, six miles south of Postville	Hopkinton	9.00	3.00	52.12	36.05	----	----	A. O. Anderson
Wilkes Williams' quarry, six miles south of Postville	Hopkinton	10.64	1.06	50.03	38.50	----	----	A. O. Anderson
Wilkes Williams' quarry, six miles south of Postville	Hopkinton	9.52	3.10	52.14	35.72	----	----	A. O. Anderson
Auburn	Hopkinton	0.68	0.50	98.52	----	----	----	L. G. Michael
Hamilton County—								
Webster City	Saint Louis	1.60	0.80	92.85	5.31	----	----	A. O. Anderson
Humboldt County—								
Humboldt	Kinderhook	0.50	1.12	97.20	2.00	----	----	A. O. Anderson
Near Gilmore	Saint Louis	----	----	99.62	----	----	----	J. B. Weems
Humboldt	Saint Louis	0.91	1.21	97.98	----	----	----	Murray

TABLE NO. V—CONTINUED

Location	Horizon	Composition: Insoluble	Composition: Iron and alumina	Composition: Calcium carbonate	Composition: Magnesium carbonate	Composition: Sulphur trioxide	Composition: Moisture and organic matter	Authority
Jackson County—								
Maquoketa	Hopkinton	0.58	0.36	30.88	21.56			C. E. Ellis
Maquoketa	Hopkinton	0.51	0.47	30.56	21.54			C. E. Ellis
Johnson County—								
Iowa City	Cedar Valley	3.08	1.97	89.79	4.66	0.06		Geo. Steiger
Jones County—								
J. A. Green, Stone City	Gower, Anamosa	0.97	0.42	57.19	41.44			A. O. Anderson
J. A. Green, Stone City	Gower, Anamosa	2.00	1.20	56.00	40.98			A. O. Anderson
J. A. Green, Stone City	Gower, Anamosa	4.46	1.70	56.08	37.80			A. O. Anderson
J. A. Green, Stone City	Gower, Anamosa	0.20	0.72	56.57	52.59			A. O. Anderson
J. A. Green, Stone City	Gower, Anamosa	1.20	0.50	58.86	39.58			A. O. Anderson
J. A. Green, Stone City	Gower, Anamosa	1.88	1.02	51.64	44.76			A. O. Anderson
J. A. Green, Stone City	Gower, Anamosa	0.96	0.72	63.56	34.76			A. O. Anderson
J. A. Green, Stone City	Gower, Anamosa	0.78	0.54	52.12	46.98			A. O. Anderson
J. A. Green, Stone City	Gower, Anamosa	1.13	1.50	58.21	38.60			A. O. Anderson
Dearborn & Sons, Stone City	Gower, Anamosa	1.97	0.89	55.68	41.53			A. O. Anderson
Dearborn & Sons, Stone City	Gower, Anamosa	2.05	0.37	54.64	43.35			A. O. Anderson
Dearborn & Sons, Stone City	Gower, Anamosa	1.70	0.60	55.70	41.74			A. O. Anderson
Dearborn & Sons, Stone City	Gower, Anamosa	1.90	1.43	56.60	39.97			A. O. Anderson
Dearborn & Sons, Stone City	Gower, Anamosa	2.00	0.40	55.18	41.70			A. O. Anderson
Louisa County—								
Morning Sun		1.60	1.20	97.02	0.32			A. O. Anderson

Madison County—								
Earlham	Bethany	7.85	1.00	91.15	0.61	--------	--------	L. G. Michael
Peru	Bethany	17.16	2.64	72.76	2.86	0.95	0.30	L. G. Michael
Earlham	Missouri	10.92	2.37	84.87	1.58	--------	--------	Geo. Steiger
Winterset	Missouri	12.63	1.18	84.34	2.19	--------	0.02	A. O. Anderson
Mahaska County—								
Oskaloosa	Saint Louis	4.01	0.59	95.30	--------	--------	--------	Murray
Marion County—								
Tracy	Saint Louis	1.57	0.66	94.60	6.66	--------	--------	Murray
Pella	Saint Louis	4.92	3.39	84.39	--------	--------	--------	Lundteigen
Marshall County—								
Oolite. Quarry	Kinderhook	0.77	0.18	98.30	0.59	--------	0.16	G. E. Patrick
Blue limestone. Quarry	Kinderhook	0.96	0.41	97.95	0.38	--------	0.30	G. E. Patrick
Iowa caen stone. Quarry	Kinderhook	1.24	0.50	90.28	7.77	--------	0.21	G. E. Patrick
Stratified limestone. Quarry	Kinderhook	1.22	0.50	90.04	8.08	--------	0.16	G. E. Patrick
Mitchell County—								
Osage	Cedar Valley	0.78	0.12	98.01	0.15	--------	--------	A. O. Anderson
Osage	Cedar Valley	0.12	0.12	98.01	0.15	--------	0.35	A. B. Hoen
Osage	Cedar Valley	2.21	3.82	90.17	1.03	--------	2.63	A. O. Anderson
Montgomery County—								
Stennett	Missouri	7.97	1.26	89.44	1.92	--------	--------	A. O. Anderson
Scott County—								
Bettendorf	Wapsipinicon	4.46	0.70	79.60	15.40	--------	--------	C. E. Ellis
LeClaire Stone Co., Bettendorf	Wapsipinicon	2.36	2.20	94.57	0.81	--------	--------	C. E. Ellis
LeClaire Stone Co., Bettendorf	Wapsipinicon	0.54	0.14	98.49	0.72	--------	--------	C. E. Ellis
Bettendorf	Wapsipinicon	1.04	0.28	90.00	8.36	--------	--------	C. E. Ellis
Bettendorf	Wapsipinicon	8.48	0.72	89.25	1.42	--------	--------	C. E. Ellis
Bettendorf	Wapsipinicon	26.40	9.25	44.82	10.84	--------	8.82	C. E. Ellis
Bettendorf	Wapsipinicon	16.08	3.26	49.72	29.06	--------	1.86	C. E. Ellis
Bettendorf	Wapsipinicon	5.98	0.30	90.91	2.77	--------	--------	C. E. Ellis
Bettendorf	Wapsipinicon	1.32	0.38	76.23	22.21	--------	--------	C. E. Ellis
Bettendorf	Wapsipinicon	1.10	0.34	80.95	17.68	--------	--------	C. E. Ellis
Bettendorf	Wapsipinicon	1.20	1.08	97.32	0.76	--------	--------	C. E. Ellis

TABLE NO. V—CONTINUED

Location	Horizon	Composition						Authority
		Insoluble	Iron and alumina	Calcium carbonate	Magnesium carbonate	Sulphur trioxide	Moisture and organic matter	
Scott County—Con.								
LeClaire Stone Co., LeClaire	Gower, Anamosa	4.76	1.22	58.72	35.38	--------	--------	A. O. Anderson
LeClaire Stone Co., LeClaire	Gower, Anamosa	7.44	1.37	51.55	40.36	--------	--------	A. O. Anderson
LeClaire Stone Co., LeClaire	Gower, Anamosa	5.60	1.40	53.96	39.00	--------	--------	A. O. Anderson
LeClaire Stone Co., LeClaire	Gower, Anamosa	7.08	1.24	53.17	35.03	--------	--------	A. O. Anderson
Sioux County—								
Hawarden	Cretaceous	21.92	6.68	64.30	5.38	--------	--------	Newberry
Taylor County—								
Fred Andrews, Bedford	Missouri	1.80	3.20	93.56	1.54	--------	--------	A. O. Anderson
Fred Andrews, Bedford	Missouri	1.48	0.48	97.42	1.14	--------	--------	A. O. Anderson
Fred Andrews, Bedford	Missouri	1.20	0.70	96.96	1.28	--------	--------	A. O. Anderson
Van Buren County—								
West of Farmington	Saint Louis	10.14	0.90	88.73	0.38	--------	0.15	C. E. Ellis
Chequest creek, Keosauqua	Saint Louis	3.12	1.38	94.81	0.52	--------	0.26	A. O. Anderson
Upper twenty feet of limestone east of Bentonsport	Saint Louis	5.28	0.52	93.34	1.00	--------	0.20	C. E. Ellis
Wapello County—								
Ottumwa	Saint Louis	6.83	2.66	88.43	0.15	0.13	--------	Geo. Steiger
Winneshiek County—								
Decorah	Galena	14.53	6.49	72.89	1.03	0.48	0.15	L. G. Michael
Decorah	Galena	3.86	2.54	91.19	0.84	--------	0.05	L. G. Michael
Decorah	Galena	6.87	1.00	88.97	2.86	--------	0.30	C. E. Ellis

TABLE

DETAILED MECHANICAL ANALYSES OF SANDS AND GRAVELS SHOW AND KAME

THE TABLE GIVES AMOUNTS IN PER CENTS RETAINED ON SIEVES RANGING FROM THE ARE ARRANGED ALPHABE

No.	County	Town	2½ in.	1¼ in.	1 in.	¾ in.	½ in.	¼ in.
15	Allamakee	Lansing				6.44	4.37	12.69
65	Benton	Vinton					3.75	9.50
66	Benton	Vinton		1.94		6.25	9.94	10.92
67	Benton	Vinton					0.75	4.37
70	Black Hawk	Cedar Falls					4.50	8.25
56	Boone	Frazer						2.56
63	Boone	Pilot Mound		1.87		1.87	2.00	11.75
68	Bremer	Waverly					4.75	16.11
36	Buchanan	Independence					6.81	5.75
23	Buena Vista	Sioux Rapids					11.25	8.81
78	Buena Vista	Storm Lake				4.12	7.25	9.44
76	Butler	Dumont	9.95	2.10		7.06	6.00	8.75
105	Butler	Shell Rock						
61	Calhoun	Lake City		3.75		4.50	5.00	14.63
116	Cherokee	Cherokee					5.90	7.40
79	Chickasaw	Ionia		3.06		2.50	4.00	9.38
125	Clay	Langdon			5.99		12.08	13.56
14	Clayton	McGregor						
13	Clayton	Elkader		14.88		7.25	2.38	6.06
2	Clinton	DeWitt		20.13		12.69	3.25	8.00
48	Clinton	DeWitt				3.13	5.31	16.00
120	Clinton	DeWitt					31.70	12.60
44	Clinton	Wheatland						1.18
42	Clinton	Clinton						
37	Clinton	Clinton		4.32		18.37	10.25	26.12
41	Clinton	Albany		2.80		13.10	7.40	17.10
49	Crawford	Denison		2.25		0.75	3.19	11.63
12	Decatur	Leon						2.44
11	Decatur	DeKalb					1.25	1.37
10	Decatur	Leon					3.25	1.56
33	Delaware	Manchester					2.12	4.44
35	Des Moines	Sec. 19, Flint River		6.25		10.25	3.87	7.50
16	Dubuque	Dubuque						0.38
106	Emmet	Armstrong						
3	Fayette	Clermont				5.87	1.44	5.88
5	Fayette	Clermont		16.75		3.75	1.94	6.00
7	Fayette	Clermont		8.69		15.06	8.37	18.63
17	Fayette	Clermont		11.44		7.38	5.25	9.38
18	Fayette	Clermont					0.38	1.19
34	Fayette	Oelwein						
81	Floyd	Charles City		9.64		0.00	2.13	3.56
73	Floyd	Marble Rock		3.69		4.00	3.56	19.25
92	Franklin	Hampton				9.25	7.37	11.93
84	Franklin	Sheffield				4.12	2.50	7.05
51	Greene	Grand Junction				1.38	3.19	11.37
101	Greene	Grand Junction						10.13
102	Greene	Grand Junction						26.60
103	Greene	Grand Junction						18.13
104	Greene	Grand Junction						23.13

NO. VI.

ING THE REMARKABLE VARIATIONS IN PIT RUN OF TERRACE, RIVER MATERIALS.

TWO AND ONE-HALF INCH DOWN TO ONE-SIXTIETH INCH MESH. THE ANALYSES TICALLY BY COUNTIES.

$\frac{1}{8}$ in.	$\frac{1}{10}$ in.	$\frac{1}{16}$ in.	$\frac{1}{20}$ in.	$\frac{1}{30}$ in.	$\frac{1}{40}$ in.	$\frac{1}{50}$ in.	$\frac{1}{60}$ in.	Remarks
14.50	5.75	10.44	7.12	18.75	14.25	------	2.69	
7.75	3.00	26.76	9.75	14.62	20.75	------	16.90	
13.89	5.75	7.19	6.82	8.34	15.81	------	9.37	
8.75	4.50	9.00	6.56	13.26	27.30	------	10.05	
12.20	6.68	9.87	8.12	12.69	22.40	------	10.05	
3.00	1.25	3.19	4.63	10.94	33.94	------	19.50	
14.00	5.50	6.25	8.50	11.62	15.25	------	8.12	
24.79	6.87	8.12	5.44	7.50	13.26	------	7.68	
5.81	1.00	5.56	3.25	16.00	38.25	------	6.43	1½ mile E. of town.
13.50	7.31	15.37	7.69	20.31	8.12	------	2.75	From J. K. Salverson.
9.68	3.81	4.81	6.00	9.44	26.28	------	10.25	
8.00	4.00	6.56	6.00	7.25	8.12	------	3.60	
------	17.50	------	18.60	21.30	------	33.30	------	4 miles S. E. of town.
18.12	8.12	12.63	8.38	8.63	9.13	------	2.75	NW. NE. 7-86-33.
12.50	11.20	------	21.90	17.50	0.70	12.50	------	Cherokee S. & G. Co.
13.89	7.19	14.44	8.81	14.62	11.00	------	3.75	
------	------	25.08	------	14.78	7.99	------	------	Sent by County Engineer.
------	------	------	0.19	4.63	40.25	------	29.56	St. Peter sandstone.
7.25	3.75	6.13	4.06	10.06	22.25	------	9.13	Terrace gravel.
12.38	7.38	15.50	6.56	5.13	2.69	------	1.06	Esker gravel, city pit.
31.50	7.06	17.00	5.25	4.12	3.00	------	2.06	Esker gravel, city pit.
10.60	------	13.20	------	16.30	------	------	12.90	From A. R. Boudinot.
1.50	1.43	0.81	10.81	28.75	29.40	------	11.75	Wapsipinicon river sand.
------	0.10	0.05	1.60	11.10	58.90	------	19.10	Mississippi river sand.
25.25	6.06	5.94	2.50	0.12	0.12	------	0.12	From Smith & Oakes.
13.50	3.25	3.60	9.70	12.00	11.25	------	3.60	
19.25	9.75	18.56	11.25	14.31	5.50	------	1.50	From Mills & Son.
3.37	1.88	3.81	3.75	8.37	34.69	------	25.63	
1.69	1.06	4.06	4.13	23.69	32.87	------	20.12	Pit of Geo. South.
3.81	2.00	5.38	5.06	13.19	36.56	------	18.00	
6.87	2.25	5.87	5.00	10.88	14.75	------	11.06	
7.25	3.25	4.25	11.87	13.56	24.25	------	4.13	From Dunn farm.
0.38	0.31	1.44	6.69	25.13	45.19	------	9.19	Mississippi river terrace.
------	51.20	------	31.40	9.70	3.70	1.40	------	
12.63	8.25	27.44	13.38	15.00	4.06	------	1.63	Buchanan gravel.
4.69	2.31	5.63	4.81	10.12	24.63	------	10.12	Buch. pit of W. Williams.
15.37	5.19	9.44	4.75	6.38	3.75	------	1.25	Used on streets.
15.25	7.19	12.81	7.81	12.13	7.81	------	1.56	Stahl's pit.
2.81	2.56	9.31	10.88	35.25	32.56	------	3.38	Finishing sand, Stahl's.
1.44	0.62	1.87	2.50	8.25	34.32	------	29.18	From Ira Hanson.
17.26	6.87	9.14	9.50	14.00	15.25	------	6.18	
21.86	9.00	14.60	6.00	7.75	5.63	------	2.00	
11.57	4.00	5.94	8.00	6.50	16.00	------	7.50	
8.66	4.62	8.12	8.00	19.00	21.75	------	7.31	
15.00	7.31	12.50	12.00	13.06	11.25	------	5.88	
14.66	------	25.20	------	24.66	------	------	18.93	C. & N. W. pit. Note
17.66	------	19.66	------	22.00	------	------	10.13	the wide variation
12.60	------	16.60	------	21.33	------	------	23.60	in samples from
14.53	------	23.33	------	20.83	------	------	13.00	the same place.

TABLE NO. VI—

No.	County	Town	2½ in.	1½ in.	1 in.	¾ in.	½ in.	¼ in.
50	Greene	Jefferson					3.00	5.75
108	Greene	Jefferson					7.30	10.50
109	Greene	Jefferson					8.50	15.00
126	Greene	Jefferson						5.20
89	Grundy	Grundy Center		16.69		4.25	1.50	7.00
71	Grundy	Wellsburg		15.25		6.38	5.25	7.37
87	Hamilton	Kamrar		12.50		5.06	7.44	10.25
88	Hamilton	Webster City				5.75	10.56	21.36
90	Hamilton	Webster City						4.00
40	Hardin	Gifford					4.70	5.75
93	Hardin	Ackley				10.31	7.38	12.00
94	Harrison	Pisgah		6.44		2.50	1.50	6.75
80	Harrison	Missouri Valley				10.81	9.13	12.50
115	Humboldt	Humboldt						
117	Humboldt	Humboldt			6.80		3.80	6.70
118	Humboldt	Humboldt			2.60		5.10	10.30
127	Humboldt	Humboldt						1.30
128	Humboldt	Humboldt						2.50
25	Ida	Ida Grove					1.81	2.50
69	Iowa	South Amana						2.81
1	Jackson	Maquoketa					2.25	4.12
129	Jones	Oxford Junction						9.00
130	Jones	Oxford Junction						6.00
107	Kossuth	Algona					5.90	8.50
82	Lyon	Rock Rapids				1.75	4.00	8.88
27	Lyon	Doon				3.81	3.88	6.37
132	Madison	Monroe Twp.						10.37
38	Mahaska	Eddyville					4.87	7.06
123	Mahaska	White City						
39	Marion	Tracy				1.80	1.00	3.00
53	Marshall	Clemons				3.50	7.31	15.50
95	Marshall	St. Anthony				7.94	8.42	12.72
119	Marshall	St. Anthony						34.80
8	Mills	Pacific Junction					1.75	3.00
75	Mitchell	Osage		9.13		5.94	2.63	8.25
91	Monona	Mapleton						3.12
121	Monona	Blencoe						8.30
122	Monona	Rodney						6.70
6	Montgomery	Red Oak					0.88	1.50
113	Muscatine	Muscatine					14.00	9.40
114	Muscatine	Muscatine					7.36	14.75
55	Muscatine	Muscatine						
59	Muscatine	Nichols						2.94
54	Muscatine	Bet. 20-21, Orono Tp.				3.87	5.19	6.25
74	O'Brien	Paullina					4.00	10.95
20	Osceola	Sibley						
9	Page	Clarinda						1.81
4	Plymouth	Le Mars						0.38
110	Polk	Des Moines					1.10	6.30
22	Sac	Early					4.25	5.88
21	Sac	Sac City					9.25	10.25
52	Scott	Davenport						0.69
62	Story	Ames		10.00		3.38	2.87	8.87
86	Tama	Clutier		3.50		7.00	5.31	10.44
64	Tama	Montour						3.44

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$\frac{1}{8}$ in.	$\frac{1}{10}$ in.	$\frac{1}{16}$ in.	$\frac{1}{20}$ in.	$\frac{1}{30}$ in.	$\frac{1}{40}$ in.	$\frac{1}{50}$ in.	$\frac{1}{60}$ in.	Remarks
8.81	5.69	9.00	10.31	15.31	27.50	------	9.25	Raccoon river sand.
19.70	------	20.40	------	19.70	------	18.10	------	W. end 'Coon river bridge.
18.40	------	15.10	------	14.10	------	17.60	------	E. end 'Coon river bridge.
9.30	9.80	------	23.80	15.80	13.30	11.10	------	Pit of A. S. Tanner.
14.50	6.56	7.69	6.06	6.55	14.68	------	6.94	
7.87	4.13	7.56	8.33	12.38	12.50	------	7.37	
11.30	5.37	6.75	7.37	8.87	9.75	------	4.87	
21.61	8.25	11.38	6.44	4.94	4.44	------	2.13	
11.00	7.50	15.75	9.36	12.00	23.12	------	6.13	
8.10	4.00	5.30	11.10	23.60	25.25	------	5.40	From R. A. Fuller Co.
14.90	4.75	12.00	6.56	9.00	11.25	------	4.50	
10.91	6.68	11.89	11.50	20.30	15.70	------	3.50	
16.00	11.34	15.57	10.25	9.81	3.44	------	1.50	
------	22.70	------	20.50	19.50	18.40	11.30	------	From C. D. Walter.
9.90	3.70	------	19.70	26.00	9.60	3.80	------	From County Engineer.
17.40	5.60	------	17.30	11.70	12.40	6.90	4.50	From County Engineer.
4.50	4.50	------	14.70	22.50	24.30	15.40	------	Hum. Cem. Prod. Co.
6.70	7.30	------	33.20	26.70	10.00	4.90	------	Hum. Cem. Prod. Co.
5.18	3.31	7.13	6.00	13.50	30.44	------	9.94	Ida Grove Concrete Co.
7.36	4.52	9.50	10.43	22.00	25.68	------	7.31	
9.44	4.50	10.38	9.19	29.25	19.87	------	4.48	
16.00	9.50	------	14.70	13.50	20.80	10.50	------	From G. Ahlff & Sons
11.80	8.10	------	13.30	14.80	25.50	11.20	------	Grand Mound.
16.79	------	21.49	------	26.10	------	15.32	------	G. J. Ferguson pit.
10.81	4.87	8.00	9.56	17.44	21.93	------	9.63	
9.75	4.69	8.94	6.25	15.94	28.19	------	6.38	Miller & Montgomery.
16.69	7.59	------	27.75	16.48	8.91	3.86	2.60	Washed sand.
11.95	6.68	11.38	16.75	15.25	16.56	------	5.19	
------	20.00	------	13.00	14.10	17.10	14.80	------	From H. R. Baker.
5.00	3.00	4.30	8.80	16.85	33.60	------	10.35	
17.13	6.94	9.87	8.75	9.31	10.25	------	4.56	From O. L. Lundon.
17.57	6.55	9.92	6.72	6.72	12.95	------	3.44	
19.90	------	18.00	------	13.20	------	9.30	------	Sent by Co. Board.
7.00	5.00	14.44	10.63	16.31	26.25	------	6.25	
12.20	4.75	7.19	9.25	13.65	16.45	------	7.06	
5.88	5.13	16.56	16.39	20.00	24.21	------	4.43	
------	31.80	------	23.00	15.00	11.60	5.50	------	Sent by L. I. Hicks.
8.12	10.33	------	19.40	16.58	17.38	11.95	------	
5.13	4.88	18.00	9.00	31.38	22.31	------	4.81	
11.20	7.00	------	21.00	24.00	------	12.00	------	Mississippi river sand.
17.80	------	21.89	------	25.19	------	11.11	------	Mississippi river sand.
------	0.44	0.31	3.06	13.63	55.31	------	16.50	
5.44	4.50	8.00	12.62	26.62	31.69	------	6.44	Ry. bridge in 16, Lake.
9.13	5.50	10.94	9.44	16.75	22.06	------	4.56	
18.75	10.95	8.50	7.88	11.25	16.70	------	7.75	
21.69	11.25	19.63	10.00	14.00	14.00	------	2.69	Sibley Cement Co.
2.81	1.75	4.81	4.63	13.06	32.00	------	26.25	
7.68	3.81	8.06	7.00	25.56	29.75	------	8.56	Kramer pit.
------	13.50	------	12.30	18.30	------	37.10	------	
9.63	5.06	11.50	9.13	19.19	24.75	------	4.56	Early Con. & Stone Co.
14.50	6.69	12.44	9.19	15.19	14.87	------	3.44	From E. W. Robbins.
1.25	1.00	2.95	3.00	15.56	48.37	------	16.00	Mississippi river sand.
11.50	5.00	7.13	6.50	9.12	17.50	------	6.00	College pit.
13.57	5.94	15.50	9.32	9.80	6.75	------	4.31	
20.26	13.75	5.37	5.32	13.50	8.38	------	1.31	

TABLE NO. VI—

No.	County	Town	2½ in.	1¼ in.	1 in.	¾ in.	½ in.	¼ in.
32	Van Buren	Farmington	----	------	------	------	------	15.56
31	Van Buren	Farmington	----	------	------	------	------	4.81
29	Wapello	Ottumwa	----	------	------	------	------	9.88
131	Wapello	Ottumwa	----	------	------	------	81.30	5.90
57	Webster	Ft. Dodge	----	------	------	2.12	2.81	11.69
58	Webster	Badger	----	------	------	1.19	1.50	7.63
19	Woodbury	Correctionville	----	------	------	------	6.63	5.94
28	Woodbury	Correctionville	----	------	------	------	5.31	16.75
72	Woodbury	Correctionville	----	------	------	3.80	4.63	7.44
124	Woodbury	Sioux City	----	------	------	------	0.84	9.00
43	Worth	Hanlontown	----	------	------	9.06	6.69	13.25
47	Worth	Hanlontown	----	9.00	------	6.94	5.56	8.44
85	Wright	Dows	7.75	0.00	------	11.70	3.50	10.88
83	Wright	Dows	----	------	------	8.68	3.63	5.63
46	Wright	Eagle Grove	----	------	------	------	------	6.19
45	Wright	Belmond	----	4.25	------	3.63	5.25	9.38

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1/8 in.	1/10 in.	1/15 in.	1/20 in.	1/30 in.	1/40 in.	1/50 in.	1/60 in.	Remarks
8.69	4.63	9.19	9.50	28.50	17.75	------	2.81	
8.00	8.50	23.25	13.50	27.94	9.13	------	2.31	Des Moines river sand.
17.75	10.75	20.50	11.50	19.00	6.69	------	2.50	Des Moines river sand.
2.90	0.65	0.80	0.30	2.10	3.48	1.52	0.55	From G. L. Bissell.
15.38	6.63	9.81	10.25	11.25	14.72	------	7.19	
22.69	10.62	17.50	9.38	10.25	7.81	------	2.69	Center of 10, Deer Creek.
8.75	4.87	11.25	10.56	31.88	13.12	------	3.63	Gilleas pit.
22.44	8.25	12.31	5.81	8.00	7.81	------	5.69	Jno. Fleming pit.
7.80	3.88	6.19	7.31	11.85	22.61	------	10.54	
13.20	6.60	11.90	3.80	10.10	10.00	7.70	8.10	From Co. Engineer.
13.62	5.25	0.12	18.87	9.12	12.62	------	5.00	Sec. 28, Danville.
8.63	5.13	3.50	12.12	11.12	14.56	------	6.75	Sec. 29, Danville Twp.
14.13	6.75	8.00	9.68	9.32	11.25	------	6.31	
6,74	3.50	5.55	7.75	12.56	30.18	------	6.62	
14.75	8.00	11.81	15.00	14.00	16.50	------	7.17	Boone river sand.
13.31	6.00	8.12	14.00	13.50	12.75	------	3.62	

TABLE NO. VII.

COMMERCIAL DIRECTORY OF IOWA STONE PRODUCERS.

*Indicates those producing crushed stone.

Owner	Location of Office	Location of Quarry	Geological Horizon	Kind of Stone
Allamakee County—				
A. V. Fetter	Quincy, Ill.	Lansing	Oneota	Dolomite
C. F. Nagle	Lansing	Lansing	Oneota	Dolomite
*Albert Simons	Waukon	Waukon	Platteville	Limestone
Appanoose County—				
*Wm. B. Swan	Plano	Piano	Des Moines	Limestone
Benton County—				
*W. O. Rambo	Shellsburg	Shellsburg	Cedar Valley	Limestone
Black Hawk County—				
Jens Nielsen	Cedar Falls (1807 Washington)	Cedar Falls	Cedar Valley	Limestone
*E. J. Buchan	Laporte City	Laporte City	Cedar Valley	Limestone
*Bartlett & McFarlane	Waterloo (1165 E. 4th)	Waterloo	Cedar Valley	Limestone
*Waterloo Dredging Co.	Waterloo	Waterloo	Cedar Valley	Limestone
Buchanan County—				
A. B. Kieffer	Hazelton	Hazelton	Hopkinton	Dolomite
Cedar County—				
*Cedar Valley Stone Co.	Cedar Rapids	Cedar Valley	Anamosa	Dolomite
Cerro Gordo County—				
*Henry Kuppinger	Mason City	Mason City	Cedar Valley	Limestone and dolomite
Quimby Stone & Fuel Co.	Mason City	Mason City	Cedar Valley	Limestone and dolomite

Clayton County—				
Daniel Ivory	Elkader	Elkader	Platteville	Limestone
J. A. Hempeler	Garnavillo	Garnavillo	Galena	Limestone
E. W. & H. D. Kregel	Garnavillo	Garnavillo	Galena	Limestone
Matthias Burr	Guttenberg	Guttenberg	Platteville	Limestone
A. C. Boyle	McGregor	McGregor	Platteville	Limestone
*Chas. M. Brooks	McGregor	McGregor	Platteville	Limestone
Decatur County—				
*Davis City Stone Crusher Co.	Davis City	Davis City	Missouri	Limestone
Delaware County—				
Jas. A. Johnson	Hopkinton	Hopkinton	Hopkinton	Dolomite
McGlade Bros.	Hopkinton	Hopkinton	Hopkinton	Dolomite
Des Moines County—				
A. V. Fetter	Quincy, Ill.	Burlington	Osage	Limestone
Albert Kirchner	Fountain City, Wis.	Burlington	Osage	Limestone
*Geo. J. Koestner	Burlington	Burlington	Osage	Limestone
Albert Bitsche	Middletown	Middletown	Osage	Limestone
Dubuque County—				
*John Becker	Dubuque	Dubuque	Galena	Dolomite
*Byrne & Saul	Dubuque	Dubuque	Galena	Dolomite
*Eagle Point Lime Works	Dubuque	Dubuque	Galena	Dolomite
*O'Farrell Contracting Co.	Dubuque	Dubuque	Galena	Dolomite
E. P. Sawyer	Dubuque	Dubuque	Galena	Dolomite
Anthony Siege	Dubuque	Dubuque	Galena	Dolomite
Thos. Welsh	Dubuque	Dubuque	Galena	Dolomite
*B. N. Arquitt & Sons	Farley	Farley	Hopkinton	Dolomite
*Tibey Bros.	Dubuque	Julian	Galena	Dolomite
Fayette County—				
Wilkes Williams	Postville	Postville	Hopkinton	Dolomite
J. W. Bopp	West Union	West Union	Devonian	Limestone
Floyd County—				
Geo. W. Kuhnle	Charles City	Charles City	Cedar Valley	Limestone

TABLE NO. VII—CONTINUED

Owner	Location of Office	Location of Quarry	Geological Horizon	Kind of Stone
Hardin County—				
*Bryant-McLaughlin Asph'lt Pav. Co.	Waterloo	Iowa Falls	Kinderhook	Limestone and dolomite
*Ellsworth Stone Co.	Iowa Falls	Iowa Falls	Kinderhook	Limestone and dolomite
Harrison County—				
C. F. Peckenpaugh & Sons	Logan	Logan	Missouri	Limestone
Henry County—				
*Victor McGuire	Mt. Pleasant	Mt. Pleasant	Saint Louis	Limestone
Howard County—				
*Cresco Stone & Concrete Co.	Cresco	Cresco	Wapsipinicon	Dolomitic limestone
Johnson County—				
*Wesley J. Lorence	Solon	Solon	Anamosa	Dolomite
Jones County—				
State Reformatory (Charles C. McCloughry, Warden)	Anamosa	Anamosa	Anamosa	Dolomite
A. M. Henry	Anamosa	Anamosa	Anamosa	Dolomite
Albert Osborne	Hale	Hale	Anamosa	Dolomite
*H. Dearborn & Sons	Stone City	Stone City	Anamosa	Dolomite
*F. Erickson Co.	Stone City	Stone City	Anamosa	Dolomite
*J. A. Green & Sons	Stone City	Stone City	Anamosa	Dolomite
*John Ronen	Stone City	Stone City	Anamosa	Dolomite
Keokuk County—				
Frank Manion	Sigourney	Sigourney	Saint Louis	Limestone
*Russell B. Royce	Sigourney	Sigourney	Saint Louis	Limestone

Lee County—				
*McManus & Tucker	Keokuk	Ballinger	Osage	Limestone
*Cameron & McManus	Keokuk	Keokuk	Osage	Limestone
A. V. Fetter	Quincy, Ill.	Keokuk	Osage	Limestone
Harrison & Dietz	Keokuk	Keokuk	Osage	Limestone
*Keokuk Ry. & Construction Co.	Keokuk	Keokuk	Osage	Limestone
Mississippi River Power Co.	Keokuk	Keokuk	Osage	Limestone
C. F. Nagle	Lansing	Keokuk	Osage	Limestone
*Burlington Quarry Co.	Keokuk	Montrose	Osage	Limestone
August Beach	West Point	West Point	Saint Louis	Limestone
Linn County—				
*C. & N. W. Railway	Chicago, Ill.	Cedar Rapids	Wapsipinicon	Limestone
*Dolese Bros. Co.	Chicago, Ill. (128 N. La Salle)	Cedar Rapids	Wapsipinicon	Limestone
*Ellis Park Stone Co.	Cedar Rapids	Cedar Rapids	Wapsipinicon	Limestone
*J. E. Colton	Mt. Vernon	Mt. Vernon	Anamosa	Dolomite
Louisa County—				
W. C. Bryant	Morning Sun	Morning Sun	Osage	Limestone
*Chas. B. Wilson	Morning Sun	Morning Sun	Osage	Limestone
Madison County—				
*Earlham Land Co.	Des Moines	Earlham	Missouri	Limestone
*Peru Stone & Cement Co.	East Peru	East Peru	Missouri	Limestone
*W. A. Hartman	Winterset	Winterset	Missouri	Limestone
*Southern Iowa Stone Co.	Winterset	Winterset	Missouri	Limestone
Mahaska County—				
H. E. Whitlatch	Beacon	Givin	Saint Louis	Limestone
Marshall County—				
*Dolese Bros. Co.	Chicago, Ill.	LeGrand	Kinderhook	Limestone
*C. & N. W. Railway	Chicago, Ill.	LeGrand	Kinderhook	Limestone
Mitchell County—				
Iowa Sugar Co.	Waverly	Osage	Cedar Valley	Limestone
A. E. Parmelee	Osage	Osage	Cedar Valley	Dolomite

TABLE NO. VII—CONTINUED

Owner	Location of Office	Location of Quarry	Geological Horizon	Kind of Stone
Pocahontas County—				
*Ft. Dodge Portland Cement Corp.	Fort Dodge	Gilmore City	Saint Louis	Limestone
Scott County—				
*Boland Stone Co.	Bettendorf	Bettendorf	Wapsipinicon	Limestone
*Bettendorf Stone Co.	Davenport	Bettendorf	Wapsipinicon	Limestone
G. W. Randall	Big Rock	Big Rock	Gower	Limestone
*Dolese Bros. Co.	Chicago, Ill.	Buffalo	Wapsipinicon	Argillaceous Limestone
*Linwood Quarries Co.	Davenport	Buffalo	Wapsipinicon	Argillaceous Limestone
*LeClaire Stone Co.	Davenport	LeClaire	Anamosa	Dolomite
		Bettendorf	Wapsipinicon	Limestone
Tama County—				
P. C. Smith	Montour	Montour	Kinderhook	Oolitic limestone
Van Buren County—				
*Hinkle Estate	Selma	Selma	Saint Louis	Limestone
Wapello County—				
Eddyville Stone Co.	Eddyville	Eddyville	Saint Louis	Limestone
*Chas. Chilton	Ottumwa	Ottumwa	Saint Louis	Limestone
Winneshiek County—				
John A. Vold	Decorah	Decorah	Galena-Plat'ville	Limestone
Maurice Halloran	Decorah	Decorah	Galena	Limestone

TABLE VIII.

DIRECTORY OF IOWA SAND AND GRAVEL PRODUCERS.

Owner	Location of Office	Location of Pit	Character of Deposit	Products
Black Hawk County—				
Bartlett & McFarlane	Waterloo	Waterloo	River	Sand
Geo. W. Pett	Waterloo	Waterloo	River	Sand
J. E. Sedgwick	Waterloo	Waterloo	River	Sand
Cement Products Co.	Waterloo	Waterloo	River	Sand
Waterloo Dredging Co.	Waterloo	Waterloo	River	Sand
Waterloo Granite Block Co.	Waterloo	Waterloo	River	Sand
P. M. Smith	Cedar Falls	Cedar Falls	Terrace	Sand and gravel
Cedar Falls Sand & Materials Co.	Cedar Falls	Cedar Falls	Terrace	Sand and gravel
Boone County—				
M. & St. L. Railway	Minneapolis, Minn.	Pilot Mound	Kame	Gravel
Ft. D., D. M. & So. Railway	Boone	Frazer	Terrace	Sand and gravel
Frazer Cement Products Co.	Frazer	Frazer	River	Sand and gravel
Bremer County—				
A. L. Woodruff	Waverly	Waverly	Terrace	Gravel
A. McClellan (operator)	Waverly	Waverly	Terrace	Gravel
J. H. Russell	Waverly	Waverly	Terrace	Gravel
Eureka Cement Tile Co.	Janesville	Janesville	Terrace	Gravel
Bremer County	Waverly	Plainfield	River	Sand and gravel
Buena Vista County—				
C. & N. W. Railway	Chicago, Ill.	Sioux Rapids	Terrace	Gravel
Butler County—				
C. G. W. Railway	Chicago, Ill.	Clarksville	Terrace	Sand and gravel
Clarksville Brick Mfg. Co.	Clarksville	Clarksville	Terrace	Gravel

TABLE NO. VIII—CONTINUED

Owner	Location of Office	Location of Pit	Character of Deposit	Products
Butler County—Con.				
P. H. Green	Greene	Greene	Terrace	Gravel
J. W. Butler	Greene	Greene	Terrace	Gravel
Illinois Central Ry.	Chicago, Ill.	Sec. 23, Washington	Terrace	Sand and gravel
T. H. Ahrens	Dumont	Dumont	Upland	Sand and gravel
Carroll County—				
Lanesboro Cement Tile Co.	Lanesboro	Lanesboro	Terrace	Sand and gravel
Cerro Gordo County—				
Mason City Sand Co.	Mason City	Mason City	Terrace	Sand and gravel
Mason City Cement Products Co.	Mason City	Mason City	Terrace	Sand and gravel
Cherokee County—				
Fred Fuhrman	Cherokee	Cherokee	Terrace	Sand
M. J. Gilleas & Co.	Cherokee	Cherokee	Terrace	Sand and gravel
Cherokee Construction Co.	Cherokee	Cherokee	Terrace	Sand and gravel
Cherokee Sand & Gravel Co.	Cherokee	Cherokee	Terrace	Sand and gravel
Illinois Central Ry.	Cherokee	Cherokee	Terrace	Gravel
Clay County—				
F. W. Fais	Spencer	Spencer	Terrace	Sand and gravel
W. T. Harris	Spencer	Spencer	Terrace	Sand and gravel
Clayton County—				
C., M. & St. P. Railway	Chicago, Ill.	Guttenberg	Terrace	Gravel
Clayton White Sand Co.	Clayton	Clayton	St. Peter sandstone	Sand

Clinton County—				
City of DeWitt	De Witt	De Witt	Kame	Sand and gravel
Scott County	Davenport	De Witt	Kame	Sand and gravel
W. H. Mackridge	De Witt	De Witt	Kame	Gravel
C. & N. W. Railway	Chicago, Ill.	Almont and Clinton	Terrace	Gravel
Clinton Sand & Gravel Co.	Clinton	Clinton	River	Sand and gravel
Geo. A. Schneider	Galena, Ill.	Clinton	River	Sand and gravel
John Sampson	Grand Mound	Grand Mound	Kame	Gravel
Dallas County—				
C., M. & St. P. Railway	Chicago, Ill.	Madrid	Terrace	Gravel
C., M. & St. P. Railway	Chicago, Ill.	Bouton	Terrace	Gravel
City of Van Meter	Van Meter	Van Meter	River	Sand and gravel
City of Booneville	Booneville	Booneville	River	Sand and gravel
Delaware County—				
C. G. W. Railway	Chicago, Ill.	Dyersville	Terrace	Gravel
Des Moines County—				
Kelly Sand & Fuel Co.	Burlington	Burlington		Sand and gravel
Zippe & Fletcher Co.	Burlington	Burlington		Sand and gravel
Dickinson County—				
C., M. & St. P. Railway	Chicago, Ill.	Milford	Terrace	Gravel
Dubuque County—				
Frank Beutin	Dubuque	Dubuque	Terrace	Sand and gravel
Dubuque Sand & Gravel Co.	Dubuque	Dubuque	Terrace	Sand and gravel
Illinois Central Ry.	Dubuque	Dubuque	Terrace	Gravel
F. A. Burns	Dubuque	Dubuque	River	Sand
Emmet County—				
C., R. I. & P. Railway	Chicago, Ill.	Graettinger	Terrace	Gravel
M. & St. L. Railway	Minneapolis, Minn.	Estherville	Terrace	Sand and gravel
Estherville Cement Prod. Co.	Estherville	Estherville	Terrace	Sand and gravel

TABLE NO. VIII—CONTINUED

Owner	Location of Office	Location of Pit	Character of Deposit	Products
Fayette County—				
C., R. I. & P. Railway	Chicago, Ill.	Clermont	Terrace	Sand
C. Miller & Son	Clermont	Clermont	Terrace	Sand
Ira Hanson	Oelwein	Oelwein	Terrace	Sand
Martin Stoll Estate	Clermont	Clermont	Terrace	Gravel
Floyd County—				
C., R. I. & P. Railway	Chicago, Ill.	Marble Rock	Terrace	Gravel
Mrs. Eliza Barnes	Charles City	Charles City	Terrace	Sand and gravel
Alfred Laun	Floyd	Floyd	Terrace	Sand and gravel
Franklin County—				
Sheffield Cement Prod. Co.	Sheffield	Sheffield	Terrace	Sand and gravel
Greene County—				
C. & N. W. Railway	Chicago, Ill.	Grand Junction	Terrace	Gravel
A. S. Tanner	Jefferson	Jefferson	Sand bar	Sand and gravel
C., M. & St. P. Railway	Jefferson	Jefferson	Terrace	Gravel
Grundy County—				
Grundy Center Brick & Tile Co.	Grundy Center	Grundy Center	Terrace	Sand and gravel
Hancock County—				
C., R. I. & P. Railway	Chicago, Ill.	Forest City	Terrace	Gravel
Amsterdam Tile Works	Goodell	Amsterdam	Terrace	Sand and gravel
Hardin County—				
C. & N. W. Railway	Chicago, Ill.	Gifford	Terrace	Gravel
M. & St. L. Railway	Minneapolis, Minn.	Gifford	Terrace	Gravel
Gifford Sand & Gravel Co.	Gifford	Gifford	Terrace	Sand and gravel
Fred Berninghausen	Eldora	Eldora	Terrace	Gravel

Harrison County—				
P. R. Cox	Missouri Valley	Missouri Valley	Aftonian	Sand and gravel
Henry County—				
C., B. & Q. Railway	Chicago, Ill.	Coppock	Terrace	Sand and gravel
Howard County—				
Howard County	Cresco	Sec. 11, Afton	Upland	Gravel
Humboldt County—				
W. C. Hayes	Humboldt	Humboldt	Terrace	Sand and gravel
Ida County—				
Robert Hall	Ida Grove	Ida Grove		Gravel
W. E. Rathburn, Jr.	Ida Grove	Ida Grove		Sand
Concrete Stone Co.	Ida Grove	Ida Grove		Gravel
Jackson County—				
Sabula Sand & Gravel Co.	Sabula	Sabula	River	Sand and gravel
Johnson County—				
Hills Sand & Gravel Co.	Hills	Hills	River	Sand and gravel
Horrabin Sand & Materials Co.	Iowa City	Iowa City	River	Sand and gravel
Geo. E. Mathews	River Junction	River Junction	River	Gravel
Kossuth County—				
C. & N. W. Railway	Chicago, Ill.	Irvington	Terrace	Gravel
C. J. Lenander	Bancroft	Bancroft	Terrace	Gravel
Northwestern Drain & Construc. Co.	Bancroft	Bancroft	Terrace	Gravel
Lee County—				
Ft. Madison Sand & Gravel Co.	Ft. Madison	Ft. Madison	River	Sand and gravel
Joseph Jaeger	Montrose	Ft. Madison	River	Sand
J. H. Einspanjer	Ft. Madison	Ft. Madison	River	Sand
Linn County—				
Kings Crown Plaster Co.	Cedar Rapids	Cedar Rapids	River	Sand
Larimer & Shaffer	Cedar Rapids	Cedar Rapids	River	Sand and gravel
Standard Construction Co.	Cedar Rapids	Cedar Rapids	River	Sand

TABLE NO. VIII—CONTINUED

Owner	Location of Office	Location of Pit	Character of Deposit	Products
Linn County—Con.				
Russell J. Tabor	Springville	Springville	River	Sand
Mrs. Rozella Corbett	Viola	Viola	Buchanan	Sand
Lyon County—				
Great Northern Railway	St. Paul, Minn.	Doon	Terrace	Sand and gravel
Miller & Montgomery	Doon	Doon	Terrace	Sand and gravel
Doon Sand & Gravel Co.	Doon	Doon	Terrace	Sand and gravel
C. R. MacDowell	Doon	Doon	Terrace	Sand and gravel
C., R. I. & P. Railway	Chicago, Ill.	Granite	Terrace	Gravel
Lehatchka & Pattengill	Rock Rapids	Rock Rapids	Terrace	Gravel
Mahaska County—				
Eddyville Sand Co.	Eddyville	Eddyville	River	Sand
Marion County—				
C., R. I. & P. Railway	Chicago, Ill.	Harvey	River	Sand
Sand Valley Sand Co.	Harvey	Harvey	River	Sand and gravel
Iowa Sand & Gravel Co.	Oskaloosa	Tracey	River	Sand and gravel
J. A. Wilson	Tracey	Tracey	River	Sand and gravel
Marshall County—				
M. N. Hawkins	Marshalltown	Marshalltown		Sand and gravel
Marshall Sand Co.	Marshalltown	Marshalltown		Sand and gravel
M. & St. L. Railway	Minneapolis, Minn.	Clemons	Terrace	Gravel
Mitchell County—				
Osage Cement Prod. Co.	Osage	Osage	Terrace	Sand and gravel
N. W. Nelson	Osage	Osage	Terrace	Sand and gravel

Muscatine County—				
C., R. I. & P. Railway	Chicago, Ill.	Fruitland	Terrace	Gravel
Muscatine Sand Co.	Muscatine	Muscatine	River	Sand
Northern Gravel Co.	Davenport	Muscatine	Terrace	Sand and gravel
O'Brien County—				
McCracken Bros.	Paullina	Paullina	Terrace	Sand and gravel
		Calumet	Kame	Sand and gravel
——— Peake	Paullina	Paullina	Terrace	Sand and gravel
Thos. Beacon	Sheldon	Sheldon	Terrace	Sand and gravel
Osceola County—				
C., R. I. & P. Railway	Chicago, Ill.	Sibley	Terrace	Gravel
Sibley Cement Co.	Sibley	Sibley	Terrace	Sand and gravel
(Ocheyedan Mound)		Ocheyedan	Kame	Gravel
Palo Alto County—				
Shadbolt Lumber Co.	Emmetsburg	Emmetsburg	Terrace	Sand
Graettinger Tile Works	Graettinger	Graettinger	Terrace	Sand and gravel
Plymouth County—				
Frank Hammon	Kingsley	Kingsley	Upland	Gravel
Kingsley Milling Co.	Kingsley	Kingsley	Upland	Gravel
G. L. Griffith	Kingsley	Kingsley	Upland	Gravel
Geo. Bainbridge	Kingsley	Kingsley	Upland	Gravel
Dalton Co.	Le Mars	Le Mars	Terrace	Sand and gravel
C., St. P., M. & O. Railway	Chicago, Ill.	Le Mars	Terrace	Gravel
Illinois Central Ry.	Chicago, Ill.	Le Mars	Terrace	Gravel
LeMars Brick & Tile Co.	Le Mars	Le Mars	Terrace	Gravel
Polk County—				
C., R. I. & P. Railway	Chicago, Ill.	Avon and Commerce	River	Sand and gravel
Geo. N. Doty	Commerce	Commerce	River	Sand and gravel
F. F. Balzer	Des Moines	Des Moines	River	Sand and gravel
C. G. W. Railway	Chicago, Ill.	Des Moines		Gravel
Coon River Sand Co.	Des Moines	Des Moines	River	Sand and gravel
Frank Cram	Des Moines	Des Moines	River	Sand and gravel
Des Moines Sand Co.	Des Moines	Des Moines	River	Sand and gravel
Leon Harris	Des Moines	Des Moines	River	Sand and gravel

TABLE NO. VIII—CONTINUED

Owner	Location of Office	Location of Pit	Character of Deposit	Products
Oak Park Sand Co.	Des Moines	Des Moines	River	Sand and gravel
Wabash Railroad	St. Louis	Des Moines	Terrace	Gravel
Des M. Building Material Co.	Des Moines	Valley Junction	River	Sand
Commercial Sand Co.	Mitchellville	Valley Junction	River	Sand
Sac County—				
C. & N. W. Railway	Chicago, Ill.	Lake View	Terrace	Sand and gravel
Lake View Sand & Gravel Co.	Lake View	Lake View	Terrace	Sand and gravel
Sac City Cement Prod. Co.	Sac City	Sac City	Terrace	Sand and gravel
Scott Sand & Gravel Co.		Lake View	Kame	Sand and gravel
Phil Shaller	Sac City	Sac City	Terrace	Sand and gravel
Scott County—				
Interstate Material Co.	Davenport	Davenport		Sand and gravel
Builders Sand & Gravel Co.	Davenport	Nahant		Sand and gravel
Sioux County—				
Hosper Cement Products Co.	Hosper	Hosper	Terrace	Sand and gravel
Joseph Hyink	Alton	Alton	Upland	Sand and gravel
John Beltman	Alton	Alton	Upland	Sand and gravel
C. & N. W. Railway	Chicago, Ill.	Hawarden	Terrace	Gravel
Hawarden Sand & Gravel Co.	Hawarden	Hawarden	River	Sand and gravel
——— Briggs	Hawarden	Hawarden	Terrace	Sand and gravel
C., M. & St. P. Railway	Chicago, Ill.	Opposite Hudson, S. D.	Terrace	Gravel
Cornelius Van der Veer	Alton	Alton	Upland	Sand and gravel
Story County—				
Iowa State College	Ames	Ames	Terrace	Sand and gravel
R. E. Carr	Ames	Ames	Terrace	Sand and gravel
Cole Bros.	Ames	Ames	Terrace	Sand and gravel
Greenlee & Greenlee	Ames	Ames	Terrace	Sand and gravel
John Glidden	Ames	Ames	Terrace	Sand and gravel

Union County—				
C. G. W. Railway	Chicago, Ill.	Afton Junction	Aftonian	Gravel
Van Buren County—				
C., B. & Q. Railway	Chicago, Ill.	Farmington	Terrace	Gravel
C., R. I. & P. Railway	Chicago, Ill.	Farmington	Terrace	Gravel
Wapello County—				
Des Moines River Sand Co.	Eddyville	Eddyville	River	Sand and gravel
Empire Sand & Material Co.	Eddyville	Eddyville	River	Sand and gravel
Palmer Sand Co.	Eddyville	Eddyville	River	Sand and gravel
Ottumwa Sand Co.	Ottumwa	Ottumwa	River	Sand and gravel
Webster County—				
Chas. Larrabee	Ft. Dodge	Fort Dodge	Terrace	Gravel
(Coon Mound)		Sec. 9, Lost Grove	Kame	Gravel
Winnebago County—				
Forest City Cement Prod. Co.	Forest City	Forest City	Kame	Sand and gravel
Winneshiek County—				
Decorah Cement Sidewalk Co.	Decorah	Decorah	River	Sand
A. J. Bernatz	Decorah	Decorah	River	Sand
J. I. Tavenor	Decorah	Decorah	River	Sand
Woodbury County—				
John Fleming & Son	Correctionville	Correctionville	Terrace	Sand
M. J. Gilleas & Co.	Correctionville	Correctionville	Terrace	Sand and gravel
H. A. Moran	Correctionville	Correctionville	Terrace	Sand and gravel
Welch Bros.	Correctionville	Correctionville	Terrace	Sand and gravel
Illinois Central Railway	Correctionville	Correctionville	Terrace	Gravel
John Bower	Correctionville	Correctionville	Terrace	Sand and gravel
Wright County—				
Belmond Cement Manufacturing Co.	Belmond	Belmond	Terrace	Sand
C. G. W. Railway	Belmond	Belmond	Terrace	Sand and gravel
C., R. I. & P. Railway	Belmond	Belmond	Terrace	Sand and gravel