The Road and Concrete Materials of Iowa

BY

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ROAD AND CONCRETE MATERIALS IN IOWA

BY S. W. BEYER AND H. F. WRIGHT.

Introduction

The materials in Iowa which properly come under the above classification are:

A. Natural Products,—including sand and gravel, limestone, sandstone, glacial bowlders and clay, mostly loess clay.

B. Manufactured products of clay and limestone.

In counties rich in road and concrete materials, especially those counties in which these materials are generally distributed over the entire county, no attempt is made to list or map all of the possibilities. Only the more important or more representative deposits are recorded. In counties poorer in such materials the records are more complete.

A. NATURAL PRODUCTS. Sand and Gravel.—Nearly three-fourths of the counties in the state are supplied with sand and gravel suitable for some form of road work. Not all of these counties have a sufficient quantity within their borders to improve all of the roads, but enough for use on the main roads. The principal supply must be obtained from the larger streams, or from their immediate vicinity. Such sands and gravels occur as terraces or so-called "second bottom deposits," and in the present channels of the streams. Terrace gravels are especially important along the streams which flow from the Wisconsin Drift area in north-central Iowa. Well-known pits in which these terrace gravels are being developed are located at Mason City, Iowa Falls, Gifford, Belmond, Clemons, in and around Des Moines, near Grand Junction, Lake View, Spencer, Cherokee, Milford, and well

within the Wisconsin area, Emmetsburg and Estherville. These terraces furnish an enormous quantity of material suitable for road and concrete work, not only sufficient for the needs of the counties in which they are located, but for neighboring counties less fortunate in available road materials. In addition to stream and terrace gravels, gravel knobs, geologically known as kames, are common in the north-central portion of the state. Some of these gravel hillocks are conspicuous topographic features. The best known examples are Ocheyedan Mound in Osceola county, and Pilot Mound in Boone county. While individual deposits of this type are usually not great, the number of mounds available will afford an important resource for road making. Interstream gravels are of some importance in northeastern Iowa, from Howard and Mitchell on the north, at least as far south as Buchanan and Black Hawk counties. Similar outwash gravel plains cover considerable portions of O'Brien and Osceola counties in northwestern Iowa and add considerably to the sum total of sand and gravel suitable for road work. Much of the terrace, stream and interstream gravels are suitable for concrete work. The kame gravels often carry too much clay for first class concrete, but can be used when the clay is washed out.

Limestone.—Limestone is available in quantity sufficient for road and concrete purposes in rather more than two-fifths of the counties of the state. The stone varies greatly in composition and physical properties, and therefore in its suitability for road and concrete work. The leading quarries and outcrops of limestone are to be found in the eastern half of the state, especially in those counties immediately bordering the Mississippi river and its larger tributaries. A few of the inland counties are well supplied with a good grade of limestone, notably Humboldt, Hardin, Marshall and Wapello counties.

Sandstone.—Sandstone is not as widely distributed in Iowa as limestone, and as a rule, barring the Sioux quartzite, which is a completely cemented sandstone, is not sufficiently indurated for road work and deserves no further mention.

Glacial Bowlders.—Granitoid and gneissoid bowlders are to be found in great numbers, and oftentimes of large size, in the north-central portion of the state. They are especially common on the Wisconsin and Iowan drift surfaces. Glacial bowlders afford material much more resistant to wear than limestone and gravel, and when crushed and properly sized could be used as a wearing surface on macadam and concrete roads. The cost per cubic yard would considerably exceed the cost of the gravel and crushed limestone.

Clay.—In certain portions of the state roads are almost impassable during certain seasons of the year on account of their sandy character. Such roads are especially common in the vicinity of the larger streams, notably on the east side of such streams. The sandy roads may be greatly improved by the addition of clay, especially the loess clays which form a surface veneer over the upland portion of the southern half of the state and large areas of upland in the eastern and western quarters of the north half. The treatment of sand roads with clay would probably be less expensive than the surfacing of clay roads with sand and gravel.

While the use of clay in road work is important in certain Iowa counties, and of more or less importance in nearly all, it is not considered within the province of this report.

B. MANUFACTURED ROAD MATERIALS. Burnt Clay Products.—Burnt clay products suitable for road work are burnt clay ballast and brick. Burnt clay ballast was manufactured in considerable quantities some years ago and used as ballast by several of the leading railroads in Iowa. There is no reason why burnt clay cannot be used for public road work where other materials are scarce, and the price prohibitive. Clays suitable for burnt clay ballast are widely distributed over the state, especially in the south-central portion where gravel and limestone are scarce or wanting. The burnt clay used by railroads is not, as a rule, sufficiently burned to be used as a substitute for either gravel or limestone. In ordinary practice not more than fifty to sixty per cent of the clay is reduced to a clinker. The under-burned clay slakes

when exposed to the weather. It is believed, however, that a better clinker can be produced by using more fuel.

2. Portland Cement.—In the manufacture of permanent roads, Portland cement is one of the most expensive and important materials used. Three Portland cement plants are in operation in Iowa at the present time, insuring a high grade of cement at reasonable cost.

Brick and concrete are certain to assume importance when Iowa reaches the stage of building "Permanent Roads." The present report is confined to a discussion of natural materials. In addition to a consideration of the geology and distribution of road and concrete materials, the report contains in tabulated form the results of several hundred tests of sands and gravels and limestones, and directories of the commercial producers of these materials.

The writers were assisted with the field work by Professors Ira A. Williams and W. F. Coover and Mr. James H. Lees, Assistant State Geologist, and later by Mr. A. W. Hess. Most of the laboratory tests were made by C. E. Scott, H. B. Tyson and L. S. Packman.

The work was carried on in cooperation with the Engineering Experiment Station of the Iowa State College. All of the laboratory work was done in the station laboratories. A brief of this report will appear as an Engineering Experiment Bulletin.

THE GEOLOGY OF IOWA ROAD AND CONCRETE MATERIALS.

GENERAL CONSIDERATIONS.

The Proterozoic.

The Proterozoic is represented by the Sioux Quartzite, which, while known to underlie a considerable area in the northwest corner of the state, exhibits outcrops over a very limited territory in the extreme northwest corner of Lyon county. Small openings have been made and small quantities of the indurated

SYSTEM	SERIES	FORMATION NAME	COLUMNAR SECTION	THICKNESS IN FEET.	CHARACTER OF ROCKS
QUATERNARY	PLEISTOCENE	Wisconsin		0-30+	BOWLDER CLAY, PALE YELLOW VERY CALCAREOUS.
		Peorian			SOIL BAND
		Iowan		0-30+	BOWLDER CLAY, YELLOW, WITH VERY LARGE BOWLDERS.
		Sangamon			SOIL, PEAT AND FOREST BEDS.
		Illinoian		0-100+	BOWLDER CLAY, YELLOW.
		Yarmouth			SOIL, PEAT AND FOREST BEDS.
		Kansan		0-400+	BOWLDER CLAY, BLUE, JOINTED, WITH INTERCALATED STREAMS AND POCKETS OF SAND AND GRAVEL.
		Aftonian		0-40+	PEAT & FOREST BEDS, SOIL BANDS, AQUEOUS GRAVELS.
		Nebraskan		0-30+	BOWLDER CLAYS, DARK, FRIABLE.
CRETACEOUS	UPPER CRETACEOUS	Colorado		150	SHALES WITH SOFT LIMESTONES, IN PLACES CHALKY.
		Dakota		100	SANDSTONES.
PERMIAN		Fort Dodge		20	RED SHALES AND SANDSTONES.
				20	GYPSUM.
CARBONIFEROUS	PENNSYLVANIAN	Missouri		600	SHALES AND LIMESTONES.
		Des Moines		750	SHALES AND SANDSTONES WITH SOME BEDS OF LIMESTONE.
	MISSISSIPPIAN	St. Louis		100	LIMESTONE, SANDSTONE & MARLY SHALES.
		Osage or Augusta		265	LARGELY CRINOIDAL LIMESTONE, WITH HEAVY BANDS OF CHERT, SOME SHALE.
		Kinderhook		120	SHALE, SANDSTONE AND LIMESTONE, LIMESTONE IN PLACES OOLITIC.
DEVONIAN	UPPER DEVONIAN	State Quarry Lime Creek Sweetland Creek		(40) (120) (20)	LIMESTONE, MOSTLY BRACHIOPOD COQUINA MOSTLY SHALES (LOCALLY DEVELOPED FEATURES, EACH LYING UNCONFORMABLY ON THE MIDDLE DEVONIAN.) SHALE
	MIDDLE DEVONIAN	Cedar Valley		100	LIMESTONES, SHALY LIMESTONES, SOME DOLOMITE IN THE NORTHERN COUNTIES.
		Wapsipinicon		60-75	LIMESTONES, SHALES, AND SHALY LIMESTONES.
SILURIAN	NIAGARAN	Gower		120	DOLOMITE, NOT VERY FOSSILIFEROUS, LE CLAIRE PHASE EXTENSIVELY CROSS-BEDDED.
		Hopkinton		220	DOLOMITE, VERY FOSSILIFEROUS IN PLACES.
ORDOVICIAN	CINCINNATIAN	Maquoketa		200	SHALE, SHALY LIMESTONES, AND, LOCALLY, BEDS OF DOLOMITE.
	MOHAWKIAN	Galena		340	DOLOMITE IN PLACES, IN PLACES UNALTERED LIMESTONES
		Platteville		90	MARLY SHALES AND LIMESTONES.
	CANADIAN	St. Peter		100	SANDSTONE.
		Prairie du Chien — Shakopee		80	DOLOMITE
		Prairie du Chien — New Richmond		20	SANDSTONE.
		Prairie du Chien — Oneota		150	DOLOMITE.
CAMBRIAN	POTSDAMIAN OR SARATOGAN	St. Croix — Jordan		100	COARSE SANDSTONE
		St. Croix — St. Lawrence		50	DOLOMITE MORE OR LESS ARENACEOUS.
		St. Croix — Dresbach		150	SANDSTONE, WITH BANDS OF GLAUCONITE.
ALGONKIAN	HURONIAN	Sioux Quartzite		25	QUARTZITE.

PLATE I—Geological section of Iowa.

sandstones have been removed from time to time. While Iowa is capable of producing much larger quantities, owing to lack of transportation facilities the trade is supplied from the quarries at Sioux Falls, South Dakota, and the Pipestone district in Minnesota.

The stone varies from a light pink to a deep purple in color, with shades of red prevailing. It also varies greatly in state of induration, texture and structure. As a rule it is typically quartzitic, presenting the characteristic porcelain-like fracture on freshly broken surfaces. Occasionally it is poorly cemented and may be crumbled between the thumb and fingers. In texture it presents normally a fine even grain, although conglomeratic facies on the one hand and slaty on the other are known. In general the quartzite occurs in fairly heavy to massive beds, in approximately horizontal position or dipping at a low angle. In places the beds thin greatly, lack constancy and even show false bedding.

The normal quartzite affords the most durable structural material native to Iowa, and is especially well adapted for heavy masonry, street paving, road surfacing, especially for the wearing course on concrete road construction and for all purposes where strength and durability are required. It is also well adapted for use in fronts and trimmings of buildings. It takes and holds a high polish and is desirable for decorative purposes. On account of its great hardness it is expensive to dress and because of this fact will never be used extensively save for the most costly and permanent structures.

The Cambrian.

POTSDAMIAN SERIES.

The Saint Croix Sandstone.

Only the uppermost division of the Cambrian is known to occur in Iowa. The principal outcrops are confined to the Mississippi river and its immediate tributaries in Allamakee and Clayton counties and are referred to the Saint Croix stage, supposed to be the equivalent of the Potsdamian of New York.

The Saint Croix comprises three rather easily separable

members, the Dresbach sandstone, the Saint Lawrence limestone and shales and the Jordan sandstone, named in ascending order. As a rule all of the beds comprising the series are wholly unindurated or are but poorly indurated and as a consequence are of but small importance as a source of road and concrete materials. Certain layers immediately below the Saint Lawrence shales are slightly indurated and have been used to some extent for structural purposes. So far as known such use has been confined to Allamakee county. The chief openings were made along the Mississippi and immediate tributaries from New Albin to Lansing and in a horizon varying from one hundred to one hundred and fifty feet above the river.

The sandstone carries a calcareous cement, lacks durability and is not readily accessible. It deserves mention only as having been used to a very limited extent as a structural material.

The Ordovician.

The Ordovician system of rocks comprises three series, a lower, the Canadian, a medial, the Mohawkian and an upper, the Cincinnatian. The first may be readily subdivided into two stages, one of which is prevailingly a massive dolomite and known in the later publications of the United States Geological Survey as the Prairie du Chien limestone* and the other, a well-marked sandstone horizon, the Saint Peter.

The Prairie du Chien limestone comprises a lower massive dolomite which the present Survey has designated the Oneota limestone, a medial sandstone, the New Richmond, and an upper dolomite, the Shakopee limestone. Near the base of the Oneota limestone, above about ten to fifteen feet of arenaceous limestone, thirty to forty feet of evenly bedded dolomite, excellently adapted for the various grades of dimension stone and other structural purposes, constitute the most important horizon in the Prairie du Chien limestone.

*In the reports on Winneshiek and Clayton counties, volume XVI of these reports, this stage is called the Lower Magnesian, but this term is now superseded by the one here used in accordance with a recent decision of the Board of Geologic Names of the U. S. Geological Survey. See Lancaster-Mineral Point Folio, page 3.

The beds representing the Saint Peter sandstone are usually not sufficiently indurated to merit consideration as road or concrete material. Occasional beds are indurated locally and have been developed to a very limited extent.

The Mohawkian series comprises the Platteville and the Galena stages, according to the present terminology adopted by the Survey. All of the members furnish some indurated material, although quarrying operations have been limited to the Platteville and to the dolomitized portion of the Galena. The most important horizon, known as the "Lower Buff Beds," attaining a thickness of more than twenty feet, occurs near the base of the Platteville and is separated by a few feet of shale from the Saint Peter sandstone.

The upper Platteville, while usually thinly bedded and often decidedly argillaceous, is quarried to some extent. The Galena limestone, as it occurs in Dubuque county, affords stone suitable for massive masonry and has been so utilized to a limited extent. To the northward it becomes less magnesian to non-magnesian and is practically worthless as a dimension stone. The Galena is separated from the Platteville by a calcareous shale, the "Decorah Shale" of Professor Calvin, the "Green Shales" of the Minnesota geologists, which is worthless save as a possible source of material for cement manufacture.

The uppermost series, the Cincinnatian, which in Iowa includes only the Maquoketa, is of small importance as a source of quarry products. The Middle Maquoketa cherts may prove to be serviceable road material, while the calcareous to dolomitic layers in the Lower and Upper Maquoketa have been quarried locally. The shales of the Lower Maquoketa afford material suitable for the manufacture of Portland cement.

It is probably true that no other rock system is potentially richer in quarry products than the Ordovician. This wealth of material has been but little developed in Iowa. The lack of development is due to several causes. In the first place, first-class material constitutes only a small proportion of the entire assemblage of beds. While the demand for the waste which could be utilized as crushed stone has been small, it is growing rapidly on account of the demand for road material and aggre-

gate for concrete. In the second place the counties in which the Ordovician beds occur are poorly supplied with transportation facilities away from the immediate vicinity of the Mississippi river. Stone of usable quality can be obtained in every township, oftentimes on every farm over considerable portions of the Ordovician area. The outlook is encouraging and greater activity may be confidently expected in the near future.

The Silurian.

NIAGARAN SERIES.

The Niagaran limestone, as developed in Iowa, comprises two stages, the Hopkinton, typically developed in Delaware and adjoining counties and formerly known as the Delaware stage, and the Gower, from Gower township in Cedar county, where this stage shows its typical development. The Hopkinton stage comprises a series of dolomites varying considerably in composition and structure. In general, they occur in heavy beds, with bedding planes obscure or wanting. At certain horizons and in certain localities, the beds are evidently laminated and even become flaggy in character. They range from hard, slightly vesicular, subcrystalline, massive dolomites, to soft, earthy deposits. Certain horizons carry large quantities of chert. The Hopkinton attains its maximum development in Dubuque and adjoining counties. According to Professor Calvin* the following members of the Hopkinton can be recognized and he assigns their thickness as follows:

		FEET.
7.	Upper quarry beds	20
6.	Cerionites beds	25
5.	Pentamerus beds	50
4.	Syringopora beds	65
3.	Chert beds	25
2.	Lower quarry beds	20
1.	Basal beds	15
	Total	220

Number 5 is often subcrystalline and essentially a pure dolomite and is of excellent quality for lime burning. It is used extensively in Jackson county.

*Geology of Dubuque county, Iowa Geol. Surv., Vol. X, page 459.

The Gower includes two fairly distinct substages, the LeClaire and the Anamosa.

The latter consists typically of soft, laminated, light buff to yellow dolomite in thin to medium heavy beds which are often practically parallel and nearly horizontal. Texturally the beds are porous, often highly vesicular, and usually present a rather dull and earthy luster. The layers are divided by occasional vertical joints.

The LeClaire beds on the other hand comprise a hard, bluish gray to a grayish yellow, subcrystalline dolomite. The prevailing color above the ground water level is some shade of yellow or buff. Texturally, while the LeClaire is usually subcrystalline, it is generally vesicular and presents a decidedly rough appearance on a freshly fractured surface. It is sometimes brecciated or conglomeratic. Structurally, the LeClaire occurs in mounds and presents a very uneven surface which is filled by the even beds of the Anamosa. It sometimes appears to be massive, the bedding planes being scarcely recognized; at other times the bedding planes are apparent but are highly inclined; in still others, the beds are evidently laminated and nearly horizontal. The LeClaire, when typically developed, is an essentially pure dolomite and excellently adapted for the manufacture of a superior grade of lime and is so utilized at a number of points in Iowa and Illinois; notably, Cedar Valley, Sugar Creek and Viola in Iowa, and Port Byron in Illinois; while the Anamosa beds are especially prized as a dimension stone on account of their unusual uniformity in bedding, composition, texture and state of induration. More than three-fourths of the bridge and dimension stone of the state is derived from these beds. The entire assemblage of beds comprising the Niagaran is suitable for concrete, and while rather soft is usable for road work. The leading quarries are located at Cedar Valley, Stone City, Farley, LeClaire and Mount Vernon.

The Devonian.

The Devonian as developed in Iowa comprises a rather diversified assemblage of limestones and shales. The latter are of interest as a quarry product only so far as they are suitable for the manufacture of Portland cement. The limestones vary

greatly in composition, texture, state of induration, thickness of beds and weathering qualities. They range in composition from a pure calcium carbonate as in the white, compact, brittle limestones, developed in Cerro Gordo and Mitchell counties, to typical granular dolomites and argillaceous limestones. They range texturally from rather coarse subcrystalline limestones and dolomites to compact lithographic stone. The range in state of induration is equally pronounced, from hard limestone which gives a metallic sound when struck with the hammer to soft, earthy limestone. In certain horizons the beds are thin and flaggy while in the "State Quarry" type, the beds attain thicknesses of five or six feet. The beds in the so-called Fayette substage are much broken or crushed and are practically worthless for coursing stone. All of the divisions of the Devonian furnish some quarry stone, though the most important horizons are found in the Wapsipinicon, Cedar Valley and State Quarry stages. In all three of these stages deposits ranging from hard, brittle limestones to dolomites prevail and afford excellent material for crushed stone purposes.

The Devonian beds occupy a belt varying from twenty-five to seventy-five miles in width and extending across the state in a northwest-southeast direction. The belt is included between Worth to Howard counties on the north and Muscatine and Scott on the south. The most important quarries belonging to the Wapsipinicon stage occur in the southern portion of the area; the Cedar Valley stage is quarried throughout, but perhaps most extensively in the northern portion while the State Quarry stage is limited to Johnson county. Detailed descriptions follow by counties.

The Carboniferous.

MISSISSIPPIAN SERIES.

The Kinderhook.

The Kinderhook is typically developed in the vicinity of Burlington in Des Moines county and comprises a series of shales below and limestones above, separated by finely arenaceous deposits. The shales constitute the most extensive member at

Burlington, exceeding one hundred feet in thickness but thinning northwestward along the line of strike, while the limestone member becomes relatively more important. The medial sandstone is fairly persistent but becomes less important northward. The calcareous member shows a decided tendency to become oölitic and ranges in texture from a compact, brittle limestone to subcrystalline and oölitic in character. It is equally variable in composition, showing all gradations from a pure limestone, as the oölite in Marshall county and the white limestones in Hardin and Humboldt counties, to the sugary brown dolomite of Hardin county. The upper member, which has been extensively exploited in Marshall and Hardin counties furnishes an excellent grade of material for road and concrete work. The shale and sandstone members of the Kinderhook are of no importance in this connection.

The Osage Limestone.

The Osage limestone occupies a triangular area in the southeastern portion of Iowa, the base of the triangle resting on the Mississippi river from Louisa to Lee counties, and the apex extending to the northwestward, reaching Keokuk county. Beds referred to this stage of the Lower Carboniferous are most extensively and typically developed in Des Moines county and especially in the vicinity of the town of Augusta. Five fairly well-defined substages may be recognized and as all are well represented in Des Moines county their detailed descriptions appear in the discussion for that county and a repetition is unnecessary here. It may be said, however, that the indurated beds are chiefly limestones and that these supply an abundance of material suitable for crushed stone purposes.

The Saint Louis.

The Saint Louis stage of the Lower Carboniferous has been separated by Bain into three substages. The lowest of these, the Springvale beds, comprises a limestone formation varying from earthy or argillaceous limestones as developed in Keokuk county at the type locality to massive limestone beds in Henry county. As a rule the beds are not important as a source of

usuble stone for any purpose. The middle member, or Verdi beds, is exceedingly variable in composition and texture, ranging from sandstones to shales or limestones. The different kinds of sediments give place horizontally one to another so that a stratum that is shale in one part of the exposure may be represented by sandstone or limestone at no great distance to the right or left. No important quarries belong to this horizon. The uppermost member, or Pella beds, is the most uniform in character and is fairly persistent over considerable areas. The beds are usually quite pure limestones, are of good thickness and evenly bedded. The Pella beds comprise the most important member of the Saint Louis stage from an economic standpoint.

PENNSYLVANIAN SERIES.

The Des Moines.

The Lower Coal Measures are not important in the production of quarry products. They consist essentially of shales, shaly sandstones, sandstones and occasional thin bands of limestones. The sandstones, as a rule, are poorly indurated and not of pleasing color. Occasionally they are sufficiently cemented to be used for foundations of unimportant structures and for other rough masonry. Such deposits usually assume a lenticular form and are exceedingly variable in texture, color and state of induration both horizontally and vertically. The most important lenses occur in Marion, Jasper, Wapello, Boone and Webster counties. The Red Rock sandstone represents perhaps one of the best known examples and is described later. The best examples of the possibilities and also of the limitations of this stone may be seen in some of the residences along West Grand Avenue in the city of Des Moines. Less extensive deposits appear in the Coal Measure outliers in Johnson county, where the stone was used in some of the oldest buildings of the district. The Coal Measure sandstones are of little or no value for road and concrete purposes.

The limestones are usually more or less argillaceous and have not proven satisfactory as a quarry stone. The best examples may be seen in Appanoose county.

The shale cannot be used directly for road work, but when burned is of some service. The waste dumps about Iowa coal mines usually contain enough low grade coal to partially slag the clay and shale. This material when intelligently used on the roads gives fair results.

The Missouri.

The Missouri stage of the Upper Carboniferous is made up largely of off-shore deposits in which shales greatly predominate. Interbedded with the shales is a series of thin limestone beds varying from a few inches to twenty or even thirty feet in thickness, and persistent over considerable areas in the southwestern portion of the state. These limestones are usually quite free from such impurities as magnesia and pyrite, but they often display a decided tendency to become argillaceous. The ledges constituting the more important limestone zones are usually separated by clay partings, varying from a fraction of an inch to a few inches in thickness. The most important horizons belong to the Bethany substage and are named after localities where they are typically exposed. From the base upwards the principal limestone members are as follows: 1, the Fragmental limestone, typically developed at Bethany, Missouri; 2, the Earlham limestone; 3, the Winterset limestone; 4, the DeKalb limestone; and 5, the Westerville limestone, from the town of the same name in Union county.

A sixth limestone horizon far above the strata of the Bethany may for the present purposes be designated the Stennett limestone. It is typically developed at Stennett in Montgomery county, and is believed to be present in the adjoining counties. The second and third members are by far the most important and have been extensively developed at a number of points, notably at Earlham, Winterset and Peru in Madison county. The stone representing the different horizons varies considerably in weather-resisting properties but when properly selected, excellent material can be secured for all sorts of structural and crushed stone purposes.

The Permian.

In the vicinity of Fort Dodge in Webster county a series of red clays associated with gypsum occur over a small area and comprise a well-marked formation. In the earlier volumes of the present Survey these beds were referred by Keyes to the Cretaceous. The concensus of opinion at the present time favors Wilder's reference to the Permian and the strata are so considered in this report.

None of the beds are sufficiently indurated to merit consideration in this connection.

The Cretaceous.

The Cretaceous system is represented in Iowa by rather loosely aggregated sandstones, clay shales and marly limestones. The sandstones are prevailingly calcareous. Occasionally they are sufficiently indurated to merit consideration as a source of structural materials. This is notably true in Woodbury county where the stone was developed formerly and sold as "Sioux City Granite." No commercial quarrying is being done at the present time on account of the excessive overburden.

The calcareous deposits have been explored to some extent but with slight promise of future development.

The Quaternary.

PLEISTOCENE SERIES.

The Pleistocene history of Iowa is recorded in the several drift sheets, the interglacial sands and gravels and in the postglacial river, lake and wind deposits. The following sequence of events can be made out quite readily:

10. Postglacial, alluvial and aeolian deposits predominate.
9. Wisconsin, glacial, represented by a drift sheet covering the north central part of the state. Capitol Hill in Des Moines is the apex of the lobe.
8. Peorian, interglacial, probably includes the loess.
7. Iowan, glacial, represented by a thin sheet of drift carrying large numbers of giant bowlders, mainly granites.
6. Sangamon, interglacial.
5. Illinoian, glacial, represented by a rather unimportant drift sheet which covers portions of the Mississippi river counties from Scott to Lee, inclusive.

4. Yarmouth or Buchanan, interglacial, represented by important gravel deposits.
3. Kansan, glacial, represented by a drift sheet which covers almost the entire state.
2. Aftonian, interglacial, the leading gravel terrane in southwestern Iowa.
1. Nebraskan or Sub-Aftonian glacial, the oldest drift known in Iowa. Rarely seen save in artificial excavations.

The interglacial and postglacial deposits are of greatest importance as sources of road and concrete materials. With the exception of the Peorian and Sangamon, these deposits are increasingly important from the oldest to the youngest, in terms of availability.

The Aftonian gravels are of wide occurrence but in general are too deeply buried by the younger deposits to be commercially important as a source of structural materials. They constitute an important water-bearing horizon over a large portion of the state. They have been developed for road and concrete work only in the southwestern portion of Iowa. The type section may be viewed at Afton Junction in Union county.

The Buchanan gravels are as a rule less deeply buried and are generally available over the northeastern third of the state. Two types are easily recognized, the valley and the upland. The Buchanan terrane is second only to the post-Wisconsin gravels as a source of road and concrete materials. Excellent examples of both types may be seen in Buchanan and adjoining counties.

The Sangamon and Peorian furnish little material of interest in this connection, unless certain of the gravels in northwestern Iowa belong to one or the other of these stages.

The post-Wisconsin gravels are by far the most important of the Pleistocene deposits for road and concrete work, when all factors are taken into consideration. The valley type is the most important here as in the Buchanan.

The leading points of production are listed in the introduction.

The drift sheets furnish large numbers of bowlders, many of which are of large size. This is especially true of the Iowan and Wisconsin. The bowlders are usually more or less con-

centrated along the drainage lines and when crushed are excellently adapted for road and concrete work.

In addition to the bowlders the Wisconsin drift contains many gravel hummocks or kames, already mentioned in the introduction. While these individually are not of great importance, collectively they are second in importance only to the valley gravels which commonly appear as terraces. Kame gravels are limited to the Wisconsin drift area.

The present streams have done and are doing some work in the classification of material. The Des Moines river has been the most efficient in accumulating materials suitable for road and concrete work. In a considerable number of counties the streams are the only sources of sand and gravel. This is especially true in the counties far removed from the Wisconsin drift.

DESCRIPTION OF ROAD AND CONCRETE MATERIALS BY COUNTIES.

ADAIR COUNTY.

Sand and Gravel.

Adair county is not far removed from the Wisconsin drift front. It so happens, however, that none of its drainage lines issue from the area covered by the youngest drift sheet and they are therefore not accompanied by the usual gravel train.

With the exception of small amounts of gravel and sand in Middle river, Adair county is practically devoid of these materials. Near where this stream leaves the county small amounts of gravel are taken from its bed, and deposits of sand continue intermittently some three or four miles north of this point in Harrison township. In places this sand is quite clean and is used by the farmers in cement work. The interglacial gravels are not known to be available in quantity.

All of the sand and gravel used on work of any importance within the county is shipped in, large amounts coming from Des Moines and vicinity.

STONE.

Adair county is included within the area in which the Missouri strata are believed to be the country rock. Cretaceous beds probably overlie in part the Carboniferous rocks in the western part of the county but the all but universal concealment of the indurated strata by the loess and glacial bowlder clays renders accurate data difficult to secure. The shales and more calcareo-argillaceous beds of the Des Moines stage of this series are believed also to appear beneath the fragmental beds of the Bethany at a few points on Middle river, along which the only quarry operations known in the county are carried on.

A well marked limestone horizon with associated beds outcrops on Middle river and its small tributaries where it crosses the northeast corner of Brown township. Below Howe, in sections 11 and 12, on a small branch from the southwest, quite extensive quarrying has been done. The openings are on the land of Mr. W. P. Perry and stone has been taken out for over twenty years. The following section may be observed in the northwest corner of section 12, close to the confluence of the above tributary and Middle river:

		FEET.
10.	Soil, loess, and drift conglomerate containing Cretaceous material..	7
9.	Limestone, broken into blocks which are rounded by weathering and solution; buff in color, fossiliferous, narrow band of chert in residual clay, both above and below.....	1 1/6
8.	Limestone like No. 9 with two inch cherty clay residue below....	1/2
7.	Limestone, firm ledge somewhat broken by weathering; marked tendency to separation into blocks by vertical joints.....	3/4
6.	Shaly limestone, chert bearing, by weathering forms a reëntrant in the quarry face	1 1/12
5.	Limestone ledge, persistent	1/2
4.	Limestone, shaly, blue to gray where unweathered, but iron-stained at crop; persistent and forms a conspicuous reëntrant	1 1/4
3.	Limestone, light brown, compact; has tendency to dissolve along joints to form caverns. At its base is a heavy band of chert which in places is pulverulent and white.....	1/12
2.	Limestone, cavernous, with tendency to jointing, separated as a rule by thin shaly partings into three distinct ledges, 5, 10 and 9 inches in thickness	2 1/8
1.	Limestone, regularly bedded, compact, brown to bluish, in six inch to one foot ledges, commonly separated by thin, brown clay partings, contains occasional chert nodules near the top; highly fossiliferous throughout to base of exposure.....	5

Stone has been taken out along a quarry face four to five hundred feet in length, the work being apparently limited by the heavy stripping. The base of the present exposure is about fifteen feet above Middle river. The lowest bed rests on earthy and carbonaceous shales, the contact being marked by numerous springs and seeps.

The best stone comes from numbers 8 and 9 near the top and from the basal member of the section. Number 1 especially affords excellent dimension material of any desired thickness. The output of this and neighboring quarries is used to a large extent locally for foundations, and for this purpose it is also hauled to Stuart and Greenfield.

To the south of the branch, and but fifteen to twenty rods distant from the foregoing, the same layers are worked. The beds outcrop also west of the road in section 11, where some quarrying is done. To the eastward, along the south side of Middle river, the limestone forms a terrace which is not deeply covered and where any quantity of stone is available.

Stone is also quarried in the southwest quarter of this same section, on the farm of Mr. Jas. Chambers. In the main the beds can be correlated with those of the Perry quarry section although the overburden is not so great and would prove less of a hindrance to development.

The Missouri beds outcrop at rare but gradually increasing intervals southeastward along Middle river to its exit into Madison county. They are quarried at a few points in Harrison township. At, and in the vicinity of the mill dam at Port Union, the following succession of strata can be made out:

		FEET.
12.	Shelly, fossiliferous limestone to be seen one-eighth mile above the dam in the hillside where rock has been quarried	?
11.	Firm ledges, good building limestone, to be seen at same place	3-4
10.	Limestone breccia, containing angular pieces of compact limestone of a maximum size of 2 to 3 inches; there are occasional fragments of dark chert in a soft limestone matrix. Conspicuous in hillside 20 rods above site of dam	?
9.	Ocherous red and purplish weathered shale, in view	2½
8.	Shelly limestone	?
7.	Solid ledge compact, durable limestone forming a shelf over underlying shale, at south end of dam at level of water in pond	5/6

		FEET.
6.	Gray shale with nodules and streaks of hard limestone, cylindrical forms, apparently vegetal remains.....	1½
5.	Bluish limestone capped with thin layer composed almost entirely of well preserved brachiopod remains.....	1/8
4.	Dark blue, clean shale	2
3.	Brownish, cavernous limestone, not persistent.....	½
2.	Black, slaty shale	1½
1.	Shelly limestone, breaking into nodular flakes and lenses on exposure; in bed of stream below dam where it causes a low falls. Known in excavation for mill wheel to consist of two 12 inch layers.....	2

Below is a "gummy" clay or soapstone which is practically impenetrable to the churn drill.

At all points observed, these strata occur beneath great thicknesses of glacial deposits. The limestone members of the section have afforded building material but their exploitation is of necessity limited. The beds above the fragmental limestone, number 10, are said to be quarried for local use on the farm of Robert Murphy on Middle river near the east county line, and at other points in this vicinity.

The two sections given above appear to include the basal members of the Missouri and the upper strata of the Des Moines stage, if regarded alone on stratigraphic position and lithologic similarity. There seems little question that number 10 of the Port Union section represents the base of the Bethany and that the nonbrecciated beds above are the equivalent of the Earlham limestone in Madison county.* The Fragmental limestone does not appear in the Perry section as a distinctly brecciated layer. In other respects, the lowest member here visible, No. 1, is its equivalent, and the underlying shales therefore belong to the Des Moines. The limestones throughout are suitable for crushed stone purposes.

ADAMS COUNTY.

Sand and Gravel.

Adams county has no streams worthy of mention, and yet the loess-covered Kansan drift surface is profoundly stream dissected. The numerous small creeks are without gravel terraces and have accumulated but little sand and gravel in their

*Geology of Madison county, Iowa Geological Survey, Vol. VII, page 511.

channels. The older interglacial gravels are thoroughly concealed and therefore are not available. Gravel and sand for large undertakings are shipped in from Raccoon and Des Moines rivers.

STONE.

The country rock in Adams county is in general deeply concealed by the glacial deposits and outcrops at but a few points along Middle and East Nodaway rivers. As in adjoining counties, the Missouri rocks consist largely of shales, which may become highly calcareous and even marly, interstratified with usually thin beds of limestone which are in some instances of a character and extent to be of value. Similar also to bordering counties, beds of otherwise valuable stone are so deeply buried that their utilization is out of the question.

The Upper Coal Measures outcrop at Carbon in Douglas township, where the Nodaway seam is mined. The "cap rock" is an eighteen inch ledge of firm limestone and appears near water in the river. It is quarried for local use here and at intervals along the stream to Mt. Etna in Washington township, but it is of little importance and is difficult to obtain.

Stone was formerly quarried at Corning in the banks of the East Nodaway. Limestone appears at a number of places in the bed of the river for a few miles southwest of the town. The abandoned French quarry is located south of the river in section 3, Jasper township. Talus obscures the old quarry face, but a few hundred feet to the north in the bottom and bank of the river, the following sequence may be made out:

		FEET.
5.	Drift	3
4.	Fine sand, iron-stained	4
3.	Shale, light blue, plastic	5+
2.	Limestone, hard, compact, gray in color, fossiliferous; breaks easily at right angles to bedding planes and apparently does not weather easily on exposure	2¼
1.	Limestone, fossiliferous, yellow, weathered, to water level	½

There is evidence that quarrying has been carried on here on a scale of some magnitude, and the Corning stone is known and has been distributed over not only Adams county, but adjacent territory as well. The limestone is of good quality, and while

extensive development is of necessity restricted by the heavy stripping, it should rank locally as a valuable resource.

ALLAMAKEE COUNTY.

Sand and Gravel.

Sands and gravels are very abundant in the valleys of the two main watercourses of Allamakee county—Mississippi and Oneota rivers—and to some extent in the smaller valleys. At numerous localities along the valley of the Mississippi or in the breaks of its wall where there is opportunity or where protection has been afforded, terraces of more or less magnitude remain as remnants of the immense bodies of detrital material which once occupied this valley. Probably the most important of these terraces is that upon which Harpers Ferry is built. This extends along the canyon wall a distance of two or three miles and reaches a height of twenty to forty feet above the river. Another deposit of considerable importance is located at Lansing. Here a small stream enters from the west, occupying a valley of considerable size, up which terraces twenty feet or more in thickness extend for a short distance. Just back of the box factory near the Chicago, Milwaukee and Saint Paul depot the deposit has been opened and a pit twenty feet deep exposes the gravels. Below eighteen inches of soil is a three foot layer of gravel mixed with some sand and clay. The pebbles of this layer reach a diameter of one to two inches. Beneath this are fifteen feet of alternatingly coarser and finer materials which gradually become finer below. At the bottom of the pit is a fine clean sand which is said to be suitable for plastering. The gravels from this pit are being extensively used on the roads and streets in Lansing.

The materials composing the deposit in this valley evidently become much finer with increasing distance from the river. At a point on the south wall of the valley opposite the cemetery and probably a mile above the river the stream impinges upon the bank and has exposed a section in the terrace material which here reaches a height above the water of forty feet. The lower twenty feet of this deposit consists of very fine sands and clays

interbedded and packed quite hard except near the top of the exposure, where they become somewhat friable.

At a few places along the west bank of the Mississippi there are, within the county limits, small terraces in addition to the two described, but none of these are extensive. The gorge of Oneota river, however, is thickly sprinkled with terraces of varying size. One of these, near the middle of the east line of section 16, Iowa township, is fifty-five feet high and consists, so far as observed, of loose fine sand, with some gravel and chert fragments. These sands are evidently of comparatively recent age, probably Wisconsin, as are those of the numerous other terraces farther up the valley. But some bear testimony to their greater age in their relations with other deposits. For instance, in the southeast quarter of section 35, Union City township, is a body of sand clinging to the hillside to a height of nearly sixty feet above the flood plain. This sand is overlain by a layer of fine silt which shows the gray color and iron "pipe stems" characteristic of the Kansan loess. Near by, the same bed of sand is covered with yellow Iowan loess. A short distance up the road, in the same section, a gully exposes Iowan loess to a height of ten feet, with an equal thickness of clean yellow sand overlying it. The sand in the latter case is probably related to the Wisconsin glaciers while that of the other is of Buchanan age.

Terrace deposits of more or less magnitude are found bordering the Oneota valley to the county line and indeed as far west as Decorah. In some cases these consist of fine sands, in others considerable gravel is present.

The smaller stream valleys of the county do not bear such extensive gravel deposits as does the Oneota, a difference no doubt largely due to the fact that the greater watercourse extended well into the region occupied by the glaciers and thus afforded an outlet for the heavily charged waters issuing therefrom, while the smaller streams rise within the driftless area or at most extend only a short distance beyond its borders and hence have never received any large quantity of material of foreign origin. Thus Yellow river displays no terraces, not even in its lower reaches, with the possible exception of one in

section 19, Fairview township. This consists chiefly of limestone pebbles with some foreign material and a little sand, and seems to be banked against two hills of circumdenudation in the valley. These latter also show some banks of detrital sand and chert overlain by loess. There is some sand in the river plain in this vicinity, but very little gravel. The sand may be of local derivation, as the Saint Peter sandstone outcrops in the hills bordering the flood plain. Farther up the river, in the neighborhood of Forest Mills, are banks of coarse material, chiefly limestone, with some foreign pebbles but very little sand. These have been used for concrete and are reported to give excellent satisfaction. Their adaptability for road work has not been tested.

STONE.

The Ordovician covers the entire county with the exception of narrow belts along Mississippi and Oneota rivers and their immediate tributaries, where the beds have been removed through erosive agencies and the Saint Croix sandstone exposed. Good quarry stone occurs at several levels, notably near the base of the Oneota and of the Platteville limestone formations. Above the ten or fifteen feet of arenaceous limestone or calcareous sandstone at the base of the Oneota there are thirty or forty feet of evenly bedded, fine-grained, buff, dolomitic limestone in layers varying from a few inches to three feet in thickness and in blocks oftentimes many feet in width and length. In the eastern portions of the county in the vicinity of New Albin, Lansing and Harpers Ferry the beds have been worked to some extent but are not of especially good quality. In the northwestern portion of the county, the same beds afford material of superior quality for the various grades of masonry, although on account of the absence of suitable facilities for transporting the product, they have been but little developed. Great blocks detached from the parent ledges through the undermining of the friable sandstones below, retain their angularity and otherwise demonstrate their durability though they have been exposed for hundreds of years. At the present time only sufficient quarrying has been done to dem-

onstrate the wonderful possibilities of this horizon as a source of wealth which may in time be utilized.

Above these beds in the basal portion of the Oneota there are occasional beds suitable for structural purposes but as a rule the stone is massive, with only occasional irregular bedding planes, which renders quarrying difficult. Besides, the beds are rather coarse textured, vesicular, and oftentimes arenaceous or cherty. The upper Prairie du Chien beds generally show layers of sandstone and shale interstratified with the dolomitic beds, and possess little to commend them for quarry purposes.

As a rule the Saint Peter sandstone is not sufficiently indurated to deserve notice as a quarry stone. There are a few small patches which are exceptions to the general rule, the stone being sufficiently cemented to be used for rough masonry. It has been so used to a limited extent. Such outcrops may be viewed three miles east of Waukon in the south half of section 27 in Makee township and in the southwest quarter of section 14, Franklin township, near Smithfield. At the latter place the sandstone carries a siliceous cement and forms cliffs thirty or forty feet in height and in some cases breaks into massive angular blocks showing marked ability to resist the agencies of disintegration.

The second important quarry horizon in the Ordovician in the county comes in the lower Platteville and is the equivalent of the "Lower Buff Beds" of the Wisconsin geologists. These beds are separated from the Saint Peter sandstone by five or six feet of greenish or bluish shale and comprise a heavy bedded dolomitic limestone aggregating twenty to twenty-five feet in thickness and composed of layers varying from six inches to three feet or more in thickness. The stone is hard and compact and yellow to buff in color and is capable of furnishing blocks of almost any desired dimensions. These beds are available at numerous points in the county, notably in the valley of Paint creek in Paint Creek township, and in Franklin township, but they have been but little developed.

The Platteville, above the Lower Buff Beds, is very variable lithologically. There is a continual alternation of shales and

limestones, the limestones predominating. The limestone in general is dull colored, shades of blue prevailing and is often argillaceous. It is generally fine-grained, compact, and occurs in thin beds rarely exceeding six inches in thickness. It breaks with a conchoidal fracture and does not tool easily. Beds which appear to be firm when first quarried, slake readily when exposed to the weather. The upper beds have been quarried to a limited extent near Waukon along Village creek. The stone is a blue to slaty colored limestone, but weathers to various shades of yellow and buff; is hard and fine-grained and occurs in layers from three to six inches in thickness. The layers are variable in composition and state of induration and, as a consequence, in weather resisting qualities, and they must be selected with considerable caution when used in permanent structures. Similar sections may be viewed north of Postville, where some quarrying has also been done.

The upper quarry beds north of Waukon are overlain by an important deposit of calcareous shale aggregating twenty to thirty feet.

The Galena as developed in Allamakee county affords nothing of importance in the way of quarry products.

A few of the quarries of the county are described in detail in the following paragraphs.

At the top of the bluff overlooking the Mississippi on the south side of Clear creek valley, opposite Lansing, and at the extreme edge of the precipice, a quarry has been opened in the Oneota limestone. From this may be made the following section:

		FEET.
1.	Heavy blocks outcropping in the talus slope above the quarry	4
2.	Rock waste	3
3.	Heavy ledge, rough, vesicular	3
4.	Fine-grained, soft, gray stone	1 1/6
5.	Two nine-inch layers, similar to that above	1½
6.	Heavy ledge of similar rock. This, with the layers above it, is seen in other parts of the quarry to break into thin layers suitable for range work	6
7.	Buff, sugary, fine-grained, dolomitic rock	1 1/6
8.	Two layers similar to above	4
9.	Heavy ledge of similar appearance	4

This quarry represents a considerable amount of rock overlying the Saint Croix over eastern Allamakee county. Along the bluffs it is difficult of access, as in the present case, but farther back from the river it becomes more easy to secure.

The quarry of John Ross, near New Albin, has been opened in the finer ledges of the Oneota similar to the upper quarry beds of the Lansing quarry.

About a mile northeast of Dorchester, in the northeast quarter of section 13, Waterloo township, stone has been removed from the lower beds of the Oneota, perhaps fifty feet above the base of this formation. Some of the layers are rather fine in texture, some coarser and sugary. While the stone is too soft for macadam it might be used to advantage in concrete, and for similar purposes. In the village is a quarry showing similar stone but bearing some flint nodules. A mile and a half northwest of town on the Caledonia road stone similar to the first is quarried. The beds in this quarry are four to six feet thick, split easily and dress well.

In an old sink hole near the road on the uplands in the northeast quarter of the northwest quarter of section 34, Union Prairie township, limestone of the Platteville stage is exposed and has been quarried to a small extent. The stone is rather soft, although some is harder, presents a granular, sugary appearance and is buff in color, stained with iron oxide. Above the stone is a dark red, jointed clay, probably geest, also numerous foreign pebbles.

An old quarry on the north edge of Waukon in the northwest quarter of the northeast quarter of section 30, Makee township, has been recently reopened by Mr. A. Simon and considerable stone has been taken out for building purposes as well as for use on the roads. About ten feet of fresh material is exposed and above this two or three feet of waste which is taken to the crusher. The stone is in layers one to two feet thick although some of the ledges show lamination on weathered faces. The crushed stone together with the residual material has been used by the city for streets and crossings. The quarry is equipped with a Champion portable jaw crusher driven by a gasoline engine.

A short distance north along the road green shales outcrop at a level below that of the quarry. These are the upper layers of the shaly and limy member of the Platteville as described by Calvin,* and the quarry rock belongs to the hard, blue member overlying these shales.

A number of openings have been made in the ravines south of Lycurgus. One of these, in the southeast quarter of the northeast quarter of section 2, Makee township, shows about eight feet of heavy blue ledges, six inches to two feet in thickness. Above these lie one to two feet of soft, thin, yellow, argillaceous layers with stony bands one inch thick intercalated. These layers grade upward into the rock waste. The blue layers are hard, firm, fine-grained, weathering to a buff, sugary, vesicular material. They should make serviceable stone for almost any purpose but are rather inaccessible.

The quarry is near the base of the Platteville as is shown by the presence up a small lateral ravine of an outcrop of Saint Peter sandstone about eight feet high and also of an outcrop of green shales, doubtless the Glenwood shale, a little farther up the ravine. The base of the quarry is at least fifteen feet below the top of the Saint Peter and there is evidently an unconformity of somewhat more than this amount between the two formations. The limestone belongs to the "Lower Buff" beds. Along the road on the ridge a mile or so to the northeast are green shales which belong to the succeeding assemblage of mixed shales and limestones.

The quarry of Peter Rude, in the center of section 17, Waterloo township, is opened in the upper two or three feet of the blue beds at the top of the Platteville. The layers are six to eight inches thick and are overlain by the green shales of the Decorah formation. These are the same beds as those shown in the lower Halloran quarry at Decorah, 200 feet lower.

In the southwest quarter of section 16, Post township, on the east side of the road is a cliff face 200 feet long whence considerable quantities of stone have been removed. The quarry is in the upper, nondolomitic beds of the Galena. It shows ten to twelve feet of beds which are in layers six to

*Iowa Geological Survey, Vol. IV, pp. 76-77.

twelve inches thick. Above them are six feet of broken stone and waste. The material appears to be quite hard and solid and should prove very serviceable for road work. It is very conveniently situated for use and could be removed without unusual difficulty.

The Cherry Valley quarry, in the southwest quarter of the northeast quarter of section 19, Franklin township, owned by Wm. Evans, shows ten feet of heavy bedded ledges which split into layers three to eight inches thick. They are light gray in color, finely granular and quite hard. Above them come four feet of thin bedded gray rock and overlying these are a few feet of waste.

About one-fourth mile to the west is the quarry of Seward Swenson. It is about fifteen feet higher than the Evans quarry and shows ten feet of rather heavy bedded blue ledges, firm and well bedded. The rock is harder than that found in the Evans quarry.

A little more than two miles north of Luana, at the turn of the road in the northeast quarter of section 32, Franklin, is a quarry which shows six feet of hard blue stone, fine-grained, in ledges three to nine inches thick. Heavy gray layers six feet thick overlie these beds and three feet of waste form the top of the exposure. This quarry, together with some about two miles south, near Luana, is somewhat similar to those in Cherry Valley. They all present clean, solid rock faces and are conveniently situated for installing crushers and removing stone. This is especially true of those near Luana, which are close by the roadside and high enough to allow the use of gravity.

Over the areas in this and neighboring counties where the Fort Atkinson, Galena-Platteville or Oneota are the surface rocks the geest is suitable for use on the roads, especially where it is mingled with chert from the limestone. If gravel or crushed rock were mixed with the geest it should make excellent road metal.

APPANOOSE COUNTY.

Sand and Gravel.

No sand or gravel is found along Chariton river. A small amount of sand of rather poor quality is obtained from Cooper creek north of Centerville, but nearly all material of this kind is shipped in from Des Moines river. Udell and Unionville obtain a portion of their supplies from Soap creek north and northwest of Unionville and from a tributary of Soap creek which joins it in the southeast quarter of section 29, Union township. The sand is somewhat dirty and carries a high percentage of fine material.

Almost no gravel is available in the county and the very limited supply of low grade sand is confined to the channels of the present streams. The older gravels are almost wholly concealed by the loess veneer, and no outcrops of commercial importance are known in the county.

Stone.

The Des Moines stage of the Upper Carboniferous underlies the whole of Appanose county, and consists of shales with several well defined limestone horizons of small thickness. The principal limestone beds are known as the "float rock," which varies from two to four feet in thickness; the "fifty-foot" limestone, ranging from four to ten feet; the "seventeen-foot limestone," or "little rock," running from one to three feet; the "cap rock," showing from two to four feet; and finally the "bottom rock," which attains a thickness of more than three feet. One or more of these beds are exposed at numerous points along the various steamways, and oftentimes are fairly accessible. All are essentially nonmagnesian, reasonably pure, and occur in moderately thick beds. They resist the weather as well as the average limestone, but on account of their limited occurrences, will never lead to the establishment of an important quarry industry. Some quarrying has been done in the vicinity of Centerville, Milledgeville, and Mystic, mainly from the "fifty-foot limestone."

The Chariton conglomerate has been exploited in a very small way in the vicinity of Moravia, but the openings have long since been abandoned, and promise nothing for the future.

A quarry producing crushed rock from the Des Moines horizon is now being operated by Mr. W. B. Swan at Plano.

AUDUBON COUNTY.

Sand and Gravel.

There is no gravel produced in commercial quantity in Audubon county. The sand and gravel used in the county are shipped in from Des Moines and vicinity, or from Platte river in Nebraska. A yellow stained gravel, somewhat clayey, is being shipped in at the present time from the Lanesboro pit northeast of Carroll.

BENTON COUNTY.

Sand and Gravel.

The gravel and sand deposits of Benton county are of two classes, viz., Buchanan gravels and sand bars in the channels of the streams. Beneath the Kansan drift the Aftonian gravels are occasionally found, but these are at too great a depth to be considered as an important source of this material.

Buchanan Gravels.—In connection with the Buchanan gravels in this county, Mr. T. E. Savage* says: "The gravels that appear in all of the known exposures of the county belong to what Professor Calvin has designated as the valley phase of this formation. (See Buchanan county report in this volume.) They consist of coarse sand and small water-worn pebbles, the latter seldom exceeding one and one-half inches in long diameter. Bowlders do not occur in these deposits. There is only a small amount of iron present, and a rusty color is not generally imparted to the beds. The materials of these gravel trains were derived from glacier-borne debris, and they came to rest along the courses of swollen streams whose waters were liberated by the rapid melting of the Kansan ice."

Beds of moderately fine gravel overlying the Kansan drift occur at several points in Benton county. This terrane is

*Iowa Geological Survey, Vol. XV, p. 206, 1905.

usually concealed beneath a deposit of fine-grained soil. In section 14, Benton township, a gravel deposit three and one-half feet in depth outcrops in the bank of a stream for a distance of several rods. Another bed of this water-laid material is exposed near the middle of section 19, Canton township, in the south bank of Wild Cat creek. At the latter place the deposit has a maximum thickness of twelve feet and can be seen continuously for more than a dozen rods. A few miles farther east, on Bear creek, a bed of gravel appears a short distance west of Shannon's brick and tile plant at Shellsburg. The latter is probably the continuation of the deposit on Wild Cat creek, mentioned above. Such beds are also exposed in sections 33, Taylor, and 35, Eldorado townships.

An area of several square miles in the south portion of Florence township is covered with this coarse material. Near the southwest corner of section 32 a pit three and one-half feet in depth has been opened on the north side of the wagon road. The presence of a gravel train is revealed in the banks of most of the streams in this portion of the township. West of the station of Walford this deposit has been utilized in the improvement of public roads. A bed of gravel four feet in depth has been worked near the southwest corner of section 10, St. Clair township.

Besides the terrace in Florence township mentioned above, these gravels appear beside the west river road one and one-half miles north of Vinton. The area of the terrace is a square mile or more, but the area of the gravel cannot be known without careful testing. The depth of the gravel and sand is four feet or more.

Stream Deposits.—Just below the bridge at Vinton, on public property, is a sand bar up to three feet deep and four or five acres in extent. Along the river here these bars will aggregate five to ten acres per mile. Another bar covering about one acre is located one-half mile east of the Ballenbaugh quarry in northeast Vinton. This bar varies in depth from four inches to a foot. The sand contains small quantities of fine gravel and is used locally for concrete and cement. Material for use in concrete bridges and culverts in the vicinity of Mount Au-

burn has been hauled from a bar on the farm of Frank Aungst, three and one-half miles north of Vinton.

Miscellaneous.—A short distance northwest of the town of Norway is an elongated paha ridge which rises to an elevation of about eighty feet above the surrounding plain. At the northwest end of this hill the drift is overlain by a bed of loose sand sixt to ten feet in depth. Passing toward the southeast the material becomes finer, so that the covering of all but the upper end of the paha is typical loess.

About a mile northeast of the town of Watkins there is a similar ridge having a trend in the same direction. Near its summit strongly oxidized bowlder clay with abundant gravel appears within two feet of the surface, while a mantle of loess, in places seven feet in depth, covers the lower portion of the slopes.

There is an abandoned river channel one-half to one mile in width extending in a southeasterly direction from the site of the old town of Benton City, on Cedar river below Vinton, to the southeast corner of Benton township. It meets the present channel of the river about one-half mile east of the Benton-Linn county border. This old valley is known locally as "Sand-Prairie." Beds of sand resembling river bars abound over the lowlands, and deposits of similar materials crown the summits of the bordering bluffs. Cedar river doubtless occupied this valley at one time.

Stone.

All of the outcrops of indurated rocks in the county belong to the Devonian. All of the important sections are found in the northeast third of the county, along Cedar river and its immediate tributaries. The best quarry rock belongs to the Coggan beds which are at the base of the Devonian series as exposed in Benton county. Good exposures of these beds are practically limited to Cedar, Harrison and Taylor townships where they have been exploited at a number of points. The rock is essentially a highly magnesian limestone, very hard and fine-grained and yellowish in color, imperfectly bedded and non-fossiliferous. These dolomitic beds outcrop low in the bluffs and are overlain by brecciated limestone belonging to the Fay-

ette substage. Near the southwest corner of section 31, Harrison township, a representative exposure may be seen. The quarry operated by Aungst Brothers is in the west bluff of Cedar river and shows the following beds below the drift:

		FEET.
2.	Limestone, brecciated, gray; the angular fragments usually small and very fine-grained in texture, nonfossiliferous....	20
1.	Limestone, buff, magnesian, massive ledge which is fine-grained, imperfectly separated into layers one to two feet in thickness, nonfossiliferous	12

Similar exposures are to be found in section 36, Cedar township, and section 6, Taylor township. The beds have been quarried at both places. The brecciated beds have been developed at several points in addition to those just mentioned, notably on the south bank of Prairie creek, near the northeast corner of section 10, Taylor township, where the following succession of beds may be studied:

		FEET.
6.	Soil and drift of variable thickness.....	
5.	Limestone, shattered, light gray, fragments irregular in size and shape	8
4.	Talus slope	12
3.	Limestone, light gray, in broken layers from three to six or seven inches in thickness	1⅔
2.	Limestone, gray, made up of imperfect layers two to eight inches in thickness.....	4
1.	Limestone, light gray, a rather massive bed which is cut by numerous oblique joints into rhomboidal blocks, some of which are slickensided; material weathers readily into small, irregular fragments.....	8

Some years ago the above quarry was operated by the Iowa Paint Company of Vinton. Number 1 was pulverized and used as a basis in the manufacture of paint. The company has since moved its plant to Fort Dodge, Iowa. In Benton county, as elsewhere, the brecciated stone is imperfectly bedded and only rough, irregular blocks can be obtained. It is suitable only for rough masonry and crushed stone purposes.

A large percentage of the stone produced in the county comes from the beds of the Cedar Valley stage. While the grade of stone furnished by these beds is not equal to the stone lower in the series it is suitable for foundations for ordinary buildings,

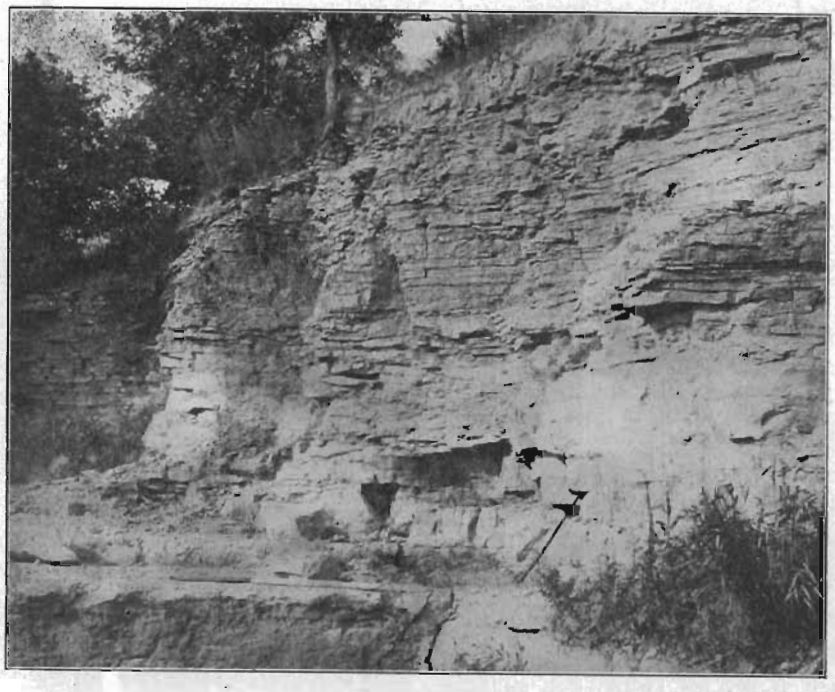


FIG. 1—Long's quarry in the east bank of Cedar river, Section 4, Harrison township, Benton county.

for walling up dug wells and for retaining walls. The stone has been used to some extent for bridge work with fair results. Near the county line a quarry has been opened a short distance below the bridge and near the northwest corner of section 6, Harrison township. The layers exposed are as follows:

		FEET.
12.	Dark colored, fine-grained, pebbleless soil	1
11.	Bed of reddish brown clay, containing numerous pebbles of quartz and greenstone with occasional granite bowlders of larger size	2
10.	Layer of much decayed fragments of brown limestone; without fossils	3
9.	Bed composed of two layers of yellow, earthy limestone, each about eight inches in thickness, fine-grained and without fossils	1⅓
8.	Bed of gray limestone which weathers into thin layers about one inch in thickness; without fossils	3
7.	Layer of very hard, earthy limestone, yellow in color and fine-grained in texture; fossils wanting	⅚

		FEET.
6.	Bed made up of layers of buff, earthy limestone two to six inches in thickness, which are fine-grained in texture and nonfossiliferous	3½
5.	Layer of yellow, impure limestone which weathers into indistinct layers three to six inches in thickness; without fossils	1½
4.	Layer similar to number 5 above	2
3.	Yellowish brown layer of fine-grained, impure limestone; carrying occasional concretions of chert which are most numerous adjacent to the division planes	2½
2.	Layer of variable, impure limestone, fine-grained and very hard. Near the base of this layer chert nodules are abundant	2
1.	Bed made up of two layers of buff, earthy limestone in which, at irregular intervals, occur bands and numerous masses of chert; without fossils; to base of the exposure which is about four feet above the level of the water	4

The layers in this quarry are cut by numerous, oblique joints which divide the ledge into large rhombic masses. The material of which the beds are composed is mostly a fine-grained, earthy limestone. Many of the layers are strongly magnesian, and some of them are so thoroughly dolomitic that they respond but slightly to the application of cold hydrochloric acid. The entire ledge is regularly bedded, and furnishes quarry stone of convenient dimensions and durable quality.

Similar sections may be seen down the river, and quarries have been opened at several points on both sides of the stream. Near the northwest corner of section 27, Taylor township, a quarry has been opened in the east bank of Mud creek. The beds exposed are as follows:

VINTON SECTION.

		FEET.
10.	Soil, dark colored, fine-grained and without pebbles	½
9.	Gravel and sand stained a reddish brown color	2
8.	Limestone, composed almost wholly of coral fragments	5
7.	Limestone, hard, gray, weathers into thin pieces, crinoidal.	3
6.	Limestone, light gray, very hard, weathers into layers ranging from four inches to a foot in thickness	6
5.	Limestone, gray, very hard, composed largely of brachiopod fragments	1⅓
4.	Limestone, similar to 5, but finer textured	1¼
3.	Limestone, drab, similar to number 8, but less compact	1
2.	Limestone, white, fine-grained; shows a bluish tinge in a fresh ledge, cherty, much shattered and weathering into thin layers	2
1.	Limestone, very hard, cherty and crinoidal	1½

The lower two numbers are supposed to belong to the brecciated stage and are equivalent to number 1 in the old quarry of the Iowa Paint Company. In the above section they are hard and the most durable stone that the quarry produces. It is used extensively in Vinton. In addition to the lower beds, numbers 4 to 7 furnish an acceptable material for foundations and the rougher grades of masonry.

Numerous small quarries have been opened from time to time in the vicinity of Vinton. Over considerable areas the stripping is not great and almost the entire section could be used for road and concrete work.

On the south bank of Bear creek near the middle line of section 14, Canton township, a quarry shows the following beds which may be considered representative for this part of the county.

SHELLSBURG SECTION.

		FEET.
9.	Soil, dark gray, without pebbles or bowlders	1½
8.	Drift	2
7.	Limestone, much decayed	3
6.	Limestone, coralline	2½
5.	Limestone, light gray, weathers into chipstone	1¼
4.	Limestone, gray, hard, in places forms a single ledge, fossiliferous	4
3.	Limestone, dark gray, two ledges of about equal thickness	3½
2.	Limestone, similar to 3, but shelly	1
1.	Limestone, in three layers	4½

East of north of the Shellsburg quarry on Cedar river, Wild Cat bluff presents an escarpment of more than forty feet of limestone. Nothing especially new is developed however.

Away from the river, westward, quarries have been opened on section 8 in Cedar township, and section 28 in Jackson township, near Garrison. The latter is the more representative and is given below.

GARRISON SECTION.

		FEET.
9.	Soil and drift	5
8.	Limestone, light gray, subcrystalline, very hard, and somewhat brecciated, containing numerous spherical stromatoporoids	3
7.	Limestone, gray, massive, dense, composed largely of various species of stromatoporoids and masses of Idiostroma-like stems, few of which can be recognized. This bed is also somewhat brecciated in places	6

		FEET.
6.	Limestone, hard, gray, weathers into two indistinct layers, and contains masses of spherical stromatoporoids.....	3½
5.	Limestone, very hard, white, subcrystalline; without fossils	1½
4.	Limestone, yellowish gray, nonfossiliferous, fine-grained and very hard. The upper portion bears numerous small cavities, the largest of which are nearly one inch in diameter	4
3.	Limestone, dense, gray, fine-grained and very resistant to weathering; without fossils.....	3¼
2.	Limestone, composed of several layers, very hard, fine-grained, white in color and without fossils. The layers are six to fifteen inches in thickness.....	5½
1.	Limestone, bed made up of two layers, yellowish brown. The material is fine-grained, and contains no fossils.....	3½

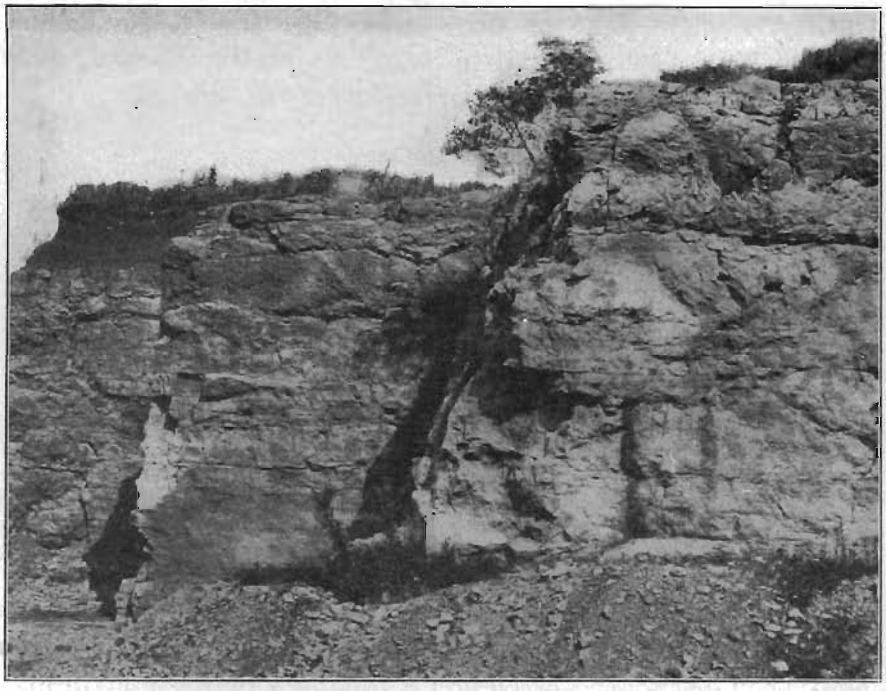


FIG. 2—Abandoned quarry on Hinkle creek near Garrison, Benton county.

The upper and middle beds in the above section more closely resemble the beds of the Cedar Valley stage as developed in other counties, notably, Johnson county to the south, and Mitchell, Floyd and Cerro Gordo, to the north. While an abundance of stone crops are available, and numerous quarries have been opened in times gone by, none of the quarries now in op-

eration are of more than local importance as no stone is exported.

BLACK HAWK COUNTY.

Sand and Gravel.

Black Hawk county is plentifully supplied with sand and gravel. The Buchanan gravels are to be found over practically the whole county, and are abundant in the vicinity of Cedar Falls.

Large quantities of sand suitable for mortar are found in the various streams.

Buchanan Gravels.—In every township in the county one or both phases of the Buchanan gravels may be found. (See Buchanan county report.) Some of these are very thin and show little stain or other evidence of weathering, but their position makes their relationship quite certain.

Along the banks of Dry run and its branches are numerous extensive deposits of these gravels. At Olsen's quarry the upland phase has a thickness of ten feet. The lower part is less ferruginous and is interstratified with layers of fine sand. The

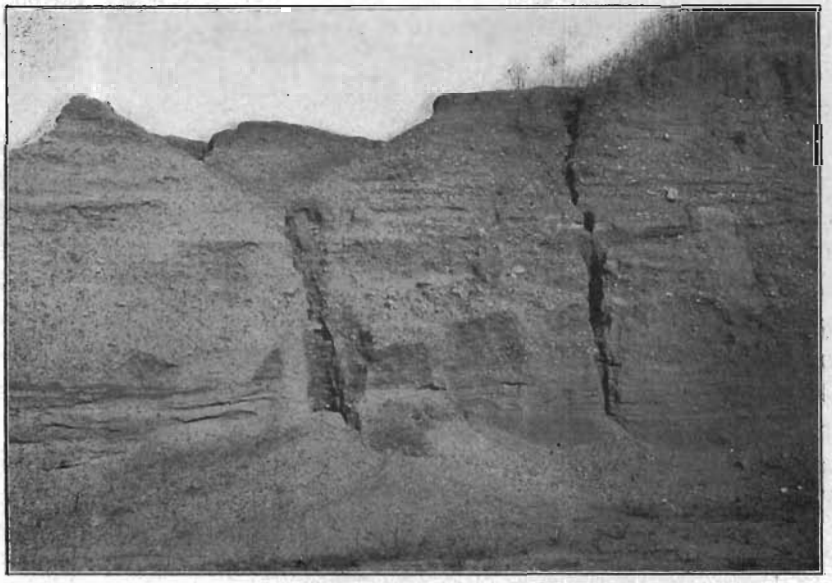


Fig. 3—Buchanan gravel east of Teachers College, Cedar Falls, Black Hawk county.

upper layers are highly ferruginous. At Carpenter's quarry the gravel is much thinner and lighter in color, but is more uniformly coarse.

On the east side of the creek one-half mile east of the Teachers' College is the most extensive deposit observed in the county. It is of the valley phase, and is very uniform in size of particles. The material is a fine gravel or coarse sand of a yellowish color and very distinctly stratified except in the upper part. It is twenty feet or more in thickness and many acres in extent. In fact, in this neighborhood the whole valley of the main stream is more or less filled with this material. In one place the gravel is a very dark red-brown and cemented into ledgelike sheets; in another it consists of pebbles and cobblestones of chert, jasper and other forms of quartz, greenstone, etc., all deeply stained with iron. For the most part the gravels are of a rather sandy nature.

On the interurban line of the Waterloo and Cedar Falls Rapid Transit Company, where it cuts into the bluff, is a deposit ten feet thick containing pebbles and cobblestones, rotten granite, iron concretions and cemented gravel, all deeply iron-stained. Spheroidal, lenticular and tabular bodies of sand are not unusual in this section. This deposit is interesting for the variations occurring within short distances, both in vertical and lateral extension.

The Cedar Falls Sand and Materials Company has a pit on the east side of the river. At this place about a square mile is practically all Buchanan gravel under a cover of soil varying in depth up to two feet. It has been worked to a depth of twenty feet and still shows good material below. Of this, about twelve feet are below the level of ground water. The sand and gravel are decidedly stratified and variable, and in most places observed the former is predominant. A steam dredge operated by Mr. P. M. Smith, a short distance east of this pit, has opened the gravel to a depth of twenty-five feet, the lower fifteen feet of which are below water.

One-half mile northeast of Voorhies, in Lincoln township, where the road crosses a small creek, Buchanan gravel appears under two and one-half feet of Iowan drift. Similar conditions

exist over the great Iowan plain between Cedar and Wapsipinicon rivers. The most characteristic occurrences are perhaps in Barclay and Bennington townships, and in the west half of Fox.

Stream Deposits.—The city of Cedar Falls obtains its supply of gravel from the bed of Dry run a few rods south of the wagon bridge near Fourteenth street. Here the gravel is coarse, ranging in diameter from three-fourths to one inch, and is several acres in extent. The depth of the pit is about six feet, which is probably greater than the average depth of gravel over the entire area.

After a freshet, sand may be found along the bed of Crane creek from Dunkerton eastward. These temporary bars will average one to two acres per mile. On the Wapsipinicon east of Dunkerton bars of sand and occasional bars of fine gravel aggregate two to five acres per mile. Much of this contains silt and produces weeds unless removed soon after deposition.

The larger valleys have been flooded at seasons of high water ever since they assumed their present character. Each overflow leaves its increment of sediment usually a fine silt. Sand is the most abundant material of these valleys, but coarser sands and gravels are variously mingled in places where stronger currents have run over the plains. Also shifting stream beds have left coarse materials in considerable quantities here and there.

Low terraces occasionally appear along the margins of the valley, but nowhere are they a noticeable feature of the topography.

Knoll Gravel.—In section 31, Bennington township, is a small pit in a knoll about one-half acre in extent. Similar deposits occur sparingly in other parts of the Iowan area.

Stone.

With a single exception all of the indurated rocks which appear at the surface in the county may be referred to the Cedar Valley stage of the Devonian. A very insignificant natural exposure of Wapsipinicon beds, according to Arey, appears along

Spring creek, on the northwest quarter of section 13 in Fox township. It is of no importance from an economic view point. The Cedar Valley limestone presents numerous outcrops along the principal drainage lines, and quarries have been opened at many points. None are of large capacity and but few are ambitious to supply more than their own immediate localities. The principal quarry districts are in the vicinity of Cedar Falls, Waterloo and Laporte, while some quarries of secondary importance near Raymond, and two quarries about three miles east of Eagle post office supply the country trade.

For the Cedar Falls district the Nielson quarry may be taken as a type. It is located west of Main street about one-eighth mile west of the old Carpenter quarry. The principal beds exposed are as follows:

		FEET.
15.	Limestone, firm, yellowish, with intermingled "geest"....	3
14.	Limestone, lithographic, somewhat nodular, more or less weathered and inconstant.....	2
13.	Shale, yellowish clay, with interbedded hard ledges in places, very variable in thickness, averaging.....	1⅓
12.	Limestone in three layers, finely laminated, fine-grained and smooth, slightly iron-stained, 6, 2 and 10 inches respectively from top down.....	1½
11.	Limestone, variable, sometimes splitting easily into layers, sometimes firm and even textured, finely subcrystalline, with earthy streaks, rusty in patches, crystals in pockets and calcitic sheets intersecting one another, making pitlike areas along the joint planes, averaging.....	1
10.	Limestone, fine-grained, bluish gray, with occasional patches of crystals, quarried in sheets, and used for window and door sills and caps, and ashlar.....	⅝
9.	Bluish gray stone of good quality, grading into a shaly parting below.....	½
8.	Limestone, gray, finely brecciated, with seams of crystals below, upper part yellowish, earthy. If quarried in cold weather, it is reduced to fragments readily, but, if dried out before freezing, it makes a durable stone.....	¾
7.	Limestone, firm, fine-grained, bluish gray, with occasional pockets of crystals, in two layers. Makes an excellent range stone. The lower layers yield fine large flags.....	1
6.	Limestone, uniformly fine-grained, yielding flags.....	7/12
5.	Limestone, heavy bedded, shelly on the under side, abounding in crystals, bluish gray.....	1⅓
4.	Limestone, fine-grained, more or less streaked or banded..	1⅔
3.	Limestone, light colored, becoming still lighter in color below, often weathers in a remarkable way, yet makes a durable stone, when it has been dried out.....	1½
2.	Limestone, yellowish, full of pockets.....	1
1.	Soft, chalky stone, exposed.	

Numbers 1 and 2 are no longer worked.

North and northwest of Cedar Falls, there are no important rock exposures. Limestone outcrops at numerous points on both sides of the Cedar river and doubtless good material for crushed stone purposes might be developed at small expense.

North and northwest of Waterloo, quarries have been opened in the well marked stone-supported terrace which faces the Cedar river. The most important section may be seen in the quarry of the Waterloo Stone Company, which is located on the northwest quarter of section 14, township 89 north, range XIII west. The beds worked at this point are as follows:

WATERLOO STONE COMPANY'S QUARRY.

		FEET.
8.	Detritus and wash	6
7.	Limestone, hard, dolomitic, subcrystalline	1
6.	Limestone, weathered, yellow	1
5.	Limestone, heavy bedded, gray-blue, cherty toward the top.	12
4.	Limestone, blue, thinly bedded, slightly argillaceous	3
3.	Limestone, buff, concretionary, with numerous cherts	3
2.	Limestone, gray-blue, subcrystalline, cherty, weathers buff.	3
	Shale parting	1/3
1.	Limestone, buff to yellow, exposed	2

All of the beds tend to weather into thin layers and weathered surfaces present a decidedly shattered appearance. Number 3 appears to break down especially easily when subjected to repeated freezings and thawings. The cherts are small and more or less irregularly distributed throughout the entire mass. The joints are stained a brownish yellow and all of the quarry rock tends to weather the same color on long exposure.

Two samples of the rock from the McWilliams-Mowry quarry were analyzed and found to be strongly magnesian. The analyses were as follows:

	1	2
Insoluble	1.92	.....
Iron and alumina	4.20	.....
Calcium carbonate	63.59	.....
Magnesium carbonate	30.92	12.18
Sulphur	Trace	.....

Number 1. Blue unweathered limestone.
Number 2. Yellow limestone.

In Laporte and vicinity a large number of quarries have been opened and operated intermittently for many years. The product is sold and was formerly reported in the mineral statistics as "Laporte Sandstone" on account of its sugary or subcrystalline character.

A quarry located along the wagon road about one-half mile northwest of town will serve as a type for the district. The beds exposed are given herewith:

		FEET.
4.	Drift and soil; some of the quarries in the near vicinity show a much thicker overburden	2+
3.	Limestone, considerably shattered; stained yellow to brownish yellow; bedding planes disappear upward	10
2.	Limestone, brownish yellow to buff, irregularly bedded, quartz geodes and chert nodules present	2
1.	Limestone, gray-blue, presents a granular appearance; in medium heavy beds ranging from 15 to 24 inches; joints weathered a yellowish brown, fossiliferous; calcite balls and geodes common	10

The beds dip to the southwest at an angle of about five degrees and appear to thicken down the dip. They appear to be strongly magnesian, especially the lower beds, which are subcrystalline.

Quarries have been opened on either side of the Eagle-Big Creek township line near the middle. The quarry west of the line is the more extensive and is as follows according to Arey:

EAGLE TOWNSHIP QUARRY.

		FEET.
13.	Limestone, thin-bedded, broken stone	7
12.	Limestone, in two layers, blue where unweathered	4½
11.	Limestone, in three layers, hard, compact, good quality, durable, brittle, having conchoidal fracture, with drab nodules of varying sizes, and in the upper part with stromatoporoid masses thoroughly coalescent with the rest of the rock	5
10.	Limestone, bluish, earthy, much jointed and irregularly bedded	3
9.	Limestone, dark, drab, calcitic at top	1½
8.	Limestone, blue, buff where exposed, calcite plentiful, in seven or eight layers	1′/₀
7.	Limestone, drab	¾
6.	Limestone, buff, earthy, finely streaked with yellow lines	2′/₀
5.	Shaly partings with very wavy lines of contact above and below	¼
4.	Limestone, hard, brittle, drab, middle portion developing layers	3′/₀

		FEET.
3.	Limestone, blue, of good quality, firm, finely crystalline, with pockets of crystals, thickness not taken.....	
2.	Limestone, gray, finely subcrystalline, yielding good flags..	½
1.	Limestone, gray, somewhat crystalline, fracture coarsely conchoidal, of good quality.....	2½

This quarry and its double east of the township line supply the southwestern portion of the county with foundation stone. Quarries have also been opened in the vicinity of Raymond. Their chief interest comes from the fact that this is one of the classic sections in the correlation of the Devonian deposits in Iowa and not on account of its economic importance. The quarries have been little worked for many years and the sections are much obscured.

The Lowell quarry located about the middle of section 5, Union township, near the village of Finchford, shows the following section:

UNION TOWNSHIP QUARRY.

		FEET.
4.	Soil and drift	1
3.	Limestone, much broken into chips which are hard and firm	2
2.	Limestone, mottled bluish and yellow; hard, fracture uneven; carries crystalline calcite.....	3
1.	Limestone, brownish gray, conchoidal fracture; slightly lithographic; exposed.....	2

The quarry floor is about ten to fifteen feet above the water level. Several acres are available here under comparatively light stripping. Other limestone outcrops occur in Finchford.

An old quarry south of Winslow near Newell lake furnished stone used for riprap work just above Washington and Union bridge. The section was obscured by talus when visited. In all of these outcrops the beds as a whole furnish a fair grade of material for crushed stone purposes.

BOONE COUNTY.

Sand and Gravel.

Boone county has sand and gravel deposits of two kinds, terraces along and beds in the channels of the present streams, and pockets in the Wisconsin drift hills.

STREAM GRAVELS. Terraces.—There are two or more terraces visible along Des Moines river. From the lower one of these at Moingona the Chicago and North Western Railway has removed enormous quantities of material. These gravels belong to the valley train of the Wisconsin ice. They usually carry from two to five feet of stripping and are rather dirty for concrete work.

Just north of its new viaduct in section 34 of Douglas township, the Chicago, Milwaukee & St. Paul Railway has opened a pit in a terrace some seventy feet above the river. Up to twenty feet of gravel has been developed here. The terrace has an area of fifty acres or more. Gravel from this pit is being used on the streets of Madrid. The same terrace is being worked near Fraser.

A gravel terrace twenty to twenty-five feet above water may be followed along Beaver creek from the Dallas county line to Beaver and beyond. The materials of this terrace, which has been opened in many places, consist of sand and gravel in varying proportions. In places these are interbedded, in others cross-bedded, and in still others piled in with no signs of classification whatever. Gravel is now being taken from various places in this terrace, among which may be mentioned a pit in the southwest quarter of section 10, and the northeast quarter of section 4, Union township, in the northern portion of section 4, Beaver township, and in southeast section 31, Amaqua township. In the first named pit up to six feet of cross- and interbedded materials are exposed under two or three feet of cover. The town of Berkley obtains its supply from section 4 of Union township, and the pit last named above supplies the town of Beaver.

Channel Deposits.—Although the deposits are not continuous throughout the county, the channel of Des Moines river is choked with gravel and sand in many places. At Fraser immense quantities are being removed for local use and to supply the needs of neighboring towns. The river has deposited large amounts along its course west of Boone, but the high steep hills bordering the river make its distribution costly. These channel gravels are, on the whole, cleaner and more desirable than the

terrace materials, and in many places excellent opportunities for their recovery by pumping are offered.

GLACIAL DEPOSITS.—Boone county lies entirely within the area covered by the Wisconsin drift, and its surface exhibits the characteristic topography of the youngest drift sheet. Many of the hills and hummocks of this drift sheet contain gravel and sand, sometimes as a sheet capping the clay, and again as lenses or pockets within the drift. The most important of the deposits of this kind is Pilot Mound, near the town of the same name. The Minneapolis & St. Louis Railroad has operated a pit here for some years, the product being used for ballast. The local demand for road and concrete materials is also supplied from this pit.

BREMER COUNTY.

Sand and Gravel.

Most of the deposits of gravel found in Bremer county belong to the Buchanan stage, which immediately followed the Kansan ice invasion.

Professor Calvin has recognized two types of these gravels (see Buchanan county report)—an upland phase of outwash composed of sand and gravel, much of the latter material being in an advanced stage of decomposition, and a valley phase of quartzose sand and gravel. This latter phase forms gravel trains and the remains usually appear as stream terraces.

In some parts of the county river bars form important sources of supply.

Valley Phase.—The quartzose gravels found in the wide valleys of the Cedar, Wapsipinicon, Crane creek and other streams are undoubtedly continuations of valley trains which in other counties have been called by Calvin the valley phase of the Buchanan gravels.

Stream terraces of the Cedar are extensively utilized for their contents at Waverly and vicinity and a number of pits have been opened. Just south of Waverly on the west side of the river, Mr. A. L. Woodruff has five acres of terrace which shows the following section:

	FEET.
Soil (with lenses of fine sand)	2–5
Gravel	14+

This gravel is stratified and cross-bedded, and two-thirds of it will not pass a one-eighth inch screen. Only five feet of the gravel are above water and this is slightly coarser than the material below. Mr. J. H. Russell owns two acres of this terrace adjoining Mr. Woodruff on the west. Directly across the river there are eight acres of terrace similar to this, except that the gravel is somewhat coarser.

Other good deposits of gravel are found in the neighborhood. The Eureka Cement Tile Company owns five acres of gravel terrace at Janesville. Numerous other localities along Cedar river have gravel terraces but little or no use has been made of them as yet.

Concrete material is obtained from a pit on P. C. Griffin's land along the East Wapsipinicon four miles east of Frederika. Several acres containing three to four feet of gravel under as much soil are known in this vicinity. The city of Tripoli has a pit along this river about one and one-half miles north of the town.

Small amounts of gravel and sand are produced from benches along Buck and Crane creeks.. Mr. Fred Stalhut has two acres of terrace about three miles west of Sumner. Here there are six feet of gravel of varying fineness under two or three feet of soil.

Upland Phase.—Deposits of the upland phase of the Buchanan gravels are found in different parts of the county, and in many places form valuable deposits. One worthy of mention is on the top of a hill in the southern part of section 14 of La Fayette township. Six feet of iron-stained gravel appear beneath one and one-half feet of soil. All the pebbles are small and the granites are thoroughly decayed. Clay till is interbedded in the gravel at one place. A few other deposits of importance are located in sections 11 and 36 of La Fayette township, 18 of Polk, and in the vicinity of Readlyn and Artesian.

Reworked Materials.—Sand and gravel bars occur along most of the streams and a considerable amount of material is pro-

duced annually from this source. These deposits are more or less transient, and many of them are quickly exhausted, although new ones are formed and readily found. Bremer county owns five acres in Cedar river near Plainfield.

STONE.

The Niagaran limestone is known to appear at the surface at but few points in Bremer county. The most important section appears along Baskin creek in the southeast quarter of section 17, range XIII west, township 91 north. The beds which may be seen in this quarter are as follows:

		FEET.
3.	Limestone, brecciated; composed of sharp angular fragments of a drab, laminated limestone of lithographic fineness of grain, in a gray matrix	1
2.	Sandstone, filled with small angular fragments of white chert, in two or three layers, apparently conformable with 1	½
1.	Dolomite, light buff, subcrystalline, vesicular, with cavities up to eight inches in diameter; in heavy, irregular, rough-faced beds up to two feet thick	13

The lower beds were quarried formerly and used in the manufacture of lime of excellent quality.

Similar, but less extensive sections occur in section 20 of the same township and in section 36 in Douglass township, three and one-half miles west of Tripoli. An analysis of the last mentioned occurrence shows its true dolomitic character, and is given below:

Silica	1.53
Iron oxide	0.48
Calcium carbonate	54.32
Magnesium carbonate	43.41
Combined water	0.26

None of the outcrops mentioned have been utilized to any extent commercially. All are located remote from towns and railways and notwithstanding their excellent quality for lime, and the fact that but little stripping is required, it is not probable that they will be important in the quarry industry for some time to come.

The Wapsipinicon and Cedar Valley stages are well represented in Bremer county. Beds of the latter age are supposed to occur immediately beneath the drift over more than five-

sixths of the county while known outcrops of the former are limited to points along Cedar river from Janesville to Waverly, and along Quarter Section run and Baskin creek southeast of Waverly. The best section available appears in the southeast quarter of the southwest quarter of section 20, township 91 north, range XIII west. The beds exposed are as follows:

		FEET.
6.	Limestone, massive, in one undivided layer weathering to scoriaceous surface in places and in other places to smooth surface. Color mottled, prevailingly a light brownish drab, weathering to lighter gray, slightly vesicular, fracture uneven	4
5.	Limestone of same facies as above in layers of about eight inches	2
4.	Concealed	15
3.	Limestone similar to Nos. 5 and 6, but in separable laminæ	1
2.	Cherty sandstone; in layers from four to six inches thick, chert fragments angular, small, those of an inch and one-half being rare, and sand fine, of moderately well rounded grains of clear quartz and of minute, angular grains of cryptocrystalline silica, cement calcareous. Not seen in place but scattered in slabs over a slope of	5
1.	Niagaran limestone, exposed a few rods down stream	8

The Wapsipinicon beds are not worked to any noteworthy extent at the present time. The Cedar Valley on the other hand is being or has recently been quarried at four leading localities, Janesville, Waverly, Frederika and along Cedar river north of Plainfield. With a single exception the individual quarry output is small. The sections given below will afford a fair idea of the potential wealth of the county in structural materials. The beds developed in Mores' quarry located on the left bank of the Cedar in the town of Waverly are as follows:

MORES' QUARRY SECTION, WAVERLY.

		FEET.
3.	Limestone, yellow, fine-grained; nonfossiliferous so far as observed, heavily bedded, crossed with close diagonal joints containing numerous geodic cavities up to six inches in diameter lined with dogtooth spar, and concretionary balls marked with reddish concentric ferruginous stains	10
2.	Limestone, yellow, argillaceous, weathering above to calcareous plates one-half inch and upwards in thickness; below more massive, weathering to irregular chipstone, geodiferous, sparingly fossiliferous	8
1.	Limestone, yellow, hard, tough layers up to four feet thick, fossiliferous; to flood plain of river	10

Extensive cuts along the Chicago Great Western railway one-half mile east of the station, show a yellow, profoundly

decayed limestone. Underneath is a soft, buff, massive limestone containing numerous geodes. It is strongly dolomitic.

The Cedar River Stone Company, formerly the largest operator in the county, has gone out of business. The plant was located on Cedar river one and one-half miles southeast of Waverly and was connected with the Chicago Great Western railway by a short spur. The quarry pit and hillside show the following beds:

		FEET.
5.	Stripping, limestone, light gray, soft, broken by the weather into layers from 2 to 4 inches thick, fossils rare	9
4.	Limestone, dense, hard, tough, yellow-gray, lowest layers about 3 inches thick, divided by diagonal joints and bedding planes into rhombic blocks 1 to 4 feet in diameter. Occasional geodic cavities an inch or so in diameter lined with drusy calcite are present; fossiliferous	25
3.	Concealed	12
2.	Breccia of Wapsipinicon stage, hard and dense	5
1.	Concealed to water's edge	3

The quarry was developed to a depth of about thirty feet. The stone presents a clean, subconchoidal fracture, is almost impervious and carries but little clay. It is considerably fissured, the openings are often large and filled with a clay of putty-like consistency of gray to gray-blue color when freshly exposed but iron-stained where weathered. The quarry drains directly into the river. At present there is but little stripping, the removal of which is done by hand. The quarry is ideally located for the installation of a hydraulic plant for removing the overburden. Practically the entire product of the quarry consisted of crushed stone of excellent quality.

North of Waverly the limestone outcrops at numerous points on both sides of the river to the north county line. On the southwest quarter of section 16 in La Fayette township the following beds may be made out:

		FEET.
3.	Limestone, light brown, weathering to drab, hard, ringing, unfossiliferous, laminated to plates one-half inch thick	8
2.	Limestone, magnesian, soft, buff	10
1.	Unexposed to flood plain of river	5

North of Plainfield, several small quarries have been opened. Seven feet of buff, compact, magnesian limestone, in layers from

six to ten inches thick, and containing irregular concretions, have been quarried. The beds are thin and argillaceous for a few inches at the top.

East of Cedar river and the immediate vicinity the country rock is deeply covered with drift and the only exposures of the indurated beds are in the immediate neighborhood of Frederika along Wapsipinicon river, and a limited outcrop of Niagaran limestone west of Tripoli.

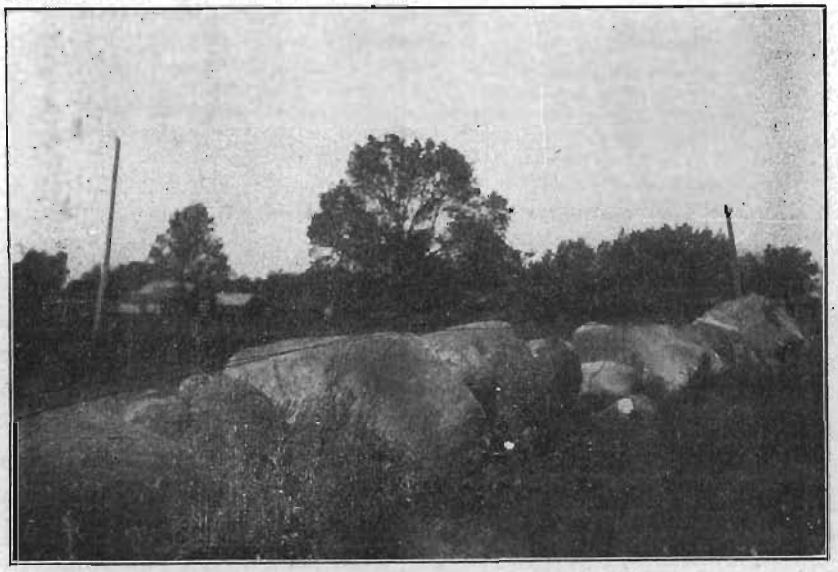


FIG. 4—Iowan bowlder fence near Horton, Bremer county.

At Frederika the drift covering is comparatively thin and the limestone bears evidence of considerable superficial weathering in the enlarged joints and limestone residuum. The Brodie quarry facing the Wapsipinicon is a fair average for the district. The following beds may be observed:

		FEET.
3.	Limestone, yellow, shattered by the weather to coarse rhombic chipstone	9
2.	Limestone, hard, yellow, magnesian, in heavy courses up to three feet thick, not laminated; bedding planes quite even and regular, geodes up to six and eight inches in diameter not uncommon	6
1.	Limestone, bluish weathering to buff; hard, ringing, subconchoidal fracture, in two layers, the lower being one foot and the upper two feet thick. Sparingly fossiliferous	3

BUCHANAN COUNTY.

Sand and Gravel.

All the sand and gravel deposits of Buchanan county are those laid down at the time of the retreat of the Kansan ice. These deposits were first studied and identified as a definite horizon by Professor Samuel Calvin, who worked in this region prior to 1897, and by him were given the name of the county. The characterization of these beds and the theory of their origin, as given here, are taken from that author's reports on Buchanan* and Howard** counties.

Characteristics of the Buchanan.—In the latitude of Buchanan county the disappearance of the Kansan ice was attended by strong currents of water flowing away from the ice margin. These currents were loaded with glacial debris including fragments ranging from fine silt to bowlders a foot or more in diameter. The course of the currents was marked by deposits of sand and gravel more or less sorted and stratified, and not infrequently cross-bedded on an extensive scale.

The Buchanan gravel presents two phases, an upland phase in which the materials are relatively coarse, and a valley phase composed largely of sand and fine gravel. Bowlders ranging to more than a foot in diameter are not uncommon in the upland deposits; pebbles more than an inch in diameter would rank among the unusually large constituent fragments in the lowland phase. The upland gravels are distinguished by the presence of coarser and less perfectly assorted materials. Cobbles and bowlders of all sizes up to ten or twelve inches in diameter are found indifferently mixed with pebbles and fine sand, and many of the larger erratics show glacial planing and striation on one or more sides. While the gravels have all the characteristics of deposits made in flowing water it is certain that the planed and striated cobbles have not been rolled or transported very far. The valley gravels, on the other hand, are quite uniform as to the size of the pebbles. It is seldom that any of the material exceeds three-fourths of an inch in diameter. The usual size is about half an inch, and the great

*Iowa Geological Survey, Vol. VIII, p. 203.
**Opus cit, Vol. XIII, p. 23.

body of the valley phase is composed of well-rounded, polished, siliceous pebbles. Cross-bedding is more common in the upland than in the valley gravels.

One of the principal characteristics of the Buchanan gravels is the distinct evidence of age. They are almost invariably much iron-stained and decayed, the granites in particular being disintegrated so completely as to be readily crushed in the hands. This feature is more distinctly noticeable in the upland than in the valley phase, probably due to the fact that these were long exposed to the weather before the drift which now covers them was deposited. The valley gravels were covered soon after deposition by a layer of silt, and the action of weathering agencies thus retarded.

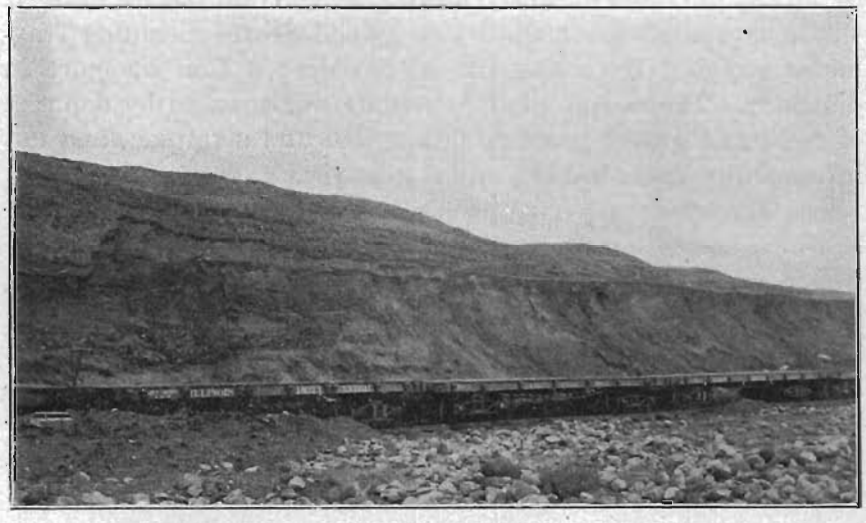


FIG. 5—Buchanan gravels, Illinois Central Railway pit east of Independence, Buchanan county.

The type exposure of Buchanan gravel occurs at the gravel pit of the Illinois Central Railroad in the northwest quarter of section 32, Byron township. Here the deposit is about twenty feet in thickness. It consists of stratified, often cross-bedded, sand and gravel with many bowlders, six, eight, ten or twelve inches in diameter. A very large proportion of the bowlders show unabraded glacial-planed surfaces which would indicate that if they had been transported by current action for any

considerable distance they were not rolled, but probably had been carried by floating ice. In some parts of the pit the gravels are very ferruginous and weather stained. Many of the granite bowlders are completely decayed and crumble to sand on the application of very slight force.

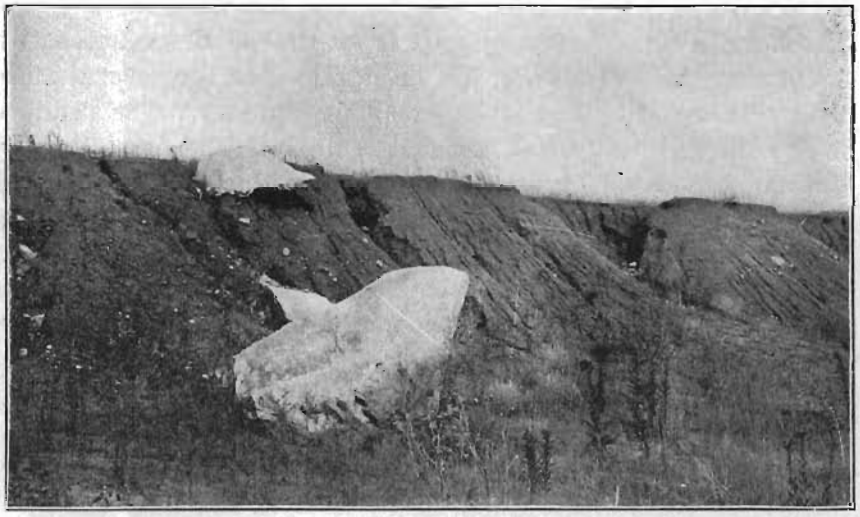


FIG. 6—An abandoned part of Illinois Central gravel pit showing Iowan bowlders, east of Independence.

There are a number of localities near Independence at which sands and gravels are found. Just north of the Illinois Central stock yards a bed of light yellow, rather fine gravel six feet thick is exposed along the river bank and this is shown to extend for some distance up the stream. Up Harter creek these gravels show in several natural exposures. They are all quite fine, none of the material exceeding one-half inch in diameter. Within a mile, however, coarser material enters and bowlderets up to six, eight and even twelve inches become common, with a large number of pebbles of two to four inches in diameter. The gravels are discernible as far up the stream as this has any valley, until it grades into the prairies of the uplands. They extend in most cases up to the grass roots.

On the summit of a hill about a mile east of Independence in section 2, township 88 north, range IX west, there is found a

capping of reddish yellow ferruginous gravels which are darker than those described above. This lower coarse bed is overlain by fine cross-bedded sands and above these is another coarser and darker layer. Above this are two feet of sandy Iowan till. This deposit extends across the road into section 36 of Washington township where it is being dug for various purposes. The "State Road" running east from Independence across the county and into Delaware, has been gravelled for several miles with this material and is an excellent highway. The roadbed is smooth and hard although a little dusty. These are the Buchanan gravels which are so abundant in this and neighboring counties. They belong to the upland phase while those along Harter creek belong to the lowland or valley type. Similar deposits outcrop along the road to Quasqueton and show the same characteristics of oxidation, granitic decay and the like.

In the west bank of Pine creek in sections 20 and 21, Liberty township, are coarse red gravels which show a thickness of twenty feet. Pebbles two, four, or six inches in diameter and even larger are not uncommon. Above the gravels is a very fine yellow sand to the grass roots. Across the creek the bank is forty feet high, cut entirely in limestone. In the stream bed one mile west of Quasqueton is a fine bank of cross-bedded sands and gravels, some of the layers of which are somewhat more ferruginous and are partially cemented. The bed is revealed to a height of fifteen feet. A mile south of Quasqueton in section 3, Cono township, is a long, well defined terrace of gravels of the rather fine valley type. It is set back from the stream and a wide, old flood plain ten feet high intervenes. A similar flood plain fifteen to twenty feet above the river occupies the northeast corner of section 33, Liberty township, and extends into section 28. It is built up of fine gravels, is very level and is bounded by old bluffs. In sections 29 and 30 of this township is a terrace which is now thirty-five feet high. It is covered with fine yellow gravels resting on a foundation of the brecciated limestone which forms the bed rock of this region and is set back one-fourth of a mile from the river. In the south part of Independence this terrace is again evident, and is here capped with fine fresh sands probably of recent age. In places

these are not over four feet thick and cover coarse, dark red sands and gravels probably of Buchanan age. The upland gravels are seen in the south half of section 32, Liberty township, crowning the hilltops. They are coarse, bowldery and of the usual type.

The road from Independence to Littleton on the north side of the river follows along a terrace of Buchanan gravels which are overlain by one or two feet of Iowan drift. This terrace is from less than one-fourth mile to a mile back from the stream and six to eight feet above the lower flood plain which in turn is about six feet above the stream. This flood plain is underlain by fine yellow river gravels which rest upon old, red, coarse gravels.

Terraces similar to those on the north bank of the Wapsipinicon border its southern bank also. A continuation of these terraces extends up the Little Wapsipinicon as far as the middle of section 32, Fairbank township.

A little beyond Littleton, in the center of section 8, Perry township, is a pit in a hill of Buchanan gravel. This is a dark red, rather coarse deposit overlain by a thin veneer of Iowan till. Indications of gravel are also seen in the northeast quarter of section 29, Fairbank township.

All along Otter creek the sands and gravels of the valley phase of the Buchanan gravels are much in evidence. Thus on the west line of section 17, Washington township, the bank reveals a bed of coarse, red gravels thirty feet above the stream. At the bridge near the southwest corner of section 5 is a twenty-foot terrace of fine, clean, yellow sand without pebbles. The terrace borders the stream very closely and leaves only a very narrow flood plain. It extends for some distance up-stream and back from the stream it merges into the Iowan plain. The same fine, yellow, unoxidized sands occur in a terrace ten to twelve feet high in the northwest quarter of section 33, Hazelton township. They bound the rather narrow flood plain and are marked very distinctly from it. The same terrace is seen again in the northeast quarter of section 21 and bears the same characteristics. The bank of a small creek on the north border of Hazelton, where the road crosses, consists of sand and clay ten feet

high and capped by a foot of coarse gravel. Beyond the bridge the road follows Otter creek and the terrace here shows red sands and gravels at the top. On both sides of the bridge over Otter creek in the center of section 4 are terraces with light yellow, unoxidized, fine sands overlain by two feet of coarse red gravels with pebbles up to two inches in diameter. These extend up to the sod. These terraces follow up the creek beyond Oelwein, as described under the caption Fayette county, until they merge with the Iowan plain.

Along the uplands bordering Otter creek the coarser, more ferruginous upland gravels are abundant. Thus on the side of a hill in the northwest quarter of section 4, Washington township, is an exposure in which pebbles up to two and three inches in diameter are abundant. Only about 100 yards back from the bank of clean yellow sands in section 21 the road is cut through a bed of upland gravels of very coarse type.

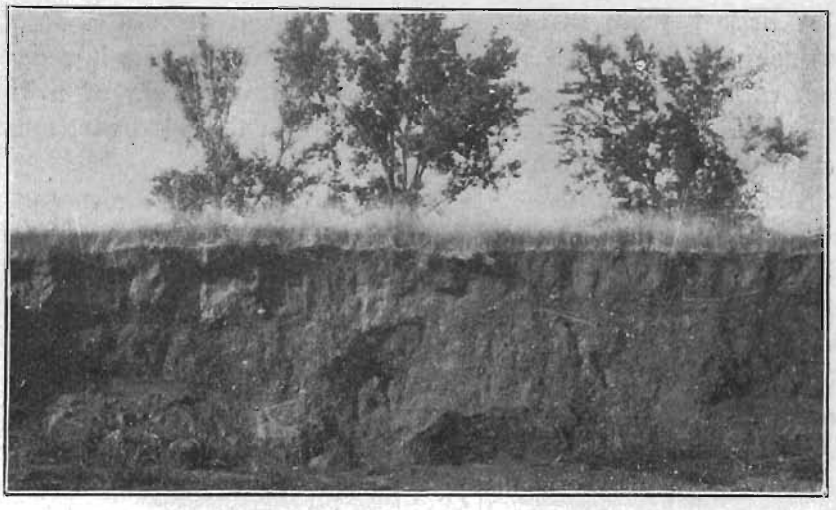


FIG. 7—Pit showing Buchanan gravel overlain by Iowan drift about two miles west of Winthrop, Buchanan county.

Banks of gravel are exposed along the east and west branches of Buffalo creek from the north county line to their junction and in places form terraces of considerable height. Many of the deposits are rather coarse and well oxidized, while in places finer gravels underlie these. At the junction point of the two

branches these terraces are well marked, are eight to ten feet high and in places are set back several hundred yards from the present stream. South of Winthrop the terraces continue in force. In section 6, Middlefield township, is a bank twelve feet high made of rather coarse gravel whose surface grades into the level Iowan plain beyond. These gravels are found for miles bordering the creek valley.

FIG. 8—A near view of the Winthrop gravel pit showing coarse material above stratified sands. This is a typical exposure of upland phase of the Buchanan gravels.

At the point where the Maquoketa river enters the county gravel appears in the banks and becomes quite abundant in the neighborhood of Lamont. The terraces here are built up of rather fine, yellowish gravels rising ten feet above the stream. They are continued into Delaware county to the east.

Upland gravels are common in this part of the county, as they are elsewhere. The hilltops between Lamont and Aurora are capped with these deposits, often rather coarse, carrying cobblestones of four, six and eight inches diameter, rusty and weathered for the most part though one bed in the southeast quarter of the northeast quarter of section 10, Madison township, well up and away from the stream, is made of fine, yellow gravel, quite like the valley type. One of the best of these

upland beds lies about two miles west of Winthrop on the "State Road" and has been opened in the northwest corner of section 3 of Liberty township. Here are several feet of fine yellow sands overlain by coarser ones. The old Illinois Central pit immediately west of Doris is the classic locality for the Buchanan gravels but it has been abandoned for years.

Stone.

The Niagaran limestone occupies a triangular area in the northeast one-third of the county. Outcrops appear along Otter creek in Hazelton township, and in Buffalo and Madison townships. The usual type exposed is the coarse, granular dolomite. Near Hazelton, in section 2 of Hazelton township, the coarse dolomite passes beneath fine-grained nondolomitized limestone, varying in color from light drab to blue. Small openings have been made in all of the above areas but little stone has been taken out.

Fig. 9—View in City quarry at Independence showing effect of crushing in the Spirifer pennatus beds, upper part of brecciated zone.

Beds belonging to the Devonian are found immediately beneath the mantle of drift over about two-thirds of the superficial area of the county. The lowest Devonian beds which afford any quarry products, are represented by a rather soft, imperfectly bedded limestone, which, as a rule, yields readily

to weathering influences. It is very much shattered and jointed, and has been referred to the Wapsipinicon stage of Norton. A number of small quarries have been opened in the beds in the vicinity of Independence. Along Pine creek in Liberty township, and on sections 33 and 34 in Newton township, the equivalent beds are harder and generally better in quality. An average section for Independence is taken from a quarry located in the eastern edge of town and is as follows:

		FEET.
3.	Limestone, yellowish, rather hard, rings when struck with the hammer, in rather thin layers, and containing numerous corals, among which *Cystiphyllum americanum* and *Acervularia profunda* are the most characteristic species.....	4
2.	Limestone, the *Spirifer pennatus* beds, showing the usual assemblage of fossil species, not definitely bedded, but intersected by a great number of joints. The phenomenon of "slickensides" is developed on the joint faces on an extensive scale	8
1.	Limestone, the barren beds, lithologically like the *S. pennatus* beds above	10

No. 3 of this section is the lowest member of the Cedar Valley stage of the Iowa Devonian.

Similar sections may be observed along Pine creek and the Wapsipinicon in Liberty township. Also along Dry creek in Newton township.

FIG. 10—O'Toole quarry east of Independence showing Cedar Valley limestone overlying the shattered beds of the Wapsipinicon.

The most important quarries have been opened in the Cedar Valley limestone. The stone is harder, resists weathering influences better and occurs in more regular beds than the Wapsipinicon. These beds have been developed at Fairbank, near Littleton, Jesup, and Brandon, and near Quasqueton, where a small outlier of the Cedar Valley occurs some miles from the main body. The beds quarried are about the same at all of these places.

At Fairbank a quarry in the west side of the river shows the following beds:

		FEET.
5.	Very dark brown residual clay or geest; a few inches to....	1
4.	Limestone, in thin layers.....	4
3.	Limestone, fossiliferous	1
2.	Limestone, yellowish, soft, evenly bedded, in layers ranging up to six or eight inches in thickness.....	5
1.	Limestone, heavy beds, not fossiliferous, exposed at base of quarry	2–3

Farther south more extensive sections are shown. At Littleton extensive natural sections aggregating seventy feet, may be seen both above and below the dam. Here is one of the classic sections in the county, but it is of little economic importance. Only the uppermost beds have been quarried, two small quarries having been opened north and northwest of town on top of the bluffs. The beds worked consist of a yellow, earthy limestone, occurring in even layers varying from two to eight inches in thickness. Nearly twenty feet is exposed in the quarry face.

At Jesup there are two quarries, one on each side of the correction line road, one-half mile southeast of town. The north quarry shows the following section:

JESUP SECTION.

		FEET.
6.	Black loam	1–2
5.	Limestone, yellow, broken and decayed, more or less disturbed	2–3
4.	Limestone, yellowish, not very fossiliferous, affords some good quarry stone	5
3.	Limestone, soft, easily affected by the weather	2
2.	Limestone containing numerous stromatoporoids and true corals. Some fair building stone	6
1.	Limestone, fissile, with few fossils	3

The strata dip slightly toward the east and are somewhat contorted. At the quarry south of the road the upper beds are worked and dip slightly to the south. The beds quarried at Quasqueton are very similar to those exposed at this point.

Several small quarries have been opened along Lime creek in the vicinity of Brandon and for several miles to the northeast. Just south of Brandon near the north line of section 34 the following section is exposed:

BRANDON SECTION.

		FEET.
4.	Limestone, soft, grading up into yellow shale, which carries silicified brachiopod individuals	8
3.	Coral reef consisting of Acervularia, Favosites, Ptychophyllum and other corals	1
2.	Limestone, evenly bedded, with few fossils or none	4
1.	Limestone, regularly bedded, and capable of being quarried, in layers from two to six inches in thickness, the thinner beds serving well as flagging	4

FIG. 11—Iowan bowlders in field immediately north of Illinois Central gravel pit, east of Independence.

FIG. 12—Group of Iowan bowlders southeast of Winthrop, Buchanan county.

While the Devonian is capable of supplying an indefinite amount of fairly good material suitable for road and concrete work, but little quarrying has been done, and that for local use only.

FIG. 13—Iowan bowlders, mostly granitoid and gneissoid, piled along fence on section 9, Fairbanks township, Buchanan county. The bowlders afford excellent material for crushed stone products.

BUENA VISTA COUNTY.

Sand and Gravel.

The sand and gravel deposits of Buena Vista county, like those of the other counties along the border of the Wisconsin drift sheet, are of two kinds, outwash gravels, in this case occurring as stream terraces, and beds in the mounds and hummocks of the drift area.

Stream Terraces.—Just as is the case in Clay and Cherokee counties the gravel terraces along Little Sioux river are of outstanding prominence. The approach of the moraine at Gillett Grove in Clay county seems to have added new material to that deposited in the river bed from sources farther north, and from this point southward high gravels appear at intervals capping jutting hills of drift. They appear kamelike, but in Herdland township (Clay county), especially in sections 16, 21, 22, 27, 34 and 33, and in section 4 of Lee township, Buena Vista, the bench is such on the east side of the river as to leave no question as to its being a remnant of a high terrace twenty-five to thirty-five feet above water. Gravels are taken out in the road on the west side of section 4, Lee township. These are in part very coarse and somewhat dirty, but good material is found in places. The low terrace which is continuous all along the river in Clay county persists at intervals here as it does farther north.

From Sioux Rapids west there appears another series of terraces now on one side (the concave side of the river curves), now on the other. The town of Sioux Rapids is built on these terrace gravels. In sections 1 and 2, Barnes township, they are on the north side, failing where the river crooks into Clay county, and appearing again at Linn Grove.

At Sioux Rapids, and especially is it noticeable in sections 1 and 2 of Barnes township, there are three terraces, the highest forty to fifty feet above the river. Often these benches are little else than drift, but vary from this through a bare veneer or capping of gravel to vast beds of great depth. The latter is the case at Sioux Rapids and again north of Linn Grove, where pits are opened along the roads in section 5. Fifteen to

eighteen feet are in view, varying from bowldery and coarse above, to fine clean gravel with depth.

At Sioux Rapids the upper bench gravels are opened for city and road use near the Minneapolis & St. Louis depot in the northeast part of town. Fifteen feet of gravel are in sight here under one and one-half feet of soil. The top two and a half feet are iron-stained, bowlders large, up to a foot or so in diameter. The granites are badly rotted. Below this is bright, moderately coarse gravel as a rule containing considerable amounts of fine brownish clayey matter throughout. There is very little clean sand in this bank. This material is being used on the road to the northeast, the same being in excellent condition for miles.

Brooke creek heads in a long depression, mapped by Macbride as alluvium, but little else than an old glacial pond with drift immediately below. Through northeast Elk township it is an erosively active stream and has cut deeply into the drift. There are no gravels except gravelly drift. Through Brooke township it has channelled its way 100 feet or more as it approaches the Sioux. In section 36 and even in northeastern Elk township it begins to show signs of gravel and of a terrace. They are conspicuous in sections 35, 26 and 25 and become even more conspicuous down the stream. In the sections last named are two benches, one very largely gravel ten to fifteen feet above the water. This has been opened on a side branch in northeast section 35. The gravel is good, and there are vast quantities of it. Here also thirty feet or so above water is a marked drift terrace, usually gravel or sand capped, which blends with the high terrace on the river. Gravels of this bench are seen in the road between sections 25 and 36 of Brooke township.

Raccoon river meanders through a narrow alluvial valley which narrows to zero where in southeast Grant township it has incised its way into hills of new drift. At the edge of Grant and Providence townships these hills are sharp and a good exposure is seen along the river. Usually there is only drift, but some sorted materials are present. There are pits in the road both east and west of the river on the south side of section 36, Grant township. After breaking through a range of hills

here the topography is milder to the union of Storm lake outlet southwest of Newell. Here again the Raccoon river has an alluvial valley.

The outlet of Storm lake is a considerable stream, and contributes largely to the Raccoon. It winds its way through drift hills, and in places along its course has put down beds of impure gravel and, in its channel, sand, that are highly serviceable on roads and for other purposes locally. Such a gravel bed appears and is used in southeast section 21, Providence township.

Morainal Deposits.—The margin of the Wisconsin drift sheet in Iowa, known as the Altamont moraine, passes through Buena Vista county in an almost due north and south direction. The moraine crosses the southern boundary of the county at the southeast corner of Hayes township, proceeds thence in an almost straight line to the northwest corner of Washington township, then follows the eastern boundary of Elk and Brooke townships almost to the Little Sioux, and borders that stream on the south side leaving the county again a few miles northeast of Sioux Rapids. The relation of the river to the drift area as mapped by Macbride would seem to indicate that the former had been pushed from its course by the advance of the ice and forced to seek a new channel.

In Buena Vista county the distinguishing characters of the drift are far more distinct than is usual in this part of the state. Over the Wisconsin area ranges of low hummocks are common, all being very gravelly drift with occasional masses of clean sand and gravel. The former affords fair road material, the latter excellent, and both have been sought out and used quite generally on the highways.

In southeast 2, Barnes township, on a hilltop 120 feet above the water in Little Sioux is a pit from which clean, fine sand of excellent quality is obtained under a few feet of good fine-grained gravel. It is near the top of an enormous mass of drift, and appears to be a local pocket and to have no relation to the river terraces. There are also sand and gravel beds on a hilltop north of Sioux Rapids in section 1 of the above township. Serviceable gravels were also observed in southwest 29, Barnes township, and northwest 31 and southwest 1 of Scott township. Sand

and fine gravel from the latter pit are used in Rembrandt for all kinds of cement work.

A notable chain of hillocks, often sharp and pointed, extends west from Rembrandt and then turns sharply south, continuing with spurs to the east, to Storm Lake. These are often very gravelly where dissected in roads, and frequently contain good gravel.

Northeastward from Storm Lake the country becomes knobby; not rugged but low round and elongated hills, always gravelly and sometimes exhibiting both gravel and sand. These hills have been opened in northwest 1, Hayes; southwest 20, Grant; and south 14 and southwest 27, Washington township. Gravel from the latter two openings is now being hauled to Storm Lake.

The eastern two-thirds of the county is all Wisconsin drift. It is impossible to predict with any degree of accuracy the presence of gravel and sand in the knobs and hummocks of the Wisconsin drift area.

Miscellaneous.—Within the area of the older (Kansan) drift in the western third of the county some deposits of sand and gravel have been found. Notable among these is a sharp knob four miles south of Alta, at the corner of sections 10, 11, 14 and 15 of Maple Valley township. From this place much material has been and is being taken. The top few feet here are dirty and much iron-stained, with numerous granite bowlders so disintegrated that they cleave with the shovel or break even with the matrix, so soft are they. Below is firm gravel and sand. This is dirty and not fit for cement work but is excellent for roads, to which latter the condition of the north and south road here attests. There is no loess here; all is gravel to the very grass.

South of the Little Maple through Maple Valley township is a more or less conspicuous range of somewhat sharp-pointed hills leading on into Diamond township in Cherokee county. Many of these are so gravelly at the surface as to be unfit for cultivation and they sometimes run into pockets of gravel and sand. Where seen in road cuts they are a very gravelly yellow till, especially notable at and south of Hanover in sections 19

and 20, and an especial prominence near the northeast corner of section 25 of Diamond township, Cherokee county.

The beaches at the east end of Storm lake furnish some material for building and concrete purposes in the town. A good quality of building sand, but somewhat dirty, is obtained here.

BUTLER COUNTY.

Sand and Gravel.

As in several counties near to and adjoining Butler, the Buchanan gravels have a wide distribution. Both phases (see report on Buchanan county) are extensively developed. All the larger streams and many of their tributaries have wide valleys largely filled with gravel, and deposits of the upland type are encountered in road cuts and other shallow excavations practically everywhere.

Valley Phase.—Along the three principal streams of the county—the Shell Rock, West Fork of Cedar river and Beaver creek—extensive valley trains are prominent, often to a depth of thirty feet or more. The larger tributaries of these streams have similar deposits on a smaller scale.

Valley trains of gravel appear along Shell Rock river within its first mile in the county. Mr. P. H. Green has a pit just north of the town of Greene and on the west bank of the river which shows the following section:

	FEET.
Soil	½–1
Gravel, coarse	2½
Gravel, fine and cross-bedded	3
Gravel, coarse, cross-bedded, and containing some fine sand	7

The terrace has an area of about twenty acres. Across the river Mr. J. W. Butler has a pit showing the following strata:

	FEET.
Soil	2
Molding sand	3
Yellow clay	3–4
Blue clay	1–1½
Gravel and sand, cross-bedded	24

A well close by did not reach the lower limit of the gravel at a depth of sixty-five feet. There are a few similar pits southeast of Greene.

A gravel pit extensively used by the Chicago Great Western Railway just northwest of Clarksville has been excavated to the depth of ten or twelve feet below the soil, which here is about two feet thick. The lower six or eight feet are cross-bedded, the grades running from a coarse sand to a coarse gravel containing pebbles and cobbles from two to five inches in diameter. In addition to pebbles of the usual kind there are iron nodules and numerous limestone fragments.

The Illinois Central Railroad has a pit in section 23 of Washington township where an area of about five acres has been excavated to water level, a depth of eight or ten feet. At present this pit supplies gravel for the manufacture of cement blocks.

The following is a typical section for other pits along Beaver creek:

	FEET.
Soil	2
Soil and gravel	1
Fine sand and some fine gravel	1
Fine gravel	2
Fine sand, some gravel	1
Fine gravel, some sand	2

The three lower members are usually cross-bedded and all are more or less iron-stained.

Dry run, a tributary of the West Fork of the Cedar, has large deposits along its course, the following being a generalized section:

	FEET.
Soil	1–3
Gravel, fine to coarse, some clay	2–3
Sand, coarse to fine, some gravel	

These deposits have smaller pebbles than river deposits and their area will aggregate two to five acres per mile.

Upland Phase.—Since these deposits were superficial until covered by the Iowan drift or loess, they appear to be much older than contemporaneous deposits of the valley phase which were

soon covered and in which, therefore, oxidation was greatly retarded.

The pit in section 30 of Pittsfield township belonging to Mr. T. H. Ahrens is one of the most important of this type in the county. The section is as follows:

	FEET.
Soil, pebbly	1–2
Gravel, coarse, some cobbles up to six inches in diameter, large and small pebbles in same stratum	4–6
Gravel, coarse, but finer than that above, stratified, a few inches very fine, with some sand	2–3
Gravel, coarse, but some fine with cobbles up to eight inches to bottom of pit	4

The granite pebbles are often completely disintegrated, especially in the lower part. In places this pit is eighteen feet deep, and several acres will probably produce a good yield if opened. A similar deposit has been opened in section 9 of Madison township.

Mr. William Hites has eight acres of gravel at the surface in section 15 of Ripley township. Other deposits are located in section 36 of Jackson township, 27 of Fremont, section 1 of Bennezette, and in the vicinity of Allison.

Stone.

The Devonian is believed to immediately underlie the drift over nearly, if not all of the county. Stone crops appear along the principal streams at numerous points, especially along Shell Rock river and its immediate tributaries. Outcrops may be noticed along the Illinois Central between Ackley and Austinville; along the North Western between Kesley and Dumont; along the Great Western between Dumont and Bristow, and from near Clarksville to Shell Rock and beyond.

Between Dumont and Bristow some quarrying has been done. The stone may be seen in street crossings and foundations in both Dumont and Bristow. The beds range from six to ten inches in thickness and can be taken out in almost any length and width. All of the stone is hard and compact and splendidly adapted to crushed stone purposes. The quarries are not in operation at present.

Along Shell Rock river small openings appear in the bluff on the east side of the river and a small quarry is being operated about three and one-half miles northwest of Clarksville. The section exposed in the pit is as follows:

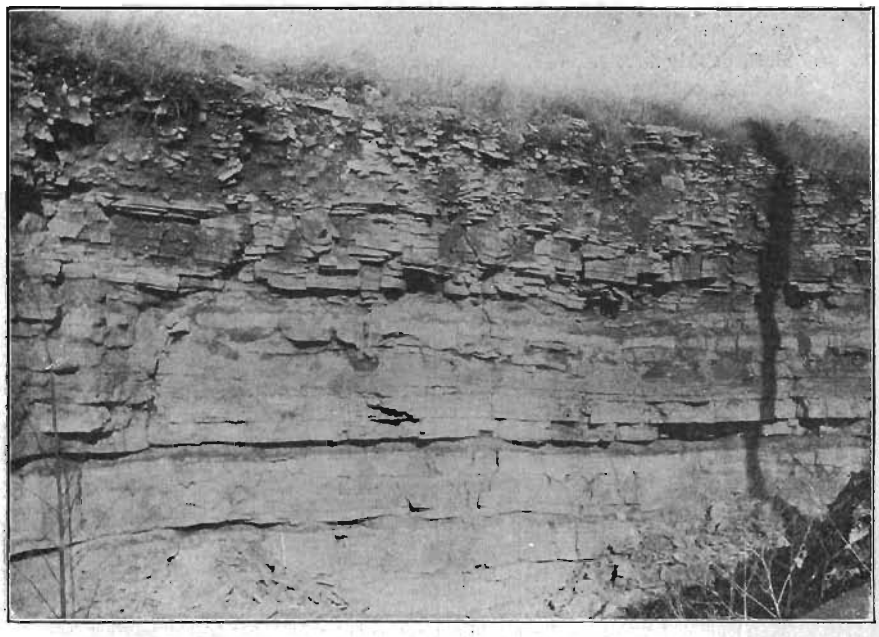


FIG. 14—Schrader quarry, Clarksville, Butler county, showing the flaggy, lithographic facies of the Cedar Valley.

		FEET.
3.	Soil and drift of variable thickness	1–3
2.	Limestone, yellow to brown, magnesian to dolomitic, in thin layers, evenly bedded	6
1.	Limestone, white to gray, hard, brittle, evenly bedded, compact to lithographic; certain of the layers show fossils in weathered surfaces but these are firmly bedded and do not show in fresh fractures, exposed	7

The beds exposed here are very similar to those which are exposed at Marble Rock in Floyd county and correspond to the two lower members in the section at that place. Equivalent beds are, however, somewhat thinner and the shaly partings are rather more pronounced, perhaps due to more advanced weathering. The brecciated layer near the top of the white limestone is equally as prominent as in the Marble Rock section. Good material is available in the small quarries east of Clarksville.

The W. H. Moore quarry may be considered representative. A similar sequence may be made out in the openings near Greene.

The Charles Matthews quarry is located in the northern part of the town of Greene east of the railroad. About twenty feet of limestone somewhat variable texturally and structurally with occasional thin shale and clay partings comprise the quarry section. The limestone beds are predominantly hard and compact and well adapted for crushed stone purposes. The stripping is light and several acres are easily available at this place.

Southeast of Greene limestone outcrops continue, the stone is of good quality and considerable quantities are obtainable at small expense. Small quarries have been opened near Shell Rock. Both white limestone and the dolomitic layers have been used quite generally throughout the eastern portion of the county for foundation purposes and formerly for the walls of some of the less important buildings. Both, when properly selected, give good service and appear to be fairly durable.

The limestone has also been used for flagging; blocks six to ten inches in thickness and of almost any dimensions in length and breadth can be obtained quite readily. The white limestone throughout is very hard and compact and admirably adapted for crushed stone purposes. The stone can be obtained at several places without much stripping but as yet the industry can scarcely be said to have been started.

CALHOUN COUNTY.

Sand and Gravel.

The supplies of sand and gravel in Calhoun county are derived from two sources, terraces along the streams, and pockets in and cappings on the Wisconsin drift hills.

Stream Terraces.—Raccoon river crosses the southwest corner of the county, cutting diagonally across Jackson township. A low gravel terrace, indistinct in places, entirely absent in others, can be followed along its whole course within the county. A bend in the river has exposed the gravels at the bridge near the center of section 25, Jackson township. The gravels which are exposed here are plainly of two generations. The lower,

the top of which is some ten feet above water, is so old that its pebbles have all broken down, and nothing is left but a deep red coarse sand. Resting on this old material and separated distinctly from it are some six feet of fine, clean, sharp sand. Above the sand are a few inches of dirty gravel, covered by a foot or so of alluvium.

A few hundred yards north and east of the bridge mentioned above is a small pit a short distance back from the road. The material exposed is somewhat similar to that at the bridge, but has a considerably larger proportion of gravel. On the north side of the river at least as far west as the junction of Lake creek the river "bottoms" will average from a quarter to a half mile in width, and farmers along the river report finding gravel and sand practically all over it at depths varying from eighteen inches to three or four feet. The river exposes the gravels in several places along its banks in sections 25 and 26. An open pit in this low bench is located near the middle of section 36, on the west side of the river.

Just west of the bridge over Lake creek in east section 22, Jackson township, is a small open pit on the edge of this same bench, in which there are exposed about six feet of somewhat coarse, iron-stained, water-laid gravel under one to two feet of alluvium. Many pebbles up to six or eight inches in diameter are to be found, but the large majority are not over three or four inches. Probably six or eight acres are available. An opening of quite similar material may be seen at the corner of the roads in east section 21. The cover is deeper here, and the available area is not to exceed one or two acres.

Farther up the river the bench becomes less and less easy to follow, and seems to merge into the flood plain of the present stream in the vicinity of the Sac county line. Although the same or similar gravels and sands may be present they are covered with alluvium so deeply that pits have not been opened.

Lake and Prairie creeks have low terraces which have been opened in a few places. Near the crossroads at the east quarter-corner of section 10, Jackson township, the bench along the latter has been opened and a considerable amount of the materials removed. This opening shows very coarse, unassorted,

slightly iron-stained gravel under one to two feet of soil. The gravel is very coarse and dirty and would probably have to be screened even for road purposes. The bench here is only six to eight feet above water in the creek, and will average perhaps a hundred yards wide for a quarter of a mile to the northeast. The same material shows along the creek south of the road and also west of the bridge at the south quarter-corner of section 10. Another pit is now open in a piece of this same bench on the east side of the river in west section 15, Jackson. The material here differs from that exposed in section 10 in that it is much finer throughout and cross-bedding is noticeable, whereas that in the latter place, as noted before, is coarse and unassorted. There are some five feet exposed, and perhaps a total of two acres or so might prove available.

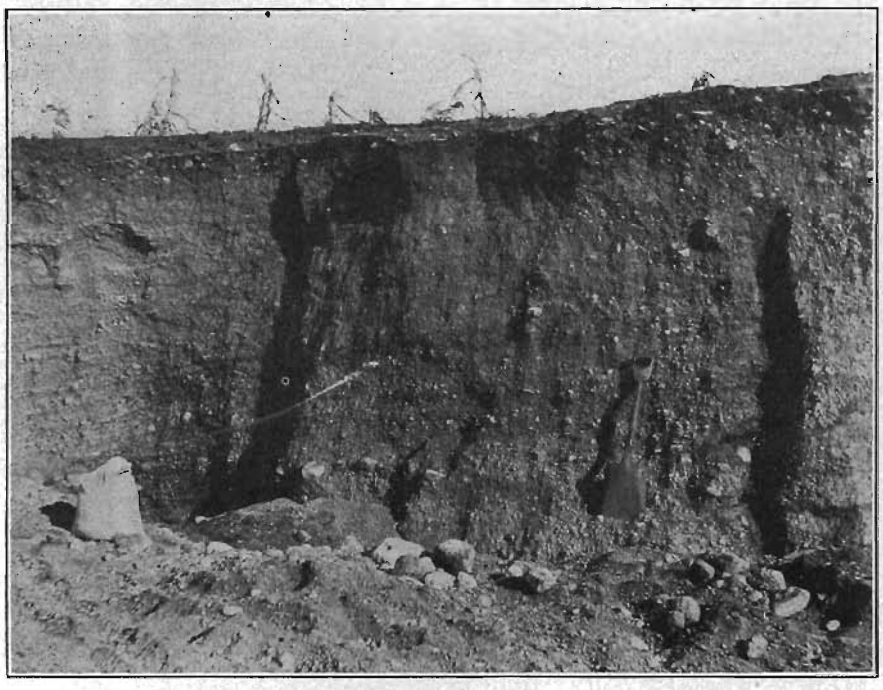


FIG. 15—Gravel pit near Lake City, Calhoun county.

The supply of sand and gravel for the town of Lake City comes from a pit on a bench of Lake creek in the northern part

of section 7, Calhoun township. Several acres of the material have been removed and large quantities are still available. The pit section is:

	FEET.
Alluvium	1–2
Gravel, earthy, with some cobblestones	2
Sand and gravel, clean	6

This terrace continues intermittently down the creek to its junction with Raccoon river.

East and northeast of Lohrville a few stray remnants of a low terrace along Cedar creek may be seen. Perhaps the most prominent one of these is that which the road cuts into slightly near the southwest corner of section 6, Reading township. The top of the bench here is about twelve feet above water. Where the road cuts into it there is exposed a fine to medium gravel which is dirty and somewhat iron-stained. The pebbles are limestone, greenstone, granite, shale and some quartz, and some of them run up to three inches in diameter. There is an acre or so of available material under one and a half to two feet of cover.

Several small pieces of the same terrace may be seen near the forks of Cedar creek in southeast section 31, Cedar township, and a small amount of gravel has been removed from one of them on the south side of the road just below the fork. Above the fork the bench is not prominent along either stream and while small pieces of it may be present it is quite certain that deposits suitable for more than local use will not be found.

Along Cedar creek from Lohrville to its union with Raccoon river in Greene county there are no gravels of any importance. The creek flows through a narrow valley in Wisconsin drift hills which becomes deeper and sharper down the stream. No signs of the low terrace above Lohrville are to be seen along this portion of the creek. The total absence of gravel on the roads in this portion of the county presents a marked contrast to the condition of the highways in other parts of this and other counties within the Wisconsin drift area.

Along Purgatory creek there is a gravel terrace which is not at all conspicuous but which may be seen in sections 9 and

10 of Union township. There are two pits here which have not been recently worked but which indicate the presence of gravel.

Upland Deposits.—Calhoun county lies wholly within the area covered by the Des Moines lobe of the Wisconsin ice. The whole surface of this drift area is thickly dotted with more or less rounded knobs and ridges, known to the geologist as kames and eskers. Sometimes these hummocks are composed entirely of sand and gravel; again these water-deposited materials form cappings on or pockets within the drift clays; and quite as often gravels are entirely absent. In Calhoun county gravel deposits of this nature are reported in practically every township. Those occurring in section 3, Reading, section 24, Twin Lake, section 11, Lake Creek and section 11, Sherman townships may be cited as being representative of this type. No definite predictions as to the possibility of finding gravel in any particular place can, of course, be made, but it is safe to say that a little careful prospecting in the vicinity of highway and bridge improvements is likely to lead to discoveries which may considerably reduce the cost of materials for such work.

Reworked Materials.—Sand and gravel beds and bars are to be found in many of the streams of Calhoun county. Raccoon river is particularly noteworthy in this respect, and many another smaller stream will furnish quantities that are usable locally in a small way. These materials vary greatly in both quantity and quality, and are not to be depended upon for work of any size and importance.

Stone.

Imperfectly indurated beds belonging to the Cretaceous are known to outcrop along Lake creek, about one and one-half miles northwest of Lake City. Similar beds are reported to outcrop along North Raccoon river in the southwestern portion of the county. Near the plant of the Lake City Brick and Tile Company, the following section may be observed:

		FEET.
5.	Drift and wash	10
4.	Shale, somewhat fissile, grayish blue to dark blue, dries a light gray-blue	4
3.	Sandstone, friable, in three ledges of about equal thickness; the lower ledge ferruginous and concretionary; the middle layer unindurated, white; the top layer stained a variable yellow	2
2.	Shale, clayey, mixed, not laminated; variable	7
1.	Sandstone, ferruginous and concretionary, exposed above bed of creek	5

Only the concretionary portions of the sandstones are sufficiently indurated for structural purposes and none of the beds exposed are suitable for crushed stone purposes when viewed both quantitatively and qualitatively.

CARROLL COUNTY.

Sand and Gravel.

The gravel and sand deposits of Carroll county, as is true with many another which lies upon or within the edge of the Wisconsin drift sheet, are of two main types, viz., gravel trains along the streams, and beds and pockets in the drift hills. The Altamont moraine, which bounds the area of this latest sheet of drift, crosses the county in a northwest-southeast direction and divides it diagonally into two almost equal parts, the surface to the east of the dividing line being Wisconsin and that to the west loess-covered Kansan.

Stream Terraces.—Terraces and plains of outwash materials from the melting ice are about as poorly developed in Carroll as in any county having a similar situation in regard to the moraine. With the exception of North Raccoon river, some ten or twelve miles of whose course lies within the county and which is terraced throughout practically all of its length from Sac county to where it joins Des Moines river in Polk, there are no gravel benches of any particular prominence within the county.

In section 17 of Jasper township, about two miles southwest of Lanesboro, the Lanesboro Cement Tile Company is removing sand and gravel from a bench on the north side of Raccoon

river. Several feet of coarse gravel were removed over a tract twenty or twenty-five acres in extent by the Chicago Great Western Railroad at the time its line was built some ten or twelve years ago. The gravel grades to sand below which in turn rests on gravel. The present company uses a centrifugal pump and is working below the level of the water in the river. Beside what is used in the manufacture of cement drain tile, screened and washed sand and gravel is shipped throughout a wide territory, and is used for practically all purposes. The minimum thickness of the gravel as worked is given at twenty feet.

This terrace continues on down the river to the county line and beyond. In most places it is not prominent, since it rises but a few feet above the narrow flood plain of the river. It is covered by alluvium which varies in depth up to ten feet or more, and has a width between the high bounding hills of drift of one-half to over a mile. Actual exposures of the gravel are very few, but almost without exception the farmers say that wells in the river bottoms are in gravel and sand.

The conditions are practically the same from the Lanesboro pit to the north county line. Where the river has cut into the west bank at the bridge on the north line of section 7, Jasper township, some six feet of sand grading downward into medium gravel are exposed. A distinct wet line shows its contact with the clay below, and it is also sharply defined from the four or five feet of alluvium which overlies it. The bench is a half mile or so in width on the west side of the river at this point.

Along the top of the bordering bluff on the east side of the river gravel and sand are exposed in several places between the southwest corner of section 8, Jasper township, and the Calhoun county line. The top of the bluff is flat, and has the appearance of a huge terrace. Beside the road at the southwest corner of section 8, Jasper township, there is an open pit at the top of the hill. The pit section shows about three feet of soil covering, then coarse dirty sand with fine dirty gravel below it, the latter grading downward into sand. The depth of cover increases rapidly back from the edge of the opening. A mile farther north, where the road cuts into the hill on the south side of the southeast quarter of section 6, there are

about three feet of fine sand, somewhat dirty, resting upon the drift clay and covered with a yellowish soil which is loess-like in appearance. Again, on the edge of the same high bench along the road near the middle of the west side of section 5 is an open pit from which sand and gravel are now being taken. This opening shows about eight feet of cross-bedded sand and fine gravel, somewhat dirty, and much iron-stained in places. The cover is up to three feet in thickness.

Along Purgatory creek there are to be seen at a few places what appear to be remnants of a low bench, but which are not at all continuous or well defined. On the west side of the creek near the middle of section 25, Jasper township, there is a small pit in one of these. The top is about eighteen feet above water. The pit shows dirty gravel which is much iron-stained throughout. There is only a small amount of it here, but sufficient to be useful locally.

At the bridge over Purgatory creek in section 1 of Glidden township coarse, dirty, iron-stained gravel may be seen beside the road. About six feet or more of gravel are exposed and seem to lie upon Dakota sandstone as mapped by Bain. The latter is exposed along the creek a few yards south of the bridge. The surface is flat over an area of two or three acres on the east side of the creek.

Along Middle Raccoon river gravel trains are developed to nowhere near the extent that might be expected of a stream bearing its relation to the ice margin. The river cuts through the moraine in section 26 of Pleasant Valley township and runs outside to section 1 of Newton township. This portion of the valley seems to have been ponded by the ice and formed a temporary lake. While in this condition it was filled up with gravel to a level sixteen feet above the present stream. Into this gravel the river has since cut until the old filling is now represented by remnants of a fringing terrace. At Coon Rapids, where the drainage of the ice was turned into the valley of the small stream from the west, a gravel terrace was formed, and the main part of the town is located on this terrace. Patches of the same terrace can be found along the river valley for some miles south of town. The terrace at its upper end

rises fifty feet above the river, but to the south it declines until it eventually reaches the level of the flood plain. Most of the pebbles of the gravel are hard and fresh, but some are decayed. Iron-stained streaks are not uncommon. A section taken on the north side of the railway pit at Coon Rapids showed the following beds:

		FEET.
4.	Loam, brown to black, with a few scattered pebbles	½–2½
3.	Gravel, stained, much rotted material, sharply limited below	1
2.	Gravel, coarse, irregularly colored and bedded	5
1.	Gravel, fine, worked farther south in the pit	1+

The gravel shows east of the river, where the railway cut crosses the small side lobes of the bluffs. This soon gives place to the unassorted material of the bowlder clay, which contains much the same pebbles as are common in the gravel.

The bowlder clay, except where patches of gravel occur, forms the surface material throughout the northeastern portion of the county.

In the vicinity of Carroll and on down the river to Pleasant Valley township gravel terraces are entirely absent. The river plain southeast of town is but a mud flat between bordering hills of Wisconsin drift, and even the bars in the stream are composed of mud. A drainage ditch some twelve to fifteen feet deep is now being dug to straighten the channel of the stream, and this excavation has revealed nothing but alluvial silts and clays.

Glacial Deposits.—All of the northeastern half of the county is covered with Wisconsin drift. The hills and ridges of this area are often composed largely of gravel, ofttimes containing water-laid materials as pockets and lenses. A good example of gravel deposits of this type is the pit on "Mount Moses," a huge esker in section 13 of Carroll township, northwest of Carroll. Other pits have been opened in sections 18, 20 and 30, Grant; sections 13 and 24, Glidden; sections 1, 12 and 24, Jasper townships, etc. In many places along Purgatory creek tributary rivulets and gullies have exposed sands in the bordering hills. This is particularly noticeable in section 36 of Jasper township, on the east side of the creek. The hills rise

some seventy-five to one hundred feet above the stream, and are deeply gullied. Some of the hills are gravel capped, and some of the gullies show gravel and sand under varying depths of drift. The materials vary from coarse rotten gravel to fine sand, clean and white.

CASS COUNTY.

Sand and Gravel.

Small amounts of sand and gravel are obtainable from terraces along Nishnabotna river in the vicinity of Atlantic. The chief supply is obtained from a pit on the farm of J. O. Fudge, about a mile southwest of town. The pit is located on the bank of a creek near its junction with Nishnabotna river. The sand at the top is fine and interbanded with clay, and immediately underlies a covering of loess which varies in thickness from three to ten feet. The upper sand zone ranges from four to ten feet in depth, and rests directly upon a lower bed which is considerably coarser and occasionally carries clam shells and bones. The beds throughout are variable in thickness and continuity.

The sand from this pit has been used for more than a quarter of a century. The pit was opened to furnish sand for the High School building, and later was also used in the Government building. The waste is utilized by the city for crossings.

East of town the Chicago, Rock Island & Pacific Railway at one time used considerable amounts of sand on its road bed. The pit from which this material was taken, and which is now abandoned, was in a terrace about fifty feet above the Nishnabotna bottoms. North of Atlantic the principal terrace of the Nishnabotna appears to be some twenty-five to thirty feet above the flood plain, but is not deeply enough dissected to show the sands which probably are present.

At Lewis and vicinity the bluffs are supported by a soft friable sandstone. About a mile southeast of town a pit has been opened, from which most of the sand used for building purposes is obtained. The bank shows a vertical exposure of about thirty feet above the creek, a tributary of the Nishnabotna from the east, and has no cover. The sand ranges in

color from almost white to various shades of yellow and light brown. Certain ledges and spheroidal masses are slightly indurated, but on the whole almost the entire section can be used. It becomes more firmly cemented, however, toward the northeast. These beds belong to the Cretaceous.

A large part of the sand used in the county is shipped from Commerce, on Raccoon river, or from Platte river in Nebraska. The latter is considered the better, and is retailed at about $2.00 per ton as against $1.60 or thereabouts for the Raccoon river product. The local material brings about $.75 per yard.

Stone.

Cass county is as a rule heavily covered with loess and drift, and the indurated rocks appear at intervals only along the larger waterways in the southern part of the county. The Missouri strata are known to be overlain in part with the Dakota sandstones of the Cretaceous.

Stone was formerly taken out at the old Fox quarries on the south bank of the West Nodaway in the southeast quarter of section 36, Noble township, and just across the road in section 31 of Edna township. The beds in these quarries belong to the same horizon as those exposed near Grant and described under Montgomery county, although no accurate correlations of individual strata can be made. The following section is compiled in large part from the *Geology of Montgomery County*:*

		FEET.
13.	Soil and loess, heavy covering.	
12.	Broken limestone, shales and residual clay	2
11.	Greenish shale, iron-stained	4
10.	Limestone, light gray to buff, contains fossils; split by vertical joints into large blocks; two ledges separated by thin band of shaly limestone, upper ledge, 2 feet 3 inches, lower 1 foot 4 inches	3 7/12
9.	Calcareous shale, fossiliferous	1
8.	Limestone, subcrystalline, gray to brown, in ledges from 9 to 14 inches; where exposed for only a few years, this stone is badly shattered and intervening shaly bands separate it into many thin ledges	7 1/12
7.	Shale, calcareous	1/3

*E. H. Lonsdale, Iowa Geol. Survey, Vol. IV, pp. 393 and 435

		FEET.
6.	Limestone, brownish, subcrystalline to dull	1 1/16
5.	Shale, in part gray, bituminous in lower portion	1½
4.	Limestone, dark gray, coarse textured	¾
3.	Shale, buff to gray, fossiliferous	1 1/3
2.	Shale, variegated, lower part carbonaceous, micaceous, and splits into conchoidal fragments	2½
1.	Limestone.	

At the present time, no quarrying is done at this point, and the lower members of the section, 6 to 1 inclusive, are largely covered up. All of the limestone ledges were used in heavy masonry work, and blocks of nearly any desired dimensions were obtainable. The base of the section is approximately twenty feet above the river. Coal blossom appears near water level in the river. The location of these quarries is favorable for supplying stone to Adams, Cass and Montgomery counties but their development has been and will be hindered by lack of transportation facilities and by the heavy stripping required.

Limestone and shale appear at a few points farther north along the West Nodaway and its branches, but always under heavy overburden. Near the southeast corner of section 20, Edna township, stone has been removed. The limestone beds appear also at points on Seven Mile creek, notably near Galion in Bear Grove township.

On East Nishnabotna river near Lewis, and on Turkey creek, its principal tributary from the east, the Missouri strata appear in places. Stone has been taken from the west bank of the river on the farm of George Roberts, southwest of the town. At present, there is exposed one foot of light gray limestone overlying eight to ten inches of yellow clay and soft, disintegrated limestone. The lower bed is fossiliferous, and is approximately thirteen feet above water in the river. The exposure is covered with drift and loess aggregating fifteen to twenty feet.

Two miles north of Lewis on Turkey creek, in the northwest quarter of section 1, Cass township, ten inches of blue, hard, partially crystalline limestone outcrop in a ravine a few hundred feet back from "Rockyford," where limestone was formerly quarried. In the northeast quarter of section 1, six feet

of weathered limestone are in view in ravines leading into Turkey creek, in places overlain with Cretaceous sandstone and plastic clays. Throughout, all exposures in this part of the county are covered with ten to sixty feet of superficial materials, which renders utilization out of the question.

Although but few exposures are known, the gravels, sandstones, and clays of the Nishnabotna substage of the Dakota probably occupy considerable areas in Cass county. The sandstone is, as a rule, friable and the grains are not sufficiently well cemented to make it of value for crushed stone purposes. Directly south of the town of Lewis in section 15 of Cass township, and to the east of the river, is an outcrop in which the sandstone is of a fairly firm texture and from which large amounts have been removed, to be used locally. It is composed largely of fine, even grains of sand, with occasional larger fragments of limestone, partially cemented together with iron oxide. Small mica scales are scattered through it. While the stone is tender and requires careful handling on first exposure, it is said to harden very materially on drying, and with age. The sandstone breaks somewhat irregularly, but as readily in one direction as in another. Eight to twelve feet of the rock are exposed. So far as known, this is the only locality in the county where the Dakota beds afford a quarry product.

CEDAR COUNTY.

Sand and Gravel.

Sand deposits of economic importance are of two types,—bar and bank deposits in and along the present streams, and subloessial. The first afford the principal supply. The Buchanan gravels are known to be present in the county, but good outcrops are exceedingly rare. Gravel deposits easily available and extensive enough to be of commercial importance are not known in the county.

Stone.*

Cedar ranks among the first counties of the state in the value of the yearly output of building stone, a pre-eminence due

*Professor Norton's excellent write up on Building Stone in his report on the Geology of Cedar county has been revised and used almost in its entirety.

chiefly to the quarries at Cedar Valley. Formerly Lime City was an important producer, but at the present time, it contributes but little to swell the county total. Building stone of excellent quality is found widely distributed over the county, and while the small quarries which have been opened in almost every township do not greatly add to the large amount contributed by the Cedar Valley district, yet their value and convenience to the rural districts and neighboring towns is greater than mere statistics could show. There is hardly a section in the county where a farmer or townsman can not get a load of cheap good stone within easy hauling distance. Thus in Pioneer township there are quarries at Peet's mill and elsewhere on Clear creek; in Cedar township at Cedar Bluff and two and one-half miles north of that village; in Gower township at Cedar Valley and Plato; in Center at several quarries south of Tipton; in Rochester along Rock creek; in Iowa near Atalissa; in Sugar Creek at Lime City and a number of quarries north of that village; in Springfield southwest of Lowden; in Massilon along the Wapsipinicon, and in Dayton township near Clarence. Nearly all of the building stone quarried in the county is furnished by the Gower stage of the Silurian, the only exception being that of the Devonian quarries in Iowa township near the Muscatine county line. The good qualities of the Anamosa phase of the Gower limestone have long been recognized and have frequently been set forth in the reports on the counties of eastern Iowa. Its even and smooth bedding, its uniform grain, its comparative softness in working with saw and chisel when fresh from the quarry, and its hardness when recementation has taken place on drying, its obduracy to all chemical agencies of rock decay, and its resistance to frost, its pleasing color and the absence of any injurious minerals which might weaken or strain the stone or impair its ease of working, all these characteristics contribute to make the Anamosa one of the best building stones of the west.

Bealer Quarries.—In value of output, and perfection and cost of machinery, these quarries are the most noteworthy in Iowa and are among the largest of the Mississippi valley. They are located some six miles southwest of Tipton on the right bank

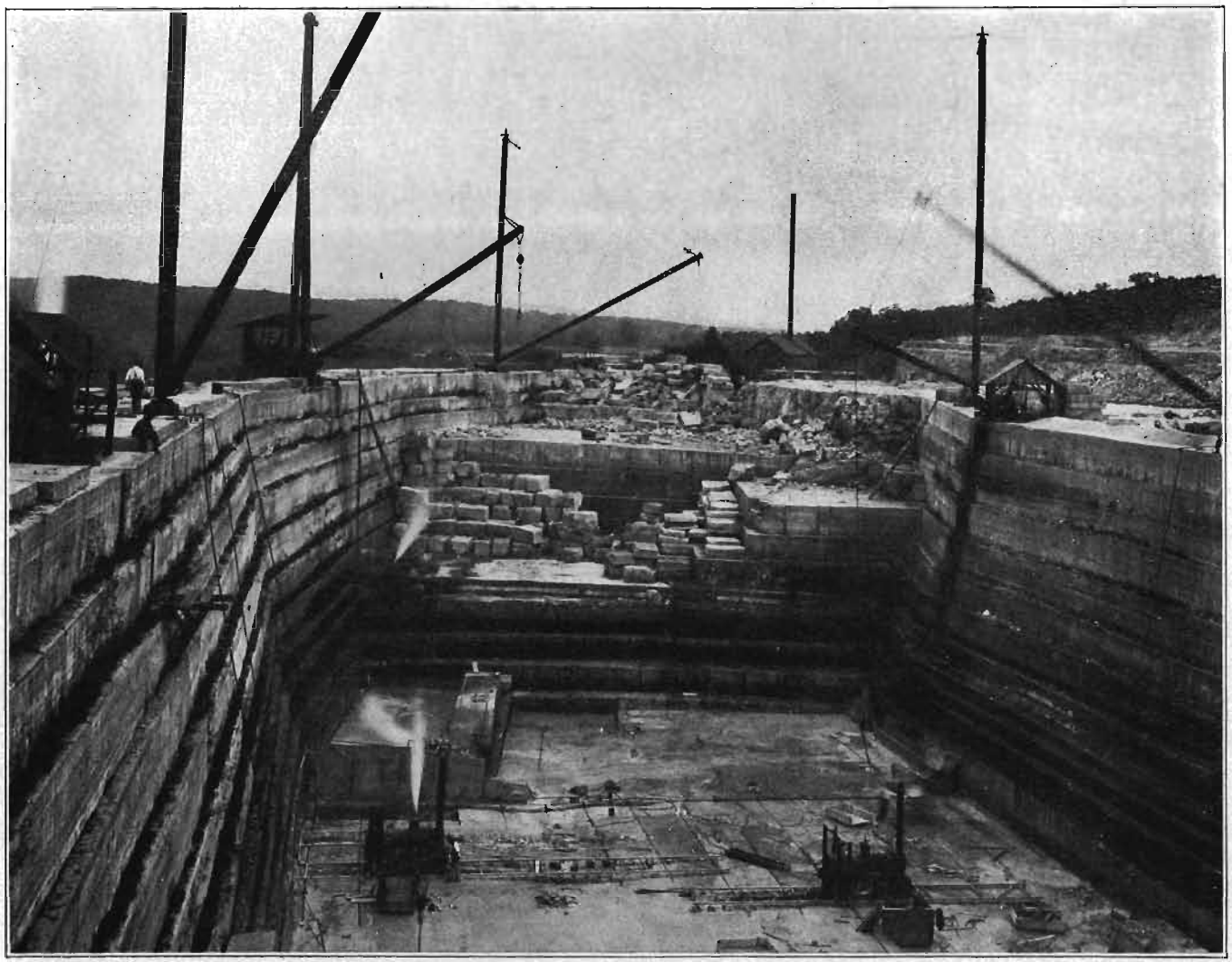
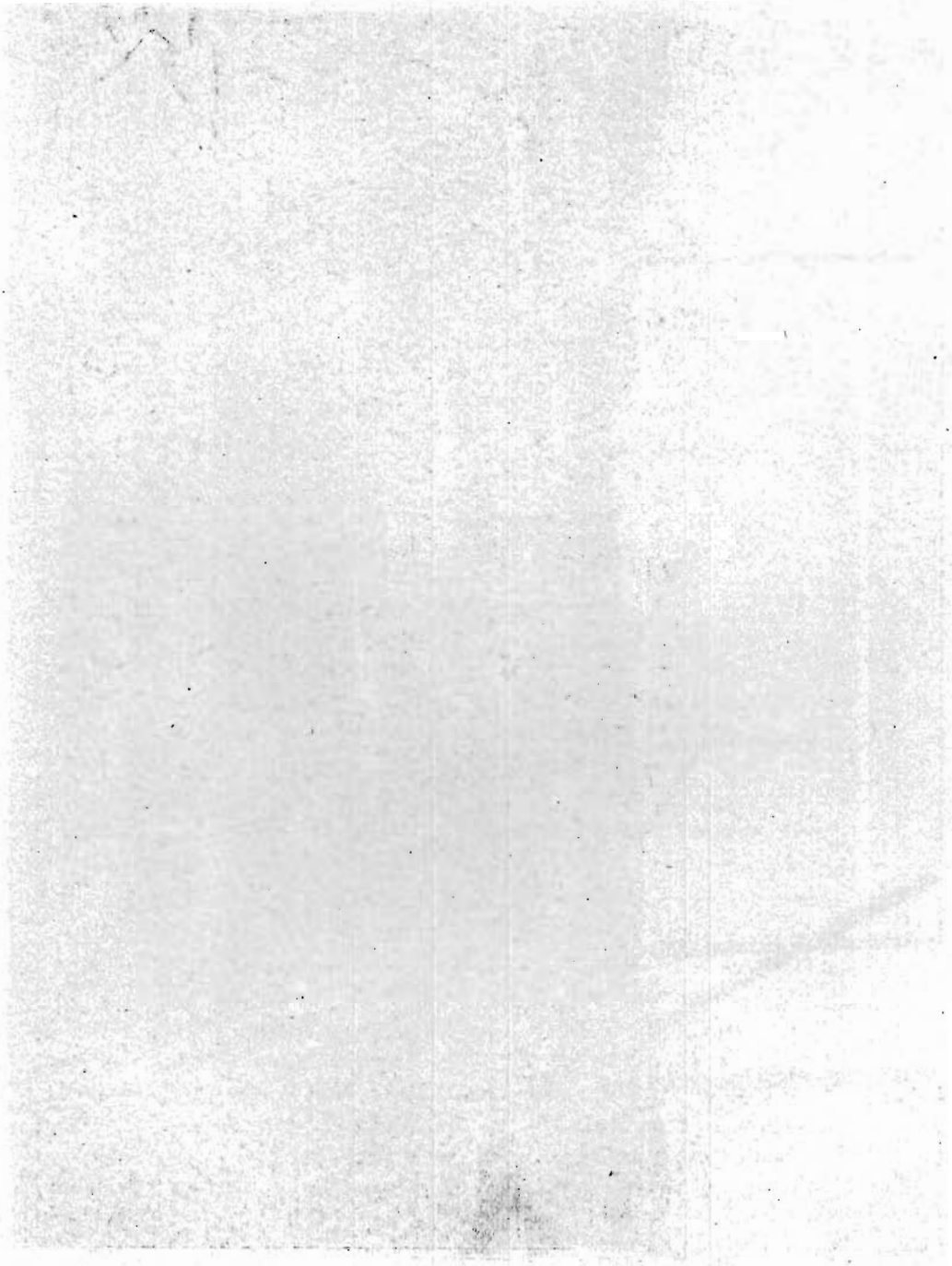


PLATE II—Main pit of Bealer quarry showing channelers in foreground. Cedar Valley, Cedar county. The chief output of the quarry at present is crushed stone and quarry methods have changed very materially.



of the Cedar. The village which has sprung up about them is called Cedar Valley, and a spur connects with the Cedar Rapids-Clinton line of the Chicago, Rock Island & Pacific Railway, near Plato, about two miles northwest. The sequence of beds is as follows:

BEALER'S QUARRY, CEDAR VALLEY.

		FEET.
9.	Limestone, buff, magnesian, very soft, Coggan stage.....	14
8.	Limestone, weathering into chipstone, in layers up to six inches	1½
7.	Limestone, light gray, rough, massive, very vesicular	3
6.	Limestone, fragmental, argillaceous	1
5.	Seam of blue argillaceous material extending for 180 feet along quarry face	0–2
4.	Limestone in thin spalls, hard, dense, "flinty"	5½
3.	Limestone, hard, rough, buff, crystalline, highly vesicular, with moulds of spire-bearing brachiopods, the spires often remaining in casts	5
2.	Limestone in layers from two to eight inches, laminated....	4
1.	Limestone, light buff, granular; lustre dull, homogeneous in grain, slightly vesicular, destitute of silica in any form, fracture even, soft when first quarried, rapidly hardening on drying, bedding planes horizontal, even and comparatively distant, laminated, joints distant, master joints running south-southeast. All quarried for building stone, together with Nos. 2–8, Gower stage	94

The quarries were opened nearly a third of a century since by Mr. E. J. C. Bealer, who, as a practical bridge architect, saw the great value of the stone at this point for bridge piers and all heavy masonry. The chief quarry now in operation was opened some years ago and no expense has been spared to equip it with modern and effective machinery. A levee costing $20,000 has been built along the river front for protection against floods. Railways tracks in the quarries are so built that the force of gravitation is utilized to the utmost and no locomotive engines are required to make up the train of loaded cars which in busy seasons is sent out daily. The stripping of the quarry, consisting of twenty-five feet of soft silt known as loess, and less than ten feet of pebbly glacial clay, is cheaply and expeditiously handled hydraulically by means of a high duty steam pump and suitable pipes and hose. In quarrying the stone there are employed one single and three double steam channellers and sev-

eral steam drills. The plant is well equipped with boilers and engines of sufficient capacity to furnish an abundance of power to operate the channellers, drills, pumps, machine shop equipment, crusher plants and numerous derricks. A large machine shop, well equipped for repairing and rebuilding the tools and machinery of the plant completes the equipment.

The output consists chiefly of bridge stone of three grades. The proprietor contracts for completed bridge piers and has a large force employed in their construction. Dressed dimension stone is cut in the yards and crushed stone, riprap, rubble and curb stone are included in the products of the quarry.

The quarries were opened in natural ledges fronting the river in the face of the bluffs, rising about 120 feet above the stream. These ledges have been quarried away over an area of several acres and on the platform thus formed an extensive pit has been sunk to a depth of sixty feet below the level of water in the river, and another of like dimensions has recently been opened. The lower ninety-four feet is used for bridge and dimension stone, the stone becoming of finer grain and better quality, it is said, with increasing depth, to the present quarry floor. Above this lies a ledge twenty-two feet thick used only for riprap, rubble, railway ballast, and macadam, for which it is admirably adapted. It includes hard, fine-grained spalls, a four-foot layer of hard, highly vesicular, crystalline limestone, and four feet of laminated limestone in layers from two to eight inches thick. On this ledge rests a bed of about twelve feet of soft, earthy limestone, called the Coggan, wholly worthless for any industrial purpose, and constituting a part of the stripping.

The quarry stone belongs to the Gower stage of the Niagaran, according to Norton. It consists of laminated, light buff, granular, even bedded dolomite which withstands chemical decay and mechanical disintegration remarkably well. Open bedding planes are so few that they are found to be practically impervious, a fact markedly at variance with similar beds at Anamosa and Stone City in Jones county. The chemical composition of the rock was found to be as follows:

BUILDING STONE QUARRY, LIME CITY.

Calcium carbonate ($CaCO_3$)	55.3
Magnesium carbonate ($MgCO_3$)	43.0
Ferric and aluminum oxides (Fe_2O_3 and Al_2O_3)	1.4
Silica (SiO_2)	0.6
	100.3

BUILDING STONE, BEALER'S QUARRY, CEDAR VALLEY.

Calcium carbonate ($CaCO_3$)	56.4
Magnesium carbonate ($MgCO_3$)	42.6
Ferric and aluminum oxides (Fe_2O_3 and Al_2O_3)	0.7
Silica (SiO_2)	0.4
	100.1

The rock, however, is laminated throughout and may be split along these planes to layers one foot in thickness without difficulty, and in places to eight and nine inches. On natural outcrops adjacent, long-weathered surfaces often show close lines of lamination, but these are strongly coherent, beyond the usual in this formation, and permit the quarrying of permanently solid blocks of as great thickness as called for. The common size of the blocks raised from the lower part of the quarry is six and one-half feet long and three and one-quarter feet wide and thick, weighing each something more than four tons.

In some of the outcrops of the Anamosa phase of the Gower stage, there are found, especially toward the summit, thin layers or laminæ of a compact drab, fine-grained limestone, called by workmen "flint" on account of its hardness, brittleness, and fracture. Such seams are a direct injury; under the weather they break into small rhombic chipstone. Since their coefficient of expansion is different from that of the adjoining layers, they tend to form in time a horizontal cleavage of the block of which they form a part. At Bealer's quarry these seams are practically absent, and the stone free from this element of weakness as well as of all deleterious accessories, can be strongly recommended as of the highest durability.

Of late years the demand for cut stone has diminished and a large part of the output of the quarries is in the form of crushed rock. The proprietors contract for concrete bridge work as well as for masonry piers and foundations and for this work the rock

from these quarries is excellently adapted. The upper layers are blasted down and crushed and the waste from the lower quarry beds is brought up and sent through the same process and mixed with the other. The crusher used is of the Blake type and has a capacity of 200 yards per day.

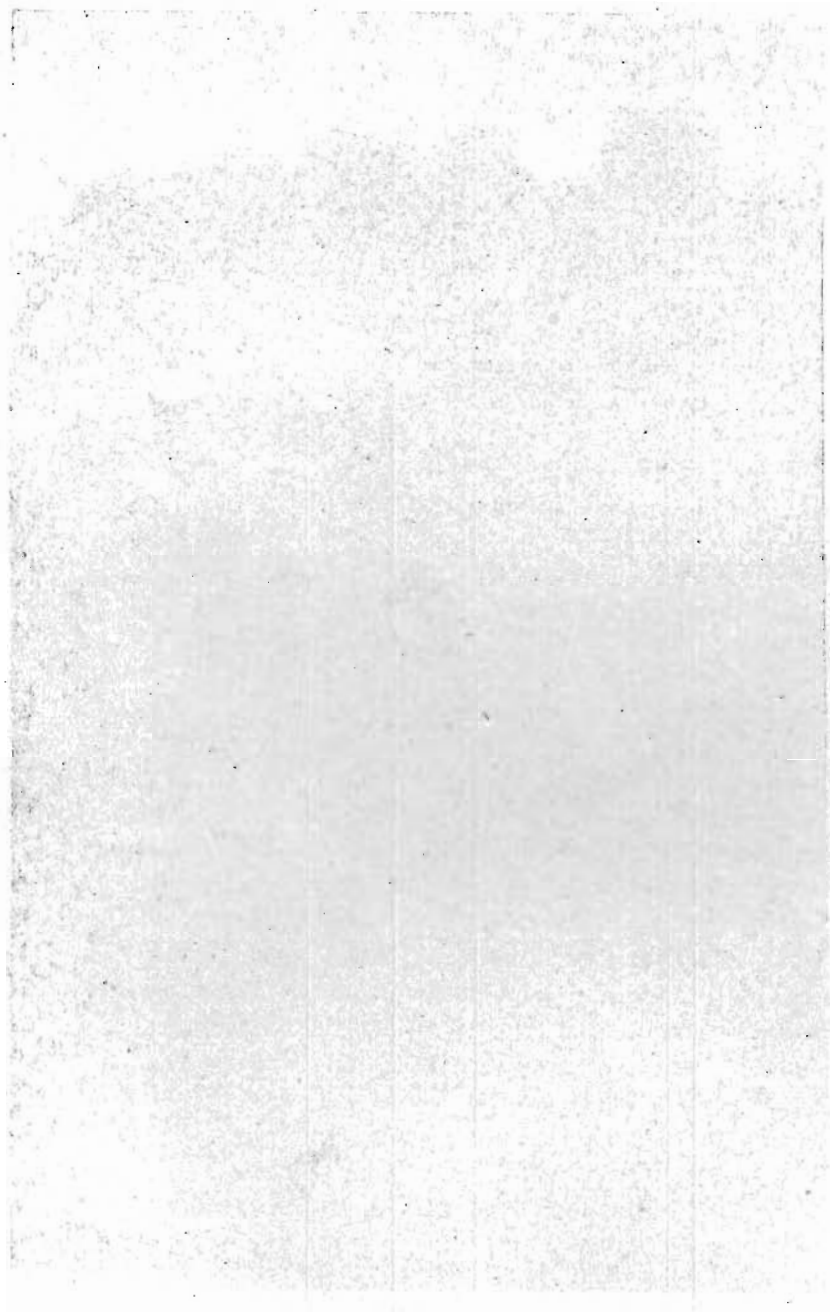
Cedar Bluff.—Immediately above the bridge at this village, a ledge of Anamosa stone has been quarried to some extent for local supply. The face of the ledge is here some thirty-five feet. The upper seven or eight feet are weathered to thin spalls. In the middle lies a stratum of seven feet of fine-grained, light yellow limestone of pure Anamosa type. Below this the stone shows an alternation of harder and softer laminæ, the harder being of finer grain and more brittle. The best building stones are said to be taken from the bed of the river at the base of the ledge.

Below the village the same formation outcrops on both sides of the river, in ledges up to fifty feet in height, showing the same granular laminated limestone, horizontally bedded in even courses, weathering in places to thin calcareous plates, but for the most part standing in undivided layers up to two feet in thickness.

Along the banks of the Wapsipinicon north of Massilon are bluffs of yellow, vesicular or granular dolomite. Some has been quarried for rough use, but it is not suitable for building. It seems rather soft for road work. The stone lies in heavy beds, eighteen to twenty-four inches thick in places, elsewhere massive. Large quantities are available and might be obtained without undue difficulty.

McLeod's Quarry, southwest quarter of section 12, Springfield township.—On the left bank of the Wapsipinicon, less than one-half mile below Massilon, this quarry shows a face of twenty-five feet of vesicular, semicrystalline limestone, the upper fifteen feet massive or obscurely bedded, the lower ten feet in rough layers from eighteen to thirty inches thick, all buff in color, and sparingly fossiliferous. Just below the village on the right bank of the stream, the same layers form a picturesque ledge about thirty feet high.

PLATE III—Quarry section showing irregularly bedded Gower limestone of Cedar county.



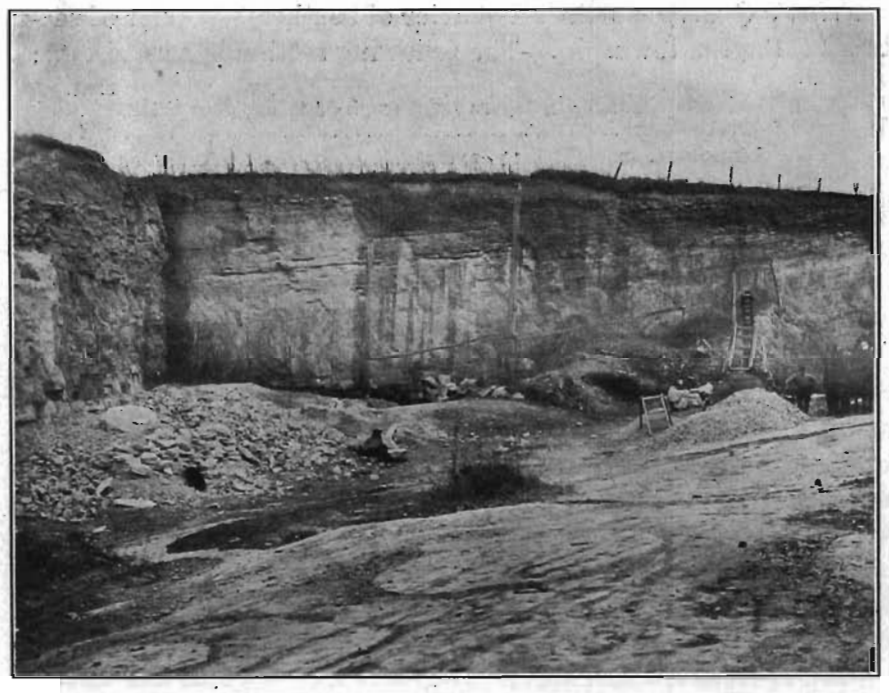


FIG. 16—Weathered face of Miller quarry showing beds dipping to the northeast. Lowden, Cedar county.

One of the largest quarries in northeastern Cedar county is that of Mr. Claus Miller, located in the southwest quarter of section 4, Springfield township. Quite a deep opening has been made here and large amounts of stone have been removed. The pit face shows at the top about six feet of thin slabs of yellow stone which grades down into six to eight feet of gray, laminated, fine-grained, magnesian limestone. Below this is a heavy, buff vesicular ledge five feet thick, following which are twenty feet of evenly bedded, yellowish stone in layers three to twelve inches in thickness. The latter weathers to a grayish color. The upper gray ledges resemble the upper beds of the Champion quarry at Stone City.

The quarry is equipped with a Cedar Rapids No. 2 crusher which has a capacity of thirty-five to forty tons per day. The beds dip steeply to the northeast and the entire quarry floor is inclined in that direction. One wall is a massif in which no bedding is apparent.

Frink's Quarry, northwest quarter of southeast quarter of section 14, Dayton township.—The following section is here shown:

		FEET.
4.	Limestone, rough, in layers from one-half to one foot thick, weathered	4
3.	Limestone, in eight inch layers	2
2.	Limestone, exceedingly rough, crystalline, deeply pitted with rounded cavities up to five inches in diameter	2
1.	To creek level, not exposed	13

The layers here form a gentle syncline dipping 2° north at the south end and 6° south at the north end.

Burrough's Quarry, southwest quarter of section 22, township 80 north, range III west.—The Gower is here quarried on a small scale on the left bank of Rock run. For eight feet above the creek, a very fair granular building stone lies in layers from seven to eighteen inches thick, weathering superficially to spalls two to four inches thick. The dip to the southeast is perceptible. An adjacent ledge reaching a height of twenty feet above water level is composed of laminated limestone, hard, gray and crystalline. A few rods away an old pot kiln attests the possibilities of the stone as a lime maker. Here a layer identical with No. 4 of Whann's quarry is found above the limerock. Across the creek and down the stream on the same farm, about fifty feet of this hard, crystalline, laminated limestone is displayed in overhanging ledges and hillside outcrops. Toward the base the rock weathers to thin spalls, but above the laminæ are coherent and the cliff breaks down in immense blocks. About fifteen feet above the limestone a few fragments of yellow sandstone were seen in a shallow ravine, but no distinct outcrop was found. All the limestone in this section resembles the Anamosa stone in its lamination and in its horizontal or nearly horizontal bedding. Nowhere is it disturbed, tilted, or conglomeratic, as is so commonly the case with the LeClaire. And yet in their hardness, color, and crystalline texture, these beds on Rocky run are distinctly of the LeClaire type.

Wallick's Quarry, east half of section 16, Linn township.—Two and one-half miles north of Cedar Bluff the Anamosa phase is quarried for local uses. The rock rises to the surface in the low hills, so that no stripping, except of weathered spalls, is necessary. The rock is of the ordinary phase of the finely lam-

inated, fine-grained, light buff building stone of the Gower. It is in thin layers, dipping 11° SE., and shows a face of twenty feet.

Hecht's Quarry, northeast quarter of northeast quarter of section 14, Dayton township.—The following section is seen at Hecht's quarry:

		FEET.
3.	Limestone, spalls, irregularly shaped chipstone, buff, resembling conglomerate of harder centres with matrix of limestone meal	4
2.	Limestone, rough, semicrystalline, cores gray, weathering to buff	1
1.	Limestone, for the most part evenly bedded, buff or gray, thickness of layers from above downward in inches: 8, 18, 10, 15, 19, 24, 12, 18, 18. At west end dip of 3° W.; in center slightly S.; at east end a perceptible dip SW	11⅚

Cary's Quarry, southwest quarter of section 13, township 80 north, range III west.—About two and three-fourths miles southwest of Tipton, two quarries have been opened on Rock creek. Mr. M. C. Cary here quarries a face of fifteen feet in layers mostly of the thickness of flagging, but some reaching nine inches. At the west end of the quarry, the stone is hard and crystalline, of the LeClaire phase, in layers six inches thick and upward and dipping 12° SSE. Two rods east this has passed into the Anamosa phase, but slightly harder and more crystalline than typical, dipping 3° E., the juncture being now concealed.

Twenty-five rods southwest of this section a small quarry has been opened showing a mound of hard limerock at the north end, and, the juncture again being obscured, at the south Anamosa stone, some layers being soft and granular, and others harder and more compact. The layers here run from one and two inches to nine and twelve, and dip from 30° WNW. to 38° NNW.

Whann's Quarry, northeast quarter of northwest quarter of section 14, township 80 north, range III west:

		FEET.
5.	Limestone, light buff, hard, fine-grained, lustre earthy, resembles Bertram beds of Linn county	2
4.	Limestone, buff, softer, with numerous branching vertical tubes one to two mm. in diameter	1
3.	Limestone, hard, gray, crystalline	1⅙
2.	Limestone, buff, more or less vesicular, in layers from 8 to 30 inches thick, with bands of harder crystalline gray rock.	5
1.	Limestone in layers as above, buff, granular, laminated	6½

The dip here is a gentle one to the southwest. A few rods up stream the ledge is seen to form a low syncline.

Beds of Devonian age cover a large triangular area over the southwest fourth of the county and numerous outcrops are to be seen along Cedar river and its more important tributaries, Rock and Sugar creeks, often showing the Niagaran beds below. Notwithstanding the availability and large areal distribution of these beds they are overshadowed in importance by the Niagaran and are of local importance only. The only producers are small quarries on the west bank of the Cedar in Iowa township near the Muscatine county line. The quarry section is given below.

		FEET.
4.	Limestone, hard, compact, gray and buff, mottled, in layers from 2 to 4 inches thick, overlain with red geest.....	1½
3.	Limestone, shaly, yellow	½
2.	Limestone, yellowish drab, splitting into irregular layers, from 2 to 6 inches thick	3
1.	Limestone, tough, hard, gray, evenly bedded, resistant to weathering, in two or three layers.....	3½

About thirty-five feet above the base of the hill layers of a comparatively barren limestone have been opened up. In the five feet here exposed no fragments large enough to identify were found. The stone is yellow, breaking up into chipstone.

CERRO GORDO COUNTY.

Sand and Gravel.

The Wisconsin drift covers rather more than the western tier of townships and for the most part the entire belt is decidedly morainal in character. The leading streams of the county head in the Wisconsin drift area and as a rule are margined with important terraces. The gravel terraces along Lime creek and its immediate tributaries are well described in Professor Calvin's report on the Geology of Cerro Gordo county*. The description is given herewith.

Within the morainic belt, in Grant township, the course of Lime creek is very tortuous, since of necessity it winds back and forth to avoid the lawlessly disposed knobs and hills of drift. In

*Iowa Geological Survey, Vol. VII, p. 137.

this region the channel is new, dating only from the retreat of the Wisconsin ice. It now occupies a mere shallow trough in loose glacial detritus, showing only an inconsiderable amount of erosion since the stream began work upon it. There is here properly no river valley, nor are there any tributary streams with definitely marked channels. The drainage waters from adjacent lands find their way into Lime creek sometimes by very roundabout courses, along broad, flat-bottomed swales, or through reedy, ill-drained marshes.

In the Iowan drift area, however, Lime creek follows a preglacial valley that was originally in places two or three miles in width. In depth the valley varies from twenty to seventy feet.

Its history is well recorded in the western part of Lime Creek township. Here the present stream flows in a small, shallow and narrow channel near the southern margin of the valley. The south bank of the stream rises abruptly to a height of thirty or forty feet. On the north side a plain with gentle slope begins near the level of the water and extends back to a terrace that is eight or ten feet in height. At the summit of the terrace there begins another plain that may be two miles or more in width and is terminated on the north by an irregular line of low hills. The history seems to have been as follows: The preglacial valley had a width reaching from the south bank of the present stream to the line of hills which form the northern border of the second plain noted above. The sub-Aftonian (Nebraskan) drift, if it were ever deposited in this region, can not be differentiated from the Kansan, but it is certain that at the close of the Kansan stage the old valley was only partially filled with detritus, and an important drainage stream of the subsequent interglacial stage followed the old depression and in part re-excavated the valley. At the beginning of the Iowan stage the re-excavation was far from complete, its amount being represented by the space between the south wall of the valley and the first terrace north of the present stream. The Iowan glaciers deposited only a very thin sheet of drift over this region; but they carried numerous bowlders that are scattered over the whole surface of highlands and lower plains. The plain between the terrace and the channel, and rising only a few feet above the

level of the water, is thickly strewn with large Iowan bowlders that have not been disturbed since they were deposited at the level at which they now lie. The present channel is a shallow trough cut in the Iowan drift of this lower plain, and represents the inconsiderable amount of erosion since the withdrawal of the Iowan ice.

The stage of the Buchanan gravels is represented by extensive gravel deposits in the valley of Lime creek, and by similar deposits along Blake creek and other tributaries. The main bodies of these gravels were deposited in the partly filled preglacial valley of Lime creek. They underlie a large area on the north side of the stream in Lime Creek and Lincoln townships, occupying the level space south of the highlands which mark the boundary of the preglacial valley. Good exposures are seen at various points north of the road near Lincoln mills, in section 15 of Lincoln township; in section 10 of the same township there is a pit, worked for road material, that shows above gravel a thin sheet of Iowan till with characteristic granite bowlders. Wells and other excavations reveal underlying gravel throughout the whole plain south of the highlands already noted. Blake creek in Lime Creek township has cut its valley through the thin sheet of Iowan till and exposed the same gravels at various points, good outcrops occurring north of the center of section 16. The higher ground on either side of the shallow valley is, in places, thickly strewn with Iowan bowlders.

A rather sandy phase of the gravels was formerly worked extensively for ballast by the Chicago, Milwaukee & St. Paul Railway, and at the present time is being developed by the Mason City Sand Company, in the southwest quarter of section 2 of Mason township. There are exposures in the northern part of Mason City on the west side of Lime creek, and from one of these, located near the greenhouse, workmen some time ago obtained the horn of a reindeer. The gravel in the northern part of the city is rather coarse but just east of the city the material is much finer, and the beds have been worked for building sand. The sand, however, contains more or less gravel; and near the base of the deposit there are many large slabs and fragments of limestone. Gravel beds of varying degrees of fineness are

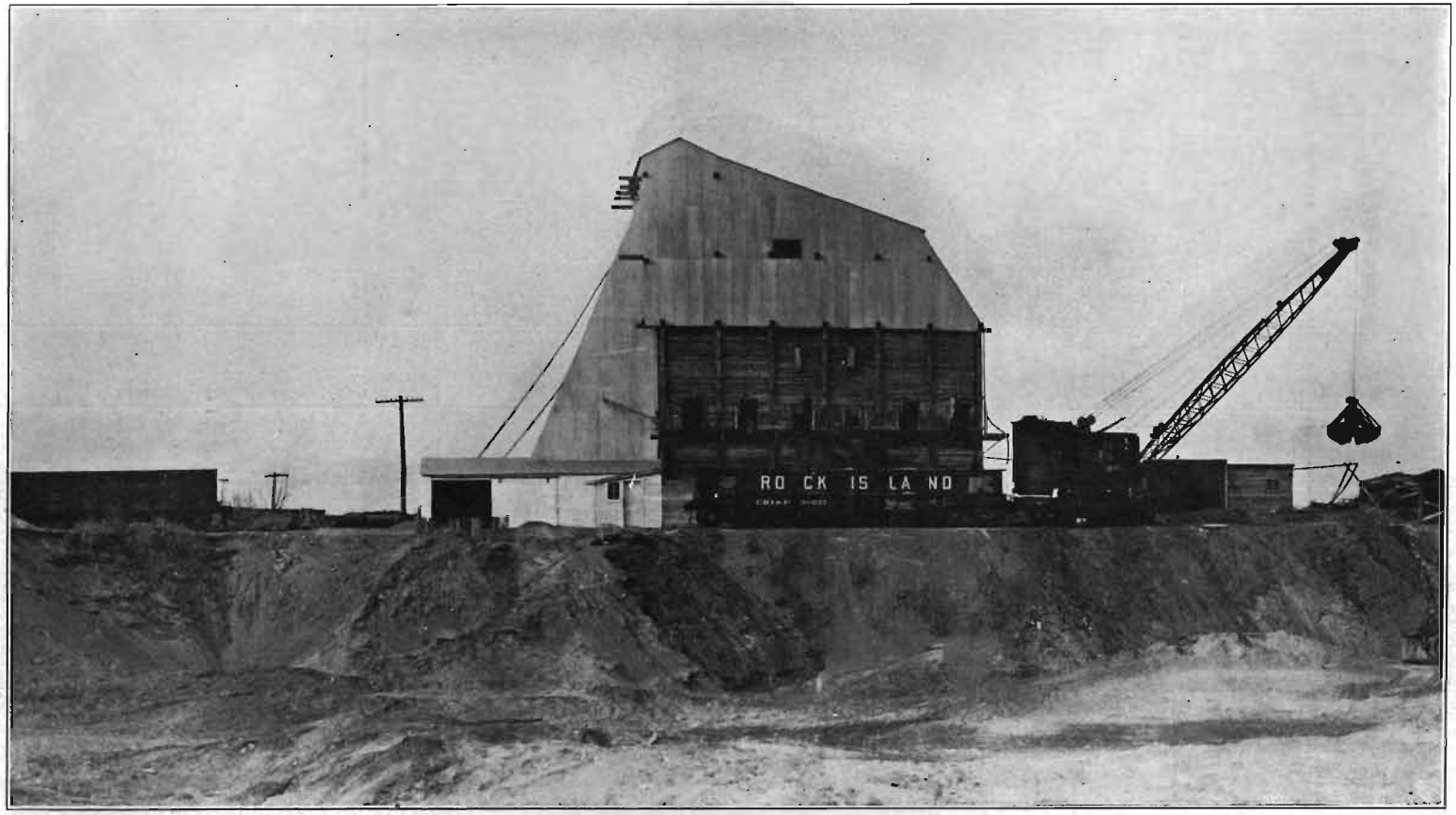
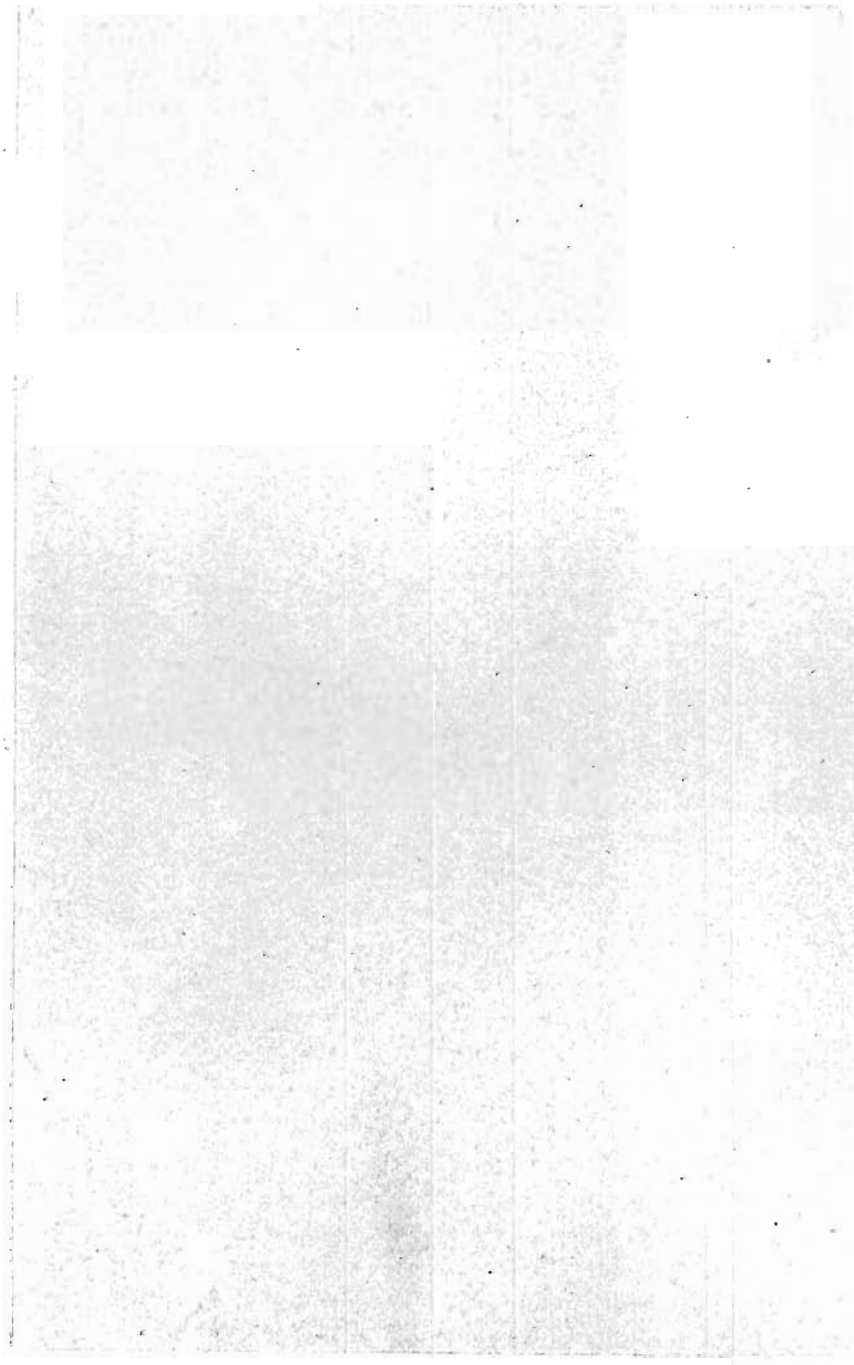


Plate IV—Pit and Plant of Mason City Sand Company, Mason City, Iowa, showing dipper so mounted that it is used for stripping, loading cars at pit and transferring gravel from cars to screening plant.

PLATE V—Pit of the Mason City Sand Company, showing screening plants in the distance and worked-over land ("Bad Lands") in the foreground. Mason City.



distributed along the valley of Lime creek throughout its whole extent in Cerro Gordo county. The old pre-Kansan valley, only partially filled with drift, seems to have carried torrents of water from the melting Kansan ice. The torrents were loaded with gravel and sand, and doubtless with finer material, and the coarser fragments were deposited to form the gravel beds above described. After the Kansan ice had retreated beyond the limits of the drainage area tributary to this valley, when the stream had shrunk to the dimensions required to carry off the normal precipitation and when the current was no longer loaded, erosion attacked the gravel beds and re-excavated a portion of the valley.

Shell Rock river bears every evidence of youth and has accumulated but little sand or gravel. Terraces are of but slight development or are entirely wanting.

Eskers and Valley Trains.—The Altamont moraine covers a large portion of the western tier of townships. The hills and bosses, many of which are gravel-bearing, that characterize the moraine become less pronounced in the southern and southwestern part of Grimes township. Indeed in the southwestern part of this township, the hills fade into the level, characterless topography peculiar to the central areas of Wisconsin drift. In this level region, parts of which are still very marshy, are the initial branches of the south fork of Beaver Dam creek which, flowing southeast, finally emerges upon the area of Iowan drift. The valley of this creek seems to have been the chief outlet in Cerro Gordo county for the waters resulting from melting of the Wisconsin ice. Accordingly, near Thornton, about half a mile southwest of the village, there is a well defined esker in the form of a long ridge of gravel resting on Wisconsin drift. This gravel, as might be inferred from its origin, contains a large proportion of limestone pebbles. The ridge, which is three-fourths of a mile in length, trends a few degrees south of east. It is not quite parallel to the present drainage. The course of the glacial stream to which it owes its origin was determined by conditions that determined the position and course of the modern streams.

In the neighborhood of Thornton the streams flow over beds of the same kind of gravel found in the esker. A heavy accumulation occurs below the village near the point where two branches flow together. Trains of gravel follow the creek valley beyond the limit of the moraine, well out into the region of Iowan drift. The last gravel beds of this age in Cerro Gordo county occur along the south line of section 36, Pleasant Valley township, where the stream passes into Franklin county.

Stone.

Beds of Devonian age are believed to occur immediately beneath the drift over the entire county, with the exception of a triangular area in the southwest corner. Two distinct substages may be readily recognized, the lower beds, which are prevailingly calcareous or dolomitic and highly indurated, often subcrystalline, and an upper series which is made of shales and marls with occasional indurated ledges. The first belongs to the Cedar Valley stage of the Devonian, of which the upper portion only is represented in the county, while the latter belongs to the Lime Creek shales of the Upper Devonian series. The principal outcrops of the Cedar Valley limestones occur along Lime creek and Shell Rock river and their immediate tributaries. All of the quarries in the county which are of more than local significance are developed in this stage. From an economic standpoint the Cedar Valley beds may be separated into four groups more or less readily recognized. The sequence is as follows, from top downwards:

		FEET.
4.	Limestone, exceedingly variable in texture, structure, and composition, ranging from a granular, subcrystalline dolomite, through magnesian limestone and argillaceous limestone, to pure limestone. The beds thicken and thin out in short distances. In places lamellar stromatoporoids are present in lower beds	25+
3.	Limestone, a well-marked reef of nodular or spheroidal Stromatoporas, characteristically developed in sections in and about Mason City	8–10
2.	Limestone, white to light gray, hard and compact, brittle, breaks with a conchoidal fracture, evenly bedded, nonfossiliferous; in layers up to two feet in thickness, about	15
1.	Dolomite, brown, subcrystalline, granular; generally in regular beds and but slightly porous or vesicular; thickness of individual layers and aggregate thickness variable. Earthy to calcareous and variable in composition below	20+

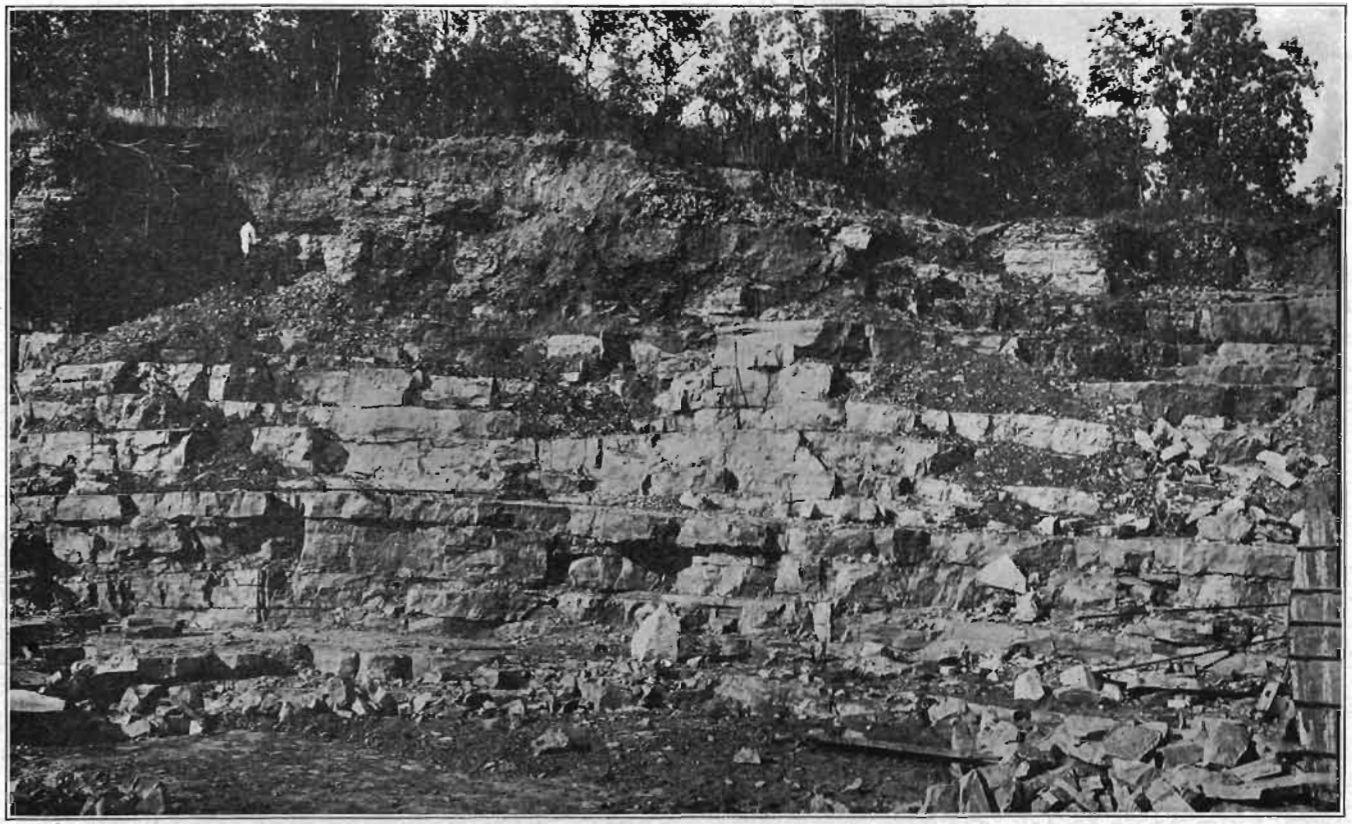
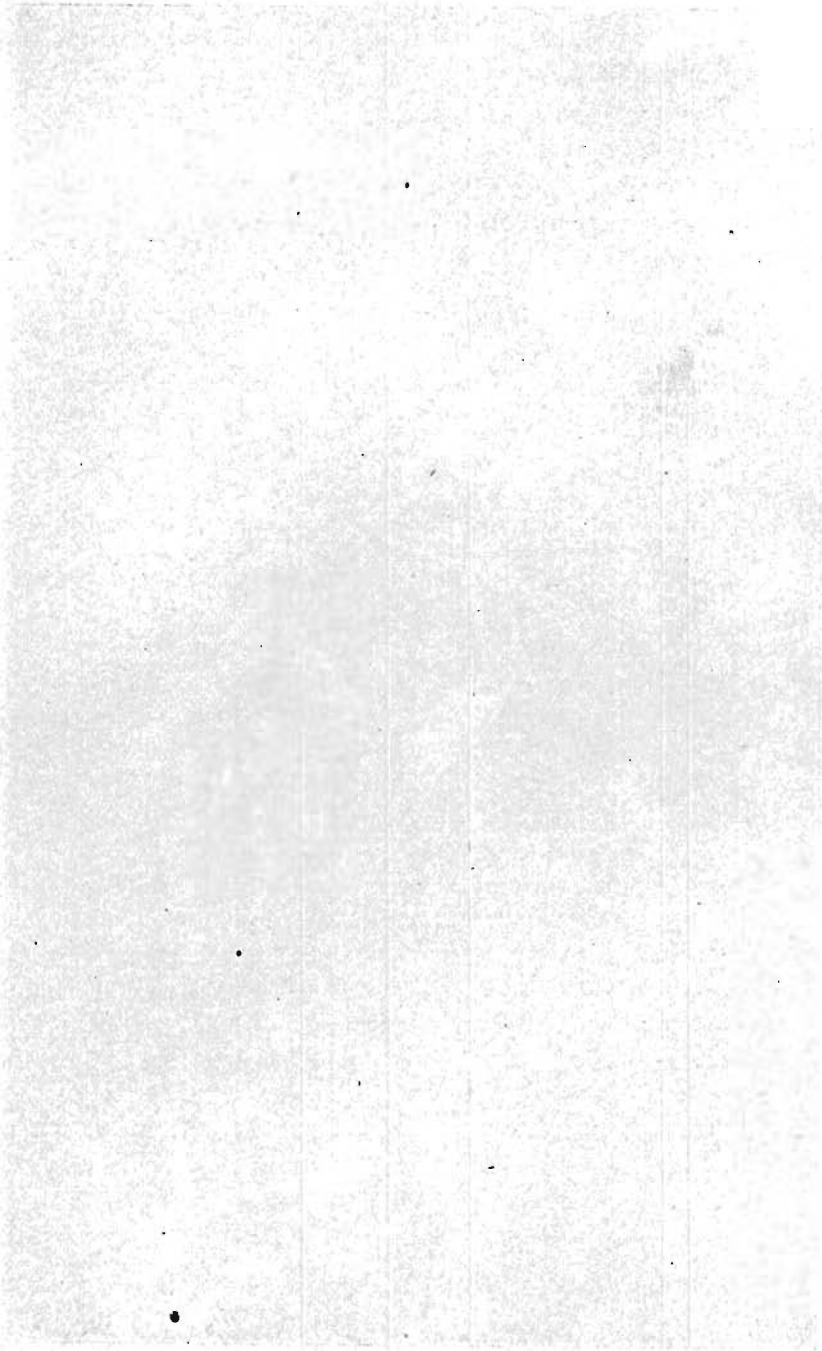


PLATE VI—Kuppinger quarry, Mason City, Cerro Gordo county, showing the dolomite below, compact white limestone in the middle and the Stromatopora near the top of the section; an average section for the district.



Numbers 1 and 2 afford all the stone used for dimension purposes. Number 3 is used for lime and is suitable for crushed stone. The principal quarries are located in the vicinity of Mason City.

The Kuppinger quarry, located on the east bank of Lime creek, between the bridge and the mill dam, in the northeastern part of Mason City, gives the following section:

THE KUPPINGER QUARRY.

		FEET.
7.	Residual clay and drift	4
6.	Somewhat regularly bedded stromatoporoid limestone	3
5.	Reef of stromatoporoids consisting largely of spheroidal coralla with concentric, laminated structure; some of the coralla are more than a foot in diameter. Weathers into spheroidal masses. Bedding obscure	5
4.	White or grayish, fine-grained limestone, breaking with conchoidal fracture, very compact; ledges ranging from a few inches to more than two feet in thickness. No traces of fossils, or traces few and very obscure	14
3.	Bluish limestone, flexuous and unevenly bedded	2
2.	Hard, crystalline, grayish dolomite, with occasional streaks of brown and red. In weathered portions of this member, the crystals of dolomite are in places very loosely cemented and the rock has the appearance of a friable sandstone. Some beds are vesicular, owing to the solution and removal of fossils. The cavities, however, are lined with crystals to such an extent as to obliterate all evidence of generic or specific characters. Ledges varying from 6 to 36 inches in thickness	8
1.	From floor of quarry to level of stream, covered with talus	2

The bluff slopes some fifteen feet higher than the quarry face, and is apparently supported by indurated rock. The lamellar stromatoporoids appear in detached blocks. Numbers 2 and 4 are the beds most prized for structural purposes. At the present time, the quarry is worked only intermittently, and then in a small way. But little labor saving machinery has been installed.

Openings have been made in the bluff up stream from the Kuppinger quarry, but no new beds are exposed. The beds exposed in the quarry of the Mason City Lime and Cement Company are essentially a repetition of the above.

At Parker's Mill on Willow creek, the following natural section is exposed:

PARKER'S MILL SECTION.

		FEET.
6.	Stromatopora reef, equivalent of No. 5 of the Kuppinger quarry	4
5.	White limestone, somewhat split up by weathering	14
4.	Evenly bedded dolomite, in ledges varying from 3 to 30 inches in thickness	12
3.	Impure dolomite, breaking irregularly by exposure to weather, and containing many cavities lined with crystals of calcite	2½
2.	Crumbling, calcareous, granular bed, light gray in color, with many nodular and branching stromatopores, some favosites and beautiful coralla of *Pachyphyllum woodmani*	1
1.	Argillaceous limestone, dark drab in color, homogeneous, but breaking up on exposure to frost	2

Numbers 1, 2 and 3 appear to be lower in the series than 1 in the Kuppinger quarry.

Several companies have opened quarries north of the city. Among others are the Belden Stone Company, the Mason City Quarry Company, and the Mason City Stone Company. The last named company has sold out to the Northwestern States Portland Cement Company.

The sequence of beds exposed in the quarries of the Belden Stone Company is given in the following section. These quarries are located in the southeast quarter of the northwest quarter of section 27, Lime Creek township.

BELDEN STONE COMPANY SECTION.

		FEET.
7.	Soil and residual clay from a few inches to	2½
6.	White or grayish limestone, shattered into small pieces; removed as part of the stripping	3
5.	White limestone in thin layers	3
4.	White limestone in layers from 2½ to 10 inches in thickness, good building stone	4
3.	Evenly bedded dolomite, suitable for heavy walls or for cutting into caps and sills; in three ledges 21, 10 and 11 inches respectively in thickness	3½
2.	"Blue cap," a bed that quarries out in shapeless, worthless blocks, in two ledges; an impure dolomite	3
1.	Brown, bluish and gray dolomite in eight ledges, varying from 4 to 13 inches in thickness	5½

The white limestone here having less overburden is more weathered, which finds expression in its being more thinly bedded and fractured.

The beds developed by the Mason City Stone Company consist of an aggregate of nearly twenty feet of dolomite and rather more than ten feet of the white limestone.

In all of these quarries the dolomite occurs in layers of good thickness and is of excellent quality. It usually presents a more or less rough surface owing to the subcrystalline, granular texture, and is known commercially as "Mason City sandstone." East of Mason City, the white limestone becomes much less important. A short distance below the wagon bridge at Portland, the following beds may be observed:

PORTLAND SECTION.

		FEET.
6.	Soil and wash up to	3
5.	Dolomite, coarsely granular, in thin layers	2
4.	Limestone, white with laminar Stromatoporas	2
3.	Limestone, the spheroidal Stromatopora reef, but more evidently stratified than at Mason City	4
2.	Limestone, white, evenly bedded	3
1.	Dolomite, in heavy beds	13

Up the river toward the mill, dolomitized beds higher in the series may be viewed. Numbers 1 to 4 may be correlated readily with the Mason City sections. The beds dip at a low angle down stream, and almost wholly disappear some two miles below the bridge. The "Clay Banks," beginning on the northwest quarter of section 35, present an abrupt escarpment facing the creek, and rest on the variable beds of the Cedar Valley stage which appear in the channel of the creek. While the Lime Creek shales which constitute the "clay banks" contain occasional hard ledges, they are not of sufficient importance in this connection to merit description.

Above Mason City, the Cedar Valley limestone presents an almost continuous section along Lime creek to Fertile in Worth county. The beds display many local undulations and the usual variations in composition and texture. As a rule the beds are lower, and the main dolomite quarried in Mason City and vicinity is not well exposed. The white limestone thins materially and is oftentimes below the water line. No important quarries have been opened, although much stone has been taken out for local use.

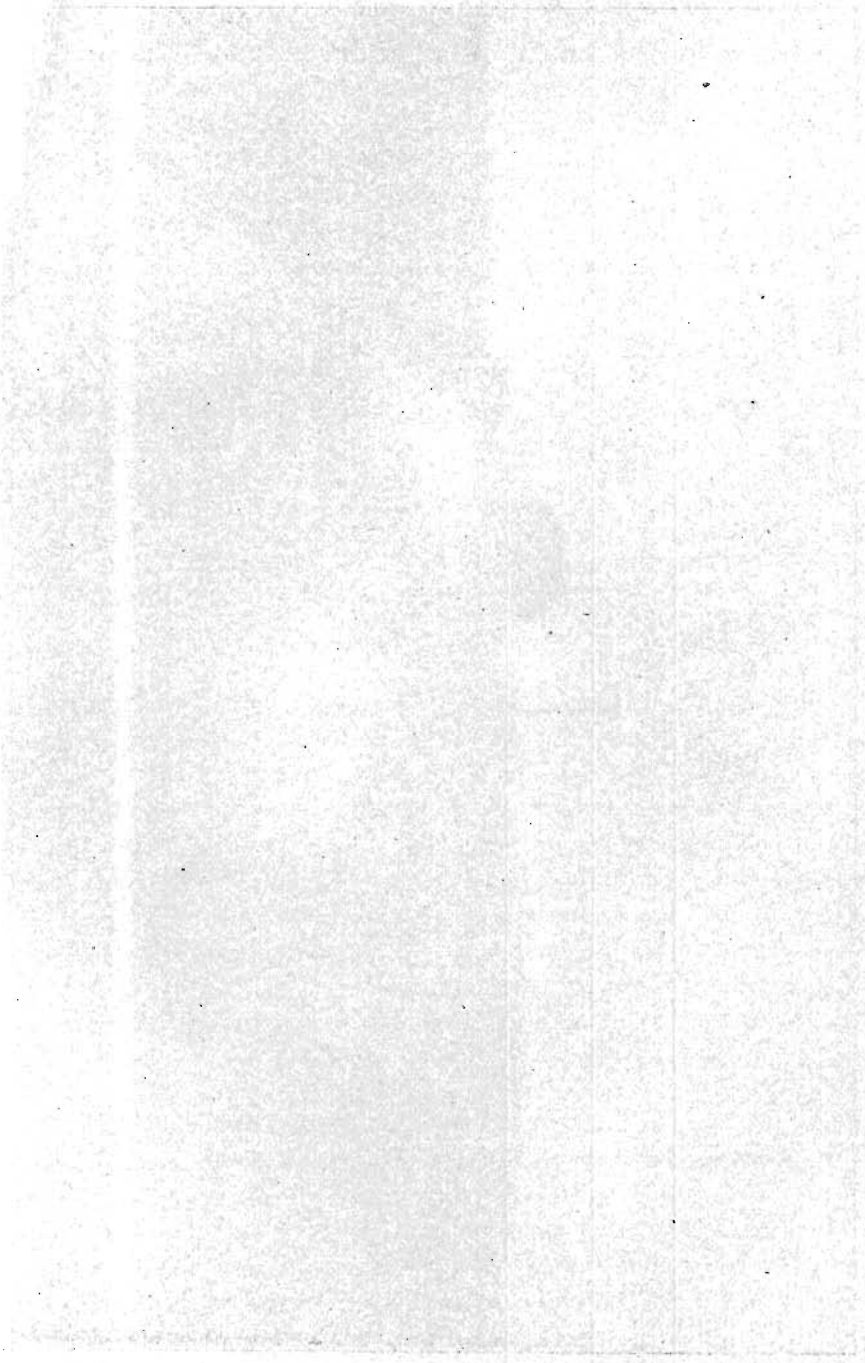
Along Shell Rock river the white limestone and heavy dolomite are the chief terranes exposed. Occasionally very limited exposures of the beds above and below may be seen. Outcrops of the various beds appear at short intervals from Foster's mill above Plymouth to the Floyd county line. The beds as a rule are more profoundly folded than their equivalents along Lime creek. In the vicinity of Plymouth dolomitic beds prevail and are quarried to some extent. They are supposed to be the equivalents of the dolomite in the Portland section above the stromatoporoid zones. The beds rise down stream. At Rock Falls beds much lower in the series appear. Below the wagon bridge, the following section is exposed:

		FEET.
5.	Drift and waste almost nothing.	
4.	Limestone, white	1–3
3.	Dolomite, in regular beds and of good quality	16
2.	Dolomite, impure and irregularly bedded, becoming nodular on weathering	3
1.	Dolomite, argillaceous	3

The lower beds in the above section are almost identical with those exposed in the Parker's Mill section in Mason City. Numbers 1 to 3 are better seen in Vermilya's bluff on the northeast quarter of section 35 in Falls township, where they show a maximum exposure of forty feet. The lower twenty feet show no definite bedding planes and the rock breaks up by weathering into angular pieces. While the beds are more or less continuously exposed for some distance, no new phases are shown within the confines of the county. While quarries might be opened at almost any point, none worthy of individual mention are in operation.

Lime Creek Shales.

While the Lime Creek shales as developed in Cerro Gordo county comprise essentially clay shales and marls, occasional indurated ledges are present, especially in the upper member or Owen beds. These hard layers are quarried at several points in Portland, Owen, Geneseo and Dougherty townships. The stone developed is usually a rather soft, yellow, earthy dolomite of fair to poor quality, and is of local importance only.



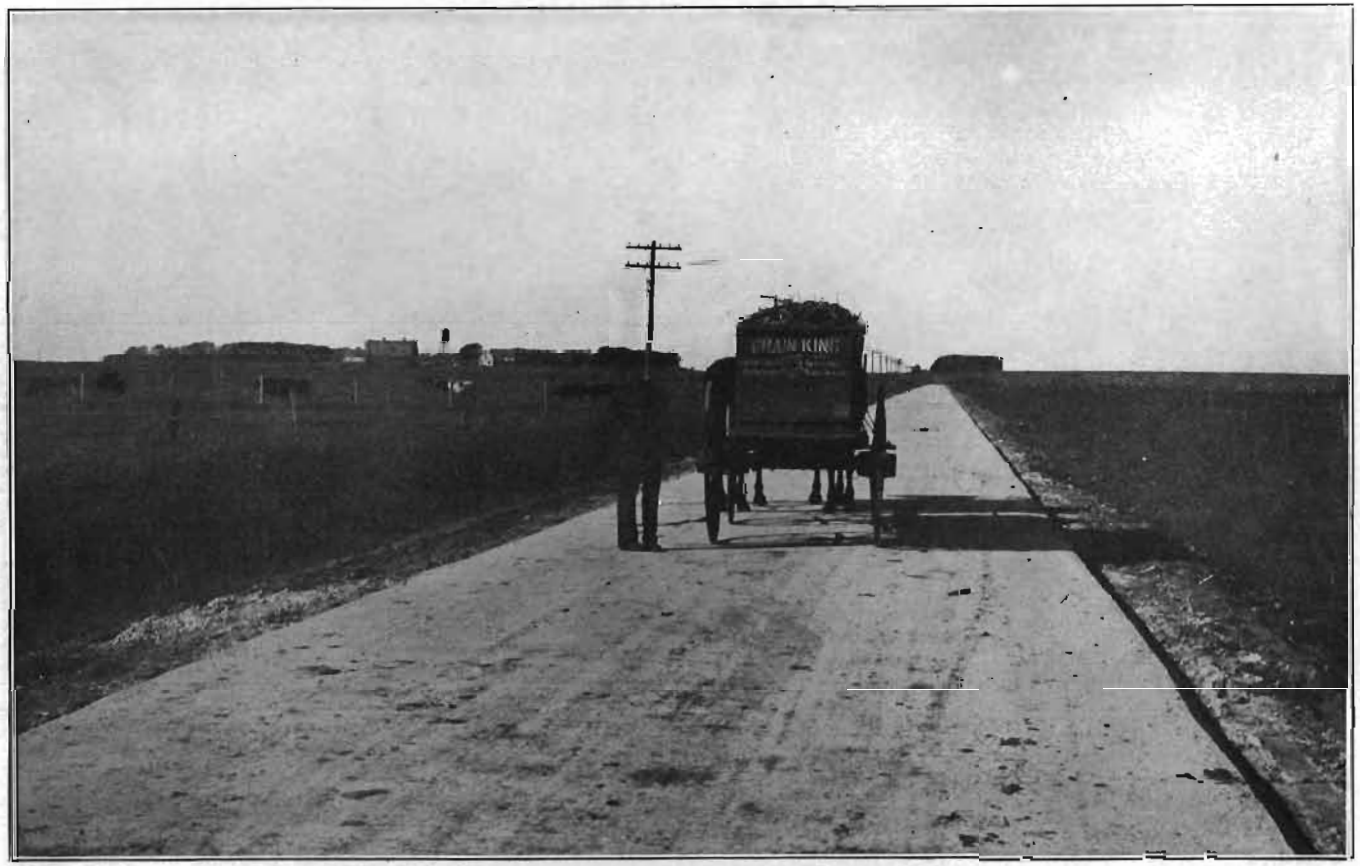
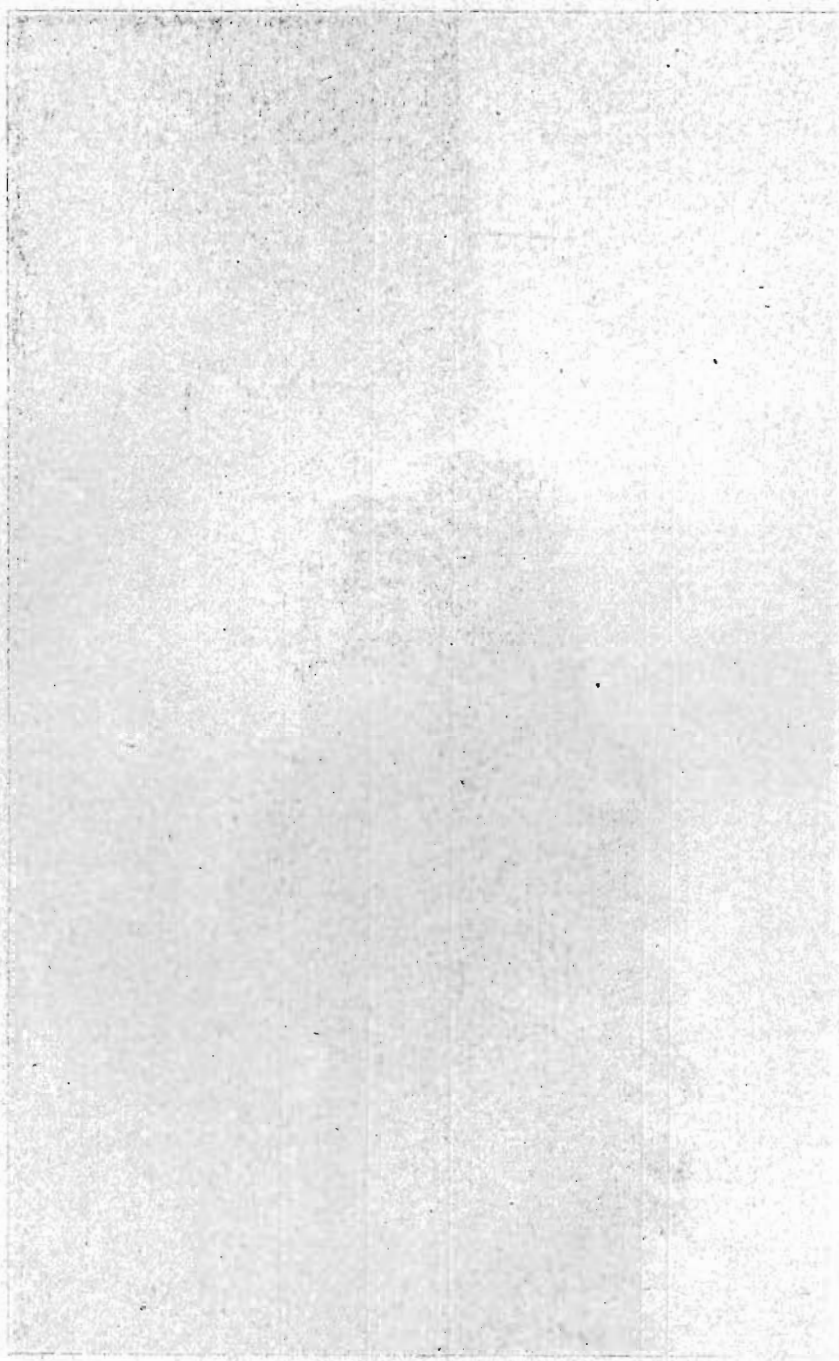


PLATE VII—Mason City-Clear Lake road after laying the concrete but before bank is done. Cerro Gordo county.

PLATE VIII—Mason City-Clear Lake road completed.



CHEROKEE COUNTY.

Sand and Gravel.

Little Sioux river and its terraces furnish practically all the gravel and sand deposits in Cherokee county. Throughout its whole course in the county the river is flanked on one or both sides by gravel terraces of mammoth size which so far surpass the sand bar and other small deposits in quantity, quality and accessibility that the latter receive but slight attention.

Stream Terraces.—As to the age of the gravel terraces along Little Sioux river there is at present some little difference of opinion. Macbride, in his report on this region, has disposed of them as Wisconsin, but in the light of later work there seems to be reason to question this classification. Be that as it may, the fact remains that these enormous deposits of water-laid materials were put down at a stage of the stream far superior to the present one, and at a time evidently, when almost unthinkable quantities of water rushed down this drainage channel. There seems now to be no cause to question the theory that the great floods which deposited these gravels were derived from melting ice, whatever the age of that ice may have been, and Macbride's description* of the manner of deposition of these materials is doubtless the correct one:

"When the glacier lay on all the plains to the east and north, the valley of the Little Sioux, as it appears in Cherokee county today, broad and deep, did its part in carrying away the waters from the glacier's front, the constantly melting margin. Indeed the valley seems to have been more than once nearly choked by deposits of gravel and perhaps in the upper parts of its course with ice. Especially north of Cherokee the banks of the river valley are everywhere marked by gravel terraces far above the flood plain of the present stream, sometimes as much as a hundred feet above it. Such deposits are not the effect of ordinary erosive process. There is every evidence that the channel of the river had been fully excavated long before these deposits came to place. Sometimes they hang as a simple residue far up on the side of the sloping bluff, as

*Iowa Geological Survey, Volume XII, p. 310.

in section 1 of Cherokee township; again they form great masses and parapets choking up half the valley, as in Spring township; sometimes two or three succeeding terraces may be traced, as in section 1 of Cherokee township. The main part of the city of Cherokee rests upon one of these benches; the Illinois Central railway follows another north of the city. South of Cherokee the deposits are still abundantly traceable but they are as a rule much lower; nevertheless they affect the configuration of the valley entirely across the county."

There are four distinct terraces traceable along the Little Sioux and all save the highest one consist partially of gravel and sand. This one, which rises some hundred and forty feet above the river, is erosional and consists of loess and Kansan drift. In many places it is quite gravelly although no pits or other exposures are to be seen along its edge. While the altitudes of the others vary somewhat it is clear that there are at least three besides the one mentioned, one thirty to forty feet, one sixty to seventy-five feet, and one about a hundred feet above the river.

The town of Washta is built on the lower terrace. A short distance north of the town a small pit shows at least ten feet of sand and gravel under about two feet of alluvium which may become thicker farther from the edge of the terrace. In section 21, Willow township, this terrace consists of a thin veneer of gravel over clay. There is gravel in this section, also in the next higher terrace, whose vertical face shows:

	FEET.
Alluvium	7
Gravel and sand	28
Clay below.	

Pebbles about the size of hickory nuts are plentiful near the top of the bed, but the lower part is largely sand. This terrace is nearly one-quarter of a mile wide by a mile long.

In sections 19, 20 and 30 of Willow township this same seventy-foot terrace is composed largely of gravel, and while definite figures cannot be given, the thickness of this material is probably between twenty-five and fifty feet.

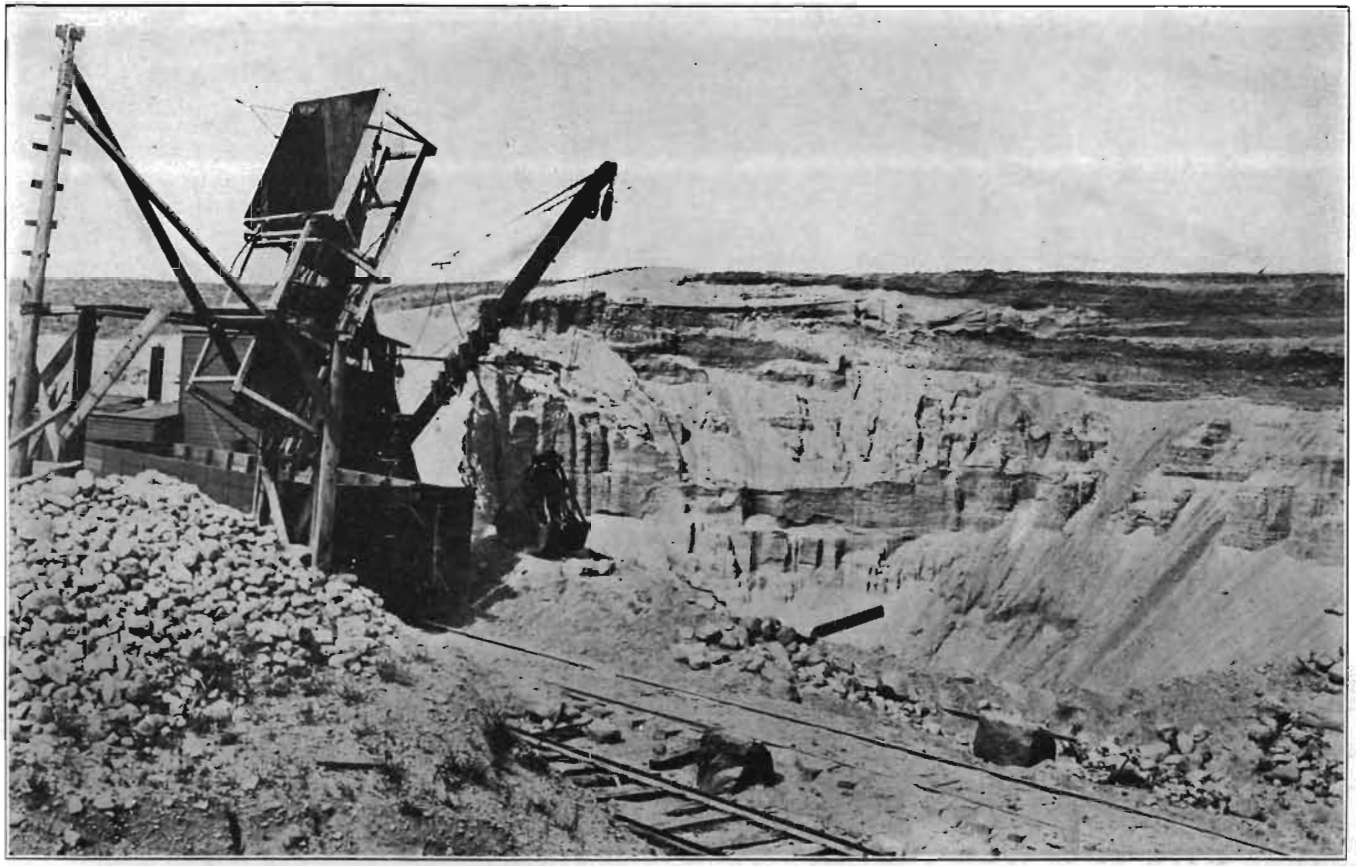
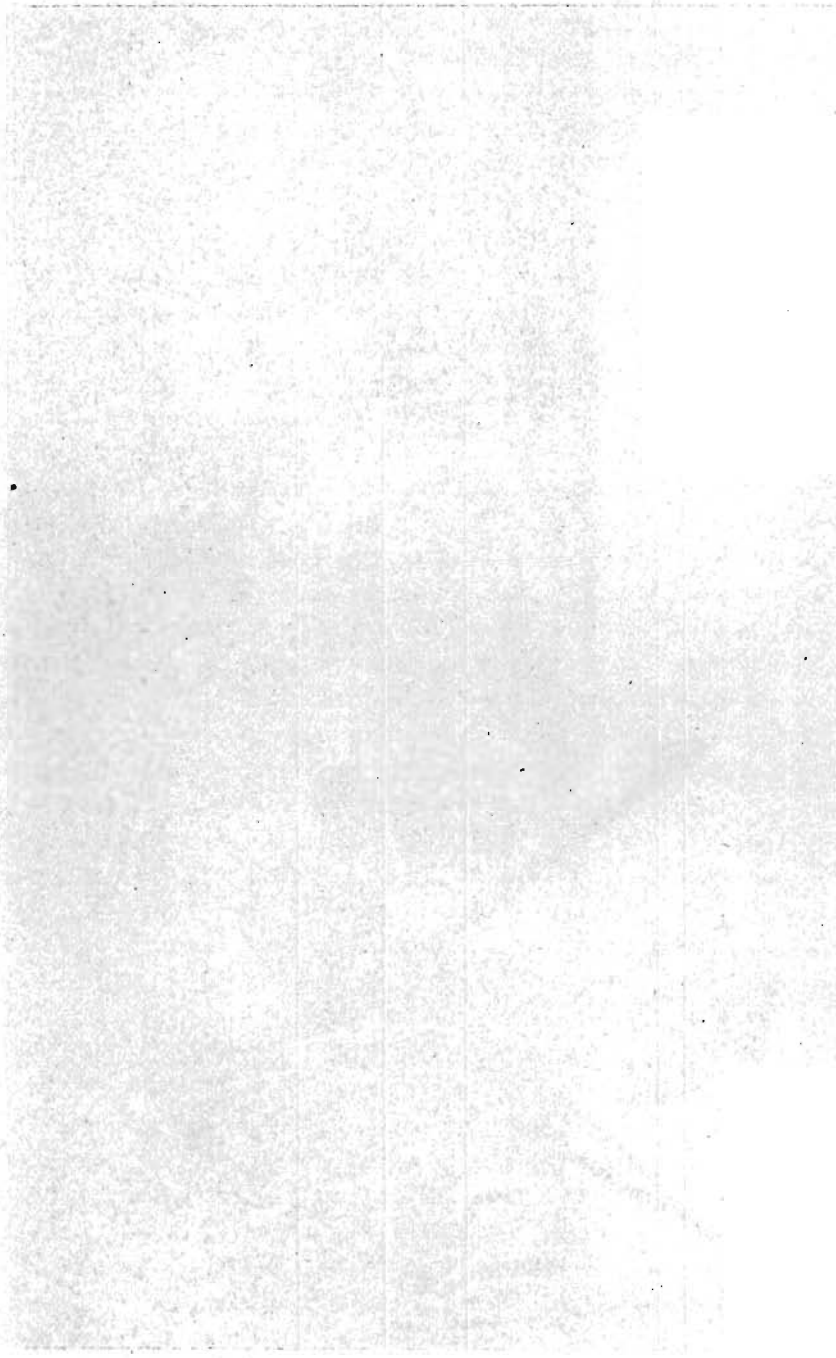


PLATE IX—Gilleas pit showing steam clam dipper working on a sixty foot face, Cherokee, Cherokee county.



The low terrace again comes into prominence in sections 9 and 16, Willow township. Here the area is about twenty-five acres and while the thickness of the sand and gravel could not be determined, the alluvium overlying it is about three feet. A number of remnants of this terrace are visible in the northeastern part of section 10, Willow township. The total area of these is perhaps ten acres.

The town of Quimby is built on the lower and middle terraces, mostly on the former. Usually the two terraces do not occur together. In the vicinity of the town, whichever may be present has a width commonly from one quarter to one-half mile. To the south of the town good exposures are wanting, but where wagon roads go from one terrace to another gravel is invariably exposed. Northeast of town, a pit in section 12, Willow township, exposes six feet of coarse and fine gravel and sand under two or three feet of alluvium. In the vicinity of the northwest corner of Silver township and on the east side of the river the lower terrace is about a quarter of a mile wide. A pit here shows three feet of alluvium over about ten feet of sand and gravel apparently suitable for road work. A part of this terrace on the opposite side of the river and just west of the railroad bridge has been worked in the past as a railroad pit. The company has now abandoned it, but farmers for miles around use the material for concrete and other uses about the farm. The face shows a depth of twenty-five or thirty feet of gravel and coarse sand, which is somewhat dirty where exposed. There are still some forty or fifty acres in the terrace here which are untouched. This same terrace is practically all gravel in the western part of section 32 and the southwestern part of 29, Pilot township. The best location from which to excavate it is in section 28 of this township. The terrace is about twenty feet above the bottoms on which the Illinois Central track is built. In places its edge is quite close to the tracks and a spur one-half mile long would open a face of about the same length. Really good exposures are wanting here, and the depth could not be determined; but the gravel shows in different places along the road in such a way as to leave no doubt of its presence in large quantities.

The seventy- and one-hundred-foot terraces are by far the most important ones from section 21, Pilot township, to the city of Cherokee. The seventy-foot terrace has an area of sixty or seventy acres in section 21. There is a pit near the school house where fifteen to twenty feet of material grading from sand to coarse gravel is exposed and the lower limit has not been uncovered. The seventy- and one-hundred-foot terraces appear together in sections 8 and 15, Pilot township. There are no good exposures in the former, though gravel is usually present on the sides and in one place there is a well-defined spring line twenty feet below the top. The higher terrace is much dissected and there is plenty of evidence of gravel in it even if good exposures do not exist. Where there are roads on the edges of this terrace they are usually good. This terrace has an average width of over a quarter of a mile. There was formerly a railway pit about a mile south of Cherokee but it has been nearly worked out.

From Cherokee north to the county line the terraces may be followed all the way. In section 14, Cherokee township, are the pits of M. J. Gilleas and the Cherokee Sand and Gravel Company, perhaps the largest openings in the county. These pits are located on a terrace which rises some eighty feet above the river. The former exposes some sixty feet of clean gravel, with occasionally large bowlders and clay balls and some clayey ocherous streaks. As much as 105 feet of this material have been opened at one time, part of it below water. In the pit of the Cherokee Sand and Gravel Company the same material may be seen. In this pit there is, near the edge of the terrace, a streak of clay three or four feet in depth which has the characteristics of Wisconsin drift, and this is again covered by gravel.

An enormous quantity of these gravels remains unopened. On the property of these two companies perhaps twenty acres are still available, and within a short distance to the north are twenty or twenty-five acres which will in all probability yield the same material.

The terrace along Mill creek which is described in O'Brien county continues to its union with the Little Sioux. It is al-

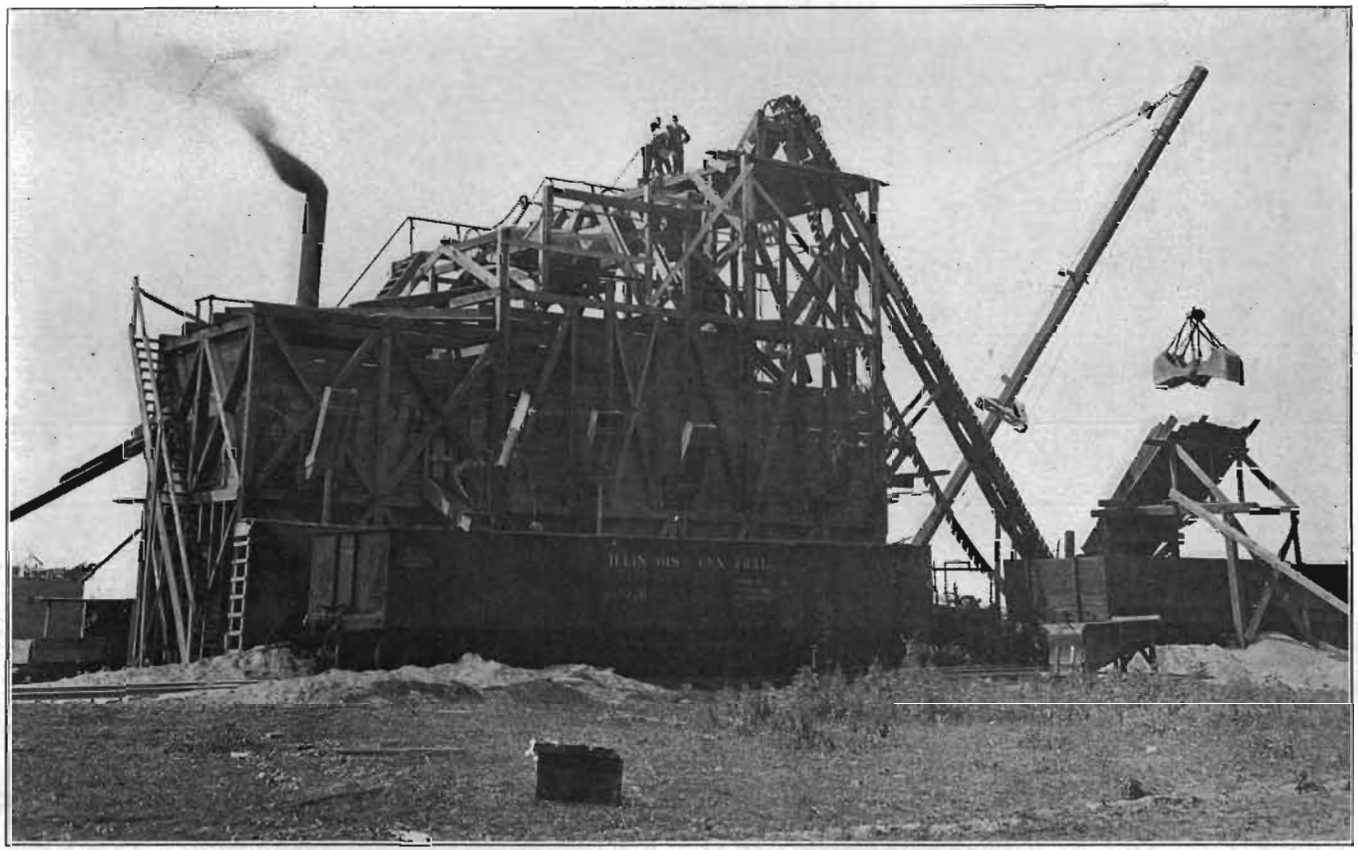
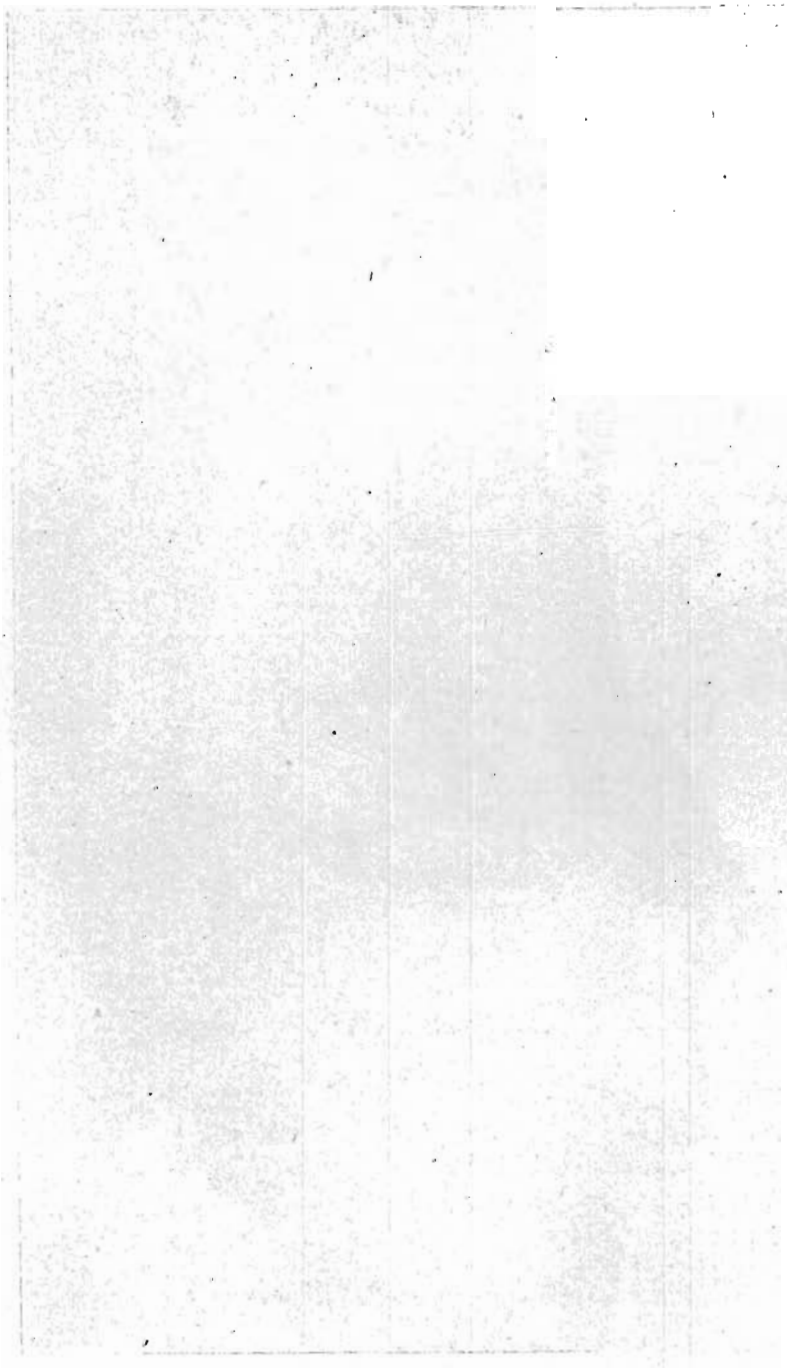


PLATE X—Washing plant of the Cherokee Sand and Gravel Company, Cherokee.

PLATE XI—Knapp wagon pit showing "coffee mill" type of screen. Cherokee.



ways drift, usually topped with gravel which varies from a mere veneer to, in certain places, up to eight or twelve feet. North of Cherokee the terrace is fifty-five to sixty feet above the creek, and bcomes gradually lower up the valley. It is perhaps forty feet high at the county line. The gravels may be seen at innumerable places and are used almost wherever the road climbs the terrace. Perhaps the best exposure is at a bend in the road in the southwest quarter of section 12, Liberty township, where twelve feet or so of fine clean gravel and sand are in view. The bench is conspicuous for some distance to the south of this point.

Mill creek has essentially no flood plain. It flows in a depression with low slopes of drift leading back to the terrace, which rises as jutting headlands of drift with gravel caps.

Good road gravel is obtained from a low bench west of the creek flowing through Larrabee. Remnants of this bench occur at intervals south, and apparently blend into those of the high terrace of Mill creek. Parts of it extend up the creek and are conspicuous in north Cherokee and Cedar townships.

Miscellaneous Gravels.—Aside from the gravel benches along Little Sioux and Mill creek and some of their tributaries from

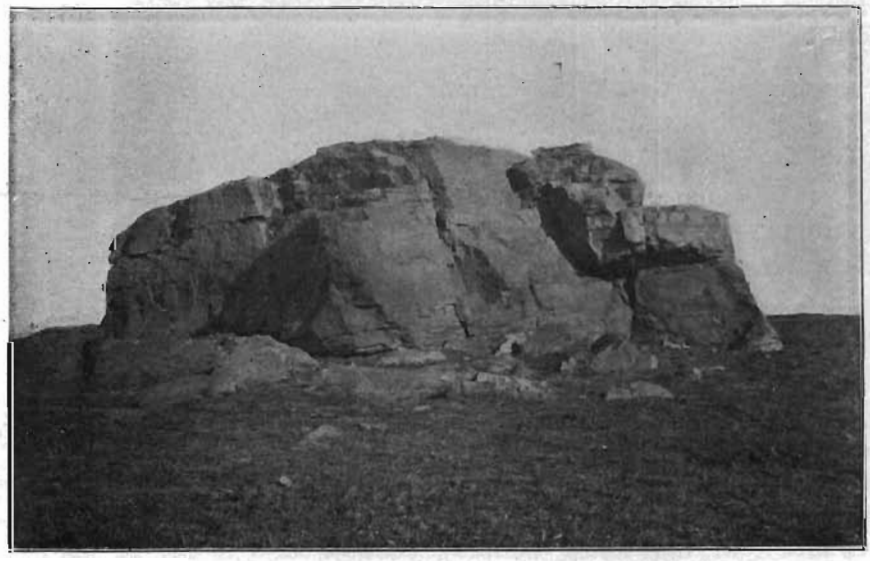


FIG. 17—Pilot Rock, a Sioux quartzite bowlder four miles south of Cherokee.

the north and east which have minor quantities, there are no important gravel or sand deposits in the county. The surface materials are Kansan drift and loess. Some of the streams have deposited beds of sand and fine gravel as islands and bars but these are not dependable in either quantity or quality, and if used at all it is only in a very small way.

The town of Larrabee obtains gravel from a mound a mile north of town in the southeast quarter of section 10, Cedar township. Similar mounds occur in west 34 of the same township. The gravel is somewhat red and clayey, and is said not to give the best of satisfaction for concrete work. This material appears to be very well proportioned.

Some gravels (Buchanan) are found beneath the loess in the northeastern part of the county where streams have cut deeply into the drift. A little farther west similar deposits are fairly common.

CHICKASAW COUNTY.

Sand and Gravel.

Deposits of sand and gravel suitable for road materials are abundant in Chickasaw county. Buchanan gravel in both the upland and valley phases constitutes by far the most important source of supply in the county.

Buchanan Gravels.—The great sheets and trains of gravel which were deposited as outwash at the time the Kansan ice was melting and gradually withdrawing from this part of Iowa are very generally distributed. Like the surface of the exposed till, these deposits suffered from the effects of weathering during the very long intervals preceding the coming of the Iowan glaciers and the distribution of the Iowan till. The gravels are red and rusty and all feldspar-bearing fragments of the transported rocks are rotted, decayed, disintegrated. As in Howard, Buchanan and other counties in northeastern Iowa, there are here two phases of the gravels, the upland phase and the valley phase. In the upland phase, which occurs in the higher areas, the beds are quite heterogeneous in that they are composed of fine sand, pebbles, cobbles, and small bowlders

FIG. 18—Buchanan gravels showing the upland phase, Nashua, Chickasaw county.

ranging up to a foot in diameter. The valley phase is made up mostly of small polished quartz pebbles, with little or no sand, and without the larger cobbles and bowlders. These deposits are discussed in more detail in the report on Buchanan county.

Upland Phase.—A number of deposits of very typical, ferruginous, upland gravels occur in and around New Hampton. The foundation for the extension of the German Catholic church was excavated in such gravels. A very characteristic bed is seen at the creamery, one-fourth of a mile south of the Great Western railway station. The gravels are very deeply stained with iron rust, the iron constituents being completely oxidized. Some parts of the beds are wholly or partially cemented into a conglomerate, and there are many hollow clay ironstones. There are the usual decayed granites and other feldspathic rocks ready to crumble to minute fragments when removed from their surroundings and there are also some hard,

undecayed cobblestones which retain the glacial striae. The bed was cut through in grading for the railway, and a section ten feet in thickness is exposed. Less than one-half mile farther south the railway has cut through another and more extensive bed of the same oxidized gravels in which are found all the characteristics of the upland phase. At this point the deposit forms an esker-like ridge, and east of the railroad there is a very large pit from which material has been taken and used in the improvement of the adjacent streets and roads. It is almost universally the case throughout northeastern Iowa that the lower part of deposits of upland gravels is made up of cross-bedded sands, while the coarser materials—the pebbles, cobbles and bowlders—are found only in the upper part of the section. This feature is very strikingly illustrated in the pit last mentioned. There is another large gravel pit at New Hampton two or three hundred yards west of the railway and south of the creamery. There is not the usual amount of coarse material in the upper part of this exposure; erosion may have carried it away; the excessive staining of the sand in the pit would indicate that such material had once been present in its ordinary position, for pure quartz sand could not furnish anything which by oxidation would give rise to ferruginous stains.

Two miles southeast of New Hampton there are some new cuts which show a comparatively thin sheet of Buchanan gravels lying between beds of blue Kansan and yellow Iowan drift. At one point the Iowan till arches over a low, narrow ridge of the gravels. Farther on, the Buchanan deposit becomes thicker, and the bottom of the cut, occupied by the sandy phase of the formation, is above the surface of the Kansan drift.

It is not necessary nor would it be profitable, to mention all the observed exposures of the upland gravels. From descriptions already given anyone interested will be able to recognize these beds at sight. For the purpose merely of indicating their general distribution, reference may be made to a typical section in a road cut on the west side of the southwest quarter of the southwest quarter of section 3, Fredricksburg township, and to

another near the opposite corner of the county, in the southeast quarter of the southeast quarter of section 21, in the northern part of Deerfield township, within less than a mile of the Howard county line. Another excellent example occurs in a cut made for the wagon road through a high ridge near the southeast corner of the northeast quarter of section 9, Chickasaw township. This is probably the thickest deposit of the gravels found in the county. Near the bottom of the hill there are a number of small springs and seeps, presumably at the line of contact of the gravels with the underlying Kansan clay. On the upland one-half mile east of Chickasaw there is a pit deserving notice for the reason that from it has been taken the material for making one of the best pieces of road in the county, that between Ionia and Chickasaw. An exposure of the upland type of gravels is seen in an unusual position at the north end of Brasher street in the city of Nashua. The bed occurs only a few feet above the level of the Cedar river, and yet it shows none of the characteristics of the valley phase of these deposits.

Valley Phase.—The valley gravels are so universally distributed along all streams that it seems scarcely necessary to do more in discussing their distribution than simply to mention the fact. There are extensive deposits about Lawler. Farther up Crane creek the valley gravels take the form of fairly well defined terraces, as near Jerico in Jacksonville township. Along the Little Cedar from above Bassett to Bradford there is an almost continuous sheet of gravel covering the bottom of the valley. The broad bottom lands through which the converging branches of the Wapsipinicon flow in Dayton township, are underlain with gravel which affords perfect underdrainage to what would otherwise be wet and swampy land. It will be sufficient to say that every stream course of any consequence has its valley trains and that no part of the county is far removed from an abundance of the best possible materials for the improvement of the country roads.

STONE.

The Devonian limestones are believed to comprise the surface country rock over the entire county, with the chief sections exposed along the most important streams, especially in the western tier of townships. According to Professor Calvin, the beds are more or less magnesian throughout the entire series exposed, some of the beds being so completely dolomitized as to resemble certain phases of the Niagaran limestone in Delaware and Dubuque counties. The predominating facies is a soft, earthy to granular, noncrystalline limestone, oftentimes cavernous. Crystalline calcite geodes are not uncommon. Rough stone for local use only has been taken out from time to time at numerous points in the county, and lime has been burned on a small scale until recently, in the vicinity of Chickasaw.

The section located near the wagon bridge in Chickasaw shows twenty-five feet of heavy-bedded dolomite, which is much broken toward the surface on account of weathering. Lower down the beds are intersected by numerous joints. A large amount of chert in streaks and bands is a striking feature of this section, and one very unusual in the Devonian.

A section which occurs about one mile north of Chickasaw, illustrates a flaggy facies of the Devonian. The stone as usual is highly magnesian and occurs in thin, even layers, varying from two to six inches in thickness. There are numerous calcite lined caverns and some very perfect calcareous geodes present.

A fairly representative section showing the variable character of the Devonian beds as developed in the county, is exposed in the southeast quarter of section 3, Deerfield township. The sequence is as follows:

		FEET.
7.	Loam and drift	2
6.	Limestone, thin-bedded, earthy and badly weathered	3
5.	Limestone, hard ledge; drab colored, purer and more crystalline than 4 and 6	3/8
4.	Limestone, thin-bedded; becomes marly and concretionary on weathering	2
3.	Shale, arenaceous, yellow and plainly laminated	4
2.	Limestone, hard, dark gray, layers six to ten inches in thickness and now forms floor of the quarry	2
1.	Limestone, hard, not now exposed, but was quarried formerly	3

It is evident from a casual inspection of the above section that the overburden of drift and worthless material is practically prohibitive. While certain ledges at numerous other points yield excellent structural material and stone of suitable composition for a good quality of lime, the high proportion of waste which must be handled makes a large production improbable. The waste materials are as a rule not sufficiently indurated for satisfactory crushed stone products.

FIG. 19—Quarry in cherty dolomitic beds at the Gypidula comis horizon a short distance above the bridge at Chickasaw.

The Chickasaw quarry just above the wagon bridge represents a long narrow strip extending north and shows the following sequence of beds:

CHICKASAW QUARRY.

		FEET.
4.	Stripping	1+
3.	Limestone, dolomitic, gray, earthy, fine-grained, much broken and mixed with clay; siliceous	5
2.	Dolomite, gray, darker than Nos. 1 and 3; thin bedded, beds separated by thin chert bands in lower half; some chert and calcite throughout; fossiliferous and siliceous	10
1.	Dolomite, gray, earthy, fine even grained, less chert and more calcite, grades up to 8 inches in diameter; calcite throughout; fossiliferous and siliceous	10

These beds furnish materials of fair quality for road and concrete work. Numerous outcrops appear to the north but little quarrying has been done. The Huffman and Herman quarries do not show anything new. The stone used in the construction of the North Washington church was obtained from a quarry located near the middle of section 4, Chickasaw township, on the H. M. Lighthall farm. The quarry shows beds less magnesian than the beds exposed in the Chickasaw quarry.

CLARKE COUNTY.

Sand and Gravel.

The interglacial gravels are almost wholly concealed in Clarke county and the present streams have done but little work in the classification and accumulation of materials suitable for road and concrete work. The loess-covered Kansan drift is the surface material, the old leached and iron-stained surface clays being visible everywhere.

The only possible source of sand in the county (the quantity of gravel is negligible) are the bars and beds in the streams. Some of these beds, while not very deep, are quite persistent, notably in Squaw creek west and northwest of Osceola. The creeks are commonly dry in the summer months, and the bottoms are lined with sands which have been accumulated from the washed materials from the hills. This sand consists for the most part of fine grains of quartz, and is usually quite dirty. Occasionally a small amount is clean and white, but most of it carries a high percentage of clay washed in from the neighboring slopes.

Road and bridge contractors and others report that occasional small pockets of dirty gravel have been encountered in the drift hills, but none of these has been known to contain more than a few yards. Practically all of the sand and gravel used for concrete and other purposes in the county is shipped from Des Moines or other towns on Des Moines river which are within reasonable shipping distance.

STONE.

The Missouri underlies practically the whole of Clarke county, but good exposures are rare, owing to the heavy drift mantle and the nonindurated character of the stratified rocks. Limestone beds outcrop along the south branch of Whitebreast creek in Green Bay township, about six miles south of Osceola, and numerous crops appear along the south branch of Squaw creek in Ward township. Several quarries have been opened along the creek last named, and a large quantity of stone has been quarried and used for foundations in the principal residences and many of the business blocks in Osceola. Two quarry sections given below afford a fair idea of the beds of commercial value.

The Carpenter quarry, located four and one-half miles northwest of Osceola, and about one-fourth mile west of Squaw creek:

		FEET.
5.	Drift, with limestone bowlders, variable in thickness; attains great thickness in the bluff, at the face	2–4
4.	Limestone, hard, brittle; ledges uneven, gray to blue, weathers almost white; fossiliferous; 2 to 4 inch clay partings near the base	7
3.	Limestone, shaly to clayey, in places clay only	1
2.	Limestone, hard, tough, fossiliferous; ranges from gray to blue. The upper layers are fairly even, and range from 6 to 8 inches in thickness	4
1.	Shale, exposed	4

The following section is taken from the vicinity of Short's quarry, which is located in the northwest quarter of the southeast quarter of section 2, Ward township:

		FEET.
7.	Drift and weathered limestone	4–10
6.	Residual clay	1 1/6
5.	Compact, gray limestone in 5 ledges: 8 inch, 14 inch, 2 inch, 2 inch clay parting, 4 inch, 1 inch clay parting, 14 inch ledge. Total	3 3/4
4.	Fossiliferous, gray limestone separated from number 3 by 2 inches of clay	1 1/3
3.	Buff limestone, hard and fossiliferous below, separated by thin clay seams	1
2.	Soft, weathered limestone	1
1.	Buff limestone, passing into gray, fossiliferous ledges below	2 5/6

Building stone only has been produced. The entire assemblage of beds is well adapted for crushed stone products.

One-half mile farther up this creek at the Carter quarry, the limestone is seen to rest on a heavy bed of yellow to bluish calcareous shale, nine feet thick, eight inches of which are exposed.

CLAY COUNTY.

Sand and Gravel.

The gravel and sand deposits of Clay county are similar in nearly every respect to those of Dickinson county. The flood waters from the melting ice carried down large amounts of material which choked the stream channels, and which appear today as terraces above the present flood plain. The morainal area in the eastern part of the county furnishes materials deposited by the ice in the glacial hills, but these are much inferior in amount and quality to the river gravels.

Stream Terraces.—The Little Sioux river, by far the most important stream in Clay county, was one of the principal outlets for the glacial flood waters. Deposits of gravel and sand have been noted along it far up into Dickinson county (see that report), and they become of even more importance through Clay and Cherokee.

In the report on Dickinson county mention in some detail will be made of the Milford terrace. This terrace proper has no direct relation to any stage of the present stream, the materials having been deposited by an older river, doubtless following the same general direction, but at a much higher level. There is however a lower terrace that may be followed from Milford south which seems to bear a much closer relation to the present stream.

The high Milford terrace grows rapidly less prominent when the Clay county line is crossed, and it is of no consequence more than three miles south of this point. Gravels belonging to it may be seen in sections 1 and 2, Waterford township, beyond which they blend into the general upland.

The low terrace flat, which has been referred to as probably the work of the present stream, appears to expand and to be

continuous with the great broad plain which lies west of the river all the way to Spencer. As will be noted in connection with Dickinson county, this bench is due to drift whose surface has been leveled by a layer of gravel. This bench occupies the broad flat between Little Sioux and Ocheyedan rivers all the way from Spencer to Everly.

These gravels are exposed at many road crossings along the river, as between sections 6 and 7, and in sections 20, 28 and on down the river. The bed is seldom over eight or ten feet in depth, and rests upon drift clay which extends up perhaps fifteen feet above water. The contact is evident from a bog spring line along the escarpment. It is often possible to get the gravels with but little stripping, but the depth of cover increases back from the stream.

Above Spencer there is no well defined terrace on the east side of the river, but a more or less gradual slope blends into the upland. Oftentimes, however, near the river and for some distance back, redistributed recent dirty gravels are opened up and serve very well for road materials. Such may be seen on the south sides of sections 5 and 6, southeast and southwest corners of section 21, southeast corner of section 26, all in Summit township.

Although the whole broad flat between Spencer and Everly is underlain by gravels they are seldom encountered in ordinary shallow excavations. It is usually possible to obtain at little depth most excellent clean fine gravel and sand in which the largest pebbles are seldom over one inch in diameter. The best exposure is at the wagon bridge just west of Spencer where a pit has been opened. The gravels may be seen occasionally at other places, as in section 7, southwest corner of 15, northwest corner of 23, and southwest corner of 13, Riverton township.

Southeast of Spencer the river valley narrows rapidly. At and east of Spencer the gravels underlie the plain on both sides of the river and are made use of at many points. In the city pit near the northeast corner of section 19, the gravel is covered with two or three feet of soil and alluvium and is itself permeated with yellow clay. Six feet of gravel are available

here, part of which is cemented by a calcareous cement. The top coarse bed rests upon cleaner material below, the latter being three or four feet deep to water level. At the top of the sand is a band of iron-stained coarse pebbles.

Excavations in the streets of Spencer show the same clayey gravel above, but fine clean gravel and sand below ten or twenty feet.

Besides these there are three or four pits close by showing the same beds. One is that of W. I. Harris, and another at the tile plant in the north part of the city. An open pit in the middle of the west side of section 19, Freeman township, has supplied some gravel for the town of Dickens, but this city now gets its material along the stream southeast of town.

South from sections 25 and 26, Sioux township, the terrace gravels occur only in isolated patches as low benches, more often on the east than on the west side of the river. The bench is inconspicuous, but may be observed on both sides of the river at the north side of section 2, Gillett Grove township, and also east of the stream at the town of Gillett Grove. It affords good gravel for any purpose, but is usually covered with two to four feet of sandy or loamy black wash, which has apparently been a hindrance to a more common and much needed use on river bottom roads in general.

The moraine at Gillett Grove seems to have given new material, and from this point on south high gravels appear capping jutting hills of drift. They appear kamelike, but in Herdland township, especially in sections 16, 21, 22, 27, 33 and 34 the bench is such as to leave no question of these knobs being remnants of a high terrace twenty-five to thirty-five feet above water. Where the river cuts back across the corner of the county at Peterson the gravel terraces are sometimes a bare veneer on drift and again deep deposits. West of Peterson and in the edge of O'Brien county is a well defined bench, and gravels are exposed at many points along the railway. These are twenty-five to forty feet above the water.

There are no gravels along Meadow brook or the large stream which is the outlet of Trumbull lake.

On Willow creek below Greenville the railway has used gravels from the hill tops. These seem to be a part of the high bench of the Sioux.

Buchanan Gravels.—Along the streams that have deeply incised the drift south of Spencer there are often exposed and used iron-stained gravels that, in position beneath a loesslike cover and passing down into the drift itself, bear the same relationships as are so commonly found in Lyon and Sioux counties. Professor Wilder calls the drift in these latter counties Kansan, to which the Clay county drift bears a close resemblance. Such gravels are opened and used at the southeast corner of section 3, Gillett Grove township. There is also a clayey phase of the same which is good for road material on the east side of the northeast quarter of section 10.

At Gillett Grove gravels similar in character to these are taken from the road at the southwest corner of section 30, Logan township. These are coarse and highly iron-stained, the abundant granites being all weathered so that the shovel cuts easily through them. They are covered by four to five feet of material which is not loess, but is loesslike except for the presence throughout of small igneous pebbles up to an inch or so in diameter.

Morainal Gravels.—The Altamont moraine, the ridge of knobby hills which marks the terminus of the Wisconsin drift sheet, crosses the eastern portion of Clay county, its maximum advance over the border being some seven miles, as determined by Macbride. South of Ruthven, in Palo Alto county, morainal knobs may be seen, and there are others in northeastern Clay county. Some isolated knobs of the Ruthven moraine in eastern Clay county are composed almost entirely of gravels. There is a mound of this type just south of Elk lake.

Near the northeast corner of section 36, Gillett Grove township, is an old pit far up on the hillside. The features here appear morainic and although Macbride maps the moraine a quarter of a mile to the east, these are no doubt kame gravels. A number of gravelly points lead to the southeast. The gravel is coarse, and there is said to be little if any sand. There ap-

pears to be an unlimited quantity of gravel here, and all from the level of the railroad to thirty or forty feet above.

These exposure are types of what may possibly be found in any of the knobs of this moraine. As a source of local, and perhaps even more than local supply, these drift hills constitute a gravel resource that is well worthy of investigation.

CLAYTON COUNTY.

Sand and Gravel.

The gravel supplies of Clayton county seem to be confined chiefly to the major stream valleys, although there are some deposits on the uplands. There do not seem to be many remnants of the old filling of the Mississippi valley, chiefly, perhaps, because the main channel is, along a considerable part of the county's extent, close to the Iowa side and so has cut away what deposits were formerly present. The town of Guttenberg, however, is built upon a terrace of gravel which extends along the foot of the bluffs for nearly three miles. This terrace is about twenty feet high at the river edge at the middle of its extent and slopes away from the stream. It gradually fades out north of the town, where it is only four or five feet above the river, and to the south it merges with the flood plain of Miners creek. Just south of the creek is a terrace of similar gravel which has been extensively used by the Chicago, Milwaukee & Saint Paul Railway Company for ballast.

The small valleys opening into the Mississippi do not carry any terraces or other extensive bodies of gravel or sand, so far as can be observed. Some of the creeks contain high banks or terraces but these seem to be composed of other material, perhaps waterlaid clays and silts.

The most important sources of supply of gravel and sand for this county are the gorges of Turkey and Volga rivers. Practically exhaustless stores are found here and these will be increasingly useful as their value becomes better appreciated. The wide plain through which the Turkey meanders across Marion township contains no well-developed terraces although some patches of rather fine sand are present. All along its course through Boardman township, however, terraces are abundant

and of considerable size. In the vicinity of Elkader these are especially large and prominent. A considerable part of the town on the east side of the river is built on terrace material and there are also some extensive banks on the west side. Near the depot a pit has been opened up and shows interstratified oxidized sand and gravel with a considerable proportion of foreign pebbles and limestone fragments. The bed is quite typical of the Buchanan gravels.

Across the river and about two blocks north of the bridge another pit was opened some years ago and showed two to four feet of fine clay above, then five feet of very coarse material consisting of limestone fragments, many somewhat waterworn, numerous foreign pebbles and rather coarse sand. The upper six inches are much rusted and somewhat indurated. Below this coarse bed come six to eight feet of somewhat finer gravels with less limestone. This layer, like that above it, shows no bedding. The bed below it, extending to the bottom of the pit, consists of rather fine gravels, strongly cross-bedded, with some layers coarser than others. This gravel is said to make excellent concrete as it packs very well and needs less cement than many gravels. The terrace extends one-half mile up the river.

In the northwest quarter of section 26, Boardman township, the river makes a bend to the west, and impinges against a bank forty feet high. It has made a good exposure of the materials filling the old valley at this point. The lower part of the exposure consists of silts and clays with interbedded sands. The upper ten or fifteen feet are gravel and sand layers intercalated. Some of the coarser layers are iron-stained and are red or dark gray. About eight feet of loess overlies these beds. This terrace extends some distance toward the town and the Catholic cemetery is built upon it.

About half a mile almost directly east of here, across the river, the terrace is well exposed along the railroad. It is about fifty feet high and is covered by three or four feet of loess. The upper part is stained with iron, especially in its coarser portions. There is much waterworn limestone in the upper few feet. The lower part is apparently finer. This terrace has an

extent of at least one-fourth mile along the railroad and is several hundred feet wide.

Some terraces and banks of gravel are seen in the valley of Roberts creek up which the railroad runs from Elkader, and some deposits of sand and gravel occur on the broad ridge which divides this creek from the master stream to the west.

Along the road leading into Elkader from the south, in the southwest quarter of section 26 and between sections 34 and 35, extensive deposits of the upland phase of the Buchanan gravels are found capping the hills. In the northeast quarter of the northeast quarter of section 34 the road has been cut into these to a depth of ten to twelve feet on the north slope of the hill. The gravels are clayey, coarse and very much weathered and in places quite well cemented. Much chert is present, doubtless derived from the Niagaran limestone. On the hilltop the gravels are capped by eight to ten feet of loess. The exposure is about 150 yards long and lies 200 feet above the river.

At Motor, in the southeast quarter of section 6, township 92, range 4, the terrace reaches a height of sixty feet above the river. The lower thirty feet are not exposed, but above this level are twenty feet of coarse gravel, with but little fine sand. Above these are six feet or more of very fine, clean sand. At some distance from the edge the terrace is overlain by several feet of loess.

In the neighborhood of Elkport the terraces are finely developed. At the junction of the Volga and the Turkey is a double terrace, the upper part of which is sixty-five feet above the river and the lower from thirty-five to forty. About half a mile up Elk creek valley is another remnant which is seventy feet above the water and is underlain by rock waste and residual material. In East Elkport is a similar terrace which extends for one-half mile along the river. All of these fragments of the old valley train are similar in character. They consist of fine, clean sand with but little coarse matter except some limestone and chert fragments.

Again, at Osterdock the terraces are of considerable size. They rise to an elevation of forty feet above the flood plain, which in turn is about twenty feet above the river. The contents

are chiefly fine yellow sand, in places with very little gravel. Such coarse material as is present is chiefly chert and limestone. The terrace is surfaced with two to four feet of loess, the two materials being quite sharply delimited. The loess often rests on a sloping face of gravel.

The terraces continue down the river at intervals to Millville and at the railroad station there is a considerable body of sand which extends for some distance up the small tributary valley which enters from the north. The terraces are about forty feet high and consist mainly of rather fine, fresh sands. Below Millville there are no terraces nor any large bodies of detrital matter, only a little clinging to the rocky walls. Little Turkey river does not seem to bear any deposits of any importance.

Volga river is bordered by numerous remnants of terraces, such as those in section 10, Sperry township, just east of Volga, in the lower course of Hewett creek in section 11 and at Mederville, Littleport and the lower reaches of the Volga valley. Some

FIG. 20—Sand and gravel wash from terrace near Littleport, Clayton county.

of the sand beds of this valley are at considerable elevations above the river and at unusual distances from it. This is especially true in sections 12 and 13 of Sperry township, where sandy hills are found nearly a mile from the river and at elevations of about 150 feet above the stream. These may possibly be of aeolian origin. Bowlders are also quite abundant in this locality.

At Littleport there is an extensive bank along the railroad composed of clean, yellow, rather fine sand with some pebbles up to one or two inches in diameter. These are of the usual foreign types, limestone and chert. The structure of the bank seems to be the same from top to bottom, a distance of about forty feet, except that a thin stratum at the top is somewhat oxidized and is rather coarser than the material below. About three feet of loess overlie the sands. Similar deposits are found across the river and also between this point and Elkport.

Several deposits of upland gravels are found near the Volga. In sections 4 and 5 of Sperry township there are coarse gravels and finer reddened sands 100 feet above the river. On top of a ridge in the southwest corner of section 27, Volga township, is a bed of coarse gravel with some large bowlders. On the hill in section 35, just west of Elkport, is a bed of badly weathered gravel with large amounts of coarse material, chert and foreign pebbles. A similar bed occurs on a hillside in the southeast quarter of section 36. Again on a hillside in section 17 of the same township, Volga, are exposed about eight feet of coarse, red, ferruginous gravels with abundant cobblestones of quartz, granite and other varieties, many of them much decayed. One or two feet of loess cover the gravels. A little farther down the road is another exposure of similar materials.

A little Buchanan gravel shows at the roadside on the north line of section 24, Clermont township, Fayette county, one-fourth mile north of the Williams quarry. This is evidently an outlier from a larger area which is exposed in Grand Meadow township, Clayton county. A pit has been opened in this in the southeast quarter of section 18, Grand Meadow, on the Williams farm, and exposes a bank thirty feet high. From this point the deposit extends southeast along the northeast face of the long ridge which is capped by Niagaran limestone. It is found in

sections 19, 20, 28 and across a gap in the Niagaran south to the Turkey river across Marion township. One well sunk in the gravel is reported to have found a thickness of 100 feet above the rock.

STONE.

All of the major divisions of the Ordovician are well developed in Clayton county and all supply products of economic importance. The principal quarry horizons are confined to the Prairie du Chien and Galena-Platteville. The outcrops of the Prairie du Chien formation are confined to the Mississippi river and its immediate tributaries in Mendon and Clayton townships, disappearing under the river a short distance north of Guttenberg. For the most part the Oneota division is composed of a coarse, vesicular dolomite, varying from light gray to buff in color and showing but few bedding planes. The lower thirty or forty feet are in ledges varying from two to four feet in thickness and have been quarried at several points near McGregor and North McGregor. The beds near the top are sometimes cherty and some of the beds carry an abundance of calcite in the caverns. Above the quarry ledges the dolomite is more massive, coarser in texture and shows a decidedly pitted surface when weathered. As a general rule the upper fifty feet of the Prairie du Chien contains thin bedded sandy or shaly layers aggregating about fifteen feet, which are overlain by brecciated and concretionary beds, the Shakopee, aggregating a thickness of about forty feet. While the Prairie du Chien attains a thickness of more than two hundred feet in the county, only the lower beds already described have been quarried, and even these only in a small way.

The Galena-Platteville supplies two well known quarry horizons which correspond in a general way to the "Lower" and "Upper" quarry beds of Dubuque and other counties. The lower horizon is sometimes known as the "Lower Buff Beds" and consists of a fine-grained magnesian limestone which occurs in layers ranging from eight inches to three or even four feet in thickness. It is blue on fresh faces but upon exposure weathers to a buff color. It breaks readily along bedding planes into slabs of almost any thickness and is cut by sufficient vertical joint

planes to facilitate quarrying. These lower beds are being developed near McGregor and Guttenburg and are easily available at numerous other points. They comprise a thickness of from fifteen to twenty feet. The lower quarry beds are overlain by thin-bedded, very fine-grained and compact limestone somewhat unevenly bedded and light blue-gray in color. In places these beds are decidedly marly in character. They attain a thickness of twenty-five to thirty-five feet. These thin beds are overlain by the "Green Shales" of the Minnesota geologists. The second important quarry horizon is near the top of the Galena-Platteville and develops the dolomitic beds of the Galena. Numerous quarries have been opened in these beds, including those in the vicinity of Monona, Elkader, Garnavillo, St. Olaf, Farmersburg, in Cox Creek township, the lime kilns at Guttenberg and numerous other points. The upper Galena comprises a heavy bedded, subcrystalline dolomite, rather coarsely granular, more or less vesicular and buff in color. It weathers very irregularly and presents a rough pitted surface when long exposed. The beds vary in thickness from a few inches to five feet or more. The heavy beds often grade downward into a less heavily bedded mottled zone which is only slightly dolomitic. A few representative sections of the Galena-Platteville are given herewith:

CLAYTON SECTION.

		FEET.
11.	Dolomite, heavy bedded (Galena)	150
10.	Shale, green, at the top of the Platteville	2–3
9.	Limestone, similar to No. 7	8
8.	Shale, bluish green	2
7.	Limestone, in regular beds four to eight inches thick, very fine-grained and compact, blue and buff in color. Occurs in thicker layers than No. 5	15
6.	Shales, green, calcareous, containing lenses and bands of limestones rich in fossils. Among the most common are *Orthis subaequata* and branching monticuliporoids	5
5.	Limestone, thin-bedded and compact, with marly layers one to two inches thick separating many of the beds. Latter are irregular in thickness and range from one to three inches. The marly partings do not always appear on fresh joint faces but stand out on weathered surfaces	25
4.	Limestone, dolomitic, compact, blue when fresh but weathering to buff on exposure; in even beds eight inches to two feet thick, contains few or no fossils. The quarry beds at Guttenberg and McGregor and the "Lower Bluff Beds" of some writers	25

		FEET.
3.	Shale, green, immediately overlying the St. Peter sandstone	2
2.	Sandstone (St. Peter)	85
1.	Limestone, Prairie du Chien, to low water in Mississippi	90

GUTTENBERG SECTION.

		FEET.
5.	Limestone, dolomitic, in heavy ledges, vesicular, coarse, buff colored, the typical Galena dolomite	100
4.	Limestone, magnesian, in beds two and three inches to one foot thick, mottled gray and buff, only partially dolomitized and containing sixteen per cent of magnesium carbonate; part of the rock is very fine-grained, compact and gray colored, while other portions are buff and have a rough, coarser feel. Contains some chert in bands and scattered nodules. In these beds are located the quarries supplying rock for the lime kilns at the base of the bluff	60
3.	Limestone, gray, nonmagnesian, fine-grained, compact, in thin and uneven beds. Lower portion not well exposed on the ridge, since it is partially covered with talus and soil	85
2.	Limestone, dolomitic, blue when fresh but weathering to buff, beds eight inches to two feet thick. In these "Lower Buff Beds" the quarries are located	15
1.	Sandstone, Saint Peter, not exposed here, but known to rise ten feet above the river.	

ELKADER SECTION.

		FEET.
5.	Dolomite, light blue, rather compact, in ledges six inches to two feet thick. Some of the upper strata are separated by thin layers of reddish fissile shale	25
4.	Dolomite, light gray to buff, containing many small cavities, ledges varying in thickness from one to five feet, most of them being over two feet thick	25
3.	Dolomite, buff, massive, weathers irregularly, forming pitted surfaces	70
2.	Unexposed	35
1.	Limestone, nonmagnesian, in thin beds, compact, fossiliferous, contains chert nodules arranged in bands, exposed to river	25

Numbers 4 and 5 in the above section are being quarried. Rock for the stone bridge in Elkader was obtained from this quarry. Numerous other sections might be mentioned but the main features are given above.

In places the entire assemblage of beds appears to be non-dolomitic, a feature which is not peculiar to Clayton county but is known to be characteristic of the Galena in northeastern Iowa.

The Maquoketa division of the Ordovician is more highly calcareous than equivalent beds in Dubuque and other counties

to the south and yet does not contain beds which have been quarried to any extent in the county. The chert beds above the middle of the formation are sufficiently indurated to be used for road material.

The Niagaran limestone covers an extensive area in the southern portion of the county, an irregular area on the divide between Volga and Turkey rivers and small outliers in Grand Meadow and Marion townships. A large number of outcrops are available along the numerous stream ways. Quarries have been opened near Gunder and Strawberry Point. An extensive quarry is opened just across the line in Fayette county. The beds developed are similar to those available in Clayton county. The Niagaran beds are somewhat variable but consist generally of a buff, heavy-bedded dolomite, the ledges varying from two to four or more feet in thickness. The Wilkes Williams quarry which is described later under the discussion of Fayette county, may be accepted as representative for the northern outliers in Clayton county. In section 15, Cass township, about one mile north of Strawberry Point, the following quarry section may be observed:

		FEET.
2.	Dolomite, coarse-textured, buff, containing chert nodules, in ledges eighteen inches to three or four feet thick	8–10
1.	Dolomite, light gray, almost white, finely crystalline, free from chert, in layers from four to eighteen inches and two and one-half feet in thickness. The thicker ledges can be split into any desired thickness along lamination planes. The rock is soft when first quarried and grows hard on exposure	6–8

Similar sections have been developed at other points in the neighborhood. The beds are some sixty to seventy feet above the base of the Niagaran. They are almost white, fine-grained and rather soft when first quarried and attain a thickness of twenty to twenty-five feet.

A description of a few other quarries and minor openings follows.

Along the river road north of North McGregor in section 10, Mendon township, is a quarry in the transition beds from the Saint Croix to the Oneota. The rock is a sandstone with calca-

reous cement and effervesces freely with acid. About twenty feet of heavy ledges are exposed with several feet of waste above. This quarry was used during the progress of river improvement. It is conveniently located for use for road work.

Along the old military road leading north from town is the Langley quarry, opened in the heavy beds of the Oneota about one-fourth mile above the village. It is fifty feet or so above the Saint Croix and about 100 feet below the top of the bluff. The stone is a hard, buff, granular dolomite, somewhat vesicular, with the vesicles stained by iron. About twenty feet of rock are exposed in ledges one to three feet thick. Four feet of waste overlie the solid rock. The slope above the quarry is very steep and unless it be composed largely of rock will necessitate a large amount of stripping.

At about the center of section 27, Mendon township, a short distance southwest of McGregor, is the quarry of Frank Boyle. As given by Leonard the section is:

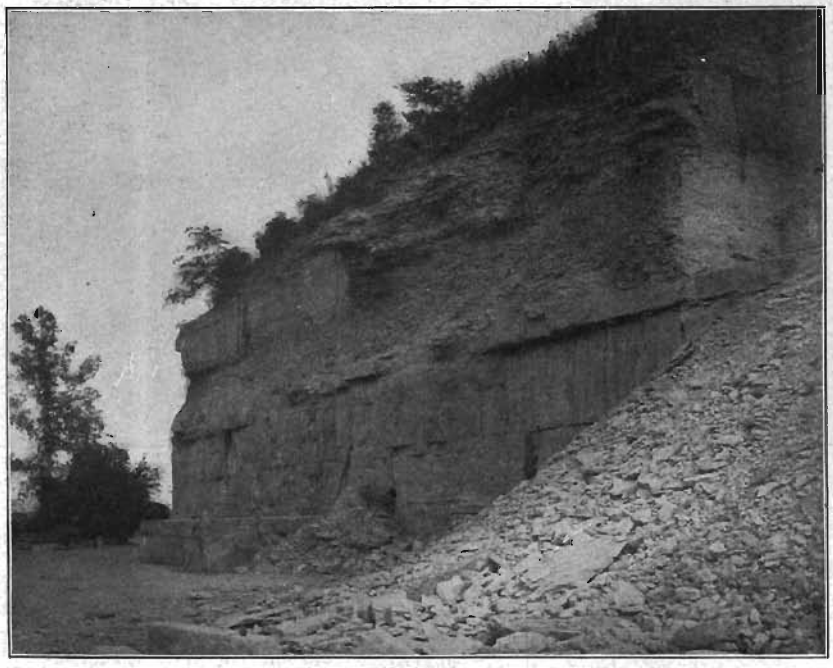


FIG. 21—Boyle quarry in lower buff beds, McGregor, Clayton county.

	FEET.
Fine-grained and compact limestone, light blue to buff.....	34
Dolomitic limestone in ledges one to four feet thick, blue when fresh, but weathering to buff; the "Lower Buff Beds"..10–12	

These beds are near the base of the Platteville limestone, only a few feet above the Saint Peter, which is exposed along the road leading from town to the quarry. At one point Mr. Boyle has utilized the outcrop for the purpose of obtaining his supplies of sand for use in laying cement and other similar work. The sandstone is so soft as to be easily removable with pick and shovel.

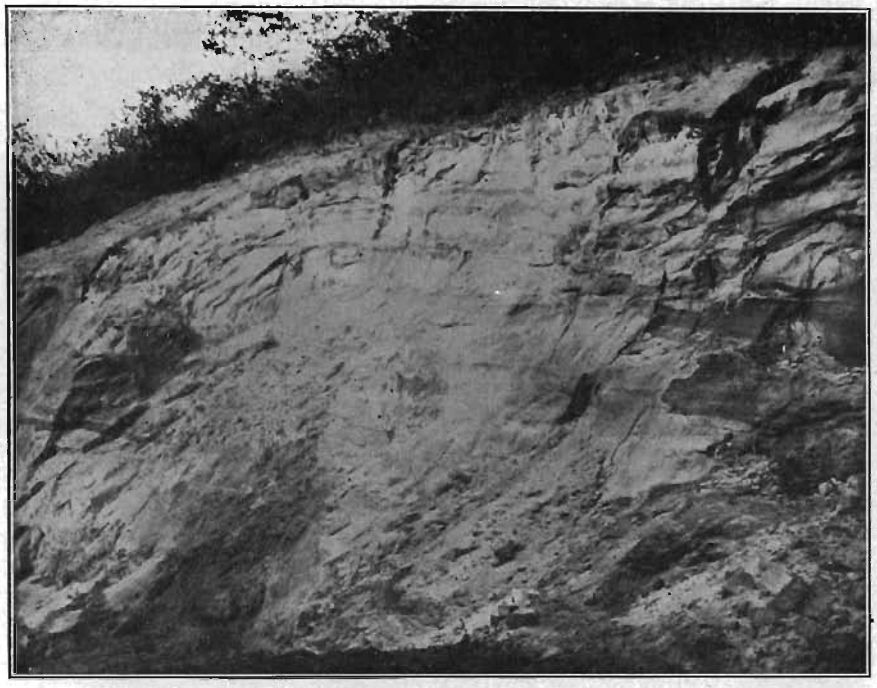


FIG. 22—Boyle sand pit in Saint Peter sandstone, near McGregor, Clayton county.

There are unlimited quantities of rock easily available in the neighborhood of Elkader. Stoops quarry may be taken as typical. It is located on the point of the ridge on the east side of the river near the county hospital. A section of the entire bluff appears above. The quarry shows:

	FEET.
Waste rock	6
Thin buff ledges, eight to twelve inches thick	6
Thin blue ledges, fine-grained, eight to twelve inches	6
Heavy beds, the upper six feet and the lower four feet in thickness; buff, sugary dolomite	10
Thinner beds, buff dolomite, twelve to twenty inches, at base of quarry	10

This is now the Clayton county quarry. The town of Elkader has a No. 10 Western rock crusher installed for making macadam and concrete material.

About two miles below Guttenberg the Knudt quarry has been operated to a considerable extent for obtaining rock for use in river work. The quarry is located in the river bluff about seventy-five feet above the Mississippi and the rock is removed by barge as the stream flows close to the foot of the bluff. It shows at the base twenty to twenty-five feet of the blue fine-grained beds described by Leonard on page 252 of his report. The layers as seen in the fresh face are from eight to twenty inches thick. Above are from four to eight feet of rather soft granular rock, probably dolomitic. Then there succeed twenty feet of gray, granular, vesicular, magnesian material. The quarry is probably located in beds 3 and 4 of Leonard's Guttenberg section.

At the south end of the ridge between Miners creek and the Mississippi at Guttenberg the Platteville beds are quarried somewhat. Here the blue beds are overlain by the thin nodular layers of the Decorah shale and above are the thin beds of the Galena. The rock seems similar to that at McGregor, as shown in the Boyle quarry.

One mile north of Luana the quarry of H. J. Walk shows hard blue, fine-grained stone in beds six to twelve inches thick. These are overlain by three to six feet of waste and loose rock. Some of the ledges are gray and softer than others. The quarry is near the top of the Galena.

This quarry, together with one across the road and one about one-half mile north, in Allamakee county, is at about the same level as those described from Cherry Valley in Allamakee county. The rock appears to be similar in character and appears fine

and solid when in the quarry ledges. The quarries are all conveniently situated for installing crushers, especially the three near Luana, which are well located, close to the road, and some of them high enough to allow the use of gravity.

The Niagaran limestone is extensively quarried in the southwestern part of the county. A mile north of Strawberry Point in the north half of section 15, Cass township, is the Sousley quarry, described by Leonard on page 277 of his report, and near it is the Kirkpatrick quarry which shows:

	FEET.
Waste rock	
Thin-bedded, very cherty, yellowish dolomite somewhat water-worn, jointed	4
Heavy-bedded, white, fine-grained rock, some cherts, tendency to split into thin layers on exposure; shows small caverns	10
Not exposed	6
Thin-bedded layers, bottom one 10 inches, light buff, crystalline, cherty	6

The quarry, like most of those in this part of the county, is located in a ravine some distance from the road. This makes the removal of stone rather difficult although the quarries are easily opened.

On the east line of section 24, Cass township, is the Smith quarry, about one-half mile north of the road. A considerable face is exposed here and rock is fairly easily obtained. The foundation for the new city hall at Strawberry Point was built of rock obtained at this quarry. The quarry shows the following section below a steeply ascending bluff face:

	FEET.
Broken ledges	2–3
Thin ledges, six and twelve inches	1–1½
Ledge of soft gray rock, rough fracture	2
Light gray to white, fine-grained rock, hard, some chert, in three or four ledges	6
Similar rock in one ledge	1½
Yellow, sandy, finely crystalline dolomite, flinty, basal layer one foot, two thin layers four inches each	1⅔

The best rock and that freest from chert is said to come from the two ledges immediately below the quarry floor. This quarry faces the same difficulty as those north of town; that is, difficulty of access.

Over the areas of this part of Iowa, where the Fort Atkinson, Galena or Oneota are surface rocks, the geest is suitable for use on roads, especially when mingled with the chert from the limestone. If gravel or crushed rock were mixed with this clay it should make good road material. Several localities in Allamakee and Clayton counties show outcrops of geest. The areas of the Niagaran also show some patches of geest and in many cases this clay is full of chert fragments. An example of this is found south of Strawberry Point at the center of section 27, Cass. Here is an exposure of residual chert and clay. This has been dug out and used on the road leading to town with good results. A little soil is used for surfacing.

CLINTON COUNTY.

Sand and Gravel.

In the southern part of Clinton county are a number of low ridges which have a general northwest-southeast trend and because of their regularity form quite conspicuous features of the landscape. These are especially well developed in the vicinity of DeWitt, and as several of them have been opened up here, their constituents are well revealed. The town of DeWitt owns and operates a large pit in one of these ridges about one mile south of town, in the southeast quarter of the southwest quarter of section 19, DeWitt township. This ridge is esker-like in outline, with the same general trend as the neighboring ones. The material is very irregular in distribution in different parts of the pit, but is chiefly rather coarse gravel above with finer gravel below. In places sand is abundant and the entire ridge is capped with loessial sand and loess. The coarse material is quite largely limestone with foreign pebbles forming perhaps one-half the mass. Much of this foreign material is decayed, some of it so much so that it can easily be broken into powder. There are some bowlders, but these are neither common nor large. Very few of them have a diameter of over one foot. Some small blocks of lime-cemented conglomerate are found in the pit. The upper part of the deposit is generally quite strongly iron-stained, and in places the entire body is somewhat discolored,

though not so strongly as are typical Buchanan gravels. The pit is twelve to fifteen feet deep.

A few rods to the northwest of this pit is another one in the same ridge. This one is owned by Scott county. A spur from the Chicago, Milwaukee & St. Paul railroad runs into this pit and cars are hauled under a platform upon which the gravel is carried by means of wheeled scrapers. It is then dumped into the cars below through a hopper in the platform.

About one and one-fourth miles south of town, in the northwest quarter of section 30, a small pit has been opened on the farm of Mr. Wallace. This is in a ridge in continuation of the series extending to the northwest, and which shows a similar constitution. There is a large proportion of limestone in the coarser material, the foreign pebbles are decayed and all the characteristics ally this deposit with others in the neighborhood.

The gravel from these mounds has been used for concrete work as well as for road material. Many of the streets and roads in and around DeWitt are macadamized with gravel and show great improvement over the sand and dirt roads. They are much less troubled with dust and maintain an even, smooth roadbed.

The ridges continue west of town toward Grand Mound, and gravel may be seen in the road cuts across these, showing that they all have a common origin and similar composition. Some of the beds show a weathered upper zone, reddened and oxidized, as is the case in the pits described above. In the southwest corner of section 14, about two miles west of town, one of these ridges has been opened up on the south side of a small stream. The bank shows on top one or two feet of sand and loess, then about eight feet of much stained gravel, which is quite coarse in places, especially in the upper portions. Bedding is not prominent in this part. Below this layer and sharply differentiated from it is a bed of clean gray gravel, rather fine and quite uniform of composition. This lower bed is about four feet thick to the bottom of the pit. The road has been cut through the ridge close by the pit and exposes four or five feet of fine sand above the gravel. However, some of this thickness may be due to slipping. Above the sand is a loesslike clay. Across the road

to the northwest is another short ridge parallel to the one here described and probably of similar constitution.

In the northwest quarter of section 16, Orange township, a little more than a mile east of Grand Mound, is an old pit ten or twelve feet deep, which was once operated by the Chicago & North Western Railway, and is now used by the town of Grand Mound. The material here is in general coarser than that at DeWitt. It is not well exposed, but where recently used shows a much weathered, somewhat indurated gravel, pebbles having diameters up to two or three inches, being in considerable abundance. In another place the gravel is much fresher and quite coarse. One bowlder three by one and one-half feet in diameter is completely decayed so that it is quite pulverulent. Many others are decayed, completely or in part. Some of the bowlders present are two, three and four feet in diameter. There is a large quantity of material left in this pit and it should prove very useful for road and concrete purposes.

Stone.

With the exception of a small area close to the Mississippi in Elk River and Spring Valley townships, which is underlain by the Maquoketa shales, the country rock of Clinton county belongs to the Niagaran stage of the Silurian. There are said to be exposures of Niagaran limestone in every township in the county, save one, Berlin township.

It is quarried particularly in the vicinity of Clinton, where considerable thicknesses of the limestone are exposed in the bluffs bordering the valley of the Mississippi. There are also many small openings from which stone is removed, that are scattered so universally over the county that it is scarcely possible to segregate them into districts. Next to the Clinton quarries, in the depth of strata exposed as well as in commercial importance, come, no doubt, the group of small quarries in the south tier of townships near the Wapsipinicon and in the neighborhood of Wheatland, Calamus and DeWitt.

The Niagaran consists typically of beds of dolomitic limestone and dolomite, varying in nature from fine-grained, yellow, thinly

laminated and porous layers, to heavy beds as great as six feet in depth, of brown to bluish gray compact stone. Chert in bands and nodules occurs very commonly throughout the Niagaran strata. As mentioned, the stone has been quarried at a number of localities in different parts of the county. The following characteristic sections will afford an idea of the quality of the rock, the succession of the beds and the extent and possibilities of the building stone industry. They are taken in the principal quarry districts.

Clinton Quarries.—The Clinton City quarry is located at Fourth Avenue and Bluff Road. The usable strata here consist of an upper four to five feet of soft, thin-bedded stone which grades into a somewhat firmer gray to bluish rock below. All of the beds are porous and often cavernous on a small scale. There are six to eight feet of weathered dolomitic residue and a varying depth of loess overlying the quarry. The lower beds are being used in city street work.

The Thomas Purcell quarry is located at Eighth Avenue and Sixth Street. A face of fifteen feet is open, running nearly a block parallel to Eighth Avenue and consisting of strata similar to those described above. Below the upper five feet the beds are heavy; in some instances individual ledges are three feet thick. The bottom stratum contains nodules of white chert. Further quarrying here is limited by the city improvements.

The Union Park quarry belonging to the Turner Society and worked by Henry Jessen is situated at the intersection of Union Street and Bluff Road. A maximum of thirty feet of the Niagaran is exposed, covered by three to four feet of drift and ten to twenty feet of loess. The upper portions of the dolomitic beds are fissured and weathered in places to a residuum or "geest." The top beds are also soft and of an ocherous yellow color. The bottom ledges are denser, of a gray color and run one to three feet in thickness. Only the latter are solid enough for foundation or other important masonry work. The quarry is worked constantly, hand methods only being practiced. The heavy and increasing amount of stripping necessary to obtain these lower strata is a great handicap to extensive development.

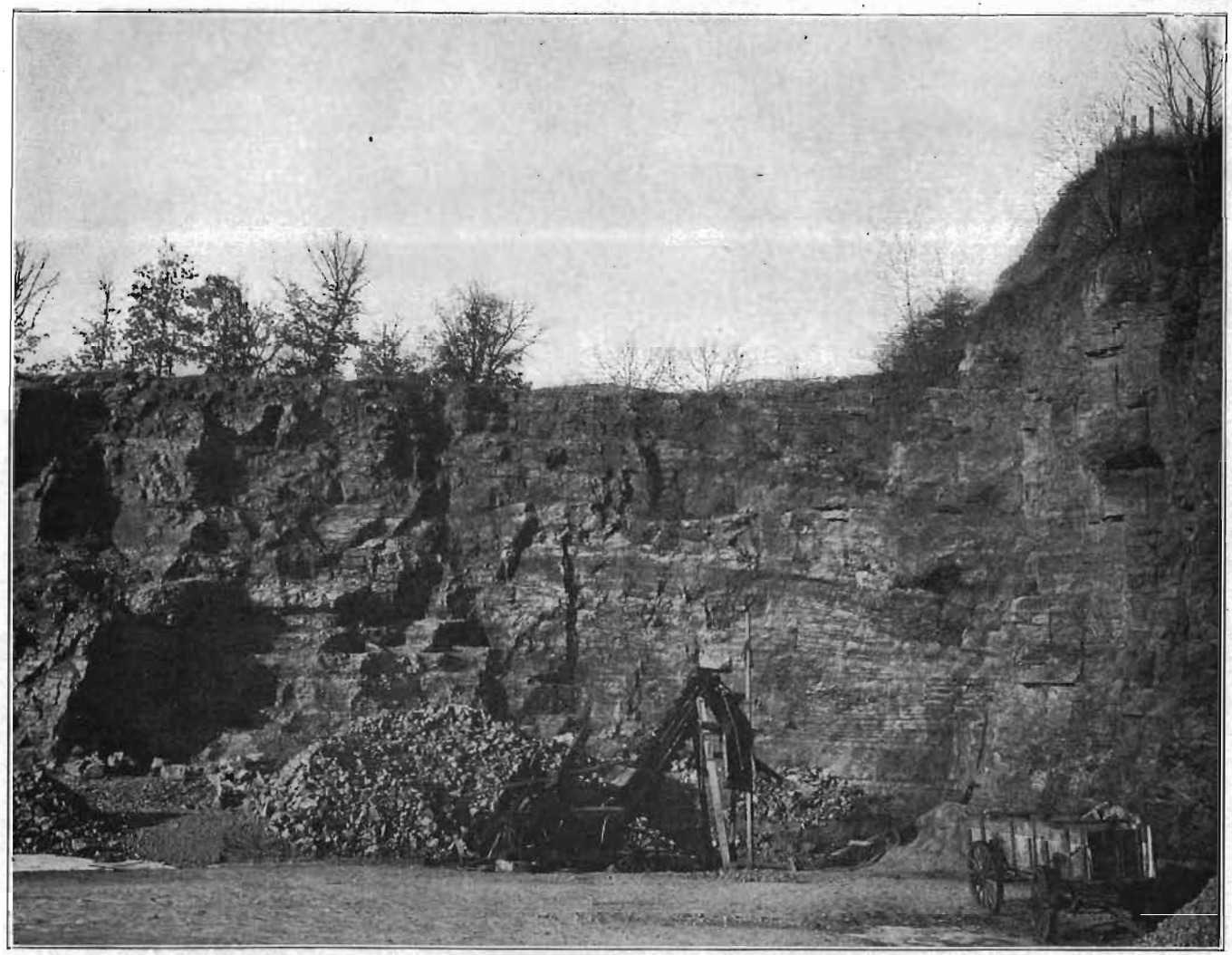
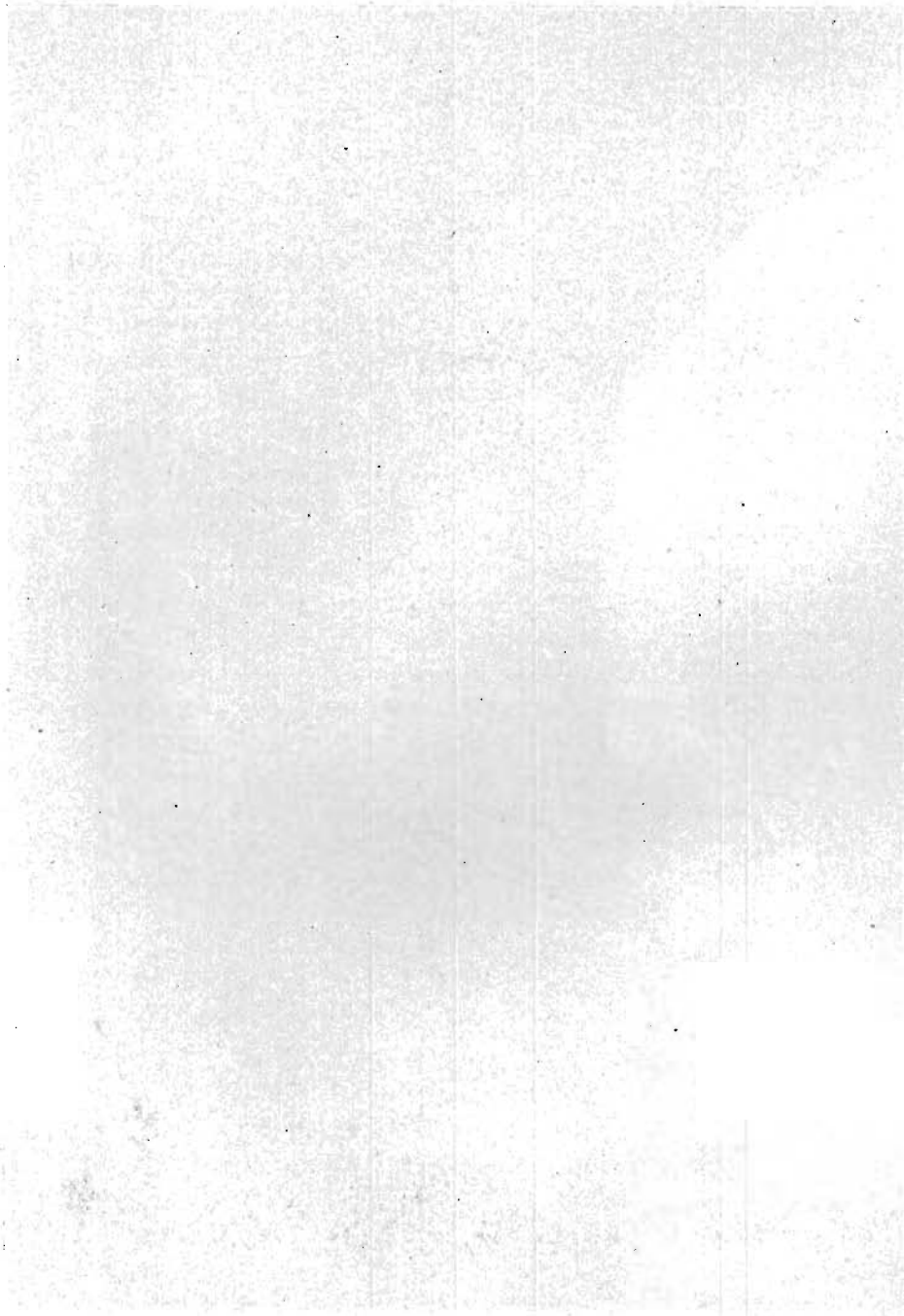


PLATE XII—Thomas Carey quarry section showing the general character of the Niagaran beds of the region. The chert beds are rather prominent in the middle section. Clinton, Clinton county.



The quarry of Thomas Carey on Fourth Street, near Lamb's, is the most extensive opening in Clinton. There is less of the worthless disintegrated material here above the solid ledges. Thirty-five to forty feet of usable stone have been opened up and a large amount taken out. The individual beds vary in thickness from a few inches to three feet and products of any desired dimensions are obtainable. Fifteen to twenty feet of loess are removed to reach the quarry beds. The output consists of foundation material and some dimension stone from the deepest beds, while the upper strata are crushed for road and concrete work. The quarry is equipped with a portable jaw crusher made by the Western Wheeled Scraper Company.

Near Agatha Hospital in the city of Clinton is a small quary which shows a face of sixteen feet of buff, vesicular, sugary dolomite with iron-stained cavities. In places the rock is massive, elsewhere it lies in layers six to twelve inches thick. At the east end of the quarry the material has been broken for macadam. The upper part here is broken into spalls, while the lower part lies in layers. The rock seems rather soft for road work. An overburden of two to six feet of geest and drift has to be removed before quarrying operations can be prosecuted.

All along the base of the bluff are outcrops of Niagaran and several quarries have been opened up. The Chase quarry showed a covering of sand below which are ten feet of soft, crumbly material, evidently waste of the heavy top ledges of the Agatha Hospital quarry. This has been taken out for road use and is said to make good metal. It packs well and does not form dust. Below it are eight feet of bedded rock, buff, similar to that of the Hospital quarry, and at the same level.

The Union Park quarry, near the head of First Avenue, shows twenty feet of yellow dolomite in heavy beds, under three feet of Kansan drift and eight to ten feet of loess.

The dolomitic beds are exposed at other points near Clinton, especially to the north in the vicinity of Lyons and in many places in the hills to the west along small tributaries. At all points the surface layers are usually badly honeycombed by weathering and solution, and often nothing remains but a yellow-

ish crumbling dolomitic sand or dolomitic clay residuum. It is therefore necessary to remove in most cases great quantities of the disintegrated portions to reach the deeper solid and more durable ledges. These surface materials are serviceable in the shape of crushed stone, although they are not of the best quality, even for this purpose.

The accompanying section is given as showing the general character of the lower Niagaran beds to which the Clinton quarry rock belongs:*

		FEET.
6.	Drift	5
5.	Geest	3
4.	Porous and yellow, dolomitic limestone, irregularly bedded, full of small crevices lined with calcareous incrustations. This is known as "shell rock" among the quarrymen	40
3.	Finely granular, yellow, dolomitic limestone with numerous small cavities, often lined with a coating of crystalline calcite. Bands of chert occur at intervals of from two to four feet. Seven of these were each about five inches in thickness	30
2.	Buff-brown, dolomitic limestone of fine-grained texture, with many bands of chert, also scattered nodules of chert. The chert is most abundant below. Some of the chert bands have a thickness of one foot. These thicker bands occur above and the thinner lie below. Thirteen bands in all were counted. The lowermost, of which some were no more than an inch in thickness, lie close together	25
1.	Blue shale (Maquoketa)	15

In Orange township, the principal exposures are on Barber creek. On the land of A. A. Barber, in the southeast quarter of section 29, the following beds are in view in an old quarry:

		FEET.
4.	Soil	1
3.	Shattered and disturbed, yellow, thin bedded, limestone	9
2.	Very thinly laminated, yellow limestone, separating very readily along bedding planes into thin slabs of even a fraction of an inch in thickness	11
1.	The above rests on a floor which dips steeply to the north and consists of heavy firmer ledges of weathered, porous limestone, some few feet of which have been worked.	

The top, No. 3, "slate," is being used as macadam and appears to give good service in this capacity on country roads.

*Geology Clinton County, Iowa Geological Survey, Vol. XV, page 401.

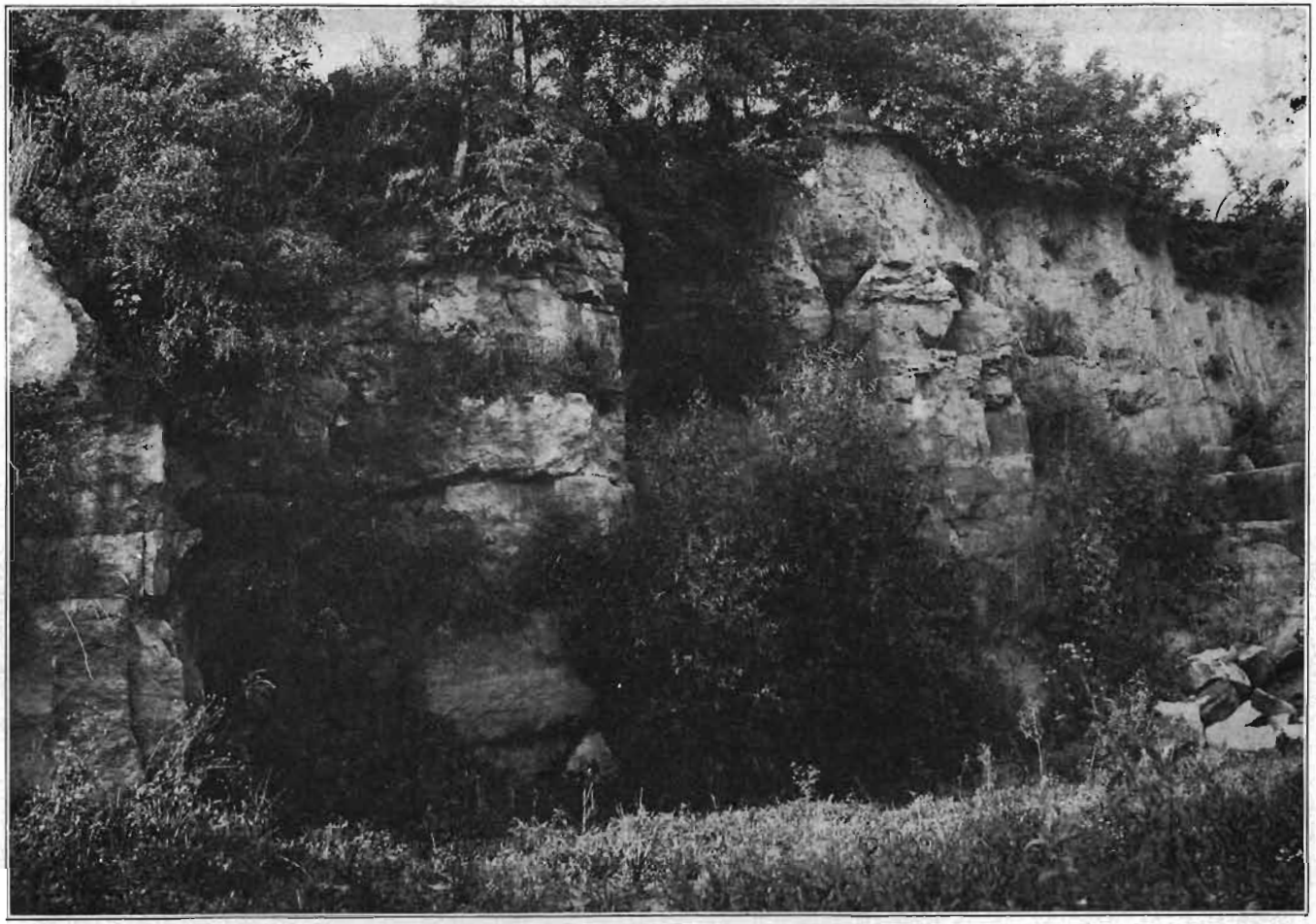
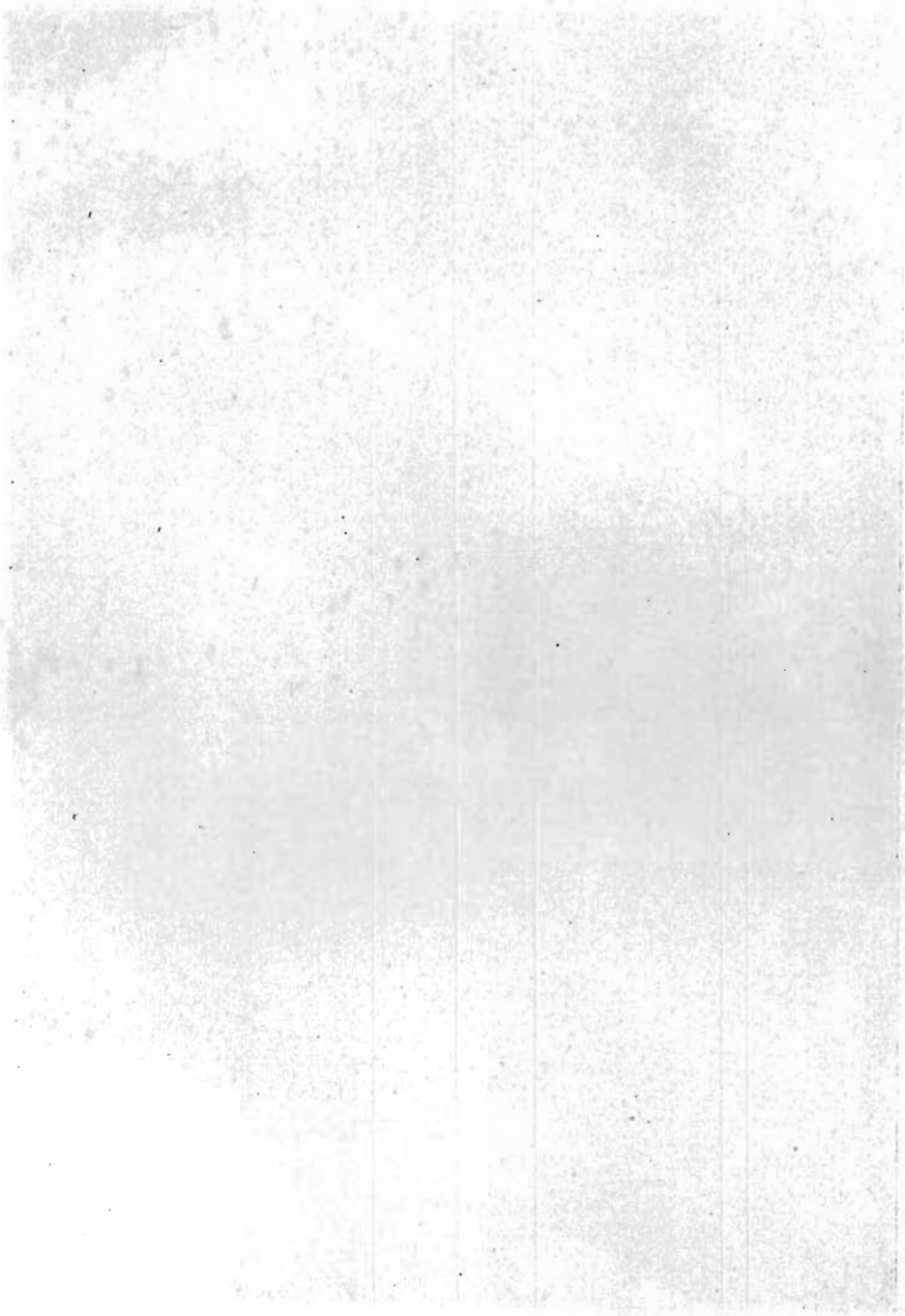


PLATE XIII—Old Randall quarry near Big Rock, Clinton county, showing heavy



Mrs. A. Smith has a small quarry south of Barber creek in the southwest quarter of the southeast quarter of section 29. Eight to ten feet of porous yellow limestone are exposed in beds from six inches to less than one inch in thickness. There is little drift or soil covering. The same stone crops out in the hills along both sides of Barber creek, southeastward, through sections 29 and 30. The strata are seldom horizontal but no uniform direction of dip was made out. In some instances the lack of horizontality is likely due to creep, but in general seems to be the result of disturbances on a broader scale, which are indicated also by the shattering of the beds themselves.

Near the southwest corner of the northeast quarter of section 9, near Buena Vista, Olive township, F. C. Huehl has worked a quarry on the land of S. B. Walker. The beds are similar to those on Barber creek south of Grand Mound. They are less weathered and harder, more durable stone is obtained relatively near the surface and without much stripping.

In the vicinity of Big Rock post office in Spring Rock township the porous yellow dolomite is exposed in the cliffs along Rock run, and at numerous places to the south of the river in Scott county.

In Sharon township, stone has been quarried on the farm of Henry Kiel, one-half mile east of Lost Nation. The beds here are porous, uneven and cherty.

The quarry section given below is exposed one-fourth of a mile east of the center of section 15, Sharon township:*

		FEET.
10.	Drift	5
9.	Geest	4
8.	Fine-grained and laminated rock, breaking along the horizontal seams into slabs from one to three inches in thickness	4
7.	More coarse-grained and porous, evenly bedded, yellow dolomitic rock, without well marked lamination	3
6.	Fine-grained dolomitic limestone, in places with very distinct crystalline texture, and weathering into slabs about four inches in thickness	3
5.	Yellow rock with occasional pockets set with crystals of calcite	4
4.	A single layer of fine-grained, dolomitic rock	3

*J. A. Udden, Iowa Geological Survey, Vol. XV, page 400.

3. Brownish, dolomitic limestone of compact texture, breaking much in quarrying, and having occasional crystals of calcite 3
2. Laminated, fine-grained and compact, dolomitic limestone, breaking into layers one inch in thickness, occasionally bearing chert 1
1. Solid and compact ledge of gray, dolomitic limestone, with some empty crevices lined with a thin coating of crystals of calcite 2

CRAWFORD COUNTY.

Sand and Gravel.

So far as surface materials are concerned, Crawford county is very similar geologically to Harrison and Monona counties. As in these, the gravel and sand deposits are of the Buchanan stage, occurring above the Kansan drift clay and beneath the covering of loess which is so general throughout the western portion of the state.

As might readily be expected, the principal exposures of gravel and sand occur along the streams where the latter have cut through the loess covering. Boyer river has removed the capping of loess in many places, and exposed the water-laid materials beneath. In the northeastern part of section 4, Union township, eight feet of sand and gravel are exposed beneath loess which varies in depth up to eight feet. The gravel and sand are inter- and somewhat cross-bedded, and in some places partially cemented.

One and a half miles down the Chicago, Milwaukee & Saint Paul railroad from Arion is a large pit where the railway has gouged into the point of a hill along Buck creek.

A distance of 300 to 400 feet is open, and considerable amounts of sand have been removed by the railway company. A maximum depth of seven feet of loess overlies most of the exposure. This is definitely separated from well-stratified sand which in the upper part is somewhat silty. The sand becomes coarser downwards, and cross-bedding is evident near the bottom. Pebbles one-half inch in diameter are included in the lower part. The sand grains are rounded, mostly clear quartz, and the deposit as a whole is bright and free from iron-staining. Twenty-four feet of sand have been exposed and the bottom

was not reached at that depth. The top of the sand is about thirty-five feet above the water in Buck creek.

The nature of this deposit, falsely bedded, coarse below and finer and more uniformly stratified upwards, indicates the work of loaded water currents under gradually changing conditions. The lower strata were dropped by a current of high velocity carrying coarse materials while succeeding layers were put down in water with decreasing volume and velocity.

This deposit forms a high terrace to the southwest of the stream. At a number of points in the next two miles up stream the gravels are exposed both artificially and naturally. About one-half mile from the above cut at a bend in the creek forty feet of interbedded gravel and sand can be seen capped with twelve to fifteen feet of loess. Here the gradation in conditions is not so clear, as coarse gravel and fine sand are interstratified indiscriminately from top to bottom. The gravel appears down to water level and seems to have no relation to the present stream. Many bowlders as large as the head appear in the gravel layers. These are glacial sands and gravels. There are any number of points along here where an unlimited supply is available with but a small amount of stripping.

The gravels appear also south of Arion as a bench along the Boyer, and pits are opened up at various points. So far the sand has been used only for building purposes.

Good gravel with some sand is taken from a terrace in sections 36, Paradise, and 1, Union townships. Some fifteen feet of gravel are exposed here under about two feet of pebbly soil. The terrace is fifteen to twenty acres in extent. It is close to the railroad and a spur could easily be run to it. In section 28, Denison township, ten feet of similar material are exposed under six to eight feet of loess, the latter becoming rapidly deeper away from the open pit.

Boyer river and its east branch in the vicinity of Denison have two terraces, the lower of which is about ten feet above the level of the flood plain and the upper ranges from thirty to forty feet higher. The first affords coarse gravel, the second fine sand with occasional bands of gravel. Small bowlders up to eight and ten inches in diameter are not uncommon in the

lower terrace materials. Both benches have been developed in a small way by the Mills Sand & Gravel Company, and are extensive and capable of much greater development. The pits operated are west of town on the main line of the Chicago & North Western Railway, which itself has removed an enormous quantity of gravel.

One of the largest pits in the county is located in section 13 of Goodrich township. At this place there are fifteen to twenty feet of cross- and interbedded sand and gravel under some six feet of loess. The upper part is somewhat coarse and grades into principally sand below.

Many other similar, though in most cases less prominent, exposures of these gravels might be cited along both the main and east branches of the Boyer. One other on the latter stream which perhaps should be mentioned here is at Vail, in section 30 of West Side township. Quite a large opening has been made here, and some six feet of gravel are visible under three or four feet of loess cover.

Besides the natural exposures of gravels made by the streams it is reported that these materials may be found quite generally throughout the county under the loess wherever a search is made. As a rule, however, the latter is quite deep, and few of the smaller streams have cut through it. Many artificial openings are scattered about the county, but the material so uncovered is usually unfit for concrete work. A large part of the materials used for construction purposes is shipped in from Lake View, in Sac county.

DALLAS COUNTY.

Sand and Gravel.

The supplies of sand and gravel in Dallas county are derived from two main sources, gravel terraces along the streams and from the hillocks of the Wisconsin drift.

Stream Terraces.—Des Moines river is the largest stream in the county, but is of but minor importance, since its total length within the borders is not to exceed six or seven miles. There is a well-defined gravel terrace some twenty-five feet above water, and a higher terrace, about seventy feet above the stream,

seems to be composed entirely of drift. In sections 11 and 14 of Des Moines township the lower terrace is prominent, being in the latter place five or six hundred feet wide and a quarter of a mile long. In section 11 the terrace has an area of perhaps fifty acres, and is composed, partially at least, of fine to coarse gravel.

The Milwaukee Railway formerly had extensive pits in the lower terrace just west of the bridge in section 11.

Beaver creek exhibits a prominent terrace through sections 3 and 4 of Beaver township. It has an area of perhaps a hundred acres, most of which is the property of the Chicago, Milwaukee & Saint Paul Railway. In section 34 of Des Moines township a small portion of this gravel terrace is again visible. Other than these two places the Beaver creek terrace is not particularly noticeable.

The terraces noted along North Raccoon river through Greene county continue practically all along its course in Dallas. From Dawson to Minburn there are many remnants of a low terrace which, though perhaps not offering possibilities of wide commercial development, affords ample supplies of sand and fine gravel for use over a large adjacent territory. A large part of the material is fine, and it is none too clean. On this account much of the material now used in Perry is shipped from Des Moines. In section 5 of Dallas township on a small creek which empties into the North Raccoon is a small terrace which contains gravel and sand in all sizes from three inches in diameter down. This has been used on the roads in the vicinity and has not been highly successful, but the fault in all probability is in the workmanship and not in the material.

In the vicinity of Redfield there are numerous remnants of terraces along Middle and South Raccoon rivers. There was at one time a gravel pit in the southwest part of the town, but this has long since been abandoned. It is reported that a well in this neighborhood showed fifty feet of gravel under eight feet of alluvium. The Chicago, Milwaukee and Saint Paul Railway formerly had a pit in section 34 of Linn township, which was abandoned before being completely worked out. Along South Raccoon river in Union township are several small ex-

posures of gravel in a terrace which will probably furnish considerable quantities.

Reworked Materials.—As might be expected of streams along which gravel terraces occur, sand and gravel bars are quite common in the rivers of Dallas county. The deposits of this nature in Des Moines river are not largely drawn upon here because of the large amounts of terrace gravels which are accessible.

Sand bars in Middle Raccoon river at Redfield contain some dirty material, but a much better quality of sand and gravel may be obtained from this stream in section 34 of Linn township. There are a number of bars of good size in the river between Redfield and Van Meter, and the same is true of the North Raccoon from the latter town to Minburn. Excellent sand and gravel is taken from the river in several places east of Van Meter and this, together with some supplies that are shipped in from Polk county, satisfies the demand for many miles to the south and west.

Glacial Deposits.—Most of Dallas county north of Raccoon river lies within the area of the Wisconsin drift. The hills and ridges of this region furnish supplies of sand and gravel which are variable in both quantity and quality but which constitute a useful and valuable asset. In the vicinity of Granger, and also of Linden, fairly good materials are derived from beds of this nature. As has been remarked in connection with other counties inside the Wisconsin drift area, the possibilities of finding workable deposits in other of these hills is well worthy of investigation.

Stone.

The Coal Measures underlie the entire county, and are made up of a series of shales, sandstones, and occasional thinly bedded limestones and thin seams of coal. The shales greatly predominate. Good sections are exposed along all of the principal streams. The sandstones occur in lenses, and are best exposed along Raccoon river. The most important lenses occur in the vicinity of Redfield. As a rule the sandstones are not well indurated, and are of a reddish brown color. At a few points, well

indurated beds are available, and have been quarried intermittently for more than a third of a century. The most important quarry sections are given below.

Section exposed on the southeast quarter of section 3, Union township, about two miles southeast of Redfield:

		FEET.
5.	Drift, of variable thickness.	
4.	Sandstone, soft, buff, heavily bedded	8
3.	Sandstone, blue, compact, hard	7
2.	Clay-shales, sandy, blue	4
1.	Sandstone, exposed to river	8

Number 3 is the only rock quarried. At the quarry it has a thickness of seven feet, but it thins out rapidly, and about thirty rods east, it is only one foot thick. The stone is of excellent quality, and is scarcely affected by weathering agencies. It was used extensively in Redfield, and was shipped to Fonda, Waukee, and other points on the Spirit Lake branch of the Chicago, Milwaukee and Saint Paul Railway.

The sandstones have been quarried at other points, notably near the mouth of Bulger creek, where a nine foot ledge of hard, well indurated sandstone appears. At the present time, sandstone is not used, save locally, and then in a very small way.

The limestone bands make up a very small part of the Coal Measure section, and as a rule, possess no commercial value. One exception may be mentioned, where the limestone has been quarried quite extensively. The section is given below.

Talbot quarry, located on the southwest quarter of section 29, Linn township, about four miles northwest of Redfield:

		FEET.
11.	Soil and drift	3
10.	Clay, sandy, buff	8
9.	Shale, black, fossiliferous	2
8.	Coal, with clay parting	1⅔
7.	Fire clay	3
6.	Shale, gray, with lime concretions	4
5.	Limestone, hard, compact, blue, fossiliferous above, mostly in solid ledges	7
4.	Shale, light gray	21
3.	Limestone, gray, brecciated above	1½
2.	Shales, gray, not fully exposed	1½
1.	Shale, black, fissile, coaly below	1½

The stripping here is practically prohibitory.

The Missouri occupies a triangular area in the southwestern corner of Dallas county. Exposures are limited to Adams and Union townships. The beds consist of a series of shales and limestones, all of which belong to the Bethany substage. Two principal limestones can be recognized and are believed to correspond to the Fragmental and Earlham horizons. The best sections appear along Bear creek and its tributaries, and a number of the outcrops have been quarried quite extensively. The sections given below may be taken as a fair average.

An abandoned quarry in the southwest quarter of section 28, Adams township, shows:

		FEET.
9.	Drift of variable thickness.	
8.	Limestone thinly bedded, slightly arenaceous	6
7.	Talus slope	8
6.	Limestone	4
5.	Shales, gray, calcareous	⅔
4.	Limestone	¾
3.	Shales, gray	4
2.	Limestone, fragmental	2½
1.	Des Moines series, exposed about	60

In the operation of the quarry, number 4 was the lowest bed removed. The quarry is located well up toward the top of the hill, and the limestone does not appear to extend much farther to the east and north of this point. The same beds may be viewed along the east and west road about a half mile south of the above quarry, in section 32. The quarry was operated at one time, a switch being extended from the Chicago, Rock Island and Pacific railway. Large quantities of stone were shipped. Most of it was used for railway ballast and construction.

Brown quarry section located on the southeast quarter of section 22, Union township:

		FEET.
8.	Drift and weathered material	1
7.	Limestone	10
6.	Talus slope, probably shale	6
5.	Shale, black, fissile	½
4.	Limestone, blue, compact, exposed	⅔
3.	Talus slope	25
2.	Limestone, impure and fragmental below	3
1.	Shale, calcareous, ferruginous, exposed	3

The above quarry was opened about fifty years ago, and was worked continuously for more than forty years. The rock quarried is No. 7, which is a blue to buff, compact and evenly bedded limestone. The individual ledges vary in thickness from eight to ten inches, and are separated by shale partings. Chert nodules in well defined bands appear at certain horizons.

The upper limestone member, No. 7, is also well exposed in a quarry on the southwest quarter of section 35, just north of the Madison county line. It has a thickness at this place of twelve to fourteen feet, and is underlain by blue shales. The quarry was opened more than twenty-five years ago, and formerly was connected by a switch with the Spirit Lake branch of the Chicago, Milwaukee & Saint Paul Railway. The rock utilized was the heavy bed of rough limestone. Almost the entire product of the quarry was used as crushed stone, and was shipped to Des Moines, and employed in the concrete foundations of the brick pavements. The amount of stripping was large, and added greatly to the cost of quarrying. The quarry has long since been abandoned.

Small quarries have been opened from time to time at other points in the Upper Coal Measures in the vicinity of Adel and Waukee, but these were operated intermittently, and were of local importance only.

DAVIS COUNTY.

Sand and Gravel.

Deposits of sand and gravel in commercial quantities are of rare occurrence in the county.

Small amounts may be obtained in the north tier of townships along Soap creek and some of its tributaries. Such deposits occur in sections 1, 10 and 12 in Soap Creek township. On the township line where the Rock Island railroad crosses Soap creek, clean sand may be seen.

Residual Gravels.—In addition to the reworked gravels which occur in the present stream, occasional outcrops of weathered gravels appear in cuts along roadways. Such deposits rest on the ferretto zone of the Kansan drift and sug-

gest the upland phase Buchanan gravels of the northern counties. These deposits lack persistence and attain but slight thickness and are of but little importance as a source of material suitable for road and concrete work. It is believed that these gravels are residual in character and were accumulated during the early stage of post-Kansan weathering.

Stone.

Rock of Saint Louis age has been taken from several small quarries along Des Moines river in sections 11 and 12, Salt creek, and in the bluff in section 13. The rock is fine-grained and makes serviceable material for foundations and similar purposes. Coal Measure sandstones also appear in the bluff in section 13. Sandstones also belonging to the Des Moines stage are found along Soap creek in the vicinity of Carbon, where they are locally used for foundation material. The rock is of no value for fine work, but constitutes, with the Saint Louis beds described above, so far as is known, the sole building stone resources of the county.

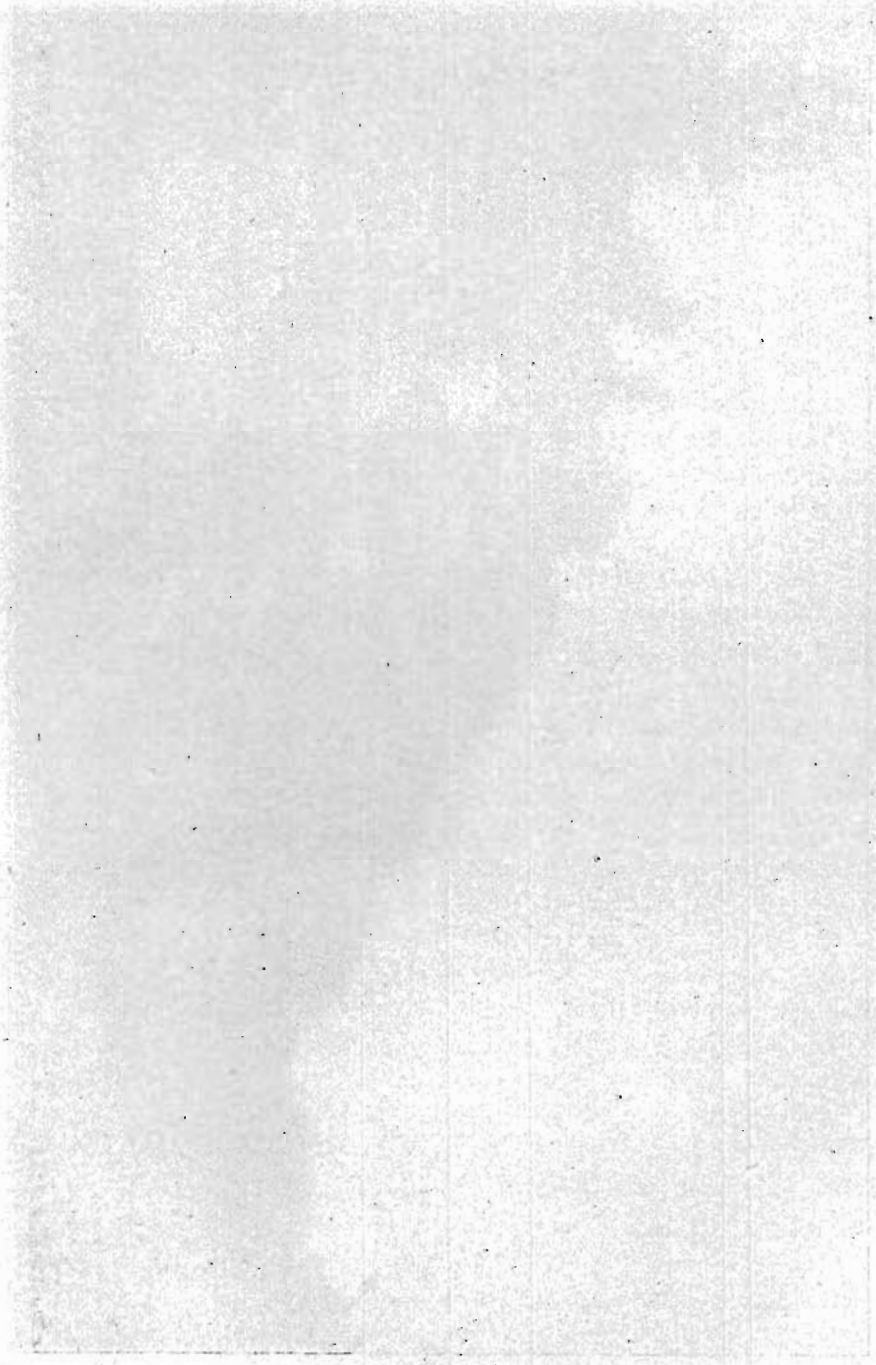
DECATUR COUNTY.

Sand and Gravel.

The sand and gravel deposits of Decatur county are of the same two classes found in Union county, viz., the old, probably Aftonian, deposits, and beds and bars in the streams which are probably derived from the former.

Aftonian Gravels.—In several places in the county, particularly along Grand river, there are exposures of gravel which seemingly are similar in all respects to those at Afton Junction and Thayer in Union county, described in detail in that report. At no place in Decatur county, however, do the exposures compare in size with those in Union, and any materials that could be derived from them would be sufficient in amount for small local uses only. Several places at which small exposures of the Aftonian gravels may be seen are: at the west end of the bridge over Grand river in southwest 30, Decatur township; where the road crosses a small stream tributary to the Grand a short way north of the same bridge; at the fords on Grand river in

PLATE XIV—The Rodnich quarries south of Davis City, Decatur county.



sections 21 and 28 of Burrell township; beside the road on the hill south of the last named ford; at the cemetery west of Burrell (Terre Haute); etc. At all of these places, with the possible exception of the first named, the gravels are under a covering which varies in depth up to twenty or twenty-five feet. From a commercial standpoint the available quantities are small.

Sand and Gravel Bars.—Along Grand river sand and gravel bars are of frequent occurrence. The river has cut its channel into bed rock nearly all the way across the county, and in most places the sand rests upon the rock surface. These bars are insignificant from a commercial viewpoint, but are quite generally used for local purposes. The town of Grand River takes all of its supply from the river, and the same is true of Davis City. Small amounts of these sands have been shipped from the latter place, and from Blockley. Large quantities for local use are to be found along Dickerson creek south of Davis City.

Stone.

The Missouri stage is represented in Decatur county by the Bethany substage, which comprises four, possibly five, well defined limestones, interbedded with variable shales, in the main calcareous. The basal limestone member represented in the county is known as the Fragmental, and is typically exposed at Bethany, Missouri. Exposures in the county are not important, and are usually obscured by the overlying drift and by talus from the beds above. Where it is typically developed, it is not sufficiently indurated and uniform in texture to be a desirable bridge or building stone. It could be used, however, for road work, concrete, and railway ballast. So far as known, it has never been utilized in Decatur county. All of the limestones are essentially nonmagnesian, are of great purity, and as a rule, contain little iron pyrite or other objectionable constituents.

The Earlham limestone appears in sections along Grand river, in the vicinity of Davis City, and in Burrell township along Pot Hole creek. At both of these points, some quarrying has been done, the largest quarry in the county being located at

Davis City, at which place the Boswell quarry shows the following section:

		FEET.
6.	Soil and loess	2-4
5.	Limestone	1
4.	Rotten stone and shale	2
3.	Limestone, 14-inch ledge overlying a 3-inch ledge	1½
2.	Shale and rotten stone	1
1.	Limestone, with wavy bedding, ledges running from 3 to 16 inches	6

The courses appear to be somewhat persistent, but are variable in thickness. A black shale appears below the basal limestone and this shale is in turn underlain by the Fragmental limestone. Higher in the bluffs, the Winterset limestone appears. On Pot Hole creek, the section given below is exposed and may be taken as fairly representative:

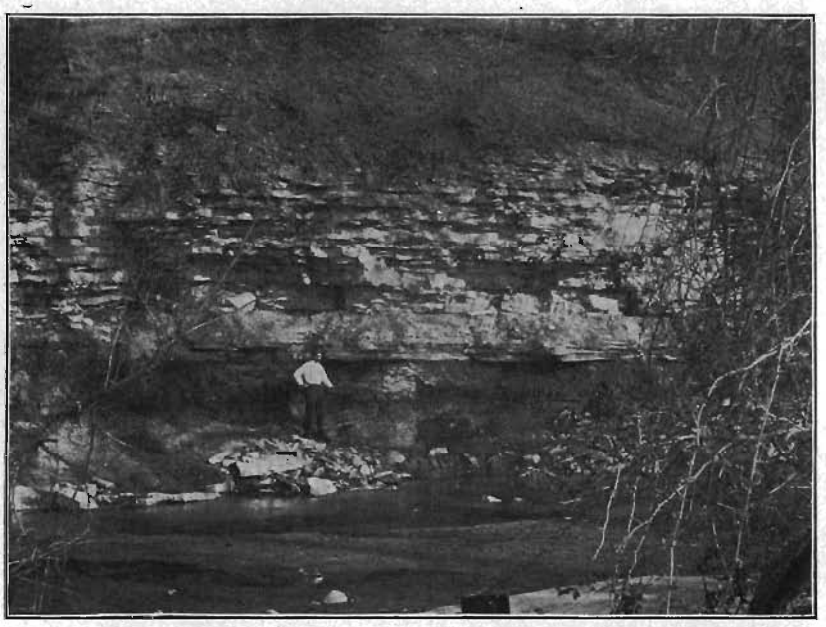


FIG. 23—Winterset limestone on Pot Hole creek with shales below extending down to the Earlham limestone. Decatur county.

		FEET.
3.	Limestone, ash-gray to brown, fine-grained, thin-bedded, with courses up to 1 foot in thickness, and shale partings	6-10
2.	Shale, drab, imperfectly exposed, but showing 1 foot of black shale	10
1.	Limestone, brecciated or fragmental type, firmly cemented and apparently nonfossiliferous	4

The beds dip to the west here, and higher up the stream the Winterset appears in the hills. Some quarrying has been done on the opposite side of the river, and blocks of considerable thickness still mark the site of the old quarries. It is reported that stone from this quarry was formerly dressed and sold for monumental work.

The Winterset limestone exhibits good exposures in the vicinity of Lamoni, along Hall and Elk creeks, in Bloomington township, in addition to the localities already mentioned in discussing the Earlham. One of the best sections appears along Pot Hole creek, about five miles northeast of Lamoni, and is given below:

		FEET.
6.	Limestone (Winterset) with *Spirifer cameratus, Productus punctatus, Productus costatus, Athyris subtilita*, etc.....	15
5.	Shale, gray to drab.....	3½
4.	Shale, bituminous	2½
3.	Coal	⅛
2.	Shale, gray	6
1.	Limestone (Earlham) in bed of creek.	

In nearly all sections of the Winterset, in addition to the shales above and below, one or more of the other limestone members of the Bethany substage are present.

The DeKalb member is exposed both east and west of DeKalb station, and at numerous other points in the county. The sections given below may be considered fairly representative:

SECTION EAST OF DE KALB STATION.

		FEET.
6.	Stripping, bowlder clay	6
5.	Limestone, irregular and waterworn.....	½
4.	Shale, hard	½
3.	Limestone, irregularly bedded	⅔
2.	Shale or bastard rock	2
1.	Limestone in five ledges that are respectively 9, 12, 6, 13, and 8 inches in thickness.....	4

SECTION ONE MILE WEST OF DE KALB STATION.

		FEET.
4.	Limestone	1
3.	Limestone	½
2.	Limestone	⅓
1.	Limestone	½

A fifth limestone horizon belonging to the Bethany and present in the county was recognized by Bain, who designated it provisionally as the Westerville limestone. It is typically exposed near Westerville, in Union county. It has not been quarried to any considerable extent in Decatur county. It occurs in the hills along Sand creek, attains a thickness of ten feet and is quite readily accessible. It is separated from the DeKalb by the usual shale layers. All of the limestones represented occur in comparatively thin beds ranging from three to sixteen or even eighteen inches in thickness, are fairly persistent, each horizon rarely exceeding fifteen feet in thickness, and are quite uniform in composition. They do not resist weathering influences well. After undergoing repeated freezing and thawing, they are subject to spalling, and the ledges break down rapidly on exposure. While quarrying operations have been carried on somewhat intermittently for more than half a century, very little stone is produced at the present time. There is but a single crusher in the county and that is located at Davis City. The general quarry products consist of rubble, rough stone for foundation and well purposes, and crushed stone.

DELAWARE COUNTY.

Sand and Gravel.

Delaware county is well supplied with gravels of both phases of the Buchanan and also with more recent deposits. The valley of Maquoketa river shows abundant outcrops and many of the hilltops and uplands bear equally large bodies. In the neighborhood of the Backbone in section 16, Richland township, there are several well-defined terraces of much weathered sand and gravel. One of these, on the west side of the Backbone, is thirty feet above the flood plain. The terraces continue down the Maquoketa from Forestville. They contain considerable coarse material and locally this is made up to a large extent of chert from the underlying Niagaran. In places the terraces are double, the lower one being about eight feet above the flood plain, the upper one twelve feet higher. An instance of this is seen in sections 17 and 18 of Delaware

township. A large amount of fine fresh sand covers all this area and in some localities seems to form the hills of the region. The valley of Honey creek seems to have been filled, in its lower reaches at least, with these old gravels, for banks of rusty Buchanan gravels overlying finer sands are exposed to heights of twenty feet and less. The terrace on the east side of the valley is continuous with the wide flat upon which the entire eastern part of the town of Manchester is built. Excavations everywhere in this flat reveal the presence of these materials, some rusty and weathered, some fresh and clean. Thus the cemetery occupies part of this level expanse whose surface extends out to the east until it meets the low bounding hills of the Iowan plain a mile or more away. On the river border sand pits and road cuts reveal the presence of the same materials and across the river at its bend the bank exposes coarse, red, oxidized gravels overlying Kansan drift. These same gravels are found in the brick yard a little farther south and also at the top of the bluff by the wagon bridge. In the immediate vicinity of the river the flood plain is filled with clean, fresh river sands.

Just south of the Illinois Central station a small run enters the river through a rather wide valley. The stream exposes several feet of interbedded gravel and sand. A pit has been opened in this valley and shows six to eight feet above the water. The valley is probably 100 yards wide and bounding it close to the railroad tracks is a tongue of gravel twenty-five feet high. These present an older, more weathered aspect than those in the valley below them and may be more ancient. There is an almost limitless quantity of material here and extensive use is being made of it for building, concrete and other purposes.

There are some terraces of gravel south of Manchester though the hills come in closer here than nearer the town and the rough, hilly region is soon entered. An ancient abandoned valley in sections 3 and 10, Milo township, shows remnants of terraces in its lower part and the stream valley into which it opens also has some remnants. The Maquoketa valley here also contains a terrace and gravels occur in a shallow valley running

across the flat Iowan-like plain occupying sections 12, 13 and 14. After the river enters its deep gorge in the hilly area terraces occur at several places, while in others the flood plain is either absent or extends to the steep hills. In section 29, Delhi township, is a terrace with a face twenty feet high. It consists of rather fine sand overlain by a thin layer of chert. Above this are several feet of loess which thickens rapidly toward the hill and so forms rather a steep slope. The top of the gravels, so far as they are exposed in the road cutting, is about level.

FIG. 24—Buchanan gravel underneath a thin layer of Iowan drift north of Earlville, Delaware county.

Above Hopkinton a few miles, where the river emerges from its narrow gorge, a broad terrace occupies the valley on the west side of the stream. Considerable bodies of sand and gravel also underlie the town of Hopkinton and are separated from the river by a high, wide flood plain. The terrace is not very wide, perhaps 200 yards, and it abuts against the stony hills which limit the old pre-Kansan valley. A quarry in the north end of town shows a bank of gravel at one end extending down at least as far as the quarry floor. On the west side of the river is a narrow flood plain and remnants of terraces are seen, but the hills approach near the river here. South of town some remnants of a terrace occur in section 31, South

Fork township. Below this for several miles there is a great amount of sand but the evidences of terraces are very slight.

Gravels are very abundant in the valley of Bear creek above Dyersville and this bed occupies several hundred acres. The gravels become noticeable in the northeast quarter of section 27, Bremen township, where they are covered by three to four feet of clay and silt. The lower part of the clay is iron-stained and appears to grade into the gravels. It is probably genetically related to them and is of immediate post-Kansan age. In section 25 the Chicago Great Western Railway formerly operated a great pit in these gravels. The opening is eight to ten feet deep and is entirely in gravel, which extends up to the loam. The deposit fills the old valley and forms a broad terrace extending to and beyond the town to the river.

There are indications of gravel along the north fork of the Maquoketa in section 13, North Fork township. These are situated well back from the river and rather high above it, but are distinctly of the valley type. They are fine, red, with but little coarse matter. Similar gravels occur in a creek valley in the southwest quarter of section 13, and seem to form terraces, backed by the rocky valley walls.

At Rockville there are gravels on both sides of the river. On the west side they are banked on a rock platform and are twenty feet thick. They contain much chert but little foreign coarse material. In the vicinity of Worthington, the valley is quite broad and the gravels extend back from the main stream up a tributary valley and underlie the village to a considerable extent.

In addition to the valley deposits the upland gravels are very generously distributed over the county. Thus the road from Monticello to Manchester passes over numerous beds, as for instance, in sections 20 and 27 of Union township, 7 and 11 of Hazel Green and many other points. A number of these are indicated on the map of Delaware county in volume VIII, Iowa Geological Survey reports, and detailed descriptions are given by Dr. Calvin of numerous pits and outcrops.

STONE.

The Niagaran limestone forms the country rock over nearly the entire county and furnishes an unlimited quantity of stone suitable for structural purposes, crushed stone and lime. Numerous outcrops appear along the principal rivers and most of their tributaries, and these have been developed to meet the merely local demands. Quarries have been opened at a large number of points, especially in the northeastern half of the county. According to Calvin, there are two horizons at which evenly-bedded, easily-quarried stone occurs, and the quality of the stone at both horizons is such as to place it among the best in Iowa. The lower stone horizon begins about thirty feet above the base of the Niagaran limestone and has a thickness of more than thirty feet. The other horizon occurs near the top of the Delaware stage, above the Pentamerus beds, and has about the same thickness as the lower quarry stone horizon.

The principal quarries of the lower horizon are located in Elk township. There are at least four in section 16, one in section 23, and two or three occur in section 2. All are worked more or less constantly during the summer season.

The Wilcox quarry is located on the southwest quarter of section 16, and is typical of all the others at this geological level. It presents a vertical face of about thirty feet. The beds range from three or four to thirty-six inches in thickness. The heavier layers are toward the top of the exposure, and some of these contain numerous cherty concretions. Near the base of the quarry the stone lies in thinner layers and is free from chert. The quarry is capable of yielding good material for cut dimension stone, all kinds of ashlar work, rubble and heavy dimension stone for bridge piers. A great number of joints trending southwest-northeast cut vertically through the strata. The best material for cut stone lies about the middle of the quarry section. Here the beds are free from chert, and the surfaces of the individual layers are comparatively parallel planes. Near the base of the quarry the layers present uneven surfaces, the irregularities resembling the effects of wave action.

The Wilcox quarry is situated on the north side of a triangular ridge separating two converging valleys. Around the point of

the hill, and almost opposite the exposure operated by Wilcox, another opening has been made in layers corresponding to those in the upper part of the Wilcox quarry. The stone is weathered at the top, and is overlain by dark brown residual clay, residual chert and a thin layer of loess. There are no signs of drift. If the Kansan drift was ever laid down in this locality it was entirely removed by erosion before the deposition of the loess. All the other quarries opened at this horizon show essentially the same details as those described.

Regularly bedded limestones, apparently similar to the beds worked, continue below the base of the Wilcox quarry for at least fifteen feet, and hence there is a total thickness of forty-five feet of beds that might be quarried. Between the quarry stone and the horizontally laminated beds at the base of the Niagaran there is a rather gradual transition through strata intermediate in character. No fossils were noted either in the basal beds or in the quarry stone.

There are quarries at the same horizon in Bremen township. One of these is located south of the center of section 13, and there are two or three in section 26. A quarry in the northern part of section 26 furnishes good stone for rough masonry. The rock is granular, vesicular, much pitted by weathering where exposed, rather evenly bedded; beds are horizontal and vary from a few inches to more than a foot in thickness. The pitted condition due to weathering is peculiar and distinguishes the rock of this locality from the equivalent beds on Elk creek. The quality is inferior when compared with stone from the Elk creek quarries. Another quarry in which the stone shows similar peculiarities of weathering occurs a short distance southwest of the center of section 26, Bremen township.

Beds of this lower quarry stone horizon, resembling those on Elk creek, are exposed at many points along Little Turkey river and its branches in the northeastern part of Colony township.

The city of Hopkinton owns and operates a quarry at the north edge of town. It is opened in the face of the scarp overlooking the valley of Maquoketa river. Although the Chicago, Milwaukee & Saint Paul railroad runs close by the quarry, there are no railroad connections. A crusher operated by a traction en-

gine is used for making macadam, and only crushed stone is being removed at present. The beds now used constitute a thickness of eight to ten feet of buff, granular dolomite in layers four to eighteen inches thick. Intercalated between the beds are chert bands, some of which also run through the strata. Above the beds used are fifteen feet of similar rock, but some of these upper layers, notably the upper two feet, break into irregular laminæ one inch, more or less, in thickness. There is no flint in the upper layer.

The beds represented in this quarry are doubtless to be correlated with the lower quarry horizon of the Hopkinton stage of the Niagaran, as defined by Calvin.

The best exposures of the upper quarry horizon are seen in Union township, a few miles southwest of Hopkinton. The Merriam quarry, in the southeast quarter of section 23, has been worked longer than any of the rest, and may serve as a general illustration. The section is about as follows:

MERRIAM SECTION.

		FEET.
11.	Layers of limestone alternating with layers of chert each about three inches thick	2½
10.	Single layer, with embedded concretions of chert	2
9.	Three to six-inch layers of limestone, alternating with two to three-inch layers of broken chert	5
8.	Fair rock with little chert	1¼
7.	Even-grained rock, cleavable	⅚
6.	Good quarry stone in several layers	3
5.	Compact layer with large, flat Pentamerus	2
4.	Lowest layer worked	⅚
3.	Vesicular ledges below base of quarry	3
2.	Cherty layers	4
1.	Cherty and vesicular layers down to talus	18

The Merriam quarry has from fifteen to twenty feet of excellent quarry stone. There are two or three other quarries worked at the same horizon in the same quarter section.

The Loop quarry is situated in the northwest quarter of section 25, Union township, about one mile southeast of the Merriam quarry. This quarry has been worked for a number of years, and it is capable of furnishing a large amount of valuable building stone. The stone is fine-grained, homogeneous, easily

worked and of good color. As the quarry is carried farther back into the hill, the aggregate thickness of the available stone will increase to twenty-five or thirty feet. The beds now exposed furnish excellent material for rubble, range courses and dimension stone up to ten inches in thickness.

Quarry stone belonging to the Merriam quarry horizon crops out at a number of points along a small ravine in the east half of section 17, South Fork township. The bedding seems to be thinner here than on the west side of the Maquoketa in Union township. Some of the beds, however, are ten inches in thickness; and quarries worked on the northeast quarter of section 17, and on the southeast quarter of the same section, have furnished a large amount of good building stone for local use. Another small opening at this same horizon was noted in section 14 of South Fork township.

There are several quarries in the upper building stone beds in Milo township. The largest are located in the eastern part of section 9, near the north end of the highlands, called in Calvin's report on Delaware county the Delhi plateau. The land on which the quarrying is done is nearly 200 feet higher than Maquoketa river at the nearest point. The rock is here less magnesian than at other exposures in the county. A large proportion of it is bluish in color, and there are many large pockets of calcite. The bedding is quite regular, but the quality of the stone is not equal to that at the Merriam and Loop quarries farther south. A much better quality of stone is furnished by the Matthews quarry, located near the center of section 4. The Matthews quarry has beds ranging from two inches up to two feet in thickness. The stone has a good color, rather fine texture, and may be used for the better grades of structural work.

In Delhi township the upper quarry stone is worked to some extent at Beal's quarry, in the town of Delhi. It is exposed and might be easily quarried, in the bluff south of Fleming's mills, in section 29, and there are a number of other exposures, though at rather inaccessible points, along the bluffs of the Maquoketa, in sections 29, 30, 33, 34 and 35. A small quarry capable of affording very excellent stone is opened on the northeast quarter of section 23.

The Pentamerus beds are usually massive and break on quarrying into shapeless pieces, but at a few points in the county they lie in comparatively thin, even layers that may be quarried without difficulty, and yield stone suitable for a number of purposes. The position of the Pentamerus beds is between the two quarry stone horizons already described. A small quarry is worked in the Pentamerus horizon in the northwest quarter of section 3, Colony township. In the same township there is another quarry at this horizon near the center of section 27, and still another is worked in the southwest quarter of section 35. The last mentioned has been operated more extensively than the other two. The quarry face is about eight feet in height. The beds are somewhat shattered near the top. Chert is abundant as partings between the layers or as concretions embedded in them. The limestone is overlain by a very reddish brown, pebbly Kansan drift.

Some of the most important quarries worked in the Pentamerus beds are located in the southwest quarter of the northwest quarter of section 31, Bremen township. In one of these quarries there is an exposed section, thirteen feet in thickness, which shows:

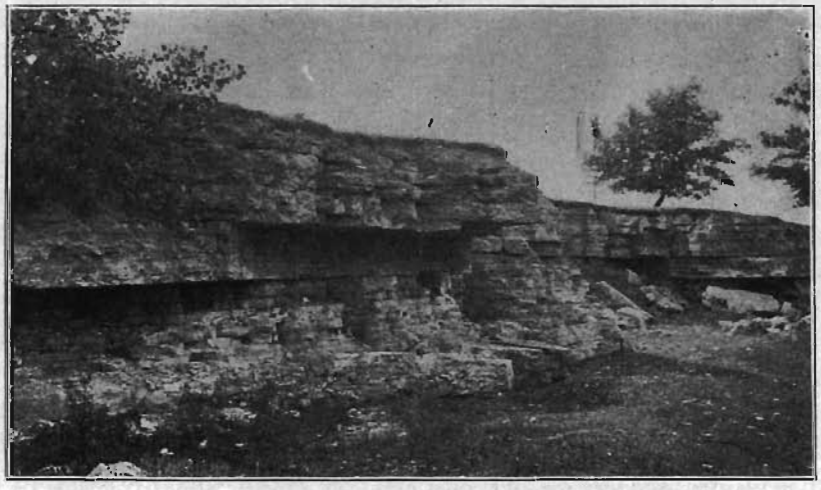


FIG. 25—Regularly bedded Pentamerus-bearing limestone in section 31, Bremen township, one mile east of Earlville, Delaware county.

		FEET.
2.	Coarse vesicular stone in heavy ledges, ledges varying from eight to thirty inches in thickness	8
1.	Evenly bedded stone in layers two to six inches in thickness. Some of the layers contain *Pentamerus oblongus* with shells partly preserved. Stone is soft earthy dolomite, with some chert	5

The massive beds of No. 2 contain Lyellia, Favosites and other corals. These thick ledges are undermined in taking out the thinner layers of No. 1, and great blocks left without support, fall down on the floor of the quarry.

Some stone is obtained from this horizon near Sand Spring in South Fork township. Pentamerus limestone is used for foundations and bridge piers at Forestville in Richland township. Near the northwest corner of section 2, Milo township, there is a small quarry that with rather coarse, thin-bedded limestone, furnishes an unusual amount of chert.

DES MOINES COUNTY.

Sand and Gravel.

The gravel and sand resources of Des Moines county are mainly of two kinds: river sands and lenticular deposits in the drift hills. River terraces also furnish some sand and gravel, but these are relatively small and unimportant.

Sands.—Sand for building and other purposes may be obtained from several geological formations. Commonly it is taken from the bars in the streams. At Burlington, where the channel of the Mississippi comes up to the very foot of the escarpment on the west side of the river, the sand used is dredged up from the bottom of the stream and carried over to the city in barges. As a rule the river sand is quite clean, sharp and well adapted for mortars of all kinds. In the drift deposits numerous lenticular beds of fine to coarse sand occur and are available in every township of the county. Often considerable coarse material and gravel are mixed or interstratified with fine sand, but this rarely prevents the latter from being utilized.

Terraces.—Owing to the westward deflection of the Mississippi opposite Oquawka, the river is brought directly against the hard

limestone wall which marks its immediate valley. Terraces consequently have an unimportant development. The principal evidences of terrace formation are at the mouth of Flint creek above Burlington, and north of the mouth of Skunk river. In the northern part of the county low terraces also exist. The terraces at the mouth of the Flint are about thirty feet above the flood plain of the Mississippi. A vertical section of the different beds comprising it is shown in the section at the mouth of Flint creek.

STONE.

The Kinderhook beds are believed to form the country rock under the Mississippi bottom lands along the entire east front of the county. They appear near the base of the bluffs, overlain by the heavy Osage, or Augusta limestones, for practically the same distance and for about six miles up Skunk river. They present their maximum exposure in the city of Burlington at Prospect Hill, and at Cascade in the bluffs and in the pit of the Granite Brick Company. According to Keyes and Weller, the Kinderhook section at Prospect Hill is as follows:

SECTION AT PROSPECT HILL, BURLINGTON.

		FEET.
12.	Loess	15
11.	Till; yellowish brown clay, with pebbles and small bowlders	8
10.	Limestone, white, thinly bedded	10
9.	Chert and siliceous shales with thin, irregular limestone beds, white and red in color	20
8.	Limestone, brown and white, rather heavily bedded, coarse-grained, subcrystalline; becoming more thinly bedded and cherty above	25
7.	Soft, buff, gritty limestone	3-5
6.	White oölitic limestone	2-4
5.	Fine-grained, yellow sandstone	6-7
4.	Fine-grained, compact, fragmental gray limestone	12-18
3.	Thin band of hard, impure limestone filled with Chonetes; sometimes associated with a thin oölite band	¼-¾
2.	Soft, friable, argillaceous sandstone, sometimes harder and bluish in color, filled with fossils in the upper portion, the most abundant of which is *Chonopectus fischeri*	25
1.	Soft blue argillaceous shale (exposed)	60

Number 7 is somewhat earthy and magnesian and ordinarily is not sufficiently indurated to be used as a quarry rock. In the

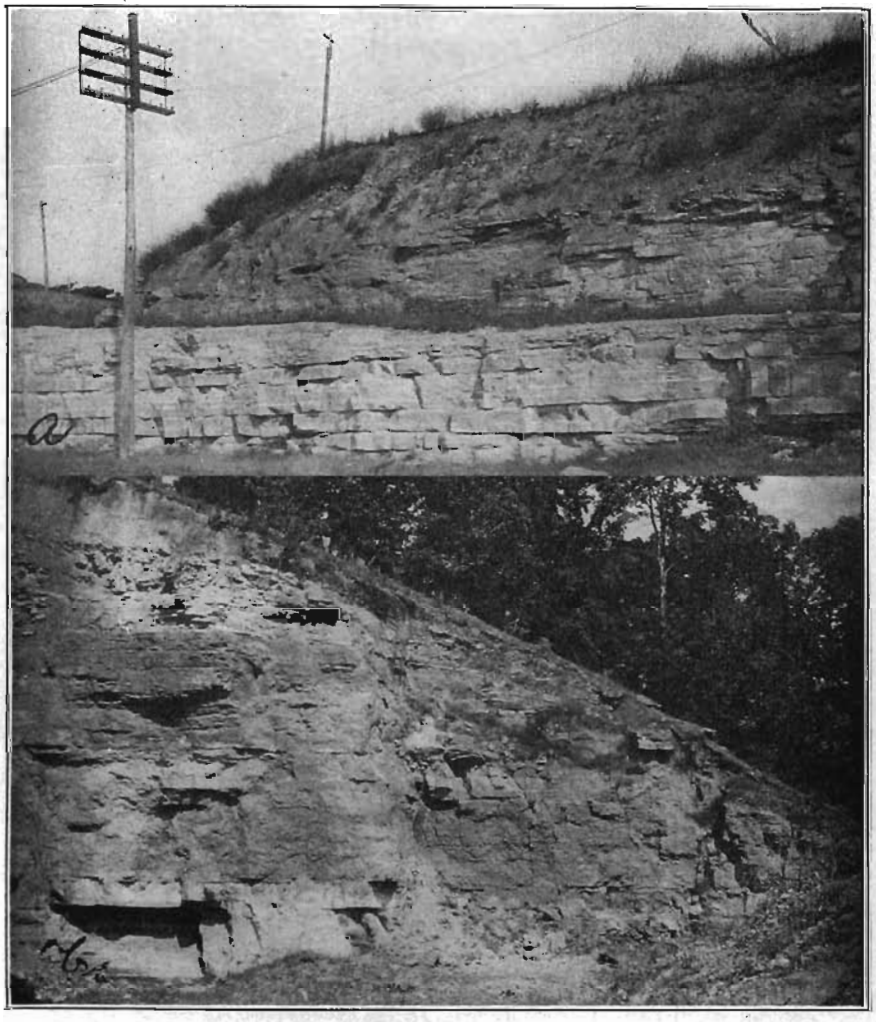
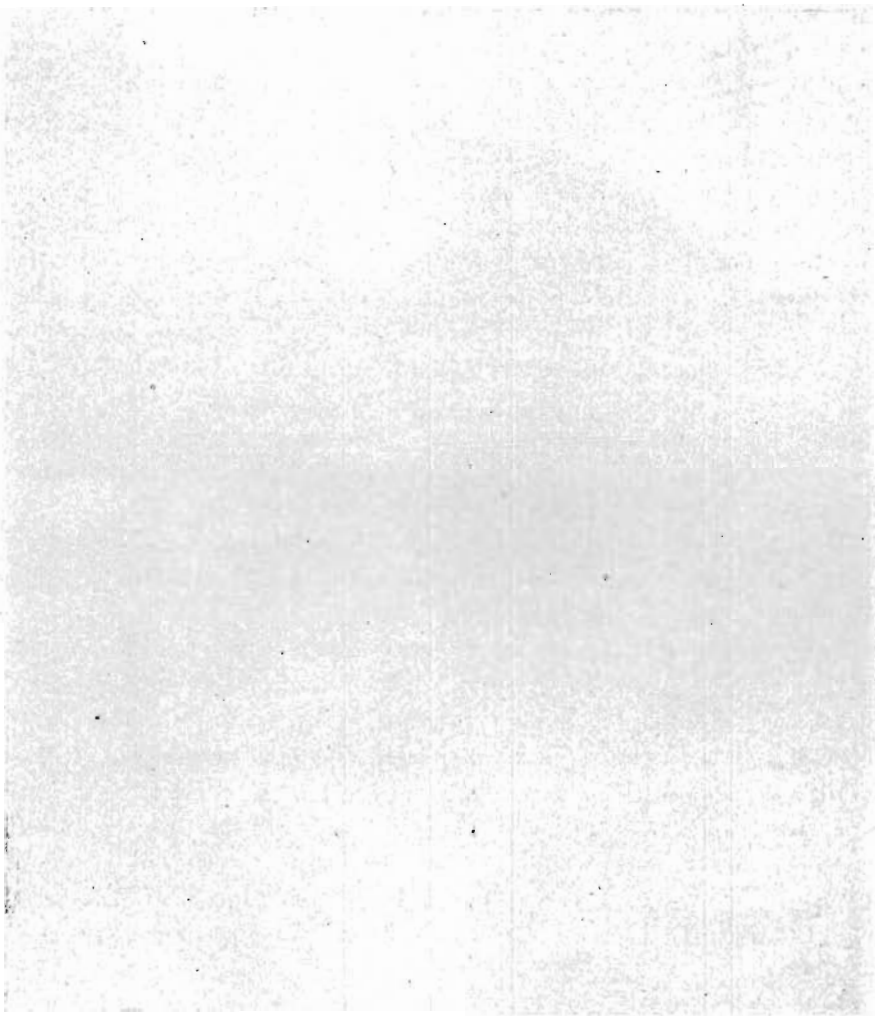


PLATE XV—a. Section at Union Depot in Keokuk, Lee county, showing chert beds.

b. North end of Government quarries below Burlington, Des Moines county, showing the Kinderhook limestone.



Government quarries below Cascade it has been taken out for use in the river improvement work. The oölite is not constant in thickness, but ranges from one and one-half to four feet. It is usually fairly massive and compact and when properly selected has proven satisfactory as a dimension stone. It appears to be persistent as it has been seen along Flint river and south as far as Patterson. Numbers 2 to 4 inclusive are usually not sufficiently indurated to be used as quarry stone. Number 4 especially is oftentimes very friable and is to some extent a source of building and molders' sand. The shale is by far the most important member from a geological and also from an economic standpoint. It is a massive deposit ranging from blue to blue-gray in color, almost gritless. The beds are almost nonfissile, high in silica and comparatively low in alumina. They show an increase in silica upward and grade almost insensibly into a soft argillaceous sandstone above. The shale shows a maximum exposure of sixty feet and is known to extend at least one hundred feet below the water level in the river.

The nonresistant character of the Kinderhook beds is in very large measure responsible for the steep bluffs which face the Mississippi river and larger tributaries.

Limestones and shales which have been referred to the Osage stage of the Lower Carboniferous, immediately underlie the drift over by far the larger portion of the county. The limestones greatly predominate, although the shales become prominent near the top of the series.

For convenience of discussion, the Osage, as developed in Des Moines county, may be divided into five fairly well defined members: the Lower and Upper Burlington limestone; the Montrose cherts; the Keokuk limestone and the Keokuk and Warsaw shales.

The limestones are prevailingly pure, crinoidal and cherty throughout. The first and fourth members are heavy-bedded and coarse-textured, while the second and third are generally thinly, often irregularly bedded limestones.

The two divisions of the Burlington are the most conspicuous formations in the county, and form the steep bluffs which face the Mississippi, and its leading tributaries for a short distance

above their debouchures, along the entire length of the county, and Skunk river across the larger portion of the county's width.

The Lower Burlington occupies about fifty feet in vertical section, including about twenty feet of calcareous shales at the top. The limestone is coarse-grained, subcrystalline, varying from pure white to brown or rusty in color, and occurs in rather heavy beds, especially near the base. Normally the rock is gray, the rusty brown being due to water staining. It is often quite cavernous. The upper shaly horizon carries much chert in concretions and bands and some calcareous ledges. The limestone is suitable for structural materials throughout, while the shale is practically worthless.

The Upper Burlington lies in thinner beds, and is more cherty and more shaly throughout than the lower member.

The most typical section of the Upper Burlington is shown in the Miller quarry, just above Cascade.

SECTION AT THE MILLER QUARRY.

		FEET.
8.	Loess	12
7.	Drift	3
6.	Limestone and chert	8
5.	Limestone, brown and white, banded with chert, thinly bedded	6
4.	Limestone, gray and white, heavily bedded	10
3.	Shale, blue, argillaceous, fossiliferous	2
2.	Limestone, heavily bedded, white	5
1.	Shale, blue, exposed	4

The majority of the quarries in the county are developing the Upper Burlington limestone. Quarries may be opened at almost any place in the faces of the bluffs fronting the larger streams, and excellent transportation facilities by both rail and water are often available. Some of the more representative quarry sections are appended herewith:

CITY QUARRY, NEAR MAIDEN LANE AND SEVENTH STREETS.

		FEET.
6.	Loess	12
5.	Drift	2
4.	Limestone, white, rather brittle, thinly bedded	3
3.	Limestone, yellowish, heavily bedded	5
2.	Limestone, poorly bedded, with considerable sandy clay and chert	2
1.	Limestone, white, solid bed	

The quarry supplies stone suitable for curbing and other dressed stone from numbers 1 and 3. The waste from these layers and from numbers 2 and 4 can be used for macadam and other crushed stone purposes.

Extensive quarries were operated by the government at Picnic Point about two miles south of Cascade. These quarries are now idle. The quarry section exposed is as follows:

PICNIC POINT QUARRY SECTION.

		FEET.
7.	Loess and drift up to	15
6.	Limestone, very cherty, brown, subcrystalline, chert weathers yellowish	10
5.	Limestone, brown, encrinital, subcrystalline, chert mainly in two zones; much weathered and cavernous in places	10
4.	Limestone, oölitic, somewhat weathered	1½
3.	Sandstone, argillaceous and calcareous, heavy bedded when fresh; weathers decidedly shaly above; occasional large cherts in upper portion	5
2.	Limestone, concretionary zone, white and blue limestone, weathers yellow, and breaks up into thin, irregular layers	9
1.	Sandstone, argillaceous, white, washes on exposure, and apparently is pyritic; has a decidedly sulphurous odor, exposed	10

About one and one-half miles below the government quarries, some quarrying is being done. Lime was burnt here and two kilns in a fair state of preservation still mark the site. The beds exposed are practically the same as these at the Picnic Point outcrop.

North of Burlington good outcrops are of somewhat less vertical extent, but equally numerous. In Flint River township a quarry on the northwest quarter of the southeast quarter of section 25 may be taken as a type and is given below:

LOFTUS QUARRY SECTION.

		FEET.
6.	Loess	4
5.	Drift	10
4.	Limestone, thinly bedded, with considerable chert	8
3.	Limestone, subcrystalline, irregular, heavily bedded	10
2.	Limestone, white, solid bed	6
1.	Limestone, dark gray, somewhat irregularly bedded, exposed	4

All of the indurated rocks may be referred to the Upper Burlington. The beds may be viewed still farther to the northwest in Pleasant Grove township. In an old quarry on the northwest quarter of section 12, the following beds may be made out:

PLEASANT GROVE SECTION.

		FEET.
9.	Loess and drift	10
8.	Limestone, heavily bedded	6
7.	Limestone, rather brittle and poorly bedded	2
6.	Limestone, white, heavily bedded	6
5.	Shale, yellow, or calcareous sandstone	2
4.	Limestone, gray, irregularly bedded	4
3.	Chert	1
2.	Shale, or yellow sandstone, calcareous	2
1.	Limestone, thinly bedded	3

Stone is supplied to Pleasant Grove, Washington, and a large part of Yellow Springs and Franklin townships from these quarries. The stripping increases rapidly back from the face of the bluff, and quarrying has been and is carried on in a very desultory manner.

The Montrose cherts, while present in numerous outcrops, do not contribute materially to the natural wealth of the county. Commercially they are suitable only for crushed stone products. They are best exposed along Skunk river. The chert beds rise to the north and only rather unimportant detached areas are known.

The Keokuk limestone occupies a broad belt across the southwest portion of Des Moines county, covering about one-fourth of its superficial area. This limestone is distinguished from the Burlington, lithologically, by its prevailingly blue color, less crystalline texture, and greater compactness.

The Keokuk limestone is a heavy bedded, reasonably pure calcium carbonate, well adapted for structural purposes. It is less quarried than the Burlington, on account of greater overburden and poor transportation facilities.

A representative section may be viewed in the vicinity of Augusta, where both the Montrose cherts and Keokuk beds are well shown. The sequence is as follows:

AUGUSTA SECTION.

		FEET.
4.	Drift	8
3.	Limestone, bluish, encrinital in places, clay partings, often highly fossiliferous (Keokuk)	20
2.	Chert, white, thinly bedded, with thin irregular bands of limestone (Montrose)	30
1.	Limestone, white, coarse-grained, encrinital (Upper Burlington), exposed	15

Farther up Skunk river the Saint Louis limestone and Coal Measures come in, and the Keokuk beds dip below the level of the stream. Small quarries have been worked from time to time in Danville and Union townships, but these were of local interest only. In many of the outcrops, cherty material is so abundant that the stone is practically worthless save for crushed stone purposes.

The Saint Louis limestone covers a small area in the southwest corner of the county. The principal outcrops occur in the valleys of Long and Cedar creeks and Skunk river. The beds comprise, in descending order, a white clay marl; gray, flaglike limestone; brown, arenaceous limestone; and a concretionary and brecciated limestone.

The gray, coarse-grained limestone is regularly bedded, and occurs in thin, flaglike layers from two to five inches in thickness. It is quite compact and outcrops on Long and Cedar creeks north of Augusta, where some quarrying has been done.

The brecciated limestone is a very fine-grained, compact limestone, light blue or ash-gray in color, and breaks with a well marked conchoidal fracture. The fragments are all more or less angular and vary in size from microscopic particles to blocks several feet in length. They are firmly embedded in a matrix of a hard, greenish, calcareous clayey material which weathers more readily than the limestone fragments. As far as known the flagstone member of the Saint Louis is the only one which has been quarried and the beds as a whole are much less important from an economic standpoint than their equivalents in Lee county.

DICKINSON COUNTY.

Sand and Gravel.

Dickinson county is abundantly supplied with sand and gravel. The melting ice of the Wisconsin glacier poured its flood waters down the valleys and over the lowlands to the south, and the courses of these floods are marked today by enormous deposits of sand and gravel. The hills and knobs of the morainal area within the county likewise add their portion of water-deposited materials to those of the drainage channels.

Stream Terraces.—Little Sioux river furnished an excellent channel for the outpouring waters from the melting ice, and received untold quantities of outwash materials, which today may be found all along the stream as a more or less persistent terrace. Gravel pits have been opened in several places, e. g., in the south part of section 15, and on the east side of the stream on the line between sections 16 and 21, Diamond Lake township. The Rock Island Railway Company has opened an extensive pit in section 29, Diamond Lake township, and one on a smaller scale on the west side of the Little Sioux in section 25, Silver Lake township. These terraces are not continuous nor do they appear to be connected. Both seem to belong to the same stream.

The terraces are more prominent farther south and after the union of the two main forks of the Little Sioux become highly important. In the northwest part of section 8, Lakeville township, enormous masses of gravel and sand have been opened. Conspicuous low hills east of the river running thirty to forty feet high and appearing for some distance north and south are composed almost entirely of sorted materials. East of the Sioux in sections 21 and 28 of Lakeville township are the same low hills thirty to thirty-five feet above the river, capped by or composed of sand and gravel. The topography is exceedingly rugged, and these gravels were no doubt deposited by the river when it flowed at a higher level than now.

Milford terrace is a huge gravel plain, a remarkable piece of evidence of the tremendous amount of materials carried out and down by the ancient flood waters. (See report on Osceola county.) It begins north of the town of Milford, where the Wisconsin

moraine ends, and seems to come from beneath the latter. To the south it is a pronounced topographic feature, extending down to the county line and having a width of two to three miles most of the way. The north portion of it is a drift surface leveled up by the deposition of gravel. In places the gravel is almost absent, in others just present, and again fifty feet thick. The first is true to the west, where the Sioux makes its "debut." The gravels are not thick under Milford as a rule. Twelve to fifteen feet may be seen overlying drift in the southeast part of section 12, on the west side of the railway south of town. Similar outcrops appear in road cuts in many places in south and southeast Milford; drift on the slopes and gravels at the top. The only opening of any size is in southeast Milford, in the terrace escarpment bordering the old mill pond. There is no stripping here. The upper four to six feet are coarse gravel with small bowlders up to six or eight inches, badly tumbled up and iron-stained. The gray granites are disintegrated and crumbly. Below comes clean, fine gravel and sand, much cross- and interbedded, but containing few pebbles over two inches. Occasionally small lenses of plastic clay occur just below the upper coarse part. Upwards of thirteen feet of good gravel are open to view.

The main pit from which gravel for cement work is being taken, is in the northwest quarter of section 8, Milford township, a mile east of town. There is less coarse material than in the opening noted previously, and the whole is rusty in appearance.

Much gravel has been taken from the John Winton pit at the northeast corner of town. Here there are exposed some thirty-five or forty feet, with a foot or less to strip. The top is coarse and iron-stained, and the upper twenty feet have occasional sand bands. Two of these are eight to ten inches thick, and contain a considerable amount of silt. These sandy-silty seams stand up well, and do not slide as does the rest. The lower part of the pit has more sand, but there is much coarse material throughout.

Thirty feet of clean gravel are exposed in a road cut on the county line at the southwest corner of section 34, Okoboji township.

In reference to this huge outwash plain, Prof. Ira A. Williams says: "It is useless to estimate the amount of sand and gravel available in Milford terrace. Where it can be observed (there are few openings), there is practically no stripping, only the top few feet are impure and bowldery, and below is clean, moderately fine sand and gravel to suit the purpose surely of the most fastidious."

Stony creek meanders through a depression often marshy, usually little below the surrounding country. It has, however, after its escape from the moraine in south Excelsior township, distributed gravels more or less continuously throughout its course in the county. These deposits are not conspicuous, but are to be found in low benches skirting the stream, now on one side and now on the other, more often on the east than on the west side. The gravels are usually covered with a few feet of soil or alluvial material; the bench itself rises but six or eight feet above the stream. They are exposed occasionally in road cuts, e. g., in southeast 8 and northeast 17 of Westport township. At the latter place a bank of four or five feet is open and is being put to much-needed use on the roads. The terrace is a plain here, being from a quarter to one-third of a mile wide. The same gravels may be seen again in south section 22 and north 27 at the creek. Little search would be required to find within reasonable distance ample supplies for the roads of the creek bottom, where it is much needed and where it is generally conspicuously lacking.

Muddy creek is for the greater part of its course a typical prairie slough. It rises in marshes in section 3 of Richland township and drains in most imperfect fashion this and Lloyd township, farther south. After passing Terril in the latter township, the stream occupies a broader and more definite valley, and becomes a prominent water course, marked here and there by gravel terraces after the manner of all south-flowing streams in this part of Iowa.

Kame Deposits.—The terminal moraine of the Wisconsin glacier (Altamont moraine) cuts across Dickinson county from northwest to southeast. The kames and eskers of this morainal

country are in many cases either capped by or composed entirely of sand and gravel, and quite a large number of them have been opened and are now furnishing local supplies. West of the bridge in the southwest quarter of section 11, Okoboji township, gravel is being taken from the top of the hills. In the south parts of sections 3 and 4 in the same township, a veneer of gravel covers low drift hills about twenty-five feet above water. These may be seen in the road along the south side of these sections and on both sides of a small stream in section 4. The low hills bordering the creek between Rush and Pillsbury lakes are kame-like in appearance and very gravelly. They have been opened for gravel in the roadway in the southeast quarter of section 31, Lakeville township. In section 1, Westport, and section 36, Excelsior townships, occurs a series of low hills, which are no doubt largely composed of sand and gravel. The town of Spirit Lake gets sand and gravel from morainal hills in southwest 33, Spirit Lake township, and northwest 2, Lakeville township.

These are but a few samples of the many openings in drift hills. They are particularly plentiful around Diamond lake and throughout the northern half of the county. Many hills not now open will no doubt yield plentifully of both road and concrete materials, and prove a valuable asset when highway improvement is considered.

Miscellaneous Deposits.—Dickinson county is the classic lake region of Iowa. Besides Spirit lake and Okoboji lake, which are widely known as summer resorts, there are a large number of smaller lakes, many of them really only ponds. Some of these lakes have sand and gravel benches, and furnish suitable material for local consumption.

Although the beach sands are white and clean, the constituent grains are usually more rounded and smoother than those of ordinary water-carried materials, characteristics not favorable to their use in cement work.

The state forbids the removal of sand and gravel from the beaches of the larger lakes, but the town of Spirit Lake obtains part of its supply from the northeast beach of Center lake.

Others of the smaller lakes supply small quantities for local use.

DUBUQUE COUNTY.

Sand and Gravel.

There are representatives of several different classes of sands and gravels in this area. The fine clean sands of the Wisconsin stage are found in the valley of the Mississippi; the coarser, or at least more weathered gravels of the Buchanan stage are strewn along the drainage course of Maquoketa river, and upland gravels occur at numerous points over the higher lands of the interior of the county.

Along the line of the Chicago, Milwaukee & Saint Paul Railway in Mosalem township there are terraces which apparently consist of fine, clean sand, and in the abandoned valley of Catfish creek in the northwest quarter of section 6 of this township, a short distance up the Illinois Central railroad track, is a bank of sand seventy-five feet high. This consists entirely of the same clean fresh sands which are shown down the river. The

Fig. 26—Gravel terrace of Catfish creek, showing an abundance of residual cherts. Dubuque county.

bank extends back to the bluff and is faced by a similar one across the valley some distance beyond the point at which the creek leaves it. Where the railroad crosses the wagon road leading from Dubuque to Rockdale, the terraces are fifteen to twenty feet above the stream. The railroad has used large quantities of these sands for ballast.

The city of Dubuque is built in part upon one of these terraces. Exposures may still be seen in the northern part of the city. North of the Dubuque Shops, for instance, is exposed a bank of fine sand twenty feet high. The lower half is cross-bedded in bands one-fourth to two feet thick and separated by streaks of gravel one-fourth to one inch thick. Above the cross-bedded part are two feet of sandy clay and then come eight feet of fine sand. The terraces extend from the Dubuque Shops to Eagle Point. At the widest point the bluffs are 300 yards back from the face of the terrace. The sand probably fills this entire space. At the face the terrace is ten to twelve feet higher than at some distance farther back. A short distance north of the pit described above are two or three other large openings thirty to forty-five feet deep. One of these, the Beutin pit, shows at the base twenty feet of rather coarse gray sand with local clay streaks up to twelve inches in thickness in the middle of the bed. Then comes a clay band sixteen inches in thickness and above it eight to fifteen feet of fine, yellow sand, like dune sand. The sands from this and other pits are used for plastering and other purposes.

Peru Bottoms is a large triangular area a few miles north of Dubuque, in which a considerable deposit of sand was laid down in slack water back from the main current of the stream. The river has since probably cut away a considerable part from the front and Little Maquoketa river has carved out a valley for its lower course, and now instead of running southeast from Sageville, it runs northeast to join the Mississippi after meandering across several miles of flood plain. There still remains, however, a large terrace which probably contains nearly a square mile. This rises about fifty feet above the river and seems to be composed of the same fine, clean sands which are found elsewhere along the river. Some coarser material up to one-fourth

or one-half inch in diameter is found. Where the Little Maquoketa has cut away the rear edge of the deposit it has left a face twenty feet or more in height.

In the old valley of the Little Maquoketa, which extends across Dubuque and Julien townships, are some hills and slopes of sand and in the mouth of a ravine which enters the valley, opposite the race track, is a small terrace. These sands are similar to those previously noted. Another sand terrace is found in section 15, Peru township. The upper valley of the Little Maquoketa does not seem to bear extensive deposits of detrital material, though small banks occur in the stream bed and may be useful for local purposes.

A number of exposures of Buchanan gravels are mentioned by Calvin and Bain in their report on Dubuque county.* These occur chiefly on the uplands where stream erosion has not yet reached them. Some of these localities are: One at Peosta and another three-fourths mile east of the same town; one at Epworth and another a short distance northwest of the village; also one a quarter of a mile south of the northwest corner of section 3, Taylor township. These beds are made up of typical coarse upland Buchanan gravels and as such are admirably suited for either road or concrete work.

In Cascade township are a number of beds of high level gravels on the hilltops. As examples may be mentioned one on the road between the south parts of sections 14 and 15, one near the center of section 16, another just over the line in section 21, near the roadside, and one near the middle of the east line of section 22. Many of these are typical of the upland phase, coarse, red, with pebbles and bowlders. That in section 16 is part of a low ridge rising above the surrounding fields. It has been worked to a depth of six feet or more and consists of very rusty gravels with much foreign material and local chert.

Along the public road and the Illinois Central track in sections 3 and 4 of Dodge and 33 of New Wine townships are gravels which form a conspicuous ridge extending for a considerable distance parallel to the roads. The gravels are dark red,

*Iowa Geol. Surv., Vol. X, pp. 467, 468.

rather coarse and contain bowlderets up to six, eight or ten inches in diameter. These gravels are of such excellent character and so conveniently located that they should be more widely used than has been the case. Where they have been applied to the roads they have made a very decided improvement.

The north fork of the Maquoketa shows numerous bodies of detrital matter from the neighborhood of Dyersville southward. A part of the town is built on a terrace of typical Buchanan gravels, which in their upper parts are of medium fineness, but are probably finer below. This terrace extends up the river a short distance above town, but the country soon becomes rough and deeply loess-covered, so that no gravels are exposed, except a little at New Vienna. In the valley of Bear creek are abundant gravels, but as these are nearly all in Delaware county, their discussion will be found in connection with that county.

Between Rockville in Delaware county and Worthington in Dubuque is a rather high terrace which is practically continuous, and upon which the town of Worthington is built. The terrace continues at intervals to Cascade. A stream valley in section 21, Cascade township, is filled with fine sand and gravel layers down to the river. Through sections 27, 26, 25 and 36 these terraces are well developed. In the southeast quarter of section 26 a gully has cut into the sands eight or ten feet, showing coarser gravels at the top, and the whole overlain by oxidized, jointed clays.

Stone.

The Ordovician system, as developed in Dubuque county, comprises four well-marked divisions, the Saint Peter sandstone, the Platteville limestone, the Galena limestone, and the Maquoketa shales. Exposures of the first occur along the Mississippi bluffs from a mile or two above Spechts Ferry to Zollicoffer Lake, a distance of five or six miles. It is represented by a rather ferruginous, variegated, coarse-grained sandstone. It is friable, though the upper beds are sometimes sufficiently indurated to be used as a quarry stone. It has been used to some extent in the vicinity of Spechts Ferry.

The Platteville limestone comprises a series of interbedded limestones and shales, some of the limestone beds being dolomitized. A general section, according to Calvin and Bain, is as follows:

		FEET.
8.	Shale to shaly limestone or interbedded limestones and shales	5
7.	Limestone, bluish, rather coarse-grained, in thin layers ranging from three to six inches in thickness	25
6.	Shale, bluish or greenish, very soft, plastic, with thin lenticular sheets of limestone distributed irregularly through it ("Green shales")	12
5.	Limestone, bluish beds, weathering brown, coarser grained and less fossiliferous than beds below	5
4.	Limestone, heavier, coarser layers, ledges up to fifteen inches, resist weathering well	5
3.	Limestone, blue, thinly bedded, fine-grained, brittle, fossiliferous, bedding planes very uneven and undulating, weathered surfaces show thin shale partings; shale often quite bituminous. With the two zones above constitutes the "Lower Blue Beds"	20
2.	Limestone, dolomitic, earthy, impure, noncrystalline, hard, firm; beds range from eight inches to three feet in thickness and are well suited for heavy masonry. "The Lower Buff Beds"	18-20
1.	Shale, bluish to greenish, weathers to ashen or yellow, "Basal Shale"	3-6

Number 2 in this section is the most highly prized for quarry purposes, although quite generally obscured by talus slopes. This is the horizon which has been so extensively developed and is deservedly popular for heavy masonry at Minneapolis and Saint Paul.

The following sections in the vicinity of Spechts Ferry give the details of the Platteville.

SPECHTS FERRY SECTION.

		FEET.
11.	Dolomite, thin-bedded, brown, with shaly partings (Galena)	4
10.	Limestone, thin-bedded, imperfectly dolomitized, with fossil brachiopod shells only slightly changed; the limestone brown, earthy, noncrystalline, but evidently of the Galena type	3
9.	Limestone, thick, earthy, imperfectly dolomitized (Galena)	3
8.	Limestone, thin beds with much shale in the partings; in part a true shale. This member is almost entirely shaly a few rods above the station on the road leading to Dubuque	5
7.	Limestone, bluish, rather coarse-grained, with disseminated fossils; in beds varying from three to six inches in thickness	25
6.	Shale, bluish or greenish, containing occasional thin beds or discontinuous flakes of limestone; the "Green Shales" of the Minnesota geologists	12
5.	Limestone, thin bedded, bluish, rather coarse-grained, weathering brownish in color	5

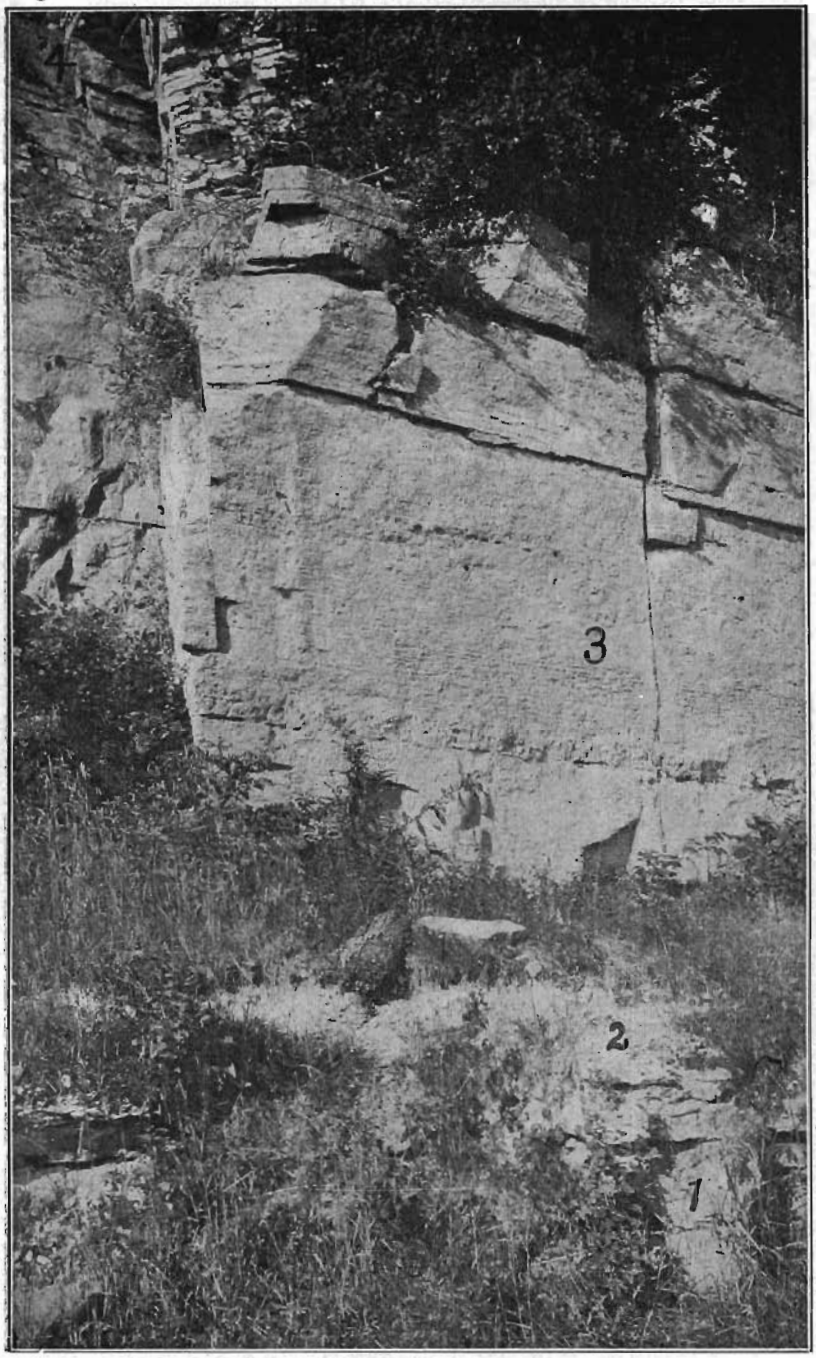


PLATE XVI—View three-fourths of a mile below Spechts Ferry, showing in ascending order: 1. Saint Peter sandstone. 2. Basal shale. 3. Lower Buff beds. 4. Thin, brittle, blue beds.

		FEET.
4.	Limestone in rather heavy layers which range up to fifteen inches in thickness; bluish on fresh fracture, but weathering to buff on exposure	5
3.	Limestone, brittle, fine-grained, blue, very fossiliferous, breaking up on weathered surfaces into flexuous layers about two inches in thickness	20
2.	Limestone, "Lower Buff Beds," exposed, about	8
1.	Limestone; unexposed to level of water in river, about	45

About three-fourths of a mile below Spechts Ferry the "Lower Buff Beds" show a thickness of twenty feet. A quarry in section 10 of Peru township, two miles below Spechts Ferry, shows the following beds:

		FEET.
5.	Limestone, blue, thin-bedded at the top of the section	2
4.	Shale, the equivalent of the "Green Shales"	8
3.	Limestone, heavy ledges of fairly good building stone, bluish, but weathering into buff on exposed surfaces, equivalent to numbers 4 and 5 of the Spechts Ferry section	10
2.	Limestone, thin-bedded, brittle, blue, fossiliferous	16
1.	Limestone, heavy, "Lower Buff Beds," good quarry stone.	10

The Lower Buff Beds are not sufficiently accessible to attain much importance in the county as a quarry stone. The pure limestone beds above, while more readily available, are not sufficiently durable to command attention.

The Galena limestone affords an important quarry horizon in the upper beds and one much more generally available than the Lower Buff Beds. Numerous quarries have been opened and operated in the vicinity of the city of Dubuque, near Graf, on the Chicago Great Western, and along the Illinois Central at the crossing of the North Cascade road.

The rock quarried is thin-bedded above, ranging from four to ten inches and separated by thin shaly partings, becoming heavier below, the beds attaining four feet or more in thickness. The rock is hard, granular, completely dolomitized, and rough and vesicular on exposed surfaces. It does not make a good appearance in dressed stone work, but is excellent for ashlar, rough dimension work and heavy masonry. In bridge work, foundations and lower courses in large buildings, it makes an excellent appearance.

One of the most complete and representative sections in the county may be seen at the Eagle Point Lime Works. The following sequence of beds may be studied:

		FEET.
15.	Loess-covered slope above the outcropping ledges of Galena limestone, culminating in a prehistoric mound at the summit of the bluff	15
14.	Dolomite in ledges, varying from two to three feet in thickness	10
13.	Dolomite, two or three rather heavy ledges containing large numbers of the problematic fossil, *Receptaculites oweni* Hall. Receptaculites is found sparingly in other members of the section. At this horizon, which will be called the Receptaculites zone, it is exceedingly abundant	10
12.	Dolomite, heavy-bedded, typical Galena, hard, crystalline and relatively free from chert; in ledges three to six feet in thickness	70
11.	Dolomite, bed containing pockets of calcite; the calcite in some cases forming large crystals	3
10.	Dolomite, bed containing large quantities of chert	4
9.	Limestone, ledges showing the characteristics of the typical Galena, hard, compact, crystalline, completely dolomitized, with small amount of chert	18
8.	Dolomite, thick, massive beds with large amount of chert	12
7.	Dolomite, thick beds, crystalline, the ordinary type	6
6.	Dolomite, ledge varying in texture, containing small pockets of calcite and some chert; a single specimen of Receptaculites found in this ledge	4
5.	Dolomite, heavy ledge nearly on a level with the top of lime kiln	3
4.	Dolomite varying in aspect according to degree of weathering; at Eagle Point showing bedding planes 10 to 18 inches apart	15
3.	Dolomite; massive, crystalline; bedding planes almost completely obliterated	20
2.	Limestone, incompletely dolomitized beds with shaly partings at intervals of six, eight, or ten inches	10
1.	Limestone, basal ledge of Galena, beginning on top of Platteville limestone and shale bearing *Orthis subaequata* and associated fauna; this lower bed is earthy, incompletely dolomitized, and weathers below into a dark brown or reddish ferruginous clay	2

Numbers 12 to 14, inclusive, comprise the most important quarry beds. The chert beds comprising numbers 6 to the base of 12 are suitable for crushed stone products and are also used for lime. They are not considered desirable for structural purposes.

From the Eagle Point Lime Works the beds dip more or less uniformly to the south and west.

Most of the quarries near Dubuque operate the beds above number 13 in the Eagle Point section. About the middle of this division occurs the "cap-rock" of the miners, a heavy, firm

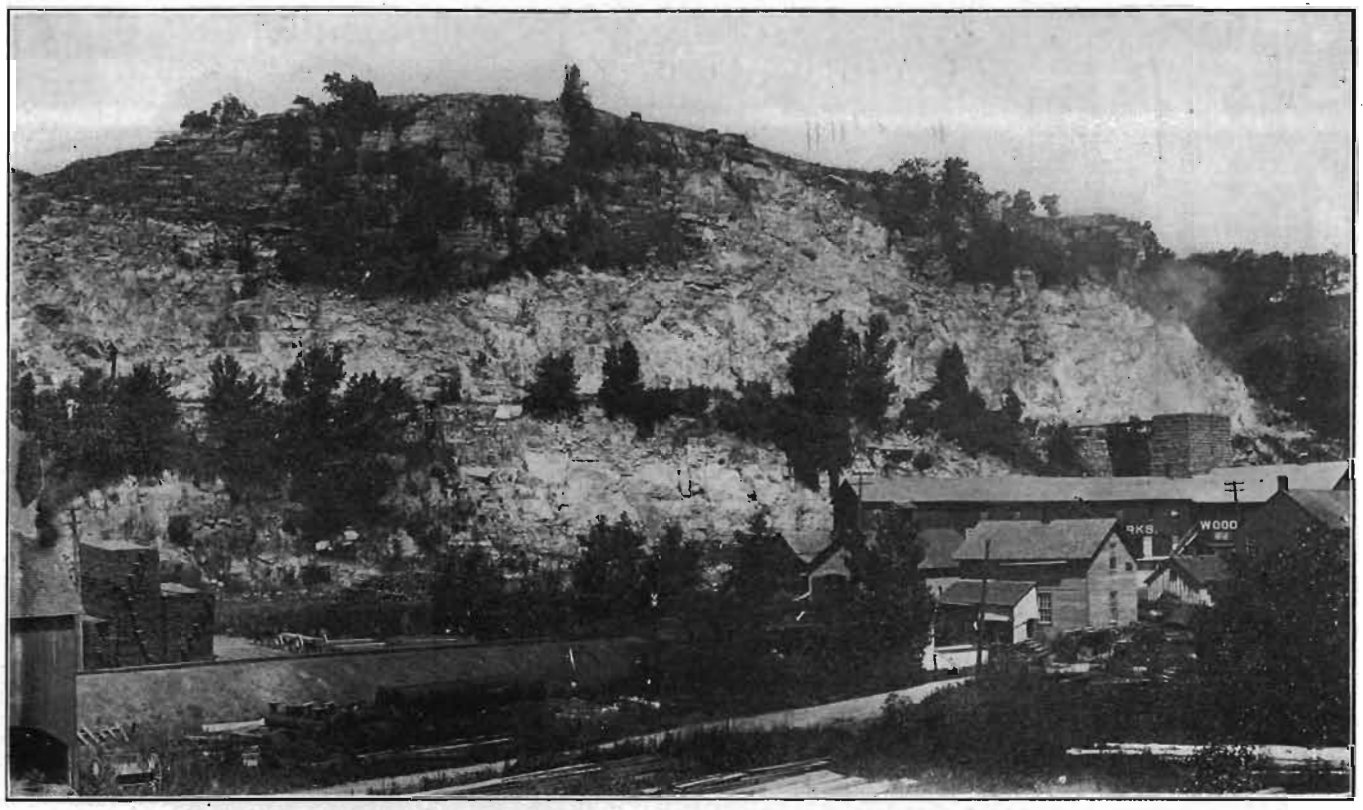
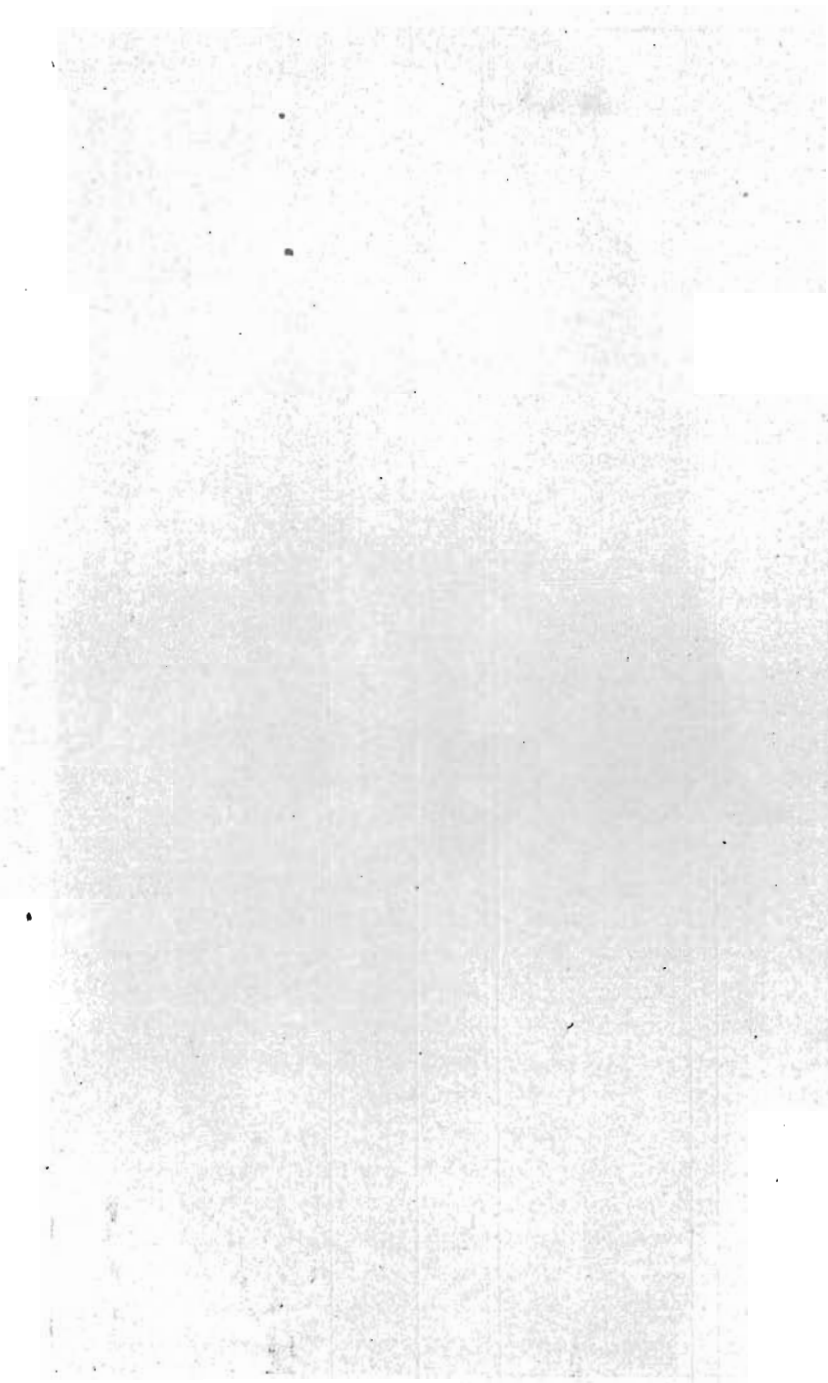


PLATE XVII—Quarry and plant of Eagle Point Lime Company, Eagle Point, Dubuque county.



layer about two and one-half feet in thickness with an eight or nine inch layer below it.

Several crusher plants have been installed and are in operation in Dubuque. Among these the Eagle Point Lime Works at the north edge of Dubuque crushes rock from the flinty beds of the Galena, which are unsuitable for lime making. An Austin gyratory crusher is used and the plant has a capacity of 400 yards of crushed rock daily. Three sizes of rock are produced. The cost delivered is about sixty cents per yard. A description of the quarry and plant is given on pages 423-424, 601-603 of the report on Dubuque county.*

Tibey Bros. operate a quarry in the southern part of Dubuque on Dodge street. This is opened in the Galena limestone and works about thirty-five feet of the thin upper beds and the heavier beds below them. A Gates No. 4 crusher was installed in 1908 and crushes the upper layers as well as waste from the quarry. The capacity is 250 cubic yards per day. The Byrne-Saul quarry across Dodge street is using the same rock, but has no crusher.

The O'Farrell Contracting Company has a crusher on Clark street near West Locust. A small quarry is located here and a larger one is opened on Seventeenth and Cox streets. These are in the same horizon as the Tibey quarry and are above the Eagle Point beds. The rock is somewhat softer than that from Eagle Point. The crusher used is an Aurora No. 2. The crushed material is assorted into three sizes. The fine material is used for walls, steps, etc. It brings $1.80 per yard. The coarser sizes are used for concrete and macadam. The surface material overlying these beds contains characteristic pelecypods from the basal layers of the Maquoketa shale.

The Maquoketa shales contain certain indurated layers throughout, and impure, earthy dolomite layers above. None, however, are of sufficient importance to be worthy of special mention for structural purposes, and have not been quarried in the county.

The Niagaran limestone covers the western portion of the county and has been quarried at several points. Two well-de-

*Iowa Geological Survey, Vol. X.

fined quarry horizons have been developed, one near the base of the series between the fifteen feet of basal beds and the chert beds, and the other at the top of the Niagaran series as they occur in Dubuque county. Each horizon comprises about twenty feet of good quarry stone, the lower beds being typically shown in the quarries about Farley, while the most important quarries in the upper beds have been opened near Cascade. The basal beds and beds between the lower and upper quarry beds, while suitable for rubble and crushed stone purposes, are not quarried extensively at any place in the county.

Typical sections of the lower beds may be seen in the quarry of Peter Milesi, east of Farley, and in the Arquitt quarry north of the same town. The Milesi quarry, located in the southwest quarter of section 8, Taylor township, on the Illinois Central railway, shows the following beds and layers:

		INCHES.
8.	Coarse-grained bridge stone	21
7.	Stone of medium grade	28
6.	Ledge of fine-grained stone, with some chert	24
5.	Stone similar to number 6	14
4.	Fine-grained stone of good quality	4
3.	Stone of same quality as number 4	17
2.	Stone similar to 3 and 4	9
1.	Stone like 2, 3 and 4	26

The quarry of B. N. Arquitt and Sons is located at North Farley on the Chicago Great Western. The quarry is similar to the one just described. The company had produced crushed stone, now the principal product, for more than a decade. The upper heavy beds are used with the exception of the uppermost soft part. The lower flint beds are also used and rock from these makes excellent grouting. The upper yellow beds are softer and more porous. The beds below the flint beds are used for rubble and the lowermost beds for range work, trimmings, etc. The flint beds are about fifteen feet thick, the yellow beds above about the same, and over them are five feet of soft rock. A No. 2 Western jaw crusher is used and cylindrical and flat screens size the crushed rock. The plant has a capacity of 150 yards daily.

The intermediate beds have been quarried in this vicinity and also near Dyersville, and other points in the county.

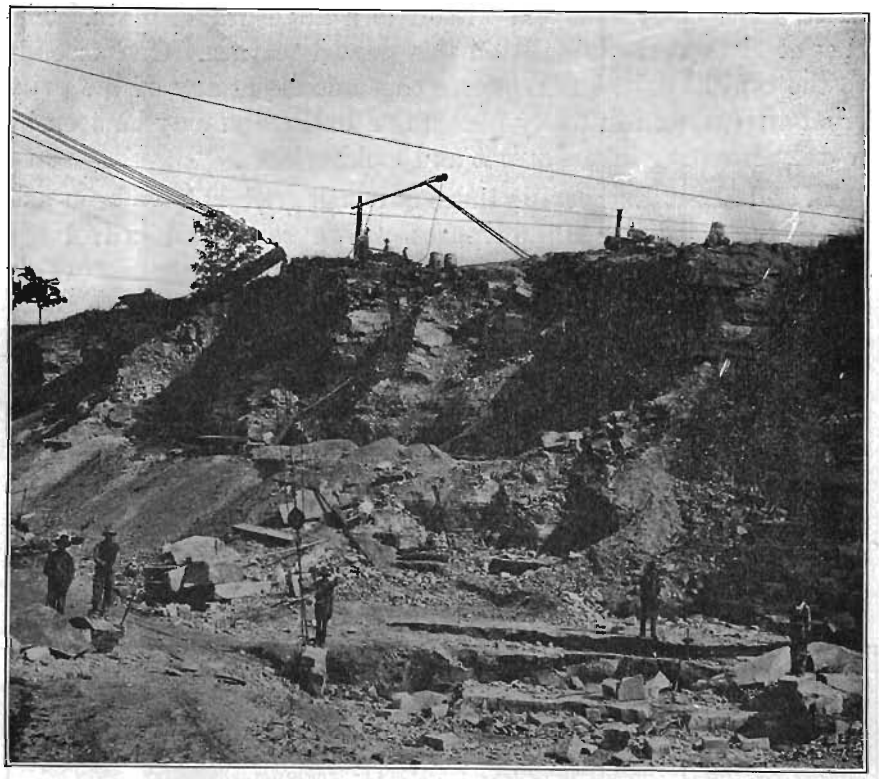


FIG. 27—Arquitt quarry, somewhat obscured by an excessive amount of talus. North Farley, Dubuque county.

EMMET COUNTY.

SAND AND GRAVEL.

Emmet county lies wholly within the area covered by the Wisconsin ice in Iowa. The deposits of sand and gravel are in the drift hills of the upland and in the gravel trains along the streams. Occasionally beds referable to the older Kansan drift are exposed. A discussion of the origin of these deposits by T. H. Macbride is quoted in the report on Palo Alto county, and to that discussion the reader is referred.

Stream Terraces.—The west fork of the Des Moines river is the most important stream in Emmet county. It flows through a broad flat valley flanked on both sides by hills of Wisconsin

drift. The river "bottom" itself is a huge gravel plain. The city of Estherville is built on this gravel terrace. One ascends to the typical drift as he passes east out along any of the principal streets, and in many places the distinction may be seen by merely standing in the street and looking east.

In and about Estherville these outwash gravels have been and are being used for all purposes where sand and gravel are needed. The Estherville Cement Products Company is working a terrace gravel some thirty feet above the river. Here there are about ten feet on the average of good gravel, with a little dirty material in the upper portion. The lower two feet contain larger pebbles and all rest on the usual bed of large bowlders and blue, pebbly drift. The gravels are in part cemented by lime and are covered by some three feet of soil. A mile north of the city, on the Griffith farm, is a small sand pit some fifty feet above the river. Only fine sand is in sight here. There is a small pit on the dairy farm on the west side of the river.

FIG. 28—Grettinger pit, showing loading and grading of materials. This pit represents well the materials composing the valley train in Emmet and northern Palo Alto counties.

PLATE XVIII—Estherville pit, Estherville, Emmet county.

At the bridge across Des Moines river in section 28 of Emmet township, gravel is piled in such a way as to give the observer a fair idea of the immense erosion changes that once went on in what we now term the valley of the river. Here the gravel on either side of the river is discoverable high up above the ordinary plain, lodged against the banks of drift some fifty or sixty feet above the river. Between lies a half mile or more of gravel plain perfectly solid and flat, the bottom of the ancient glacial river.

From Estherville south to the county line the gravel plain continues uninterrupted, varying in width up to one and one-half miles. What is said of this enormous gravel plain in Palo Alto county holds with equal force here. The deposit has been opened in many places as a source of local supply.

The Rock Island Railway Company has a big pit in sections 32 and 33, High Lake township, from which untold quantities of ballast have been removed. In this pit there are about twenty feet of gravel exposed. The upper portion is coarse, but shades off gradually into finer material below. It is iron-stained throughout and contains a large proportion of limestone and granite pebbles. Many of the latter are badly weathered and may readily be crumbled with the hands.

South of Estherville, in the openings made by the Minneapolis and Saint Louis Railroad Company the gravels referred to the Kansan by Macbride (see Palo Alto county) may be seen. At the extreme south end of this artificial exposure storm-water erosion has supplemented the artificial excavation to the complete uncovering of the old blue clay. Here, resting directly upon the blue clay, is a more or less indurated brownish gravel. This is very similar to the bottom deposit in several openings in the neighborhood, and may readily be recognized as being strikingly different from the upper portion of the beds. To again quote Macbride in reference to this older deposit, "It seems as if it may be looked for almost anywhere as a bottom deposit of what has here been denominated the gravel plain."

Reworked Materials.—While gravel and sand bars are not at all uncommon along the streams of Emmet county, they by no

means form an important source of supply. Variations between wide limits in both quality and quantity of the material in these bars render the terrace and kame deposits far more reliable, and as a consequence, the former take a minor place. They do, however, furnish a handy and easily available supply for small local consumption.

Morainal Deposits.—Many of the knobs throughout the entire area of the Wisconsin drift are either composed entirely of sand and gravel or have gravel as pockets or cappings under a veneer of soil. Where these drift hills do contain gravel they constitute a valuable source of supply. These deposits are widely different in character, some of them furnishing a clean, sharp product which is most excellent for concrete, and others supplying only a dirty, iron-stained material which is fit for nothing save road surfacing or ballast.

FAYETTE COUNTY.

Sand and Gravel.

Fayette county is abundantly supplied with gravels, both in its major stream valleys and upon the uplands. The border line between the areas of Iowan and Kansan drift may be defined briefly as following the Chicago, Milwaukee & St. Paul railroad from the east county line to Fayette, thence to West Union, Eden and St. Lucas. Northeast of this line the surface has been much eroded, and such deposits of upland gravels as may have been formed have probably been largely carried away. The larger valleys, however, carry extensive beds and terraces.

Southwest of the above line erosive agencies have not been so effective, the land lies more nearly level and the stream valleys are shallow. Here gravels are widely distributed and nearly every hilltop has its capping. Every township in the county has a more or less abundant supply, so generously are these gravels scattered.

Along almost the entire course of Turkey river in Fayette county there are terraces of gravel and sand, well defined and of considerable extent. Between Elgin and Clermont, these ter-

races are about thirty feet high and consist so far as observed of rather fine, fresh sand and gravel. In some places a lower terrace, about ten feet above the flood plain, is developed.

The banks of the creek which crosses the north part of the town of Clermont contain large quantities of gravel, and the flood plain is also underlain by similar material. These gravels consist largely of rounded limestone fragments, with some foreign material and moderate amounts of sand. Extensive use has been made of the gravels for macadamizing the streets of the town and with results which are apparently very satisfactory. They pack well and form an excellent roadbed.

In the river banks just across the bridge at the south edge of town, Mr. Stahl has a sand pit which yields sand of good quality for finishing concrete work as well as for wall plaster, although it is a little coarse for the latter purpose. Another pit near by yields excellent gravel for concrete work. Some of the layers

FIG. 29—Buchanan gravels and Kansan loess, section 23, Dover township, Fayette county.

have limestones and foreign pebbles intermingled, although the lower layers contain larger proportions of finer materials and less limestone.

In addition to supplying local demands, these sands and gravels are shipped quite extensively to nearby towns which are not so well supplied. The Miller pits along the Rock Island tracks about a mile below town also ship large amounts. The gravels from these pits are used in large quantities for concrete although they are said to contain a little more clay than those in the town.

There are well marked terraces from Clermont up the river to Eldorado. For the most part these are built up of fresh sands with some foreign pebbles, chert and limestone, the latter predominating locally. Some of these sands have been used on the roads and furnish some improvement on the sandy roadbeds at least. In sections 23 and 24 of Dover township is a broad valley

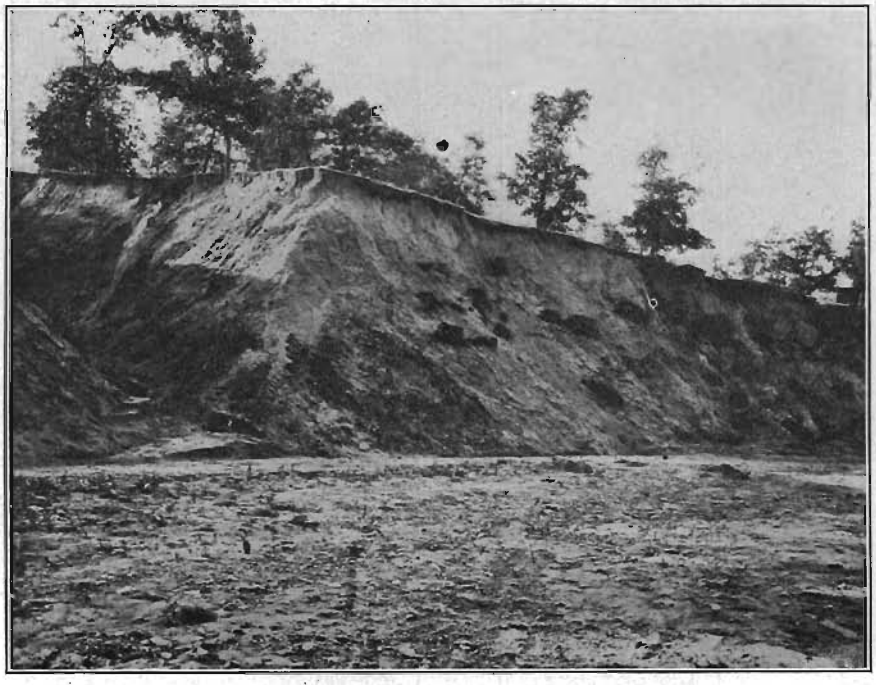


FIG. 30—General view at the same locality as Figure 29.

with a gentle slope toward the river. This seems to be filled with sand and gravel, probably a back water filling.

In the northeast quarter of section 23 a small creek has undermined its bank, exposing a clean face eighteen to twenty feet high. This consists largely of fine yellow sand, well bedded. It is overlain by an old, gray, weathered and jointed loess, upon which rests a foot of black sandy soil. This is surmounted in turn by a dark gray sandy silt, probably modern alluvium. Above it comes the humus. The bank has been dissected at right angles by a small gully, which is cut entirely in the fine sand and shows a great body of it. From its relations it would appear to belong to the valley phase of the Buchanan gravels.

About two and one-half miles east of Eldorado, at the site of the old Huntsinger bridge, the terrace is about twenty feet

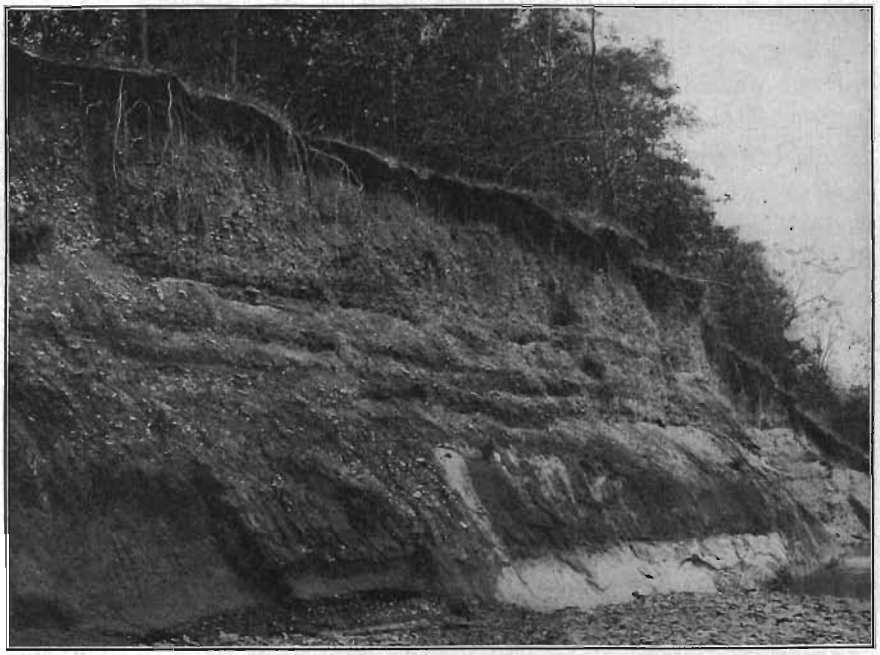


FIG. 31—Gravel terrace along the Turkey river near the old Huntsinger bridge two and one-half miles east of Eldorado, Fayette county.

high, and extends for one-half mile along the river. The lower half consists of very ferruginous and decayed materials of Buchanan age, while the upper part is made up of fresh sands

and gravels related to the Iowan. Limestone pebbles are very abundant in the upper part and foreign pebbles and cobblestones are numerous.

The village of Eldorado is built upon a wide flat of 300 acres extent, which is underlain by rather coarse, fresh-appearing gravels. These rest upon a rock platform twelve to fifteen feet above the river and are found to an elevation of thirty-five feet. Above the town the terraces continue until the river narrows on the southwest corner of section 12, Auburn township.

The Little Turkey, a tributary of Turkey river, draining the northwestern part of the county, is bordered by deposits of gravel from the vicinity of Waucoma at intervals to West Auburn. A short distance above Waucoma the stream valley merges into the Iowan plain and such gravel beds as may be present are obscured by later deposits.

The road leading into the village from the south through the eastern part of section 16, follows the edge of the terrace, which is here fifteen to twenty feet high. It presents a steep river front, but grades into the drift plain to the west. The upper foot or two of this terrace consists of coarse gravel. These are underlain by finer, yellow sands, with which are intercalated darker, harder bands. Exposures show considerable quantities of these materials in the town as well as for one-half mile or so north. On the east bank of the river at the north edge of town a gravel pit shows rather fresh gravels two feet thick below a foot or two of soil. These gravels contain considerable coarse material, chiefly of foreign origin. This bed ends rather abruptly and rests on weathered indurated yellow gravels, which are quite coarse above, but grade quickly down into fine sand. These gravels have been used extensively in the vicinity for concrete and road purposes and are quite satisfactory. They pack well and make good road material. For several miles below Waucoma the deposits seem to be continuous, and have been used somewhat for improving the roads. Some of them are fresh Iowan sands, while others are rusty, weathered Kansan gravels. The lower course of Crane creek also shows some banks and terraces of similar material.

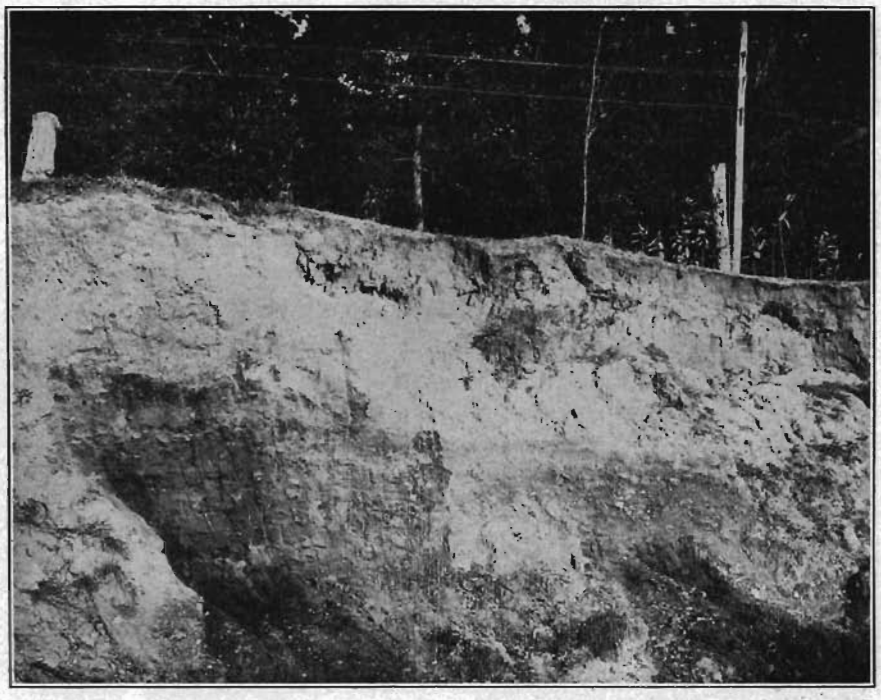


FIG. 32—Gravel pit showing fresher gravels above and more weathered ones below. Waucoma, Fayette county.

The valley of Otter creek carries no terraces or other extensive gravel deposits between West Union and Elgin, but the courses of Volga river and of the short creek which enters it from the north just below Albany are bordered by abundant supplies. Those in the creek valley are in the form of terraces and banks, and are fine, light yellow and unweathered. Comparatively little coarse foreign material is present, although the gravels carry some chert and limestone. They present a marked contrast to the typical Buchanan gravels in freshness, in fineness of grain and in their lack of coarse material. The village of Albany is built on a wide flat terrace of such gravels which occupies the old valley of the Volga. These fine materials are doubtless derived from the detritus brought down by the Iowan glacier, as the eastern margin of the Iowan drift lies only two or three miles west of the creek and the tributaries of the latter head within, or at the edge of, the Iowan plain.

A short distance west of Fayette the Volga leaves the shallow, ill-defined valley in which it has crossed the Iowan drift plain, and enters the deep, winding gorge which it has cut in the region of mature Kansan topography. The upper valley contains some beds of gravel, but they are not well defined. Several exposures occur near the line of the Chicago, Rock Island and Pacific Railroad between Maynard and Randalia, in the main valley or in tributaries. There are terraces and flats in sections 30, 31 and 32, Westfield township, and a flat of wide extent underlies the town of Fayette, but where exposures occur some alluvium is mingled with the gravel and sand. Farther back from the river the gravels may be purer.

Between Lima and Wadena in the wider parts of the valley are high terraces extending forty or fifty feet above the river. At Wadena these terraces are quite wide, but are only about twenty feet high. They are built for the most part of rather fine, light yellow sand and gravel. The valley of a small creek entering the main valley just east of Wadena is filled with these sands. They form banks and terraces east to the county line and far beyond.

From Wadena to Volga in Clayton county the valley is broad and comparatively level. There are large quantities of fine, fresh, light colored sands which extend up the slopes to the projecting cliffs of Niagaran limestone. In section 36, Illyria township, is a high hill of circumdenudation. On the south side of this hill the fine sands mentioned above extend to within forty feet of the top. In this case, then, the sands rise 160 feet above the river and in several cases they are 100 feet or more above the water. In some localities there are isolated hillocks of the sands. It seems unlikely that these sands owe their present altitudes to river action alone, but they have probably been blown up by winds.

In the southwest part of the county is another Otter creek, whose headwaters are gathered in Harlan and Fremont townships. A mile or so above Oelwein terraces begin to be developed and continue down the valley until it unites with that of Wapsipinicon river. West of Oelwein a wide flat extends from

the town to the creek, a mile and a half. These flats and terraces consist of fine yellow sands overlain by coarser gravels.

The pit of Ira Hanson on the south side of the road, opposite the cemetery, about the center of section 20, Jefferson township, will serve as an excellent type of these deposits. This is fully twelve feet deep and its face presents a succession of layers of clean, fine, yellow sands, with some coarser materials interbedded.

The valleys of the east and west branches of Buffalo creek and of Maquoketa river, so far as they are developed in Fayette county, all bear quantities of gravel. Some of this is quite coarse, is red and is usually underlain by finer gravels.

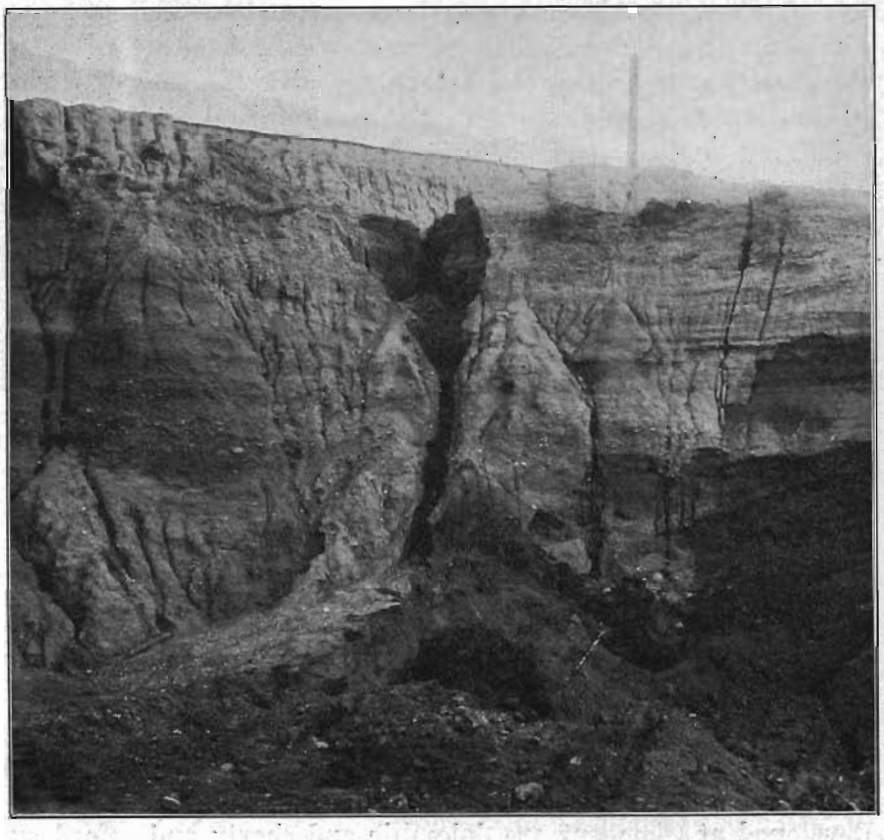


FIG. 33—Buchanan gravels, West Union, Fayette county.

The upland phase of the Buchanan gravels is represented all over that part of the county covered by the Iowan drift. It would be impracticable to describe all the localities where these gravels have been observed but a few typical exposures may be mentioned. A large number are noted on the geological map which accompanies the report on Fayette county by Mr. Savage.* On the southeastern border of West Union, capping the hills in the southwest quarter of section 16, Union township, is an extensive bed of gravels whose characteristics ally them very definitely with the Buchanan gravels. A pit opened in the hillside by Mr. Bowers exposes under two to five feet of loess about eight feet of cross-bedded, yellow to dark red sands and fine gravels. Below these are two or three feet of very coarse gravel which contains many cobblestones and bowlderets up to six, eight or ten inches in diameter. Some of these are so badly decayed that they may be broken up with the fingers. The coarse layer seems to be rather inconstant and is apparently underlain by finer sand. Similar deposits are found on several hills south and west of West Union and near the margin of the Iowan drift. These have only a thin covering of black soil or loesslike clay. As examples may be mentioned those on the south line of section 33, Union township, on the north line of section 32, same township, on a hill in sections 7 and 18, Windsor township, and those on a hill in sections 27 and 28, Eden township. This last exposure is ten or fifteen feet deep.

Stone.

The Maquoketa stage occupies a considerable area in the northeast corner, practically the entire area north of Turkey river, and appears along the principal streams in the northeast third of the county, notably along Volga, Turkey, and Little Turkey rivers, and Otter and Bear creeks. Some quarrying has been done in the vicinity of Clermont, the Lower Maquoketa beds being developed. In a few places the less cherty layers of the Middle Maquoketa division yield a material suitable for rough masonry. The chert beds of the Middle Maquoketa as developed at Clermont are dolomitic and cherty and afford an

*Iowa Geol. Surv., Vol. XV, pp. 433-546.

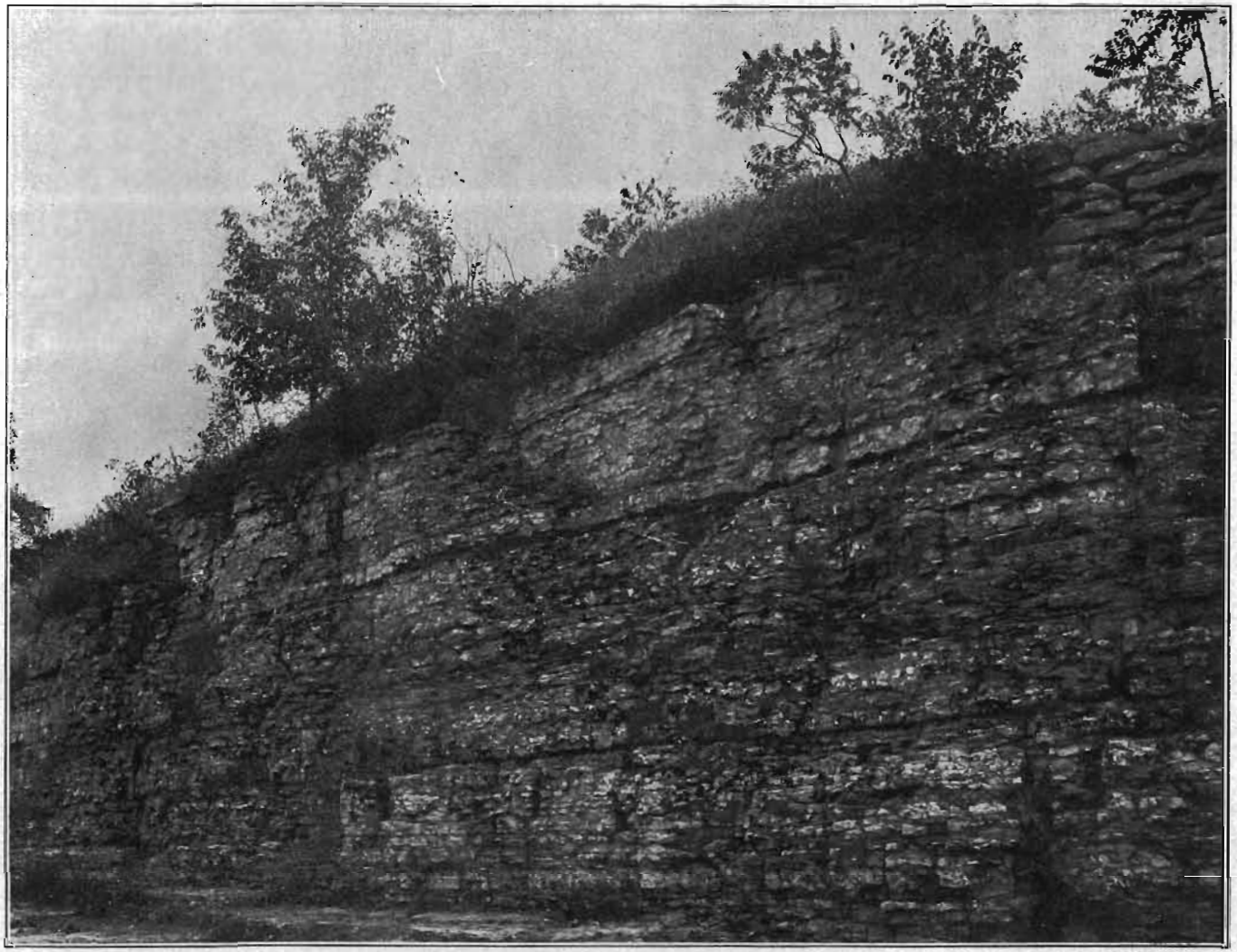
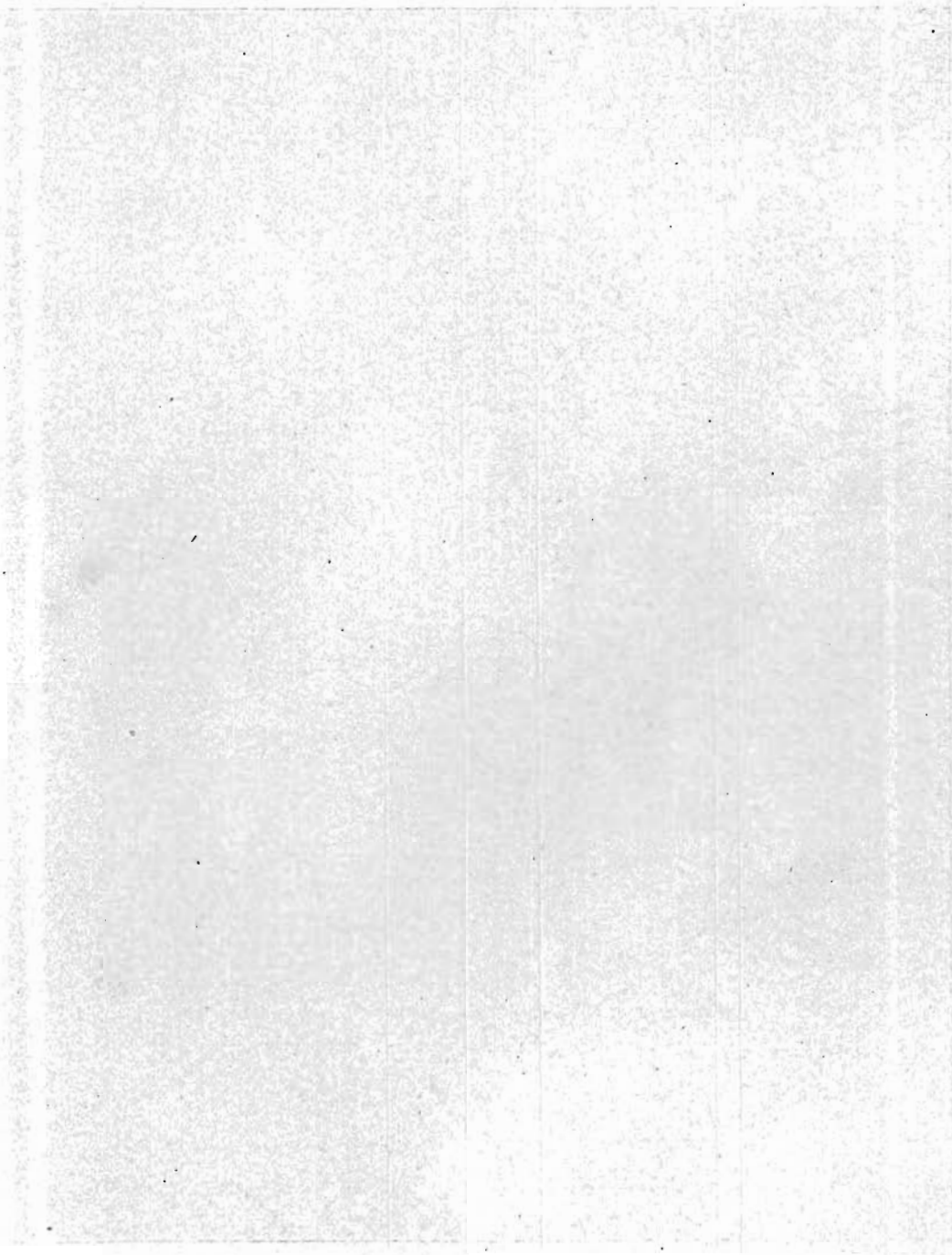


PLATE XIX—The chert beds of the Maquoketa afford excellent material for road work. Clermont, Fayette county.



abundance of material suitable for road work, railway ballast and concrete. The beds of the Upper Maquoketa are predominantly argillaceous and are, therefore, of little importance as a source of material suitable for road and concrete purposes.

The Hopkinton stage of the Niagaran occupies a very irregular area over the north, east and south portions of the county. The larger streams of the area have cut entirely through the heavy beds of limestone and expose the Maquoketa shales, the undercutting of the softer beds tending to produce and maintain escarpments facing the streams. Numerous outcrops appear upon the entire area and quarrying on a small scale has been done at a number of points. The most important quarry in the county is located on the northeast quarter of section 24, Clermont township, and is owned and operated by Wilkes Williams. The beds exposed are as follows:

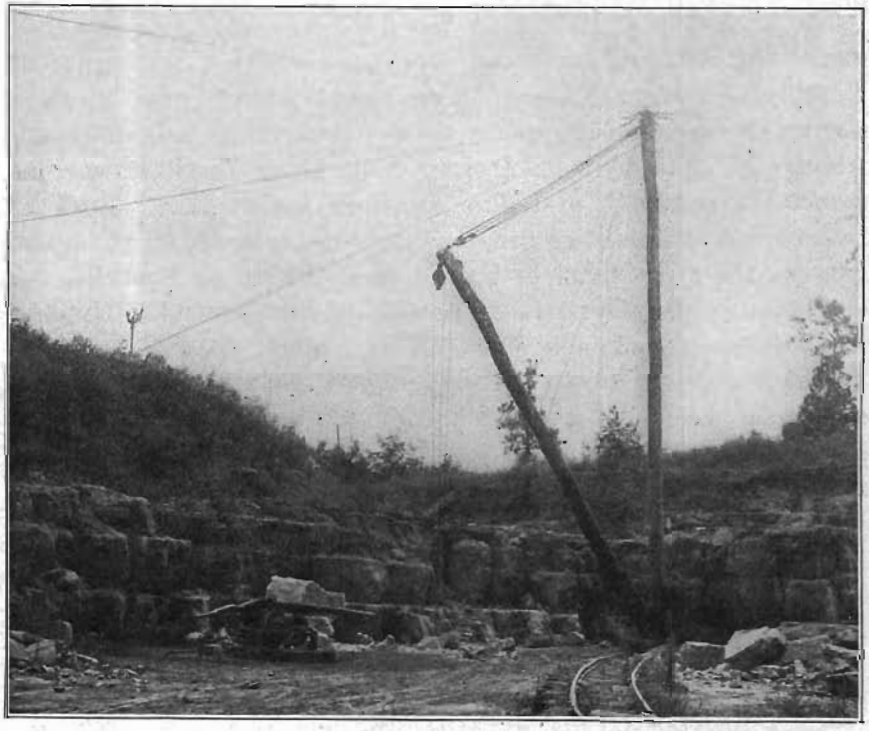


FIG. 34—Wilkes Williams quarry showing the rough, heavy bedded facies of the Niagaran, section 24, Clermont township, Fayette county.

WILLIAMS QUARRY SECTION.

		FEET.
8.	Clay, reddish, largely residual, but containing occasional pebbles and small bowlders of greenstone and granite..	3
7.	Dolomite, much decayed, yellow, containing very abundant nodules of chert; long exposed surfaces present numerous cavities from which chert masses have weathered; lamination planes irregular and imperfectly developed, indicated by bands of chert	14
6.	Dolomite, coarse-grained, yellow, containing a large amount of chert in the upper part	2
5.	Dolomite, heavy ledge, yellow in color and rather coarsely granular in texture, without chert	3½
4.	Dolomite, coarse-grained, yellow in color, containing no chert	1
3.	Dolomite, regular layer, rather fine-grained, without chert	1⅝
2.	Dolomite, yellow, resembling No. 1 in texture, two and one-half feet in thickness at the south end of the quarry, increasing to four feet in thickness at the north	4
1.	Dolomite, heavy ledge, homogeneous, fine-grained with no tendency to split along planes of lamination, and containing no fossils or chert nodules; increasing in thickness toward the north	4

The quarry is located near the Clayton-Fayette county line, and the beds which are being developed belong to an outlier of Niagaran separated from the main body. Several other outliers similar in character appear in the immediate neighborhood. About twelve to fourteen feet of stone are utilized for various structural purposes and give excellent satisfaction. Lack of transportation facilities greatly limits the capacity of the quarries, as the stone must be hauled to Clermont or Postville for shipment. Over the northern portion of the county the Hopkinton beds are remarkably pure. Near Auburn the beds are prevailingly a gray limestone, in layers two to six feet in thickness, somewhat vesicular and lamination planes not evident. The stone is very hard and brittle, breaking with a conchoidal to uneven fracture and in one direction about as readily as in another.

Auburn Mills is an inland town and while both shale and limestone are exposed in unlimited quantities they are not available commercially at the present time.

Over the southern portion of the county the Niagaran limestone is a rather coarse-grained, yellowish brown dolomite, and belongs much higher in the series than the beds exposed in the Williams quarry. In places it becomes arenaceous and usually

carries large numbers of chert nodules. In the vicinity of West Union the material is often fine-grained, very hard, light gray limestone, containing a large amount of chert concretions. Near the northeast corner of section 22 in Union township, the following succession of beds is exposed:

WILLIAMS AND DAVIS QUARRY SECTION.

		FEET.
8.	Limestone, impure, yellowish gray in color, and fine-grained; no chert	1½
7.	Limestone, gray colored, very hard, in places showing a tendency to separate into layers eight, three, two, four and eight inches in thickness respectively; without fossils, and containing no chert	2
6.	Limestone, much shattered, gray, containing a very large amount of chert in the form of nodules and irregular masses	1½
5.	Limestone, dense, fine-grained, gray in color, without fossils, almost free from chert in the middle portion	1
4.	Limestone, gray, consisting of layers two to four inches in thickness, which are separated from one another by bands of chert	4
3.	Limestone, fine-grained, gray, in two layers one and one-third feet and one foot in thickness; containing much chert and separated by a chert seam	2½
2.	Limestone, massive, containing a very large amount of chert in the form of bands and imbedded nodules	43½
1.	Limestone, gray, cherty, in layers three to six inches in thickness	

Number 1 in the above section is believed to be the equivalent of the upper portion of number 7 in the Williams quarry. The beds here are not dolomitized save for a few feet near the top.

Small quarries have been opened at other points in Fairfield and Auburn townships to supply the local demand. Good natural outcrops are available at many other places.

Indurated rocks of the Devonian immediately underlie the drift over the middle and western portions of the county, constituting one-half of its superficial area. Outcrops are limited to the immediate vicinity of the streams on account of the great thickness of the drift, especially over the west portion of the county.

Quarries have been opened at a number of points, notably in the town of Fayette, in the northwestern corner of Windsor township, near the towns of Alpha and Waucoma in Eden township and near Fairbank and Maynard in Oran and Harlan town-

ships respectively. The quarries are of small capacity and supply only the local demand.

The Westfield bridge section, which is located on the northeast quarter of section 29 in Westfield township, is one of the most extensive Devonian sections in the county and shows the Devonian contact with the Niagaran. The sequence of beds is as follows:

		FEET.
9.	Limestone, much weathered, in thin fragments, fossiliferous	1
8.	Limestone, yellow, impure, fine-grained; in layers two to six or eight inches in thickness	5½
7.	Limestone, yellow, impure, in three heavy beds	7
6.	Limestone, yellowish gray, rather massive, less magnesian than number 7 above and somewhat broken	8
5.	Limestone, argillaceous, light colored, consisting of brecciated material in which small limestone fragments are imbedded in a clayey shale matrix	7
4.	Limestone, brecciated; composed of dense, fine-grained drab colored fragments of limestone, surrounded with lighter colored cementing material	10
3.	Limestone, yellowish gray, very fine-grained; weathers into thin fragments	11
2.	Limestone, yellow, magnesian, in two ledges, the upper dense, rather fine-grained, one foot thick, and the lower softer, vesicular, two feet in thickness	3
1.	Limestone, yellowish, magnesian, heavily bedded, cavernous, cherty and fossiliferous	22

In the above section numbers 1 and 2 belong to the Niagaran. The balance of the section belongs to the Devonian. The upper beds only are quarried in and about Fayette and their equivalents are quarried near Fairbank and Maynard, but at the latter localities the beds have become much less magnesian and as a consequence do not afford as durable structural material as the same layers at Fayette.

In the northwest quarter of section 6, Windsor township, the following beds are available:

		FEET.
6.	Limestone, residual	1
5.	Limestone, magnesian, yellow, in layers two to six inches in thickness. The layers are much shattered	6
4.	Limestone, yellow, fine-grained, earthy, in layers six inches to two feet in thickness; somewhat nodular	3½
3.	Limestone, yellow, impure, resembling number 4; in layers eight to thirty inches in thickness, somewhat fossiliferous	6
2.	Limestone, yellowish gray, in rather indistinct layers which are checked by numerous joints, fossiliferous	8
1.	Shale, light colored, containing occasional fragments of limestone. Shale fragments become more abundant in lower parts; talus covered to bed of stream	7

Similar sections appear at other points in the neighborhood.

Beds higher in the series than those in Windsor township are quarried in the town of Fairbank in the southwest corner of the county. The quarry section is as follows:

		FEET.
5.	Soil, drift and residual materials	5
4.	Limestone, yellow, much decayed, in thin layers, fossiliferous	2½
3.	Limestone, hard, gray, in thin layers, fossiliferous	2
2.	Limestone, yellowish gray in rather even layers with occasional bands of shaly material; showing numerous spots of concentrically arranged lines of iron stains; fossiliferous	6
1.	Limestone, gray, massive, containing numerous geodes of calcite and bearing but few fossils	3

Other quarries have been opened in the neighborhood but developed nothing new. The quarries in the vicinity of Maynard are less extensive than those at Fairbank and show no new phases.

Some of the more important quarries of the county are briefly described in the following paragraphs.

An abandoned clay pit of the Clermont Brick and Tile Company, at the north edge of Clermont, shows the indurated beds of the Middle Maquoketa of Savage, the Fort Atkinson dolomite of Calvin. Above the Clermont shales of the Lower Maquoketa are shown three layers of soft, yellow dolomite, the lower one two feet thick but considerably broken up, the middle layer solid, two feet thick, and the upper layer, solid, eighteen inches thick. The two upper layers are coarsely vesicular. Above these is a heavy cherty ledge of yellow vesicular rock four feet thick, and surmounting this is an eight inch ledge. The uppermost member is a four-foot series of thinly bedded, broken, cherty dolomite. All the beds are too soft for ideal macadam but the rock might be suitable for some purposes.

About one and one-half miles west of Elgin, in the southeast quarter of section 16, Pleasant Valley township, is the Loetcher quarry, located by the roadside. This is opened in the Niagaran beds not far from their base. Below two or three feet of stripping are six feet of heavy bedded, vesicular, light gray dolomite with sandy texture. These overlie five heavy ledges of buff, rather finely crystalline dolomite which are respectively two

feet and eight inches, two feet, one foot, two feet, and eighteen inches in thickness, counting from the bottom. The two upper ledges have lines of small cavities one to two inches in diameter. The quarry is well situated for removing rock and a considerable amount has been taken out and crushed by the county for use on the Elgin-West Union road over the hills. The road is surfaced with the residuum.

The Peter Banning quarry in the northern part of section 28, Westfield township, across the river from Fayette, shows the various beds of the Wapsipinicon stage of the Devonian as developed in this county. It is situated well up in the bluff and is easy of access or for installing machinery. The quarry shows the following succession:

	FEET.
Broken and weathered slabs, grading upward into residual material	6
Thin beds, two inches to a foot, gray, fine-grained	6
Heavy ledge, gray, fine-grained, similar to lower layers, but not so bluish	3
Two heavy ledges, similar to those below, split into thin flagstones	4
Heavy ledge of blue-gray, fine-grained stone, conchoidal fracture, split into several thinner layers	1⅔

The whole quarry face up to the spalls is of similar appearance except that the upper ledges are grayer and show zones of iron stain. The rock is a pure limestone. All the ledges break up into thinner bands.

Below the quarry is an exposure of sixty-five feet to the flood plain. The basal portion of this is made up of the Niagaran dolomites while the remainder belongs to the Devonian. The section is about as follows: At the base are exposed eight feet of heavy, cherty, vesicular beds belonging to the Niagaran. Then come three feet of thinly bedded, gray, fine-grained rock, succeeded by a heavy vesicular ledge three feet thick. Three feet of thin layers are then overlain by six feet of broken argillaceous beds grading above into a foot of soft sandy limestone in the upper part of which are fragments of a fine brownish limestone. Above this sandy limestone is a one-foot ledge of buff, fine-grained rock, broken into angular blocks by vertical fractures and succeeding this comes a foot of gray, fine-grained,

finely laminated limestone. There follow in order eight feet of gray, fine-grained rock in very thin layers; sixteen inches of rock similar in appearance, somewhat finely brecciated, conchoidal fractures, in two ledges, the lower one six inches, the upper ten in thickness; two feet of thin layers with wavy lamination, a single heavy ledge a foot in thickness and a six-foot brecciated bed. Between this bed and the base of the quarry are fifteen feet of much broken ledges, some scarcely showing bedding, the upper ledges thinly bedded.

Mr. Kidder has opened a small quarry west of town on the West Union road. The beds exposed here are at the same level as the upper beds of the Banning quarry.

In the vicinity of Waucoma some small quarries have been opened in the Devonian. Two of these are located in the northwest quarter of section 9, Eden township. One is a few rods west of the railroad and on the south bank of a small dry run which is crossed by the track. The other is opened in the field back of a farm house just beyond the run. Both show the same beds except that the one on the valley side is a little deeper. The beds are very much broken up and do not show bedding. The upper beds are gray with iron-stained streaks, are fine-grained and rather finely vesicular and break with a rough fracture. The lower beds are apparently very massive but are somewhat broken up, less so, however, than the upper beds. The stone is gray-buff, fine-grained, and more vesicular than the upper beds. The material is probably too soft for macadam though making good building stone. The smaller quarry exposes about six feet; the larger one about nine feet of rock.

In the middle of the west half of section 6 of Windsor township is a quarry in the bluff face. It shows eight feet of thinly bedded Devonian strata similar to that shown at Waucoma, fine-grained, gray, some layers iron-stained. The quarry is above the heavy broken beds and is thirty feet above the stream. If the quality of the rock is high enough to justify the effort the rock could be easily taken out and crushed. The overburden is quite light.

Across the road, in the southeast quarter of section 1, Bethel township, is a small quarry in about the same layers as that just described. In the southwest quarter of section 6, Windsor, along the east-west road is another small quarry opened in the hillside at the same level as the others. Higher up in the hills the thin flaky beds of the Wapsipinicon crop out.

Several quarries have been operated near West Union, and these use the lower beds of the Devonian. The city quarry on the western edge of town shows at the base two heavy ledges, the lower, fourteen inches, the upper twenty. The stone is light gray, with rough fracture, locally broken up, elsewhere showing fine laminæ. Above these comes a six-inch ledge of fine-grained stone with conchoidal fracture, and then follow five or six feet of badly broken material brecciated in different parts of the quarry, broken or massive, but quite definitely laminated.

The stone is rather soft for road work. A Foster's patent jaw crusher has been used in the quarry.

In the southeast quarter of section 22, Union township, is the Grimes quarry showing:

	FEET.
Soil and rock waste	1-2
Broken rock	2-4
Thinly bedded, fine-grained gray rock with thin shaly beds intercalated	2
Heavy ledges of gray stone	
Blue, fine-grained rock, thinly bedded, in three layers, quite hard; exposed	1

By barometer the quarry is about ten feet above the West Union City quarry.

FLOYD COUNTY.

Sand and Gravel.

Immense quantities of gravel and sand are available in Floyd county, the deposits which are important at the present time being located along the principal streams. Cedar and Shell Rock rivers are particularly noteworthy in this respect, and large quantities have been removed from their terraces.

There are two well-defined terraces along Cedar river; the lower, composed of limestone, rising some fifteen to twenty

feet above the water in the river, and the upper gravel being about the same amount higher. Both terraces are covered with a thin veneer of mixed alluvial and glacial materials. Near the top of the upper terrace bowlders ranging up to three feet in diameter are not uncommon. The largest of these are granitoid, and limestone fragments are very common. The upper horizon, which varies from two to four feet in thickness, is largely gravel, often mixed with dirt. The beds become cleaner and carry less gravel below. They show evident sorting, but are imperfectly stratified and are variable throughout. The total thickness runs up to fifteen or eighteen feet. This material rests upon limestone, upon the surface of which bowlders are occasionally reported to be found. These materials are excellent for masonry work and plastering, and fair for concrete. They are also satisfactory as road materials. Large quantities are easily available.

On the west bluff of the Cedar in the southeastern part of Charles City is a pit owned by Mrs. Eliza Barnes. The pit shows:

		FEET.
4.	Soil covering	1-2
3.	Sand and clay	2-3
2.	Sand, fine, and fine yellowish gravel	2-3
1.	Gravel and sand, fine, much cross-bedded, some small lenses of sandy clay, flat slabs and cobbles in places, exposed, about	10

There are about five acres in the immediate vicinity of this pit which may all be underlain by similar materials.

A face similar in general characteristics, but varying somewhat in detail is exposed in the pit of Alfred Laun at Floyd. This pit is in a terrace similar to that at Charles City described above, and shows in section:

		FEET.
5.	Soil, etc	2-3
4.	Gravel, fine to coarse, some sand and clay, brownish	3-4
3.	Gravel, fine to coarse, some sand and flat chips of lithographic stone	2-3
2.	Gravel and sand, fine, clean, a few small lenses of clay, much cross-bedded, some coarse pebbles and flat chips of country rock	10
1.	Gravel, horizontally stratified, more sand and clay than in No. 2	3

Very similar conditions obtain along Shell Rock river. At Marble Rock three terraces are present on the west side of the river. The upper terrace has been opened at several points. In this terrace the gravel is mixed with a considerable quantity of dirt. The middle terrace is composed of good material, coarser in the upper than in the lower part. From a well section taken in the neighborhood it would seem that in places the gravel continues down to the level of the river bottom. The lower terrace is about twenty feet above the flood plain of the river, and the upper two rise about ten and twenty feet respectively above this level. South of Marble Rock the terraces are repeated on the east side of the river. The Rock Island Railway Company has a pit on the middle terrace from which some fifteen feet of material of excellent quality have been removed. South of the cemetery a pit which has been opened in the upper terrace shows gravel that is coarser and dirtier than that of the middle bench.

These terraces continue down the river into Butler county. Gravel for local use has been taken out at several points.

Stone.

The Devonian limestone and shales form the country rock over the entire county so far as known at this time. Numerous outcrops appear along Shell Rock river, Floyd creek, Cedar river and Little Cedar river. Outcrops of the Lime Creek shales are confined to Rockford and vicinity, while all of the limestones belong to the Cedar Valley stage. The limestones are prevailingly hard, white, compact, often lithographic, evenly bedded and almost pure calcium carbonate. They are often associated with or interbedded with magnesian or dolomitic layers.

Along Shell Rock river, sections at Nora Springs, Rockford and Marble Rock give the range of beds which may be observed. At Nora Springs the following beds appear in the bluff at the foundry about one hundred and fifty yards up stream from the Milwaukee railway bridge.

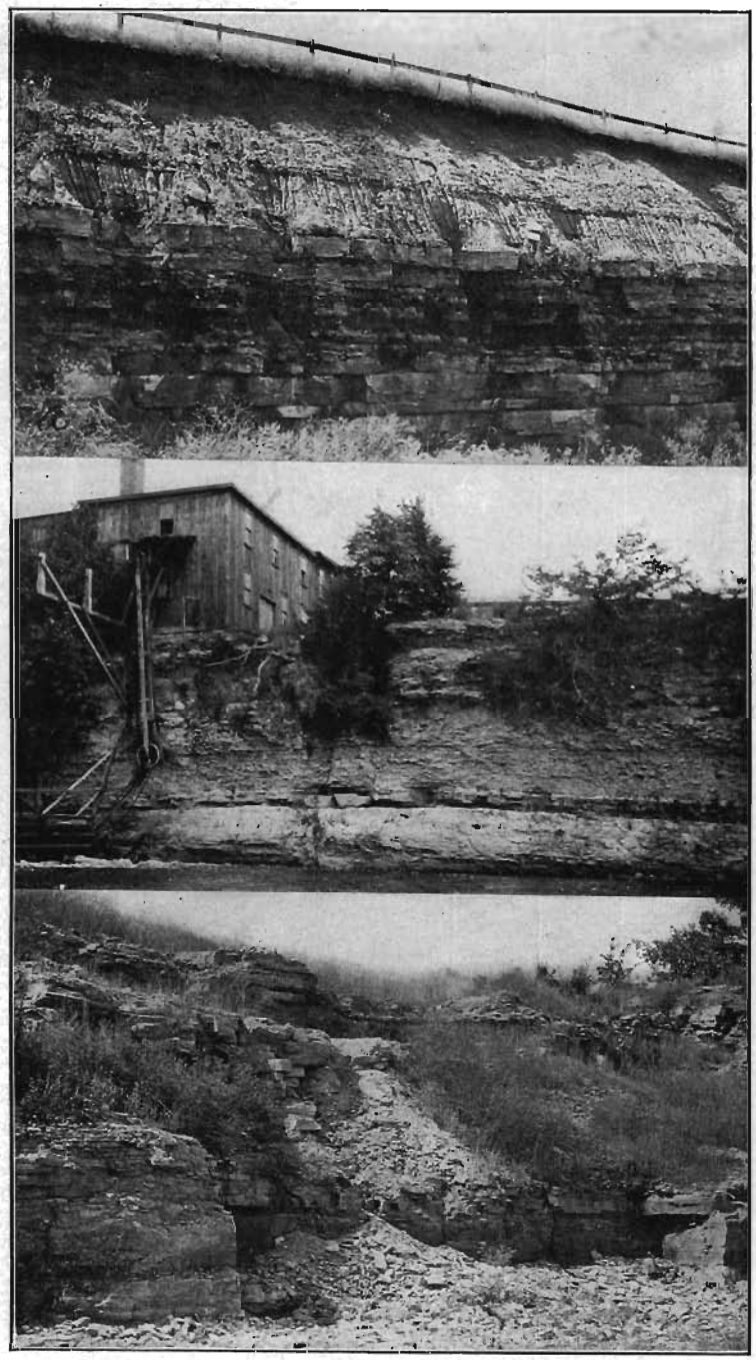
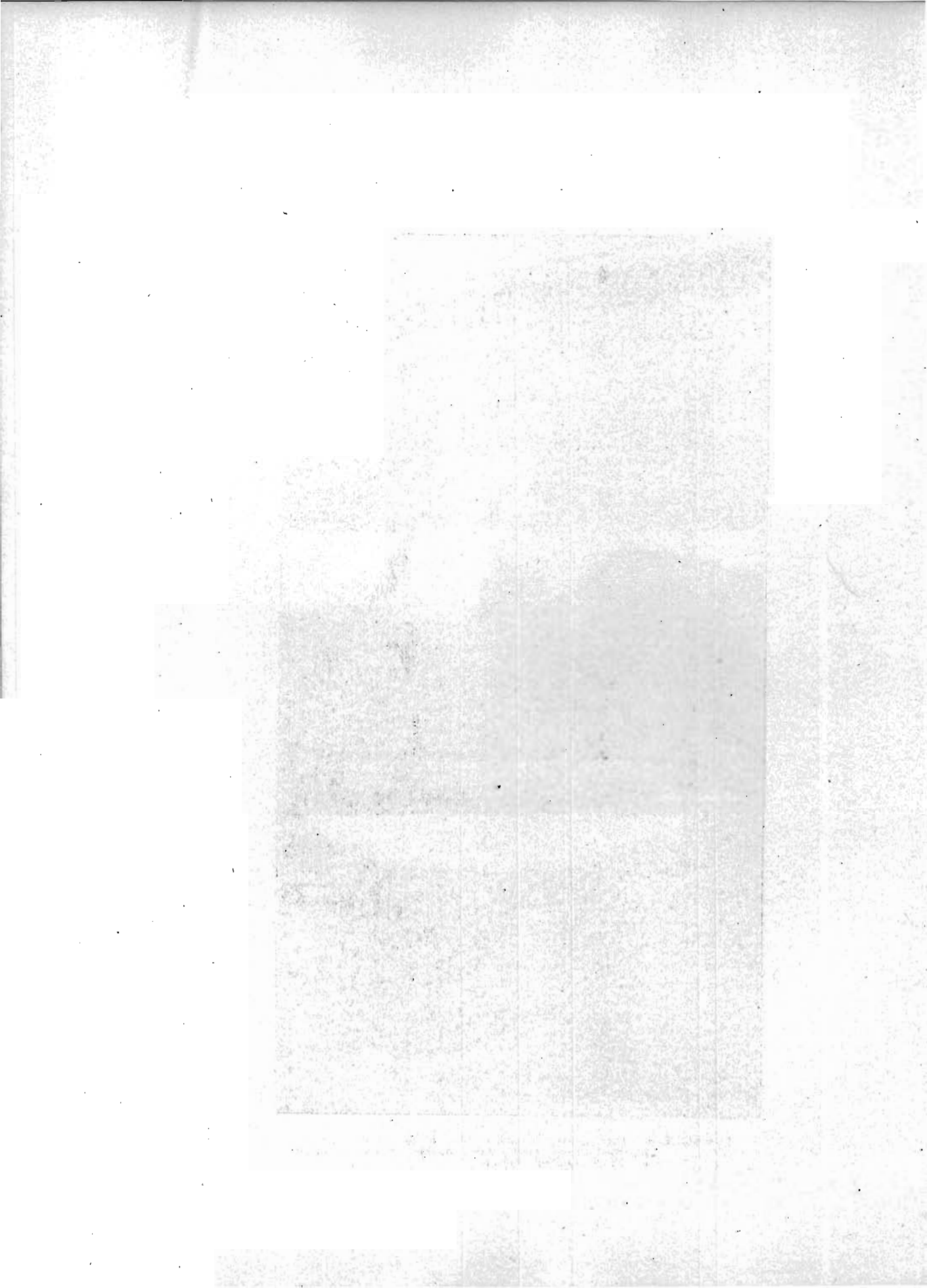


PLATE XX—a. City quarry, Charles City, Floyd county.
b. Shell Rock river, Nora Springs, Floyd county.
c. Floyd quarry section.



		FEET.
7.	Soil and drift of variable thickness	1-4
6.	Limestone, coralline zone, colonies very much flattened, bedding planes not very distinct	6
5.	Limestone, buff to gray-buff, otherwise similar to number 4; bedding planes rather more apparent	4
4.	Limestone, white, much shattered, compact and brittle; bedding planes not apparent	3+
3.	Limestone, spheroidal Stromatopora zone; appears to be decidedly concretionary where weathered, spheroids up to 10 inches, horizontal diameter somewhat the larger	8
2.	Limestone, gray-buff, evenly bedded, compact to somewhat earthy fracture, less brittle than 1, grades upward into white limestone	2
1.	Limestone, white, apparently brecciated; bedding planes not well defined, compact and brittle, exposed at this point above low water	6

Just below the mill, some three-eighths of a mile farther up stream, several small quarries have been opened. The same beds are exposed but show considerable variations, especially in bedding. All of the beds up to number 4 are massive. Number 2 appears as a single ledge, in places. Although the spheroidal masses can be seen, number 4 takes on a somewhat shaly character and is thicker than at the foundry. In places, however, this member appears as a single massive ledge. The beds all dip up stream. The stone derived from these beds is used quite generally throughout the town and adjoining country.

At Rockford, beds higher in the series appear and only the uppermost member of the Cedar Valley limestone appears in the low escarpment along the river. Back from the river the Lime Creek shales appear. While the actual contact between the Cedar Valley and the Lime Creek was not seen, the section which can be viewed along the river and in the pit of the Cream City Brick and Tile Company is as follows:

ROCKFORD SECTION.

		FEET.
10.	Soil and drift, variable in thickness	0-2
9.	Marl, blue-gray, oxidizes to a yellowish color, highly fossiliferous	12+
8.	Clay-shale, gray-blue, slightly gritty and more pervious than beds below	15
7.	Iron-stained zone, containing concretions; of variable thickness	½-2
6.	Clay-shale, similar to number 5	6
5.	Shale, gray-blue, slightly gritty	12

		FEET.
4.	Limestone, shaly, exposed but thickness not determined....	
3.	Limestone, white, similar to uppermost beds along the river at Nora Springs; coralline, thinly bedded	12
2.	Dolomite, or dolomitic limestone, brown and porous.....	3
1.	Limestone, gray-blue, in medium heavy ledges, exposed..	4

The marls and shales continue more or less uninterruptedly to the "Clay Banks" south of Portland in Cerro Gordo county and can be traced southward from Rockford two or three miles. They are not known to occur in any considerable quantity north and east of Lime creek or of Shell Rock river. The marl is used to some extent for road work and appears to cement well. The lower limestone beds have been quarried in a small way but are too near the water level in the river to permit their extensive development.

At Marble Rock a number of quarries have been opened and are operated at the present time. About three-fourths of a mile above the wagon bridge a quarry has been opened on the east side of Shell Rock river and presents the following beds:

MARBLE ROCK SECTION.

		FEET.
5.	Soil and drift	1-4
4.	Limestone, white, with spheroidal Stromatopora, hard and brittle, beds heavy where unweathered; becomes cavernous in part and the middle portion is brecciated, exposed....10-12	
3.	Limestone, magnesian or dolomitic, much weathered and stained in places, yellowish brown, evenly bedded, ledges shaly in part	8
2.	Limestone, dolomitic, shaly, iron-stained.....	2
1.	Limestone, white, the details are as follows: 10 inch ledge, lithographic. 10 inch ledge, brecciated. Two 10 inch ledges, separated by shaly parting. 10 and 12 inch ledges, lithographic in character. 20 to 24 inch ledge, almost lithographic. 14 inch and 18 inch ledges, separated by shaly parting, hard, compact.	
	Total	9

The ledges in number 1 constitute a compact, hard, brittle limestone almost lithographic throughout, with the exception of the ledge next to the top of the series, which is distinctly brecciated. All of the layers are evenly bedded and all but the third and fourth layers are separated by shaly or marly part-

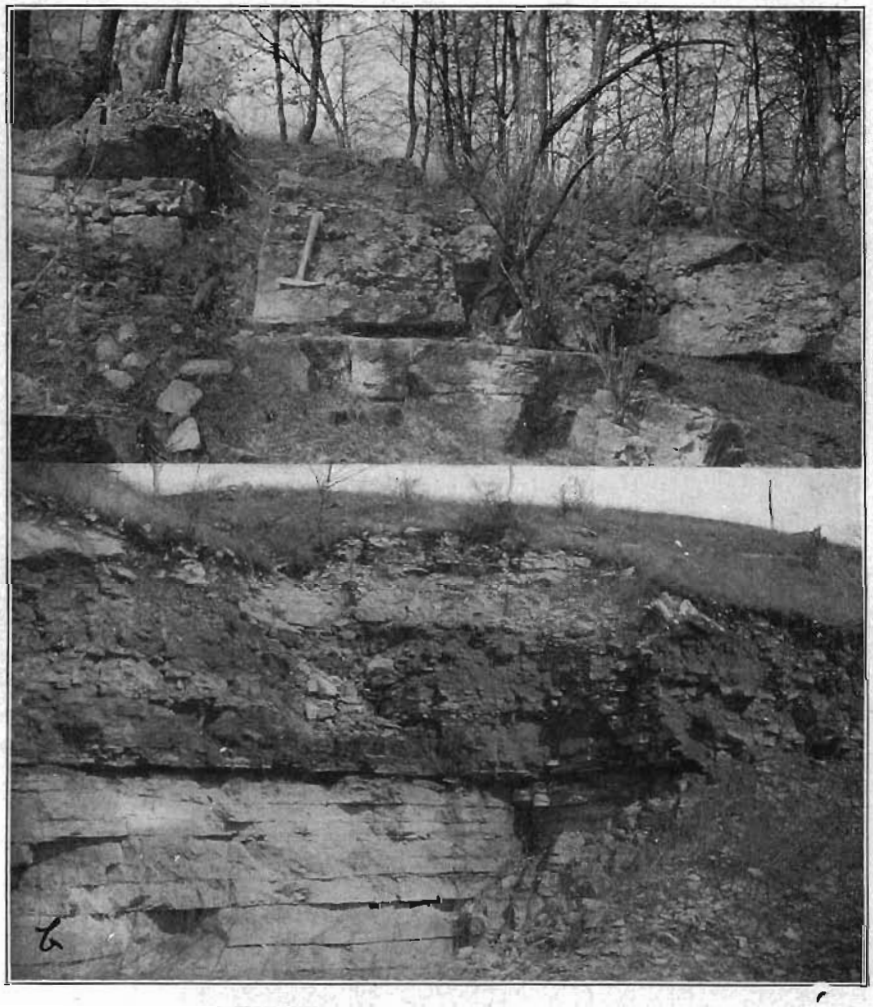
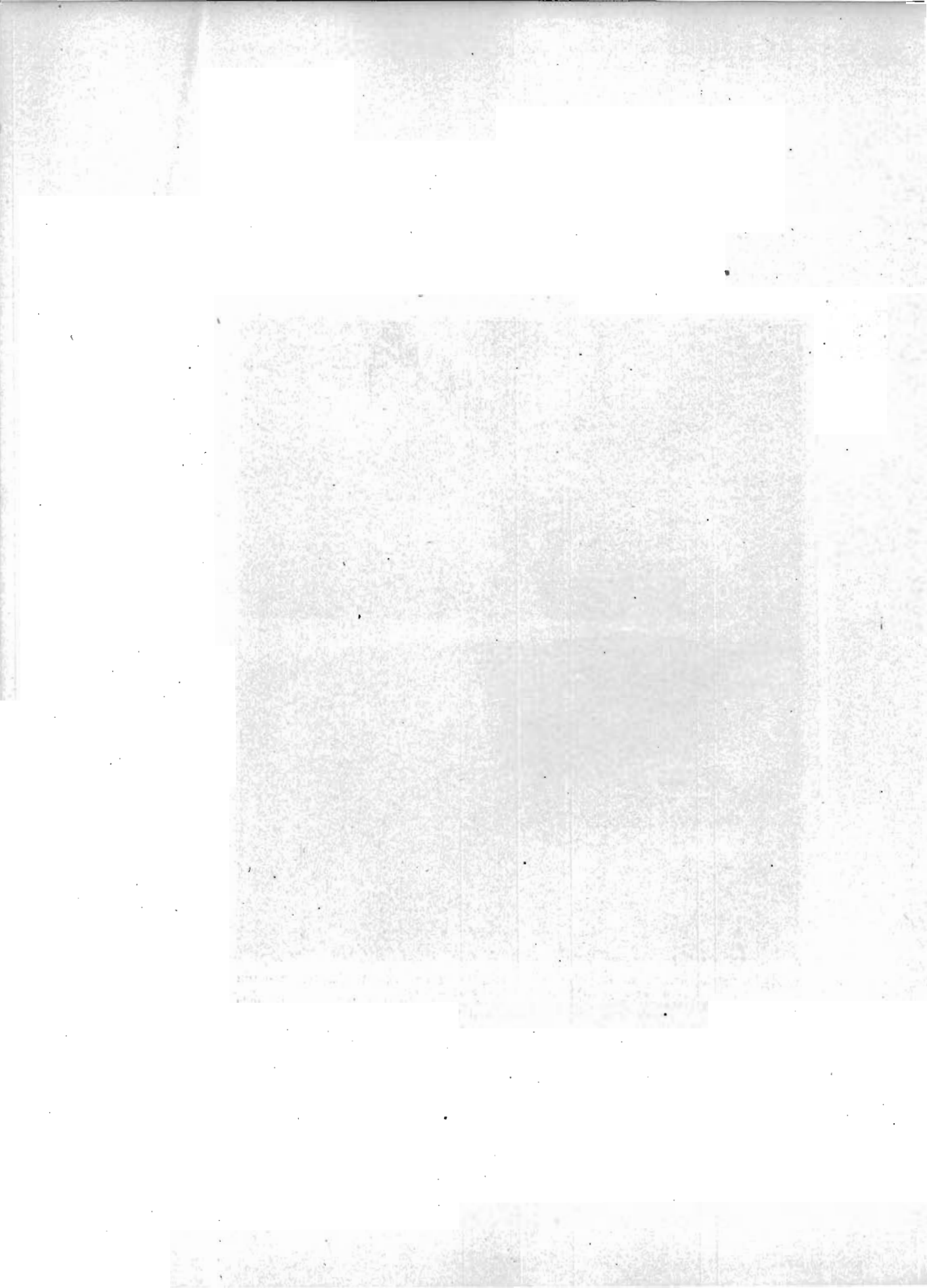


PLATE XXI—a. Old lime quarry above Marble Rock, Floyd county, showing Stromatopora zone and brecciated zone.
b. Marble Rock quarry showing evenly bedded, lithographic beds below, and Stromatopora and brecciated zone above.



ings, thus facilitating quarrying by very simple methods. All of the lower limestone beds show good ability to resist weathering influences. The lower limestone beds are most highly prized for quarry purposes although the dolomitic beds, when not too much weathered, are also used. Both the upper and lower limestones are well adapted for crushed stone products. Old quarries were opened in the upper limestone, which was also burned for lime. The remains of an old pot kiln may still be seen in the immediate neighborhood.

Along Cedar river and its immediate tributaries an abundance of indurated rock is available, often with very little overburden. The principal quarries are located at Lithographic City, Floyd and Charles City. The Interstate Development Company has made extensive openings at Lithographic City and is planning to operate its property on a large scale in the near future. Two quarries have been opened. The beds exposed are as follows:

LITHOGRAPHIC CITY SECTION.*

		FEET.
11.	Soil and drift	1
10.	Limestone, lithographic	5
9.	Limestone, yellow-gray, friable, coarsely granular and thin-bedded	½
8.	Limestone, dense, compact, buff to grayish white, thin-bedded	3½
7.	Limestone, lithographic, shattered and unevenly bedded, brown, variegated	1
6.	Clay parting	1/6
5.	Limestone, compact	1¾
4.	Clay parting	1/6
3.	Limestone, buff to pink, lithographic	1½
2.	Limestone, gray, subcrystalline	¼
1.	Limestone, lithographic, dense, exposed	3

A large number of specimens have been selected from the various beds in the quarry and polished. Enough has been done to demonstrate thoroughly the superior quality of certain of the layers for lithographic purposes. It has also been demonstrated that the lithographic stone can be obtained in large slabs practically free from fractures, calcite balls, clay seams and other imperfections. Other beds take a good polish and are of a

*From notes supplied by Mr. C. L. Webster, Charles City, Iowa.

pleasing color. They can be quarried in blocks of almost any lateral dimensions and will undoubtedly find a ready market. The waste from the quarries would make an excellent grade of crushed stone. A large area is available with almost no overburden. A short line of railway has been surveyed and the company contemplates building in at an early date.

At Floyd, extensive quarrying has been done through a period of many years. A quarry just north of town along the main roadway shows the following beds:

		FEET.
8.	Drift and soil up to	4
7.	Limestone, brown, dolomitic	8
6.	Limestone, white to gray, compact, brittle	3
5.	Limestone, subcrystalline, sugary, gray to brownish, apparently dolomitic	4
4.	Limestone, gray-white, blue above, compact, weathers concretionary	3
3.	Limestone, blue-gray, shaly above	4
2.	Limestone, brown, vesicular, dolomitic	1
1.	Limestone, compact, exposed	3

Many of the older buildings and nearly all foundations in the town attest the popularity of the stone for structural purposes.

Charles City is the chief quarry center in the county. Of the numerous quarries which have been opened and operated from time to time, a large quarry located in the southwestern part of town may be taken as a fair average. The beds developed are as follows:

CHARLES CITY SECTION.

		FEET.
4.	Soil, drift, and terrace materials, the latter constituting the larger portion of the overburden	4-8
3.	Limestone, ledge persistent	1-2
2.	Limestone, magnesian, light brown, vesicular and subcrystalline, less evenly bedded than number 1, concretionary in part	5-6
1.	Limestone, gray, weathers white, compact and brittle; evenly bedded, but beds undulating; comparatively free from flaws and remarkably uniform, exposed	8

The layers in number 1 are separated by thin clay partings which greatly facilitate quarrying operations. According to Mr. C. L. Webster, the stromatoporoid zones lie from fifteen to twenty feet below the base of the quarry. Number 1 in the

above section is the chief quarry rock and has been used extensively in Charles City and the adjacent country. The M. E. Church and First National Bank buildings are among the more important structures constructed from local materials; the former bearing the date of 1854. Both are in good repair and the stone appears to possess excellent weathering qualities. The Charles City Marble Company owned and operated the quarry. This company also attempted to cut and polish the stromatoporoids for ornamental work but with indifferent success as a commercial venture, although some very handsome pieces were turned out.

South of Charles City, quarries have been opened at several points. On the south half of section 20, township 95 north, range XV west, east of the wagon road and north of a small creek, the following layers may be seen:

		FEET.
11.	Soil and drift, thin, up to	1
10.	Limestone, light colored, magnesian, shattered and fossiliferous	1
9.	Limestone, nodular, containing many stromatoporoids, badly broken, fossiliferous	4½
8.	Dolomite, brown	1′/₆
7.	Limestone, lithographic, thinly bedded, where weathered, separating into thin plates	1′/₆
6.	Limestone, compact, brown, becomes thinly bedded below in weathering	2
5.	Limestone, impure, earthy, forming a reëntrant in cliff face and breaking down, on weathering, to a yellow, clayey mixture	²/₃
4.	Limestone, thinly bedded and light brown to bluish in color; laminæ separated by bands of weathered clayey residue	2½
3.	Talus slope	7
2.	Limestone, ledges similar to number 4, but heavier and firmer, with fewer clay partings and deeper brown in color	10
1.	Talus slope to creek bed	4

Some quarrying was formerly done at this point. An abundance of material is easily available and under very light overburden.

In the southeastern portion of the county some quarrying has been done. The most important opening, the Allen quarry, two and three-fourths miles northwest of Nashua, is given herewith:

		FEET.
3.	Drift and soil of indefinite thickness.	
2.	Limestone, in thin beds, varying from one to five inches in thickness, some layers soft and granular, others hard and fine-grained	8
1.	Limestone, consisting of the following ledges from the bottom upward: eighteen inch, twelve inch, fourteen inch, eight inch and five six inch ledges respectively	7

The bottom ledge affords stone suitable for bridge work, while several of the other ledges yield satisfactory building stone. The limestone members throughout are excellently adapted for crushed stone products.

FRANKLIN COUNTY.

Sand and Gravel.

The important sand and gravel deposits of Franklin county are, genetically, of two classes, viz., gravel trains derived from the Wisconsin drift and now appearing as terraces along the streams which furnished outlet for the flood waters from the melting ice, and pockets within the drift hills themselves. Buchanan gravels are also present, but are available in hardly sufficient quantity to be valuable as a source of supply.

Stream Terraces.—The Altamont moraine crosses the county in a direction slightly west of north, and divides it into two nearly equal parts. All of the streams that issue from the moraine are bordered by more or less continuous beds of gravel, which usually appear as valley terraces in the Iowan drift area, which lies to the east of the Altamont moraine. The gravels are especially noticeable on Bailey, Otter and Buffalo creeks, along which they may frequently be seen within the borders of the Wisconsin drift. They occur along Mayne creek in Reeve and Geneva townships. The materials are well sorted as a rule and are products of the streams while they were flooded during the melting of the Wisconsin glacier. More or less sand is always present and cross-bedding is a prevailing feature. The fineness of the pebbles composing the gravels increases with the distance from the Wisconsin border—as would be expected with the decrease in declivity and hence in the carrying power of the streams.

Where the West Fork of the Cedar enters the county it is skirted by a gravel bench, twelve to fifteen feet higher than the flood plain. This terrace unites in section 18 of West Fork township with the Bailey creek terrace, which forms a very conspicuous bench along the latter stream throughout its course in the county, and is here ten feet above the flood plain level. Beyond section 28, West Fork township, the gravels are not conspicuous. The terrace in places extends a mile back from the stream, the town of Sheffield being built on such a flat north of Bailey creek. The gravels in Sheffield are twenty-five to thirty feet thick.

The Sheffield Cement Products Company has opened a pit west of town just south of the Saint Paul and Kansas City Short Line railroad station. About fifteen feet of gravel are being developed. The stripping ranges up to four feet in thickness.

The gravels are also seen along Otter and Hartgrave creeks and vary in height above the water from fifteen feet at the moraine to disappearance in eastern Ingham township. The terrace on Mayne creek is not so conspicuous as are those along the other streams in the eastern part of the county, and is not important beyond the eastern boundary of Reeve township. A gravel train flanks Iowa river, but does not occur as a bench, being seen only in road cuts and but little above the river. The gravel underlies the thin layer of alluvial silt that has been put down in places by this river.

These terraces furnish excellent and abundant supplies of gravel and sand for road construction and concrete work. For road building the gravel beds are worked at many points where the public highways cross the stream valleys.

Pits have been opened in the terraces in many places. North of Dows are two pits, one of which shows ten to twelve feet of fine and coarse gravel with some sand under two feet of covering. In southwest section 36 of Osceola township is a gravel-bearing terrace about eleven acres in extent. This shows six to eight feet of mostly fine gravel resting upon sand and covered by some two feet of soil. There is also an opening in section 35 of the same township which is owned by the county.

Drift Gravels.—Gravel and sand deposits are a common occurrence in the hills of the Wisconsin moraine and in the low knobs and ridges which dot the whole surface of this formation. On the road between sections 5 and 6 of Reeve township stratified sand and gravel occur beneath a thin layer of partially assorted Wisconsin drift. Six to eight feet of the deposit have been opened up and large amounts removed from both sides of the roadway. Gravel and sand are hauled from this pit to Hampton for use in the manufacture of cement blocks and for filling material in other lines of constructive work.

In the northwest quarter of section 19 in Morgan township is a series of morainal knobs. One of these has been dissected and found to be composed of well stratified clean sand, quite free from iron-stain and other impurities. The strata are neither horizontal nor continuous, but are interrupted and irregularly tilted at all angles. The sand is suitable for use in mortar and plaster mixtures. Several other examples of drift deposits may be noted. Three miles southwest of Hampton ten feet of sand of varying nature are reported in a hill. In southwest section 32 of Ross township Mr. Dean has a hill covering some two or three acres which contains up to six feet of fine to coarse gravel.

Buchanan Gravels.—At a few points in section 2 of Geneva township outcrops of coarse, clayey and deeply iron-stained gravels were observed, and they appear to underlie considerable areas. In the road running east and west through section 2 they are exposed near the east side of the section and are covered by a few feet of loess. They may also be observed at various points in Butler county, but are not generally easily accessible.

Stone.

The Owen beds of the Lime Creek stage outcrop at various points along the east side of the West Fork of Cedar river in the northeast corner of Ross, and throughout its course in West Fork township. In section 7, West Fork township, a small quarry has been opened, from which some rock has been removed. These beds furnish a supply of building material which

has been utilized locally at many points. It is seldom, however, that the stone is sufficiently coherent to permit of any extended use for structural work.

The quarry opening just north of the road along the south side of section 7, West Fork township, affords the following section:

		FEET.
2.	Shale, yellow, magnesian, with chert nodules and, near the base, interbedded, subcrystalline limestone, apparently dolomite. In places, definite bands of chert permeated with brachiopod impressions, *Spirifer whitneyi* most abundant	3½
1.	Dolomite, brown, thinly bedded, fossiliferous, partially crystalline; much shattered at top and badly rifted throughout, exposed	7

Only the lower bed can be used, and this on account of its coarsely granular and partially weathered condition, is not a durable material. It has been used to a limited extent for sidewalk flagging, and in walls, where it is fairly satisfactory.

The Carboniferous rocks present in the county belong to the Kinderhook stage. In the eastern portion of the county, beyond the border of the Wisconsin drift, Kinderhook rocks are exposed along the channels of all the principal streams. The rocks of this stage consist in this county of limestones and shales, the former varying from soft, marly, argillaceous beds containing large quantities of chert, to compact, partially crystalline, fossiliferous or semioölitic dolomite. The shales range from magnesian and calcareous beds which in many instances represent the firmer limestones in a state of decay, to typical yellow or bluish plastic clays.

Weathered Kinderhook limestone appears along Bailey creek in Richland township. Along Otter creek these beds are also exposed almost continuously from section 30 of Ross to its union with Hartgrave creek in Ingham township. One mile west of Chapin at the southwest corner of section 29, limestone is quarried. The following section may be viewed:

FIG. 35—Kinderhook limestone quarry one mile west of Chapin, Franklin county.

		FEET.
3.	Thin drift soil	1
2.	Badly weathered and iron-stained argillaceous limestone	7
1.	Regularly bedded blue-gray to sugary brown dolomitic limestone, containing Orthothetes, related to *O. inequalis* Hall, and Orthis (?), exposed	8

This quarry is worked by Mr. Wm. Low. A quarry face eight to ten rods in length is open. The usable portion of the section is covered by six to eight feet of argillaceous weathered rock which must be removed by stripping. The lower beds are regular and the individual layers vary from six to eighteen inches in thickness. The stone is granular and fossiliferous and ranges from brown to blue-gray in color. It yields readily to shaping for dimension work and affords the most durable building stone now produced in the county. A moderate local demand is supplied, none as yet being shipped.

Ledges of this rock form the east boundary of Otter creek valley and appear for some distance both north and south on both sides of the stream. Outcrops are to be found in the vicinity of Buffalo creek in section 36 of Richland township, and section

31 of Ross; it is also found along the west side of section 6, and across sections 5 and 4 of Mott township, where the bordering hills are all supported by the limestone, which stands twenty-five feet above the stream. Throughout the remainder of its course in Mott and Ingham townships, Otter creek valley is bounded by limestone walls, and evidences of the presence of limestone are to be seen, aside from natural outcrops and hillside talus, on nearly every section line where the public highway crosses this creek.

Limestone is also found along Spring creek in sections 21 and 22, and along Squaw creek in the city of Hampton. Stone has long been quarried in the north part of the town. A poor grade of limestone is now being used from an opening a few hundred yards west of the cemetery. This opening shows the following section:

		FEET.
3.	Earthy, shattered and iron-stained limestone with numerous bands of chert	5
2.	Thin-bedded, earthy limestone permeated with chert in bands and irregular concretions; somewhat cavernous, brachiopod impressions preserved in chert	6½
1.	Heavier beds (6-8 inches) and less chert, caverns lined with botryoidal calcite	7

The rock is weathered and contains intermittent bands of chert, which cause it to break very irregularly. It is used for only the rougher masonry work and would not give satisfaction in exposed positions.

There are innumerable exposures of the lower limestones, and occasionally of the shaly beds, not in the immediate vicinity of the streams, in the north-central part of Ingham and in the corners of Mott and Ross townships, where the main features of the topography are expressed in these older rocks. In the northeast quarter of section 28, Ingham township, south of the railroad track, a small quarry is opened on the land of D. W. Mott. The sequence is:

		FEET.
3.	Soil and decayed limestone	4
2.	Plastic, light blue shale with very thin bands of limestone	2
1.	Fossiliferous, crystalline brown dolomitic limestone, exposed	8

The beds are much rifted horizontally and fractured by vertical joint planes.

On Mayne creek the greatest thickness of beds is to be seen near the north side of section 21, Reeve township. The section is partially obscured by talus materials, but it is approximately as follows:

		FEET.
8.	Drift	8
7.	Thinly bedded shattered limestone with much chert in oval nodules and more or less persistent bands	14
6.	Heavier bedded, arenaceous limestone, carrying chert as above, and occasional caverns and calcite geodes	6
5.	Shaly limestone with bands of firmer rock	12
4.	Compact, resistant ledge of limestone	1
3.	Argillaceous limestone containing some chalky appearing chert nodules grading into No. 2	2
2.	Firmer but weathered and iron-stained limestone	1½
1.	Compact, evenly bedded dolomitic limestone	3½

Judging from its lithologic character, No. 1 appears to be equivalent to the rock quarried one mile west of Chapin. In the southwest quarter of the southeast quarter of section 10, Geneva township, just east of the wagon bridge over Mayne creek, is a quarry belonging to Mr. Oren Benson of Geneva, which exposes beds as follows:

		FEET.
4.	Soil	1½
3.	Weathered magnesian limestone with abundant small flint nodules	5½
2.	Heavy bed showing no lines of separation; brown where weathered and fossiliferous (Productus bearing long spines being very abundant); interior of large blocks, light in color or mottled by pink interstitial calcite, distinctly oölitic in texture	10
1.	Calcareous shale resting on limestone	1

A few feet below the base of this quarry and eight feet above the water in the creek the top of the impervious shales is marked for some distance eastward along the south side of the valley by a line of springs. The drift covering is very thin and the limestone forms a ridge extending eastward into sections 11 and 14. In a quarry near the north boundary of section 14, on the land of Mr. H. H. Andrews, the same succession of strata may be observed as noted above in section 10. The beds are here broken by vertical jointing which in places has produced

open fissures six to eight inches in width. Unweathered samples of the lower stratum show an abundance of crystals of iron pyrite. The limestone rests on yellow shale which is exposed in the trench cut by a small stream a few hundred yards from the quarry.

The Kinderhook limestone is removed for local use at a large number of other points in Ingham, Geneva and Osceola townships, but at the above mentioned two localities only have quarry openings been made of sufficient extent to show the nature of the unweathered rock. Away from the weathered parts the rock is light in color and compact, and resembles in general appearance the Bedford stone. In natural outcrops this bed separates into numerous laminæ, each a few inches thick, but where newly exposed, slabs of almost any desired size can be obtained.

A small amount of stone is removed each year from these quarries. It is believed that continued development might open up unweathered portions of the bed which would furnish very good building stone. It seems likely also on account of the extreme thinness of the drift that prospecting along Mayne creek in this vicinity would discover places where it would be possible to obtain desirable stone that is not buried beneath so great a thickness of weathered residuum which must be removed.

FREMONT COUNTY.

Sand and Gravel.

Road material is exceptionally scarce along the Missouri river bluffs in Fremont county. In only one place is good gravel exposed, and that is in section 30 of Sidney township. The section is:

	FEET.
Loess	10
Sand, medium	8
Gravel, fine and sandy	7

The sand and gravel sell for seventy-five cents per yard. The loess will surely increase in depth as the pit is worked.

Sand in small quantities can be obtained in a few places, as in section 2, Scott township. This pit shows eighteen feet of sand, carrying from five to twenty-five feet of overburden.

The interior of the county contains neither sand, gravel nor stone suitable for road and concrete work in commercial quantities.

STONE.

The Missouri as exposed in Fremont county comprises a complicated series of interbedded limestone bands and shales. While numerous limestone beds are present, and are fairly persistent, none are of sufficient thickness to merit distinctive names or individual notice. In general the individual beds rarely exceed four feet in thickness, and are almost inaccessible on account of the excessive overburden. Some quarrying has been done, mainly along the base of the Missouri river bluff. A few unimportant openings have been made in the interior of the county in the vicinity of Riverton, and along Plum creek in Green township. The limestone beds when first exposed appear to be well indurated, and the layers range from four to eight or ten inches in thickness, occasionally attaining even greater thicknesses. The stone is used for rough masonry, such as foundations for buildings, well-curbs, retaining walls, and other rough work. On exposure to the elements, it does not resist weathering well, but rapidly takes on a pseudoconcretionary structure, evidently due to its fragmental character and imperfect cementation. This effect is well shown in the retaining wall north of Thurman along the Thurman-Bartlett wagon road. All of the limestones appear to be nonmagnesian; on account of their limited thickness and heavy overburden, they are never more than of local importance. The following sections may be considered fairly representative.

Section in the bluff near the south line of section 14, Scott township:

		FEET.
9.	Thick loess cover.	
8.	Limestone, fine-grained, oölitic texture	3
7.	Limestone, impure, fossiliferous	2½
6.	Limestone, gray, massive, with thin shaly partings	11
5.	Limestone, gray, highly fossiliferous	½
4.	Shale, gray, with black shale partings	1½

		FEET.
3.	Limestone, bluish, with occasional crinoid stems	1
2.	Shale	1½
1.	Coal reported	1½

Section on Mill creek, near the center of the southwest quarter of section 33, Riverton township:

		FEET.
10.	Drift and loess of indefinite thickness.	
9.	Shale, weathered, yellow	10
8.	Limestone, gray to white, with greenish shale partings, somewhat pyritic, small blocks of durable stone obtainable	3
7.	Limestone, weathered, marly, iron-stained	2½
6.	Shale, blue to black, calcareous, with yellow blotches and small compact concretions, slightly arenaceous	4
5.	Talus slope, probably limestone	2
4.	Sandstone, fine-grained, soft	1/6
3.	Silt, shaly, and friable	4½
2.	Sandstone, fine-grained, calcareous, varying in color from bluish gray to brown, well indurated	2
1.	Shale, bluish gray, with reddish arenaceous seams, and large irregular calcareous concretions lodged in the vertical or inclined joints	8

Numbers 1 to 4 inclusive appear in the bed of Mill creek, but are not well exposed.

All of the limestone ledges are fairly compact and are sufficiently strong for road and concrete work. The stripping is, as a rule, prohibitive and it is improbable that the county will ever be able to produce enough for home use.

GREENE COUNTY.

Sand and Gravel.

The gravel and sand resources of Greene county are of the two main types mentioned so often in this report in connection with counties lying within the area of the Wisconsin drift, viz., gravel trains, and lenses and pockets of water-laid materials in the drift hills.

Stream Terraces.—North Raccoon river, throughout its entire course in Greene county, follows a somewhat winding and tortuous route between high bordering hills of Wisconsin drift. The valley, or bottoms, will average half a mile in width most of the way. The river plain is perfectly flat or has a very gentle

slope toward the river, and the bordering hills rise abruptly from its edge. In places the plain is but a deposit of alluvium covered with weeds, and is in all probability the portion which is inundated at the time of high water. At other places the surface is but little higher, and is all cultivated fields. Residents along the river state that "the whole bottom is underlain by gravel," and it is quite possible that commercial quantities of road and concrete materials could be found in many a field where there is little outward evidence of their presence.

Along the west bank of the river in sections 5 and 8 of Kendrick township there is evidence of the presence of large quantities of gravel and sand. In the bank of the stream near the middle of section 5 there are eleven feet of gravel and sand visible under a cover of alluvium some two feet in depth. The gravel rests upon clay about three or four feet above water. The bench is a quarter of a mile wide and a half or three-quarters long at this place, and the surface is almost perfectly flat. Mr. Black, the owner, says the presence of gravel has long been known and that the possibility of opening it commercially has been considered.

At the bridge in northeast 9, Kendrick township, is a broad flat bench about twenty feet above the river, and perhaps thirty or more acres in extent. No gravel is actually visible, but surface indications are favorable.

In northwest 14 and southeast 23, Kendrick township, the river road passes over similar benches, but all indications here point to the absence of gravels. Sandy soils in a cornfield on the north side of the river in southeast 30, Bristol township, would seem to indicate that gravel or sand may underlie the top dressing of alluvium.

In northwest 21 and northeast 20, Grant township, is a pit worked by the Chicago, Milwaukee & St. Paul Railway. The present exposure is poor, but there seem to be at least ten feet of dirty gravel covered by alluvium up to four or five feet in depth. To the west and northwest of the opening the bench is flat over a considerable area, and the chances seem good that this tract will still produce large quantities of usable material.

Through the south half of section 22, Grant township, the whole river bottom for a quarter of a mile back from the stream is under cultivation, and the finding of gravel in post holes and other shallow excavations over practically all of it is commonly reported. An open pit between the river and Hardin creek shows coarse, dirty, iron-stained gravel in which the granite pebbles are much iron-stained. This material has been used on the roads in the vicinity and is quite satisfactory as a surfacing material.

On the west side of the river a few rods north of the bridge in section 1 of Franklin township the river has exposed sand in its bank. The material is clean, sharp sand with some gravel, many of the pebbles being several inches in diameter. There are up to four feet of alluvial covering at the edge of the bank, and this doubtless becomes deeper away from the river.

At the bridge in section 18 of Washington township the river has uncovered fourteen feet of gravel and sand under four feet of alluvium. The material is roughly classified, dirty, and many of the granite pebbles are weathered to the point of crumbling. The river bank is strewn with pebbles up to a foot in diameter.

The bench along the west side of the river, almost the whole extent through Franklin and Washington townships, is perfectly flat, and will average a quarter of a mile or more in width. From exposures in the bank of the stream it would seem that gravel and sand might be found under all of it. That there probably is a marked variation in the character of the materials may well be inferred from the exposures in section 1, Franklin, and section 18 of Washington township. In the former place, as noted previously, the materials are fine, clean and sharp, and show no signs of age. In the latter, practically the opposite is true.

Along the county line and west of the river in sections 31 and 32, Washington township, are several remnants of a terrace about forty feet above water. What seems to be the same bench appears again just northwest of Perry, in Dallas county, but there are no indications of gravel in it.

Along both branches of Butterick creek in Hardin and Junction townships, gravel and sand are present in a few places.

The most noteworthy of these is in section 24 of Hardin township, where the Chicago and North Western Railway is now securing gravel for ballast. Here there are about fifteen feet of water-laid gravel and sand exposed under cover which varies up to six or eight feet in depth. The material is dirty and iron-stained in streaks but seems to make excellent ballast. The pit is in a bench on the west side of the river and the present face is about one-half mile in length. Enormous quantities of these materials are still available.

Other than the railroad pit just mentioned the signs of gravel along West Butterick are very meagre. The valley grows gradually narrower up the stream, and at several places the creek has cut into the bordering hills of drift and exposed faces up to twenty-five feet in height. With the exception of an occasional sand bar, the flood plain and valley bottom are composed entirely of alluvium.

The same things are true of East Butterick in its upper reaches. Gravels are not a notable feature until the creek enters section 20 of Junction township. Here, on the east side of the stream, in a bench about fifteen feet above water, coarse, dirty, iron-stained gravel is exposed in a shallow ditch beside the road. The material is quite clayey where opened and contains many pebbles up to five or six inches in diameter. As nearly as may readily be ascertained, there are upwards of ten feet of gravel available under a depth of cover which in all probability will at no place much exceed four feet. This bench was formerly worked on a large scale in east section 20, but the pit has been abandoned for some time. Large quantities of gravel are still available, however, and the old pit could easily be opened on a commercial scale.

Along the south side of the stream through section 20 several smaller pieces of this same bench may be seen, but on the north side it is entirely absent. These remnants might easily be opened on a small scale, and quantities of gravel sufficient for all needs within many miles be readily obtained. In southwest 30, also, is a remnant of what is probably the same bench. There is a small pit open here.

A few rods west of the bridge over Butterick creek in the northeast quarter of section 26, Grant township, is a small bench about eighteen feet above the creek. The stream has cut into it and exposed fine to medium grained gravel under twelve to fifteen inches of alluvium. Where exposed at the edge of the bench, the gravel is quite dirty. There are perhaps 35,000 to 40,000 yards easily available here.

In its general characteristics Hardin creek is very similar to Butterick creek. The stream flows through a flat narrow valley, and is bounded by low rolling hills of Wisconsin drift. Where the road crosses it east of Churdan, three feet of coarse, dirty, iron-stained gravel are exposed under one and a half to two feet of alluvium. The gravel rests upon yellow clay. The river bottom is perfectly flat over an area of several acres, and while there is no definite evidence of gravel under it all, yet there is doubtless sufficient for road purposes in the vicinity.

Reworked Materials.—Sand and gravel bars are quite common in the principal streams of Greene county. In Raccoon river these are especially prominent, but the varying quality of the materials composing them is such that they are used for local purposes in small quantities only. An exception to this, however, is a large bar in north 18, Grant township, now being worked by A. S. Tanner. The material in this bar is clean, sharp sand and gravel; the latter varying from twenty-five to sixty per cent of the whole. The pebbles run up to three and four inches in diameter, but the large majority are one inch or less. The gravel is removed from the river by means of a scraper bucket, screened, and hauled into Jefferson, where it is utilized in the manufacture of cement goods.

Another large bar is located at the bridge in section 18 of Washington township. Sand is hauled from this place for use in cement work over a large adjacent territory.

Along Hardin and Butterick creeks small sand bars may be seen in many places. These are especially noticeable near the mouths and in the lower reaches, although they are present more or less continuously far up the streams. As mentioned previously in connection with Raccoon river, the varying qual-

ity of material and the usual nearness of better and more dependable deposits renders them unimportant for other than small local supplies.

Glacial Deposits.—The drift hills of Greene county are quite generously supplied with deposits of sand and gravel. These are sprinkled promiscuously throughout the whole county and are used as sources of local supply in many places. North and northwest of Jefferson these gravel-bearing hills are particularly prominent and it is reported that there is hardly a section of land in this portion of the county in which gravel is not found. Pits in drift hills have been opened in Highland township in sections 27, 28, 29 and 34; in sections 19, Hardin; 30, Dawson, etc., which are typical of this class of deposits.

GRUNDY COUNTY.

Sand and Gravel.

The sand and gravel resources of Grundy county are of three classes: Buchanan gravels, sand and gravel hills in the Iowan drift area, and stream terraces.

Buchanan Gravels.—In the north half of the county sands and gravels that may be referred to the Buchanan formation without hesitation are not infrequent. They are of both the upland and valley phases (see Buchanan county report) and are usually of a character to make them valuable for use in improving the roads, though no such extensive use has been made of them for the purpose as in the adjacent counties of Butler and Black Hawk. The Buchanan gravels are always oxidized and iron-stained. The granitoid constituents are usually in a condition of advanced disintegration; the upland phase exhibiting these features in a higher degree usually than the valley phase. The topography of the county has not favored the exposure of the beds to the same extent as in adjoining counties and it is doubtful if the deposits themselves are as extensive. At and around Grundy Center, Holland and Wellsburg they are abundant but the loess covering makes access to them somewhat difficult.

*Iowan Drift Gravels.**—"Near the middle of section 8, Beaver township, is a neat conical hill rising higher than any of the surrounding elevations, which in this vicinity are relatively low. Near the middle of section 17 of the same township a cemetery has been located on a somewhat lower and broader hill. A road cuts the south slope of the latter near the base, exposing a rather fine sand somewhat oxidized and containing about 5 per cent of pebbles and an occasional cobblestone. Among the pebbles a few decayed granites and iron nodules were seen. Eight feet of this material are exposed, and there are indications that the whole elevation is made up of sand or gravel.

"Eight miles farther south in sections 30 and 31, Lincoln township, a low esker-like ridge of gravel and sand with a northwest-southeast trend, terminates abruptly in a conical hill of sand of about the same elevation as those in Beaver township. A few rods south is a smaller hill, and within two miles two or three smaller ones may be seen."

Similar kame gravels occur in other places in the county. John E. Smith, working in Grundy county in 1911, reported gravel and sand in drift hills in Washington, Lincoln, Shiloh, Beaver, Fairfield and other townships.

Terrace Gravels.—Terraces occur along many of the larger streams of the county, and have been used as sources of supply for concrete material in places. At the pit of the Grundy Center Brick and Tile Company a fine gravel, coarse in places and irregularly stratified and mixed with sand, occurs under a cover of loess and Iowan drift up to ten or twelve feet in thickness. On the farm of F. S. Fogt, one and one-half miles northwest of Reinbeck, a pit has produced several hundred loads of sand and some gravel. The section shows interbedded sand and gravel, the latter being rather fine, under several feet of loess. The owner has, however, been using material shipped from Cedar Falls in preference to his own supply.

Miscellaneous.—In the south half of the county sand and gravel are by no means common, especially in the four south-

*From Arey, Iowa Geological Survey, Vol. XX, p. 85.

west townships. Along the railroad an eighth of a mile east of Beaman, beneath three or four feet of loess, there is exposed a slope of four or five feet, the lower part of which is made up of a greenish marly clay in which are fragments of a gray-green rock. In the upper part the proportion of clay lessens; the rock fragments are of a red-brown sandstone with which are mingled pebbles and gravel. At the top gravel predominates.

Stone.

Grundy county is covered by a thick mantle of glacial debris and the only exposures of indurated rock known appear along Wolf creek near the southern border. The only quarry worthy of the name is located just south of the Chicago and North Western railway depot in Conrad, on the south bank of Wolf creek. The following section is exposed:

CONRAD SECTION.

		FEET.
5.	Drift (modified Kansan probably)	5
4.	Limestone, residual, consists chiefly of cherty concretions embedded in a matrix of greenish clay streaked and mottled with ferruginous and marly material	3
3.	Limestone, slightly oölitic, composed essentially of a shell breccia almost identical with No. 1, in the Eagle City section in Hardin county	4
2.	Limestone, hard, subcrystalline, containing numerous brachiopod casts	2
1.	Limestone, typical oölite in heavy beds; a Straparollus and a turreted form of gastropod were noted, also numerous brachiopod casts	5

The base of the section is about four feet below the Chicago and North Western railway track and 1,010 feet above tide.

The beds exposed here may be correlated with the upper oölite in the Marshall county sections exposed in the quarries at Rockton, Quarry, LeGrand and Timber creek, and also in the Eagle City section in Hardin county. The Conrad quarry has been operated more or less continuously for a number of years. The limited outcrop and rapid thickening of the drift compels one to conclude that the quarry industry will never attain much development in this vicinity.

Limestone outcrops appear on the farm of M. B. Brown, one-half mile southeast of Beaman, in Clay township. The principal

stone crops are on the south bluff of Wolf creek and continue for a distance of more than a quarter of a mile. The stripping is thin at the face of the bluff, but thickens gradually toward the upland. The beds exposed probably correspond to numbers 2 to 4 of the Conrad section. Other outcrops of limestone occur in the neighborhood. While the quality of the stone exposed is not high grade test-pitting is certainly warranted.

GUTHRIE COUNTY.

Sand and Gravel.

With the exception of the southwestern part, Guthrie county contains numerous small deposits of gravel belonging to three classes: kames, conglomerate and stream terraces. Appearances also indicate that a few large gravel deposits of the stream terrace type may be opened in places along Middle and South Raccoon rivers.

Kame Deposits.—At present most of the gravel obtained within the county comes from kames, these being accessible and easily opened. Practically all of the country north and east of Middle Raccoon river is covered by Wisconsin drift which contains these kames. The towns of Bayard and Bagley are supplied from nearby kame deposits. Kames east and north of Panora supply that town with most of its sand and gravel, although a little comes from river bars. There are a number of kames containing gravel in the northwestern part of section 24, Victory township.

Where any kame gravel has been used on the roads, it has proven satisfactory, but has not been very good for concrete work except when small clean pockets of material have been found.

Conglomerate.—The conglomerate consists mainly of quartz pebbles about hazelnut size, with small greenstone and limestone pebbles of about the same size. The whole is very much iron-stained, far too much so for good cement work. Gravel to be used for that purpose must be shipped in, usually coming from Commerce or Des Moines. In no place does the conglomerate

occur as uncemented pebbles, though it can usually be picked down. Still, in some places, it must be blasted out, but the cementing material is so weak that this is neither difficult nor costly. The conglomerate is found in many places in a district

FIG. 36—Dakota conglomerate near Glendon, Guthrie county.

about six to ten miles wide and extending from the northwest corner of the county nearly to the southeast corner, and including both Raccoon rivers. It underlies a brown, rotten sandstone which extends over the area mapped by H. F. Bain as Dakota. Sometimes the conglomerate is found directly beneath the soil, as in the northwest part of section 33, Victory township. A pit in the southeastern part of Guthrie Center has about ten feet of the conglomerate under as much sandstone and drift. There are five to ten acres of conglomerate eight feet thick in section 22 of Valley township. The conglomerate here has little or no cover at any place. There are other places nearby where the conglomerate might be found if a little prospecting were done, as along the middle of the east side of this same section. There are at least ten and probably twenty-five feet of the conglomerate in the northern part of section 30, Jackson township. This might possibly prove sufficient to furnish a shipping supply of gravel.

Stream Terraces.—While stream terraces along the two Raccoon rivers do not furnish much sand or gravel at present, yet when opened up they may become the principal sources of supply of these materials. There are eight feet of gravel under one to three feet of alluvium in section 2, Orange township. The area is small. There are twenty to forty acres in section 20, Highland township, that show gravel and sand under two feet of alluvium. No more can be said on account of poor exposures, except that the Chicago, Milwaukee & St. Paul Railway Company prospected it. There is a big flat some ten to fifteen acres in extent and forty-five feet above the Middle Raccoon in the northern part of section 15, Victory township, that looks like a terrace. There is no reliable exposure, but small pebbles are plentiful and the corn on the flat was badly fired. The drainage is good enough to warrant prospecting for gravel. There is an area of thirty or forty acres in the southwest corner of section 31, Cass township, that looks like a remnant of a high terrace. A deep cut along the road shows from ten to fifteen feet of gravel and sand overlain by two feet of alluvium. The Chicago, Rock Island & Pacific Railway Company has prospected an area of about forty acres in section 19, Jackson township. The owner said they found from seventeen to twenty-one feet of fine gravel. The alluvium cover is three feet or less. An advantage of this place is that it would not be difficult to build a railroad to it. There are a number of parched hills on the north side of the South Raccoon between here and Dale City that probably contain gravel.

Stone.

Suitable material for building purposes is to be had from the Missouri, in Guthrie county. Strata belonging to this stage are known to be present over about one-third of Beaver township and to occupy essentially the whole of Penn in the southeast corner of the county. This stage is represented by the Fragmental and Earlham limestones of the Bethany and by a portion of the Winterset section. Those rocks appear along the lower portion of Beaver creek, Deer creek, Long Branch and South

Raccoon river, in ledges varying from six to twenty-four inches in thickness and separated by shaly or clayey partings. The following typical section, taken from the *Geology of Madison County,** will serve to show the nature and succession of the beds. It is taken from along Deer creek, section 19, Penn township. Good exposures are lacking as the stone has not been quarried extensively at any point.

		FEET.
5.	Limestone, coarse, gray; with Fusulina similar to that occurring at Winterset	2
4.	Shales, exposed only in part	8
3.	Earlham limestone, ash-gray, with conchoidal fracture, in layers two to ten inches thick, separated by shale partings	12
2.	Shale, gray, argillaceous, becoming bituminous and slaty at the top	10
1.	Limestone, fragmental, made up of irregular bits of limerock filled in with calcareous clay. In places the rock can be picked to pieces with the fingers; elsewhere it hardens up into massive layers two feet in thickness....	10

The lowest member of this section rests on sandy shales which form the top of the Des Moines stage. Ten to thirty feet of loess and drift overlie the exposures along Deer creek, and wherever the beds appear along the other streams mentioned they are also invariably buried beneath a heavy mantle of the same material.

The Des Moines strata furnish some sandstone and limestone that are found of service locally in the eastern part of Guthrie county. A gray sandstone belonging to the Coal Measures has been quarried on a small scale at Panora. The usable beds of this stage are thin and so associated with argillaceous strata that they are very seldom worked for building stone alone.

Suitable materials for building purposes are to be had from the Cretaceous strata, which supply unlimited quantities of sandstone and which are available over the western two-thirds of the county. These are, however, fit for local rough work only, as they are in general but partially consolidated and will endure neither much handling nor shaping. The sandstone has been quarried on a small scale at many points in the county, particularly along the Raccoon and its branches in the vicinity of Glen-

*J. L. Tilton and H. F. Bain, Iowa Geological Survey, Vol. VII, p. 448.

don, in Beaver township. Both the conglomerate and sandstone are quite commonly employed in foundations for farm buildings. The sandstones are, as a rule, not of suitable quality for road and concrete materials.

HAMILTON COUNTY.

Sand and Gravel.

The sand and gravel deposits of Hamilton county are to be found in the kames and eskers of the Wisconsin drift and as terraces and bars along the principal streams.

Wisconsin Drift Gravels.—Hamilton county lies wholly within the Wisconsin drift area. The general surface is the typical prairie plain and is but slightly stream dissected. Chains of hillocks abound in various portions of the county, e. g., in and around Jewell Junction. Many of these hills are gravel bearing, and have been opened for road and concrete materials. One and one-half miles southeast of Kamrar, in the northwest quarter of section 1, Hamilton township, is a kame about forty feet high and covering some two acres. This kame exhibits three to five feet of fine to coarse gravel with sand and bowlders under twelve to fifteen feet of soil, sand, silt and clay. All of the beds are variable in thickness, position and extent. This opening is a fair illustration of the gravels of this type which may be found in similar positions throughout the county.

Terraces.—Between the brick and tile works and the pumping station in Webster City is a pit in the Boone river terrace. In this pit are exposed some ten or eleven feet of sand and gravel with thin horizontal layers of blue shale and yellow clay. Benches are to be seen along the courses of both Boone and Skunk rivers, but they are not continuous and are of limited extent.

Other River Gravels.—Along Boone river south of Webster City is a large deposit. Northwest of town there are bars in both the old and present channels of the stream, but these rarely exceed one acre in extent. Gravel has been shipped from here.

On the flood plain of Boone river northwest of Webster City, Mr. Wilke has opened a bed showing cross-bedded sand and gravel under one or two feet of soil. Sand is also found along Skunk river near Randall.

STONE.

The Saint Louis limestone comprises the only available beds in the county which are sufficiently indurated to be used for structural purposes. On account of the distribution of the Coal Measures over almost the entire county and the great thickness of the drift, exposures are limited to the vicinity of Boone river and its immediate tributaries from a short distance above Webster City, to section 31 in Independence township. Along a small creek which flows into Boone river just below the mill in Webster City, a quarry has been opened and operated more or less continuously for a number of years. The section which can be made out is as follows:

SWANSON QUARRY

		FEET.
5.	Loam and drift	2+
4.	Sandstone, clayey, fissile, ash-gray in color	2
3.	Limestone, impure, thinly bedded, much weathered, in places altered to a calcareous, arenaceous clay	4
2.	Limestone in fairly heavy beds, with occasional quartz geodes	4-5+
1.	Sandstone, light colored, somewhat friable but in places hard enough to be used for structural purposes, exposed	4

Number 2 constitutes the principal quarry rock, and was formerly much used locally, and is practically the only native stone available for structural purposes. It is fairly pure limestone, of fine, even texture, varying from a gray to a yellowish buff. It shatters when subjected to changes of temperature when wet, but gives good service when put in the wall dry. The upper members exposed are rather inconstant and in places are absent, the drift here resting directly on number 2.

While similar sections are exposed both up and down the river from the Swanson quarry, the excessive overburden, the small thickness and the indifferent quality of the beds make quarrying on a commercial scale impossible.

The phase of the Saint Louis exposed in Hamilton county closely resembles its development in Story county and probably represents the Verdi substage, which is typically exposed from Marion to Washington counties.

HANCOCK COUNTY.

Sand and Gravel.

Hancock county is abundantly supplied with sand and gravel. The county lies entirely within the area of the Wisconsin drift. The gravels occur as stream terraces, the materials of which were deposited by the waters from the melting glacier, and as pockets within the hills of drift themselves. Sand beds and bars occur in small amount in the streams, but are of little economic importance.

Stream Terraces.—Gravel terraces are present along both branches of Iowa river, except in the upper courses. Above Garner no terrace is evident along the East Branch, but the wide bottoms of the stream consist largely of sand and gravel.

An indistinct terrace about twenty feet above water occurs along East Branch in the northern part of section 12, German township. There are no actual openings in this bench, but a small pit in the northeastern part of section 11, along a tributary of the East Branch shows:

	FEET.
Pebbly soil	2
Gravel, mostly less than one inch in diameter; large percentage of lime pebbles; little iron-stained, and contains coarse sand	3
Sand, exposed	4

The town of Klemme is supplied from a pit in the southern part of section 35, German township. There are at least ten feet of gravel under about two feet of alluvium here. One peculiarity of this pit is the bedding, which is unusually persistent and distinct. The terrace in which this pit occurs has an area of perhaps ten acres. In sections 9, 20 and 29 of Avery township, the terrace has been extensively developed. Some of the remnants are as much as forty and fifty acres in extent, and the width is commonly 400 or 500 feet. There are few if any

good exposures; perhaps the best one is in the southwestern part of the last named section. Here twelve or fifteen feet of sand and gravel are exposed. The town of Goodell obtains its supply from this pit.

The West Branch of the Iowa is similar to the East Branch in all of the essentials and most of the details. A twenty-foot terrace appears in the southern part of section 28, Twin Lake township. This seems to be composed largely of fine gravel rich in limestone pebbles. From this place to the county line the terrace is not so well developed as on the East Branch, but is found in various places. A notable example is in the western part of section 35, Twin Lake township. A mixture of sand and fine gravel similar to that found in the East Branch has been taken from the channel.

Gravel deposits are also to be found intermittently along the course of Lime creek. The Rock Island Railway Company has removed large quantities of it from a point about two miles south of Forest City. In section 1 of Madison township gravel is taken from a terrace along the creek and is used in the manufacture of cement tile. Some of this material has been used on the roads in the vicinity. A pit in the next section south shows fine gravel containing a high percentage of limestone pebbles. The depth of the cover does not exceed two feet. Along the creek in Ellington township a terrace about eighteen feet above water may be seen in several places. In section 16 at least six feet of sand and gravel are inter- and cross-bedded. The deposit is clean, and some of the material has been used in concrete and cement work. In the eastern part of section 23 the terrace is about a quarter of a mile wide.

Kames.—Kames are particularly abundant in the northeastern part of the county. There is a large one in section 27 of Ellington township, in which the gravel is rather dirty. In sections 9, 10 and 11 of Madison township is a series of kames, the material from which has been used on the roads with satisfactory results.

HARDIN COUNTY.

Sand and Gravel.

The sand and gravel deposits of Hardin county that are of any economic importance are all of Wisconsin age and include stream terraces and deposits of water-laid materials in the drift hills. Buchanan gravels are known to be present, but available outcrops are so few as to be commercially unimportant.

Stream Terraces.—All of the principal streams of the county flow from the Wisconsin drift plain, and all exhibit one or more series of gravel terraces. The greatest of the gravel trains is genetically related to and has its source at the Gary moraine. This terrace is best seen in the vicinity of Gifford, along both the South Fork and the Iowa proper. The bench along South Fork rises from twenty feet at Gifford to nearly thirty to the westward above the flood plain of the present stream. The gravels are coarsest above and show more or less evident but interrupted stratification planes throughout. The bedding is at all conceivable angles. The gravels vary from fifteen to twenty feet in thickness and rest upon a basement of bowlder clay, the top of which rises from five to twenty feet above low water level. On the Iowa proper the materials are much coarser, indicating a higher gradient, but the bench is much narrower and more fragmentary on account of the gorgelike character of the valley. Steamboat Rock is built principally upon this bench, which is fifty feet above the flood plain. Terraces referable to this system may be found along the two leading tributaries of South Fork, and also along Honey creek. Below the junction of South Fork with the Iowa the Gary terrace continues but fades out toward the Marshall county line.

Fragmentary terraces above the Gary are present along the Iowa, but are of little importance. A terrace below the Gary may be noted along Iowa river, South Fork and Tipton creeks, in which the streams of today are engaged in cutting. It rises from five to fifteen feet above the present flood plain. The Iowa Central railway has sought it out for a roadbed below Steamboat Rock.

These terraces have been utilized as sources of sand and gravel in many places. At Gifford and vicinity both the Chicago & North Western and the Minneapolis & St. Louis Railways operate pits, and private pits are also being developed. From twenty to twenty-seven feet of gravels are available. The material is comparatively free from clay, silt and other impurities, but runs rather low in gravel. The material in the railroad pits is handled with steam shovels, and the smaller pits load by hand into wagons and thence into cars.

Morainal Gravels.—A large part of the surface of Hardin county was overrun by the Wisconsin ice, the Altamont moraine crossing the county from Providence to Aetna townships. West of the Altamont, at least two recessional moraines may be made out within the limits of the county, marking temporary halts in the retreat of the ice. Many of the morainal hills contain gravel and sand as cappings upon or pockets within the drift, the latter being widely variable both in quantity and quality.

Aside from the moraines numerous sand and bowlder knobs rise above the general level and tend to break the monotony of the drift plain. These prominences are most numerous in the immediate vicinity of the morainal tracts, but are widely distributed over the intramorainal areas. In certain instances the constituent sands and gravels show stratification planes evidently due to running water. One of the most conspicuous groups of these hills may be observed south of School creek in sections 15 and 16 in Hardin township.

Reworked Materials.—All of the streams furnish an abundance of sand, either in their terraces or in their channels, suitable for building purposes.

Buchanan Gravels.—Deposits referable to the Buchanan are present but not conspicuous. In the loess-Kansas area, which includes all of Union, most of Eldora and parts of Providence and Clay townships, the loess is usually separated from the drift by a more or less constant gravel layer. This deposit is usually rather deeply buried and is not readily available as a source of supply.

STONE.

While the Kinderhook beds are supposed to comprise the country rock over a considerable portion of the surface in Hardin county, good exposures are confined to the immediate vicinity of Iowa river from Gifford south to the county line, and from Eagle City to Alden. Quarries have been opened at several points, notably at Gifford, Eagle City, Iowa Falls and Alden. Only those at the two latter places are, or promise to be, of more than local importance. The beds exposed exhibit two well marked facies; an upper brown, earthy to sugary dolomite, and a lower white to gray limestone. The latter often contains layers semioölitic in character above and argillaceous to arenaceous below. At Iowa Falls there appears to be a decided arching up of the strata and a maximum section of eighty feet is exposed in the river gorge. The limestone beds are known to rest on shales or arenaceous shales believed to be continuous with those which outcrop along Mississippi river at Burlington and which underlie the limestone series in Marshall county. The section exposed along the river and along Rocky run, its leading tributary, at Iowa Falls, is given below and comprises one of the most important Kinderhook sections in central Iowa.

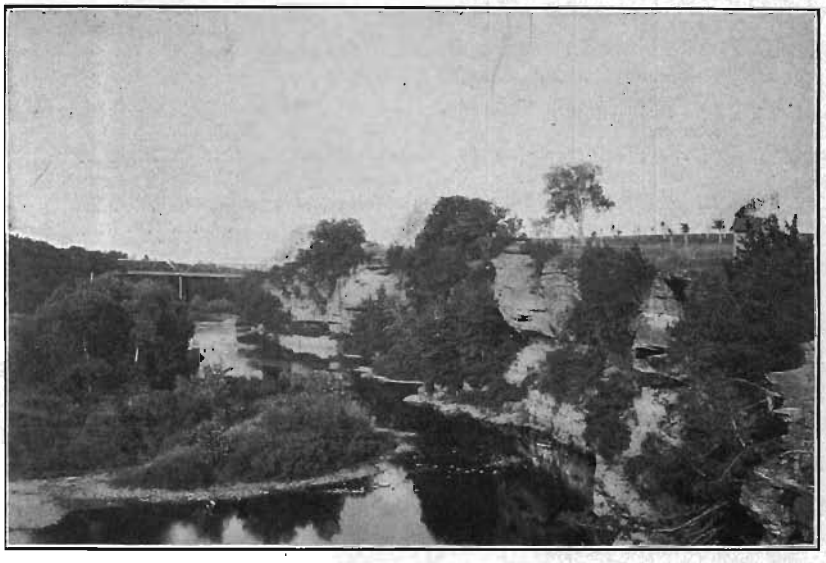


FIG. 37—Iowa river gorge, Iowa Falls, showing the Kinderhook limestone, Hardin county.

IOWA FALLS SECTION.

		FEET.
6.	Drift, reduced to a heterogeneous mixture of bowlders and fragments of country rock at the face of the escarpment but thickening greatly in the bluffs. Considerable areas are practically without a drift covering	0-80
5.	Dolomite, brown, saccharoidal, heavy-bedded below, but thinner bedded and much shattered above; often exhibits an earthy fracture when weathered. Numerous casts of *Straparollus obtusus* present in places	20-30
4.	Limestone, light gray, composed largely of shell breccia and containing a brachiopod fauna; has a mealy appearance, but on close inspection is found to be but slightly oölitic	5
3.	Limestone, gray-brown, is finer textured, more compact and evenly bedded than the above	3
2.	Limestone, light gray; weathers white and so appears in the gorge walls, exhibits a conchoidal fracture and is heavy-bedded	5
1.	Limestone, shaly to slightly arenaceous in certain layers, in places forms a slight reëntrant in the cliff walls; exposed above the water level	5-10

The most important quarries are situated east of town on the river. The Ellsworth Stone Company is operating a quarry on the northeast side of the river, which was formerly known as the Biggs quarry. The sequence of beds is as follows:

THE ELLSWORTH STONE COMPANY'S QUARRY SECTION.

		FEET.
6.	Drift, very thin; consists chiefly of a bowldery gravel	0-3
5.	Dolomite, brownish buff, much weathered in places and presents an arenaceous or earthy facies	4
4.	Limestone, white, oölitic, fossiliferous	6
3.	Limestone, blue, compact, of firm texture and very brittle	1
2.	Limestone, white, lower three feet very compact and brittle; fracture conchoidal to uneven, contains numerous blebs of crystalline calcite; almost lithographic in texture	5
1.	Limestone, gray, dolomitic, very slightly arenaceous to argillaceous, exposed	5

The usual method of quarrying is to drill deep holes vertically nearly parallel to the face of the cliff, and then to use heavy charges of explosives to shoot loose the ledges. An ordinary churn drill is used with a traction engine for power. This leads to great shattering, and scarcely more than thirty per cent of the entire section can be used for dimension stone. A large proportion of the remainder was formerly considered to be waste material and was thrown into the river. This was true not only of the quarries here, but of those near Alden. At the present time a

large crusher of the Gates type has been installed and the entire assemblage of beds is utilized. In fact, dimension stone and rubble stone are only incidental products in the production of the various grades of crushed stone.

Southwest of the Ellsworth plant, on the opposite side of the river where it turns toward the east, the Barber Asphalt Company has opened a quarry and installed a modern crusher plant. The beds developed are similar to those in the preceding section, but higher in the series. The principal part of the section being developed at the present time consists of earthy dolomite which affords an inferior grade of crushed stone.

West of Iowa Falls the Lower Carboniferous rocks are much more rifted and shattered than to the eastward, and the limestone layers become subcrystalline in texture. The stone takes a good polish, possesses a pleasing color, and if large blocks could be obtained, the rock would possess great value for ornamental and structural purposes. Unfortunate it is that the same agency which produced the partially crystalline structure, so essential in marbles, was also responsible for the shattering and rifting of the beds. In fact the marbleization was rather a result of the rough usage to which the beds were subjected. The beds continue shattered and subcrystalline in texture to the point of their disappearance beneath the drift at Alden. Formerly the Ivanhoe Quarry Company put in a steam crusher and operated quite extensively near the Chicago and North Western railway tracks on section 16, in Hardin township. The building containing the machinery burned down, and the plant has long since been dismantled and abandoned. The beds exposed at this point are as follows.

IVANHOE SECTION.

		FEET.
3.	Drift (of great depth in the bluff)	0-3
2.	Limestone, grayish white, subcrystalline, very hard and much shattered; thinly bedded	20
	Apparently a local unconformity.	
1.	Limestone, much disintegrated and cavernous. In places a residual clay appears between 1 and 2. Surface very uneven, exposed	6

Westward from the Ivanhoe quarries to Alden the river flows between low limestone walls varying from ten to thirty feet in

height. These limestone barriers are almost cut out in one or two places by Coal Measure outliers. In Alden the beds greatly resemble a portion of the Ivanhoe section. The beds are as follows:

ALDEN SECTION.

		FEET.
3.	Drift, as in previous sections, is thin at the face of the scarp; a number of large granitic bowlders were noted...	3
2.	Limestone more or less evenly bedded, appears to be lithologically the same as No. 1; a marly or shaly band separates 1 and 2 generally.....	12
1.	Limestone, light gray, hard, subcrystalline and oölitic in texture. The lower four feet show marked cross-bedding; false beds dip to the southwest; the upper surface is somewhat undulating and dips gently to the south.....	5

Here, as in the preceding exposures, the beds are much rifted and shattered. Individual layers rarely exceed four or five inches in thickness, and two well developed series of fissures are visible. The fissures of the major series trend north and south and are apparently parallel to the corrugations, while those of the minor series stand approximately at right angles to the folds. Genetically the two series probably form but one great system and were formed at the time of rock crushing.

North of Alden, the indurated rocks dip rapidly and were not observed beyond the corporate limits of the town.

Eastward of the Falls limestone ledges are more or less continually present to Eagle City where the following section is exposed:

		FEET.
5.	Drift, exposed	5-10
4.	Dolomite, yellowish brown, much shattered where viewed; contains a few siliceous nodules.....10-25	
3.	Limestone, gray, subcrystalline and semioölitic.....	1½
2.	Dolomite, yellow to gray, sugary.....	3
1.	Limestone, gray, oölitic; very similar to the Bedford oölite in texture, and also to the oölite exposed at Conrad, in Grundy county	4

The base of the section is about five feet above low water in the river. These indurated beds support a bench which rises forty or fifty feet above water level and continues some distance on either side of the wagon bridge. Beyond Eagle City the beds disappear rapidly and the surface outcrops of the Kinderhook beds are almost entirely obscured by glacial debris and Coal

Measure talus. At Hardin City, Steamboat Rock and one or two points between, No. 4 of the Eagle City section is visible and rises some six or eight feet above the water level. In all cases it is greatly weathered and shattered, making its identity difficult to establish. Between Steamboat Rock and Eldora, the Lower Carboniferous passes entirely below the stream channel, but rises again immediately south of the wagon road bridge at Eldora. Going down stream from the Eldora bridge a weathered dolomite appears in the stream-bed and also in the right bank about sixty rods below the road crossing. The ledges rise eight feet above the water and appear to be identical, both lithologically and faunally, with the upper member at Iowa Falls. These beds appear more or less interruptedly from this point to Union, forming low benches on one or both sides of the river. At Xenia, and again between Gifford and Union, the white limestone member is visible. The maximum exposure is south of Gifford, near a small stream which enters the Iowa from the west. The beds exposed to view are:

		FEET.
4.	Drift and wash	0-3
3.	Limestone, light gray; white when weathered	0-3
2.	Dolomite, yellowish brown, much shattered and unevenly bedded	6-8
1.	Dolomite, red-brown, heavy but unevenly bedded, exposed	4-6

Numbers 1 and 2 are, in a sense, complementary. Where one thins the other thickens and the two aggregate twelve feet exposed. Not the slightest trace of organic remains could be found. Southward and southeastward the beds are cut out within 100 yards by the Coal Measure shales only to come into view again a quarter of a mile down the branch on the terrace of the Iowa. Beyond Union the Kinderhook beds are carried below the river, but reappear west of Liscomb in Marshall county.

In Hardin county the Coal Measures are represented by an upper heavy-bedded, ferruginous sandstone which often presents conglomeratic to concretionary facies and is cross-bedded throughout; and by a lower shale which carries some coal and often contains highly calcareous, fossiliferous ledges. The main body of the sandstone is dissected by Iowa river, which forms

a gorge extending from Xenia to Steamboat Rock. The sandstone reaches its maximum development in the vicinity of Eldora where it attains a thickness of eighty feet. The Eldora section is as follows:

ELDORA SECTION.

		FEET.
7.	Drift (on the face of the scarp)	0-3
6.	Sandstone, weathered and shattered; ferruginous, conglomeratic and concretionary; quartz pebbles ranging up to a third of an inch are common. False bedded throughout; some fossil wood fragments present	40
5.	Sandstone, heavy-bedded	10
4.	Talus slope	20
3.	Shale, carbonaceous	1
2.	Shale, light colored above and variegated below	20
1.	Kinderhook limestone (top about ten feet above the water level)	6

The Eldora sandstone has been used to a certain extent in the foundations of numerous structures in and about Steamboat Rock, Eldora and Xenia, but at the present time none of the quarries are operated, save intermittently and then only on a small scale. The stone is extremely variable in texture, structure, and state of induration, and these factors, taken with its dark red-brown to yellow-brown color, make it certain that it never will be popular as a structural material. Vast quantities are available and easily accessible, and when the stone is carefully selected it gives good service in the less imposing structures. Its use might be safely and profitably extended in backing walls faced with more expensive materials.

HARRISON COUNTY.

Sand and Gravel.

There are few counties in the state which equal Harrison and Monona in the quality and abundance of road materials. The coarser gravels and the impure beds of the Aftonian, in which silt, sand and gravel are mingled, are admirably adapted to such uses, and their wide distribution makes them available in all the territory within or adjacent to the uplands. The loess bluffs and hills, together with the belts of exposed Kansan, furnish an abundance of material for building up roads across

the lowlands, and the sand and gravel may be used for a top dressing.

Aftonian Gravels.—In order that the occurrence and general features of the Aftonian gravels may be understood, a general section of the surficial deposits of the county may well be incorporated here. Professor Shimek*, in his report on Harrison and Monona counties in 1909, gives the following section as typical of the relations existing between the various formations composing the Quaternary system in these counties:

7. A yellow loess, light in both color and texture, probably post-Wisconsin, found chiefly on the bluffs bordering the Missouri valley and valleys of larger tributaries. Usually blends more or less with (6).
6. A yellow, rather heavy loess, probably post-Iowan, blending with (7), but sharply defined from (5).
5. A bluish gray, compact, post-Kansan loess.
4. The Loveland, a heavy joint clay, usually reddish, evidently closely associated with the close of the Kansan, reaching a thickness of at least 40 feet.
3. Kansan drift, very variable in thickness.
2. Aftonian gravel, sand and silt, up to 40 feet in thickness.
1. Nebraskan drift (pre-Kansan) which is not fully revealed in sections, being largely buried under other deposits.

In structure and composition the Aftonian of this region varies within well defined limits. It consists of gravel, sand and fine silt, variously interbedded and cross-bedded, and evidently deposited by currents of different velocities.

The gravel and sand are variously disposed. Sometimes the gravel is at the very base of the deposit, as in the Peckenpaugh section; again it forms the uppermost part, as in a portion of the county line exposure; or it is intermediate between beds of sand, as in the Cox pit; or it is irregularly interbedded with sand, as in parts of the county line exposure, Peyton pit, etc.

In several sections fine sand only was exposed, but as the sections were not complete it is probable that gravel occurs in the deeper parts. Both sands and gravels vary in coarseness and in degree of intermixing. The gravel beds commonly contain pebbles and bowlders up to four inches in diameter; and rarely very large bowlders of Sioux quartzite or granite occur. The

*Iowa Geological Survey, Volume XX, p. 273.

sand and finer gravel frequently interbed and cross-bed and the wedges and strata of sand are often sharply set off by lines of fine gravel. The wedges and strata are of all degrees of coarseness, and vary in color. Beds of almost pure white sand occur, as in the Cox or Peyton pits; or the gravel and sand are stained with iron oxide, the stain sometimes permeating the entire wedge or stratum, or merely marking its limits with a more or less distinct line; or there is a similar black discoloration due to manganese dioxide (MnO_2) which occurs uniformly in greater or lesser quantity in all the sections examined. Some variation in color is also due to the different materials which compose the sand and gravel. Dark colored pebbles and bowlders, such as occur in both the Nebraskan and Kansan drifts, are common, but there is a preponderance of rather light colored materials.

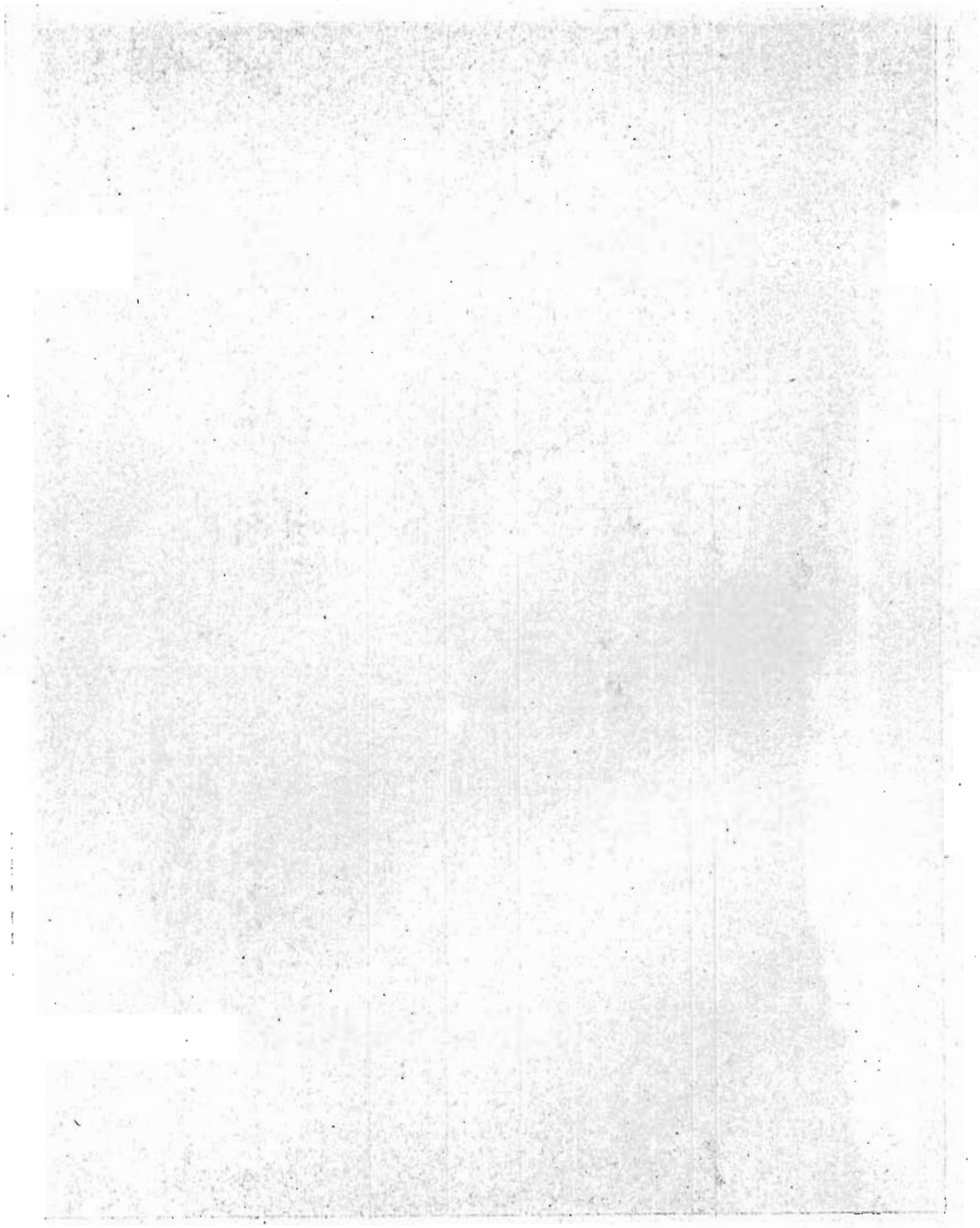
The finer sands contain rather small, very soft, chalky, pure white, usually rounded calcareous nodules; and calcareous nodular plates usually two to four inches in thickness frequently separate the Aftonian from the Kansan.

Occasionally more or less cylindrical masses of silt or sand penetrate the gravel beds irregularly in the upper portions of the formation. These were evidently formed by silt and sand being carried down by water into cavities formed upon the decay of roots and plants. They appear in cross section as round spots.

The following series of descriptions of various openings is taken from Shimek's report. The system of numbering is purely arbitrary, and in its entirety covers both Harrison and Monona counties. Classified by townships in Harrison county, the descriptions here listed are:

St. Johns	No. 1, 17
Washington	18
Jefferson	2
Raglan	3
Boyer	20
Douglas	19
Jackson	6, 7
Little Sioux	4, 5, 21

PLATE XXII—Cox pit, showing rather heavy stripping and variable sands and gravels interbedded. Missouri Valley, Harrison county.



1. Cox Pit.—On Boyer bluffs in northeast 24, St. Johns, two miles southeast from Missouri Valley. Pit shows the following section:

		FEET.
1.	Aftonian:	
	Sand, varying in coarseness, beautifully cross-bedded...	21
	Gravel, light colored, cross-bedded, with small bowlders..	6-8
	Gravel, dark colored, much MnO_2.....	6-8
	Fine bluish silt.....	½
	White sand, penetrated	5

About thirty-three rods east of the pit, at Mr. P. R. Cox's house, and about one hundred feet above the valley, a well section showed forty feet of yellow clay and blue joint clay, below which a great bed of sand and gravel was penetrated to a depth of eighty-seven feet. Just south of the road and south of the Cox pit on the same slope is the abandoned Diehl pit.

2. Peckenpaugh Sections.—Located on the east side of Boyer river near the mill dam, Logan. The section shows:

		FEET.
4.	Loess and soil	20
3.	Loveland, reddish, somewhat sandy.....	6
2.	Aftonian:	
	Sand, cross-bedded	7
	Coarse ferruginous gravel.....	2
1.	Missouri limestone, exposed	4

A well located just opposite the dam showed approximately the same section. A sand pit, excavated at the level of the road showed:

		FEET.
2.	Aftonian:	
	Sand and fine gravel.....	9-12
	Fine silt, about.....	1
	Coarse ferruginous gravel.....	1½
1.	Missouri limestone.	

3. Robinson Pit.—Located in the southwest quarter of section 16, Raglan township. Shows typical Aftonian section with Kansan drift, Loveland joint clay and loess above. The Aftonian rises to a height of forty feet above the valley and is sharply separated from the Kansan by an oxidized band and by large nodular calcareous plates. It contains very little silt, but is made up chiefly of sand and gravel of the usual Aftonian type.

4. Wallace Pit.—In the bluffs of Little Sioux-Missouri valley just north of Sol. Smith lake in northwest 31, Little Sioux. Section is cut into the edge of a narrow bench, and shows that these benches are not ordinary river terraces but exhibit the usual structure of the uplands. It faces the great valley and shows:

4-3-2. Loess, Loveland and Kansan till respectively.
1. Aftonian, exhibiting two distinct phases:
   a. Mixed and interstratified sand and silt, 15 feet. Silt is yellow, and sand very fine.
   b. Fine and coarse sand, and fine gravel, variously interstratified and cross-bedded, containing the usual soft calcareous concretions and plates of sand and iron oxide. Lower part covered with talus.

About sixty yards south of this pit Mr. Wallace opened another, and found the upper Aftonian sand and silt layer reduced to about one foot, and below a bed of gravel sixteen to eighteen feet in thickness.

5. County Line Exposure.—This is a section made by a road cut along the Little Sioux in the north half of section 5, Little Sioux, less than one-half mile south of the Monona-Harrison line. The road here is about twenty-five feet above Little Sioux and parallel to it. Three cuts appear in close proximity, making an almost continuous section more than 500 feet in length. The southmost cut is the best, and shows:

	FEET.
5-4-3. Loess, Loveland and Kansan, respectively.	
2. Aftonian:	
Fine whitish silt, about	15
Fine silt, mixed with sand, shell-bearing	5
Coarse gravel, very ferruginous	7-10
Fine cross-bedded sand	6-12
1. Nebraskan drift, exposed	10

The Aftonian is more or less variable in the distribution of its materials. In some parts fine silt appears above, and the sand and gravel are variously disposed. However, they show the characteristic structure already noted, and are typical. Large slabs or blocks of sand-conglomerate are found in the sand beds. At no point do all of the several parts of this formation appear together, the total exposure at any one point being about twenty feet.

6. Peyton Pit.—Located in northeast 23, Jackson township. The Aftonian here rises about forty feet above Soldier river bottom, but with beds and wedges of gravel, and presents all the characters of typical Aftonian. Near the base of the section a bed of white sand six to eight feet thick appears, and just above it, in sand and gravel, a Sioux quartzite bowlder measuring 4x2x1½ feet was found. Mr. Peyton reports a dark blue clay under the sand and gravel.

7. Sand Pit in Northwest 26, Jackson Township.—This is located south of the creek and east of the wagon road, and is only a few feet above the creek bottoms. Shows two or three feet of typical Kansan lying over six to eight feet of mixed sand and Kansan, and below this an exposure of five feet of Aftonian sand.

17. McGavern Pit.—Located south of Missouri Valley in southeast 27, St. Johns, on a rounded point formed by the Mis-

FIG. 38—McGavern pit, showing variability of the Aftonian gravels, Missouri Valley, Harrison county.

souri and Boyer valleys, on the south side of the latter. About eighteen feet are exposed, of which about three feet in the upper portion are a horizontal bed of cross-bedded sand and gravel, overlain by about eight feet of sand. The whole series has been distorted by action of Kansan ice.

18. Persia Pit.—In the west bluff of Mosquito creek one block south of the Chicago, Milwaukee & Saint Paul depot at Persia, Washington township. This is an old sand pit about twenty-five feet above the valley. It is an irregular mass of Kansan till containing numerous pockets of sand, some of which are so large that they have been worked as sand pits.

19. Mefford Pit.—In southeast 31, Douglas, on the south side of a small creek. The Aftonian is exposed to a depth of ten feet, and consists of sand which passes below into fine gravel. This is typical cross-bedded Aftonian, with ferruginous and MnO_2 stains, and is separated from the Kansan by calcareous nodular plates. Outcrops of Kansan and Aftonian occur a few rods farther down the creek.

20. Sand Pit in Northeast 28, Boyer, Two and One-half Miles Southeast of Woodbine.—Here there are Aftonian gravel and sand beds variously folded and twisted and containing bowlders of silt covered with a calcareous deposit.

21. Murray Hill Section.—In southeast 8, Little Sioux. Exposed in part by the road which ascends the hill. The section is of great interest because it shows Aftonian sand and gravel piled up to a height of at least 120 feet above the valley. That part displaying the Aftonian follows the road for a distance of more than 800 feet. A sand pit eighty-five feet above the valley shows:

3. Kansan drift, 6 feet.
2. Aftonian, sand 8 feet above, gravel 6 feet below.
1. Nebraskan drift.

The lower or western part shows a mass of sand and gravel which seems to be standing almost on edge.

Also the following exposures have been noted; sand pit near the middle of the west line of 10, St. Johns; John Hull pit in northwest 3, LaGrange; Fred Mefford pit in southeast 28, Douglas; Tuttle pit in southwest 24, and sand pit in northeast 28, Boyer; Jardine pit, north of Robinson pit, and Hagerman pit south of Robinson pit in 16, Raglan; an irregular exposure along the road between 17 and 18, and a similar one north of the county line exposure on the north line of 3, Jackson township.

Miscellaneous Deposits.—Sand bars are quite plentiful along Missouri river. The channel is winding and tortuous, and the open waterway is continually shifting with the change in position of these beds of sand. The material in the bars is largely quicksand of a highly variable quality, and but few of the beds are readily accessible. While they are not at present used to any extent, future years may see large quantities of a commercial product derived from them by the process of pumping and washing.

Over the broad flats stretching back from the Missouri are many sandy tracts, probably islands and bars in some former channel of the stream. Sand dunes composed of wind-swept material derived from the river to the west are also plentiful. The largest of these dune areas is located near the Blair railway bridge west of California Junction.

STONE.

Exposures of formations older than the Pleistocene are found in Harrison county at a few points along Boyer river. At Logan, both above and below the mill, limestone has been quarried at the east side of the river valley. Some six miles farther up the river, and two miles below the town of Woodbine, considerable stone is said to have been quarried in the left bank of the Boyer.* The strata are prevailingly limestone, and belong to the Missouri stage of the Upper Carboniferous. So far as known, they are the most northern exposures of these measures in Iowa.

*C. A. White, Geology of Iowa, Vol. II, 1870, p. 180.

No stone is now taken out at either of these localities, and the old quarry faces are greatly obscured by rock debris. The following section is in view just above the mill and across the river from the town of Logan:

		FEET.
5.	Loess, passing into sands below	40+
4.	Sand, containing coarse gravel and bowlders of a variety of igneous types, plainly Pleistocene	1½
3.	Limestone, decayed above, and splitting irregularly along bedding planes; color buff, contains much crystalline calcite, and is fossiliferous. *Productus longispinus*, *P. costatus* and *Spirifer cameratus* are abundant. Ledges are but a few inches thick, and but small blocks can be obtained	1
2.	Limestone, coarse in texture, composed largely of a shell breccia. *Spirifer cameratus*, *Athyris subtilita* and crinoids are common. Badly weathered and iron-stained in places, the iron frequently distributed in concentric bands, giving the appearance of a sandstone; occasional nodules of both light and dark chert	½-⅔
1.	Limestone, gray to blue, splitting in ledges a few inches thick; highly fossiliferous; said to extend down several feet. Breaks into small blocks, but is the principal quarry stone, exposed	2

A face perhaps 100 feet in length is open at this point. The base of this section is about three or four feet above the water in the river, which is but fifty feet distant. While the rock is suitable for ordinary rough work, quarrying has been limited by the excessive overburden. This same factor determines the amount of stone available in the other localities mentioned. Since the county is in general covered with a great thickness of recent deposits, which require removal, the production of stone will of necessity be very limited in the future.

HENRY COUNTY.

Sand and Gravel.

Buchanan Gravels.—At various places over Henry county there is exposed above the Kansan drift a bed of interstratified sands and gravels. The deposit is not uniform in depth, nor is it continuous over wide areas. The pebbles are usually small, rarely exceeding three inches in diameter, and are generally rounded and much water-worn. These materials were deposited soon after the drift was spread out, and before any change

had taken place in its surface. They record the action of swift and variable currents in streams which carried a large volume of water and were highly charged with rock debris. The stratification is very irregular, fine sand and coarse gravels not being sorted so perfectly as is usually the case with water-laid materials. The beds were probably laid down along the channels of the streams which carried away the waters resulting from the melting of the Kansan ice.

Sand.—Sand suitable for building purposes is found in abundance at a number of places in the county.

The soft sandstone beds of the Verdi division of the Saint Louis are sometimes used. The best deposits occur at various points along the flood plain of Skunk river and of Big Cedar and Big creeks, where almost unlimited quantities can be obtained. The wind-formed hills of sand which occur in Jefferson township are also an important source of supply. Very little of this material is met with over the northeastern portion of the county.

STONE.

The various substages of the Saint Louis limestone immediately underlie the glacial debris over practically the entire county. The Coal Measures fringe the south and west borders more or less interruptedly, with small patches in the interior, and two narrow bands of the Osage limestone are exposed along Skunk river in the south central and southeast portions of the county.

The lowest member, or Springvale substage, is dolomitic in character, occurs in heavy beds, and affords material suitable for heavy masonry. The best sections occur in Baltimore township, and to a less extent in Jackson and Center townships. As a rule, the beds suitable for structural purposes are under a heavy overburden and can be quarried only at great expense. The following sections will serve as fair examples.

Section about one mile east of Lowell, in Baltimore township, north of wagon road:

FIG. 39—St. Louis limestone, Baltimore township, Henry county, showing slight fold and hard, compact beds.

		FEET.
7.	Clay, reddish colored and gravelly	6
6.	Limestone, impure, rusty brown	2
5.	Limestone, brown, magnesian, similar to 4	4
4.	Limestone, magnesian, obscurely laminated	3½
3.	Limestone, brown, magnesian, in layers three to seven inches thick	8
2.	Limestone, fine-grained, magnesian, brown, in layers one to three feet thick	10
1.	Limestone, variable, partially concealed down to geode beds of Keokuk substage	9

The heavy dolomitic beds would undoubtedly give good service for heavy masonry, but have been little developed and are not readily accessible.

The middle member of the Saint Louis, the Verdi, as developed in the county, is characteristically variable in composition, texture and structure, and has little to commend it commercially save for crushed stone purposes. It has not up to this time been exploited on its own account. It has been worked only to a limited extent in connection with the beds above and below.

The uppermost member, or Pella beds, is the most widely distributed and most generally accessible of any of the divi-

sions of the Saint Louis and has been more extensively developed than any other formation in the county. While the quarrying industry amounts to but little at the present time, large quantities of stone have been produced by the quarries near Mt. Pleasant, along the Keokuk and Western division of the Chicago, Burlington and Quincy Railway. The old Winter quarry located in the south bank of a small stream emptying into Big creek from the north, near the railroad bridge in the southeast quarter of section 17, Center township, shows the following section:

		FEET.
12.	Drift, reddish brown	4
11.	Limestone, gray, weathered, shaly	6
10.	Limestone, light gray, compact, layers ten to twenty inches in thickness	5
9.	Limestone, gray, evenly bedded, in layers two to eight inches in thickness	6
8.	Limestone, gray, flaggy, two to four inches in thickness	1
7.	Limestone, fine-grained, in undulating layers one to three feet thick	8
6.	Limestone, fine-grained, gray, brecciated, in places much shattered	5
5.	Sandstone and shales in lentils and irregular beds	6
4.	Limestone, light colored, arenaceous, in places flexed and often brecciated	6
3.	Chert in a band rather than in nodules	1½
2.	Limestone, impure, yellowish; the upper portion in thin layers, the lower a single bed three feet in thickness	4
1.	Laminated beds, one to three inches in thickness, consisting of brown, magnesian layers above, thin layers of oölitic limestone in central portion and arenaceous magnesian limestone below	5

The upper surface of number 1 presents numerous dome-shaped elevations ranging from two to four feet in height and ten to twenty feet in diameter. Both 1 and 2 show well defined ripple marks in places. (See plate XXIX, b.)

The Pella beds are exposed at numerous other points, but on a less extensive scale than in the above section, and do not present any new features worthy of mention. While quarries have been opened and operated from time to time in practically every township in the county, those in the vicinity of Lowell, Salem, Oakland Mills, and Mt. Pleasant are the most important.

FIG. 40—St. Louis limestone near Oakland Mills, Henry county, showing typically variable beds.

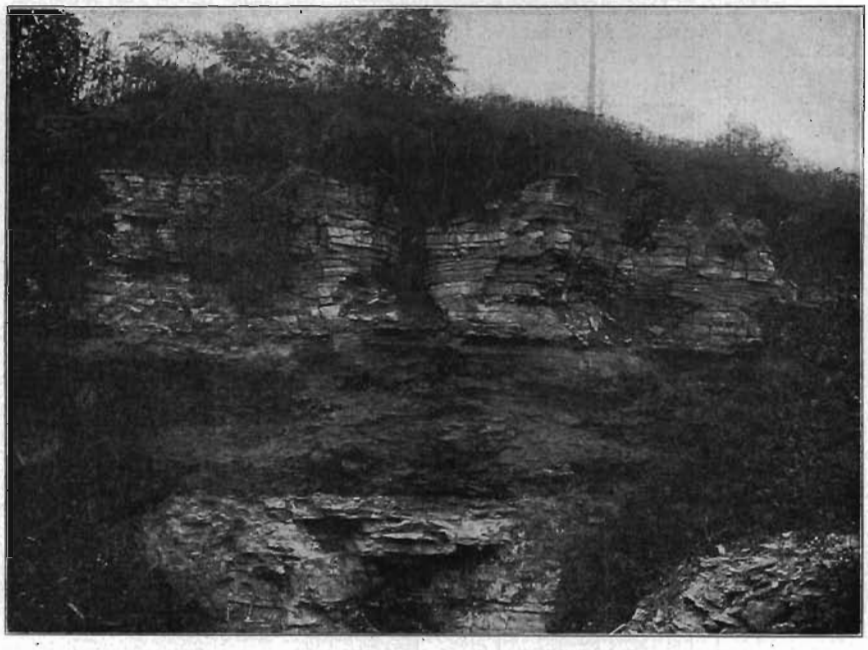


FIG. 41—St. Louis limestone near Winfield, Henry county.

HOWARD COUNTY.

Sand and Gravel.

All the gravel deposits of Howard county belong to the Buchanan stage of the Pleistocene. Reference is here made to the report on Buchanan county, where the characteristics of these deposits, as first pointed out by Professor Calvin, are enumerated. Both the valley and upland phases, as distinguished by that author, are represented.

Valley Phase.—The valley phase of the Buchanan is much more extensively developed than the upland phase. Deposits of this kind, the gravel trains of the Kansan ice, are present along Upper Iowa river, which passes through each of the townships of the northern tier. For some miles above Chester is a wide, well-marked, continuous terrace occupying an area of several hundred acres. The great beds of valley gravel about LeRoy, Minnesota, which have been used for ballast by the Chicago, Milwaukee & St. Paul Railway are similarly situated, and are but a part of the enormous gravel trains which the floods from the melting Kansan ice strewed continuously along the valley of the Upper Iowa.

Similar gravel trains are found along the branches of Wapsipinicon river in the southwest part of the county. The county owns a fraction of an acre in the northwestern part of section 11, Afton township, at which place the opening shows about six feet of iron-stained, stratified, fine and coarse gravel under six inches of soil. Probably an acre or so additional could be exploited here. At Busti and for a mile eastward there is very coarse gravel, it being a mixture of Buchanan with Iowan drift. It contains a high percentage of clay, and the areas over which it occurs are small.

These are mentioned as typical examples of outwash gravels from the Kansan ice, as are also those in west section 7 of Vernon Springs township.

Valley gravels occur also along the courses of Crane creek and Turkey river. At Lourdes, between the former and a tributary from the east there is a deposit which has an area of some

three acres or more. At present, however, there is no exposure. The town of New Oregon, on Turkey river, is built upon a large terrace. There is also a terrace of Iowan gravel on the north bank of Turkey river at this place. The pit of Mr. J. B. Mitchell, which is located in the latter, shows:

	FEET.
Soil and loessial material	3-6
Gravel, coarse to fine, with slabs and chips of limestone, brown above to yellow below	4
Gravel, fine, 8 inches; sand near top; some coarse material with limestone chips, for the most part clean and sharp	15

The area of this terrace is perhaps five acres.

A few miles east of New Oregon, in section 1 of the township of that name, the gravel is in places cemented into a firm conglomerate. This cementation is likewise not uncommon in other localities.

Upland Phase.—The upland phase of the Buchanan is represented in several places throughout the county. A very good example of this type may be seen in a large gravel pit in southwest section 27, Vernon Springs township. The material here is very rusty from the oxidization and alteration of the iron-bearing constituents, and in places the amount of iron is sufficient to cement the gravel into a conglomerate. Granites up to ten inches in diameter fall to pieces when removed from the mass. The pit is fully fifteen feet deep and does not show the whole thickness of the deposit. There is practically no stripping, the cover being but a bed of humus-stained gravelly soil.

In the adjacent parts of sections 34 and 35 there are similar esker-like knobs of Buchanan gravels which have not been worked.

In the southern part of section 18, New Oregon township, Mr. O. A. Borlang has a two-acre knoll which contains considerable amounts of gravel but which has not been opened in such a way as to expose its contents clearly. Mr. Borlang also has a small pit half a mile northwest of this knoll.

STONE.

Both members of the Ordovician as developed in Howard county are exposed in the vicinity of Florenceville. Excellent

FIG. 42—Esker of Buchanan gravel in the southwest quarter of section 27, Albion township, Howard county.

sections of both the Galena-Platteville and the Maquoketa occur in the northern tier of sections in Albion township, but as yet the beds are almost wholly undeveloped. The quarry below the mill at Florenceville shows the following beds:

		FEET.
2.	Limestone, irregularly bedded, fine-grained, fossiliferous, with shaly partings; some of the layers represented by detached nodules and irregular lenticular slabs of limestone imbedded in shale	10
1.	Limestone, regularly bedded in layers a foot or more in thickness, without shaly partings, rather coarse-grained, beds cut by definite joints, joint faces pitted and roughened by weathering	8

Number 1 furnishes a durable grade of building stone. The rock is magnesian, subcrystalline and practically nonfossiliferous.

Outside of two small areas marking the extensions of Ordovician beds which have been uncovered by the streams into Vernon Springs and across Albion township into Forest City township, the Devonian covers the entire county. The Devonian beds are accessible at numerous points and have been quarried principally at Vernon Springs and vicinity, Cresco, Lime

Springs and vicinity, Chester, Elma and in section 33 in Saratoga township. The lowest beds developed may be viewed in the quarry located on the northeast corner of section 14 in Forest City township. The principal quarry rock consists of a massive, rough, rather soft, noncrystalline, vesicular dolomite. The quarry section is as follows:

		FEET.
5.	Limestone, dolomitic, ledges decayed and badly broken up, comparatively thinly bedded	8
4.	Dolomite, coarse, vesicular, full of fossil casts	5
3.	Dolomite, coarse, pitted like number 4	4 1/3
2.	Limestone, dolomitic, light yellow	3
1.	Limestone, similar to 2 but softer and more granular; in four beds which in places appear to be completely blended into a single bed	4

Similar sections may be seen at other points in Forest City and Albion townships.

Beds somewhat higher in the series have been quarried at Vernon Springs and vicinity. The Salisbury quarry, located in the southwest quarter of the southwest quarter of section 34 in Vernon Springs township may be selected as a fair sample. The section is as follows:

SALISBURY SECTION, VERNON SPRINGS.

		FEET.
5.	Black soil mixed with broken rock	1
4.	Limestone, broken, angular fragments affording an illustration of how the stone yields to frost and weather	4
3.	Limestone in heavy courses of good building stone, soft, magnesian, yellow or brown in color, containing numerous spheroidal cavities lined with crystals of calcite, fossils rare and represented only by casts	8
2.	Limestone, softer, more argillaceous, in three or four layers, calcite lined cavities numerous	3
1.	Limestone, more solid and purer, in courses from one to three feet in thickness, fossil shells preserved	7

The most important quarry in the county is operated by John Hallman and is located in the northwestern part of the city of Cresco. The quarry pit shows the following beds:

		FEET.
4.	Drift and wash	1-4
3.	Limestone, in thin layers but evenly bedded and hard, magnesian	6-8
2.	Limestone, blue-gray, hard and tough, in beds ranging from 6 to 18 inches thick; works fairly well	7-8
1.	Limestone, dolomitic, base ledge in northwest corner of quarry; weathers brownish yellow, exposed	2

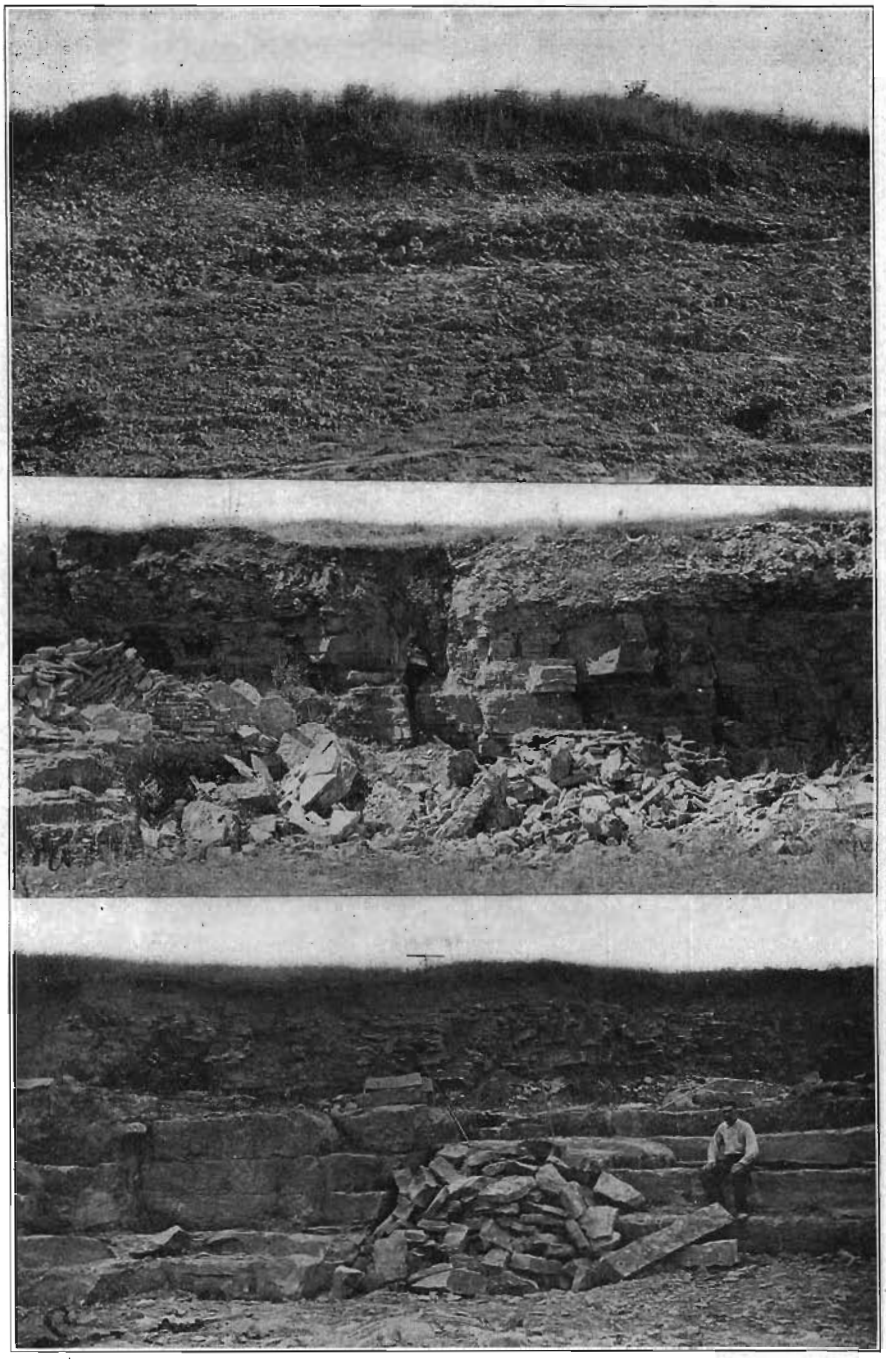
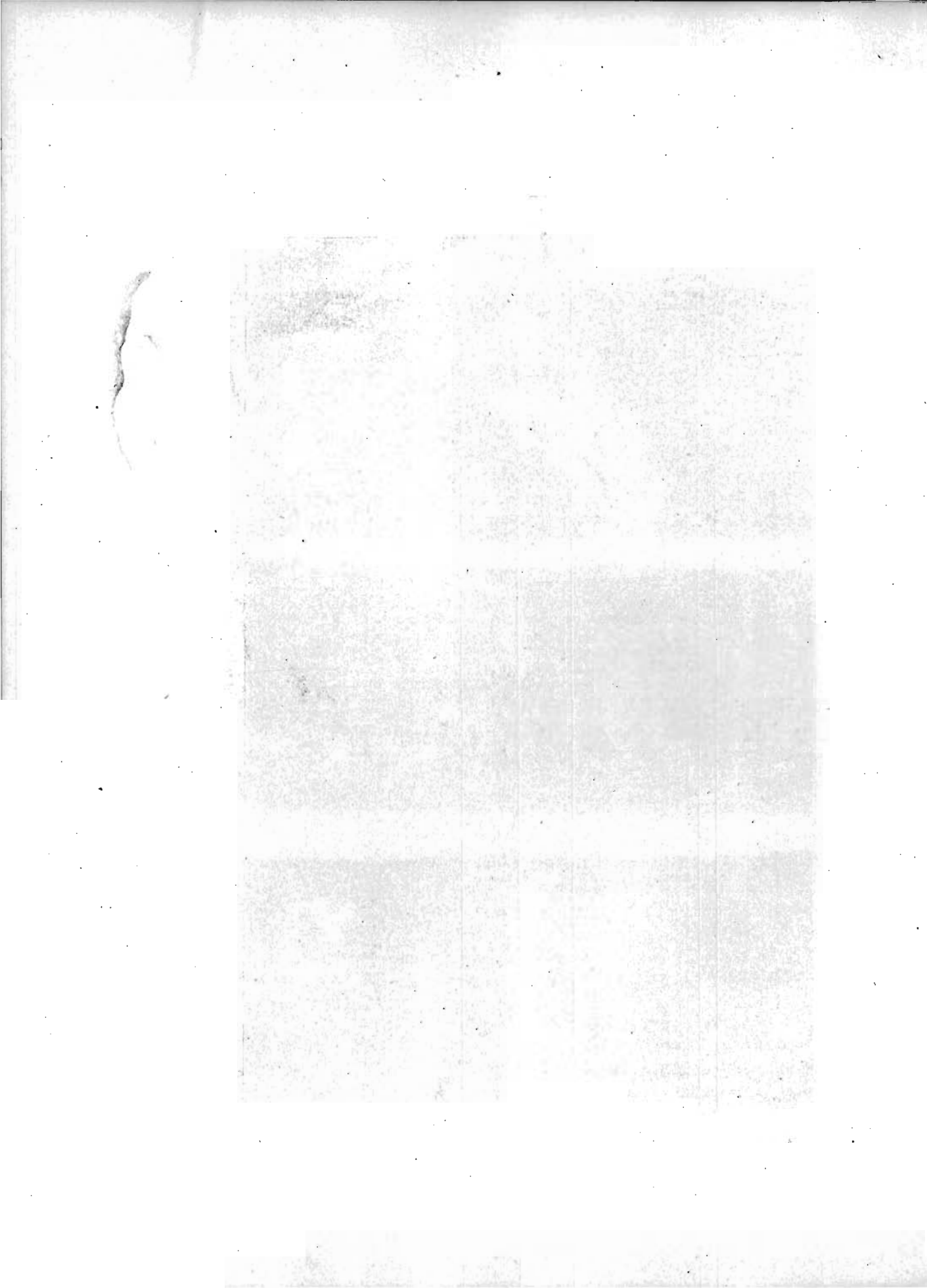


PLATE XXIII—a. City quarry about one and one-half miles north of Cresco. The product is a natural macadam.
b. Quarry northeast of Elma showing flaggy character of beds.
c. Hallman quarry showing principal quarry beds. Cresco, Howard county.



Numbers 1 and 2 contain considerable crystalline calcite in stringers and balls and the entire assemblage of beds is strongly magnesian. The quarry beds appear to be much disturbed in places, such disturbance being manifested by crushed layers and slickensided surfaces. The products of the quarry include some dimension stone, rubble and ordinary range stone. The principal beds are comparatively soft and work easily.

The quarries at Forest City and Chester work beds similar to those which have been developed at Vernon Springs.

At Elma several quarries have been opened and dolomitic limestones have been quarried, which, according to Professor Calvin, are below the beds occurring at Cresco. A quarry along the Chicago Great Western railway, north of Elma, displays the following beds:

		FEET.
4.	Soil and drift	0-3
3.	Limestone, much weathered, bedding planes almost obliterated, somewhat concretionary in appearance	3-5
2.	Limestone, magnesian, stained yellowish brown where long exposed; breaks up into thin layers although apparently in heavy beds	3-5
1.	Dolomite, brown, subcrystalline and cavernous, calcitic, in heavy beds	4

Small quarries have been opened and operated from time to time at other points, but none are worthy of special mention.

HUMBOLDT COUNTY.

Sand and Gravel.

The gravel and sand deposits of Humboldt county are of three kinds viz., stream terraces, sand and gravel bars, and pockets and cappings in and on drift hills. Of the first kind, there are two classes, Buchanan gravels, derived from the Kansan, or older drift sheet, and the younger, fresher deposits laid down by outwash waters from the Wisconsin ice.

Stream Terraces.—Although both forks of Des Moines river served as outlets for the Wisconsin flood waters, Humboldt county sems to have received hardly its full share of the deposited materials. This may be due to the fact that the river

had cut its way down into the Carboniferous rocks which underlie the surface deposits of the county as we see them today, and had made but a narrow channel, through which the water poured with such velocity as to carry all suspended matter with it. In Kossuth and Palo Alto counties the terraces suggest the possibility that the gravel was deposited in ponded waters; and the benches in Webster county may have been dropped when the velocity of the current had been reduced after passing through this constricted channel. At all events, the gravel terraces in Humboldt county are scarce, and any gravel that may have been deposited in the river bottom is today covered so deeply with alluvium as not to be available.

On the north side of the river near the northwest corner of section 28, Rutland township, is a pit from which the town of that name obtains its supply. In this pit one to one and a half feet of alluvium covers some two feet of coarse, somewhat dirty gravel. Under the gravel are to be seen a foot or two of cross-bedded sand, iron-streaked and containing numerous pebbles up to several inches in diameter. This sand seems to grade into coarser material below. The top of the bank is about fifteen feet above water, and the productive area of the terrace aggregates six or eight acres.

South of Humboldt, on the farm of W. C. Hayes in the north part of section 13, Corinth township, is a pit from which sand is being hauled to town by the Humboldt Cement Products Company. This pit is in a low bench, in fact it is really located in the flood plain on the west side of the river. Just south of the pit is a flat bench practically the same height but which is composed of indurated rock under a thin cover of alluvium. At this opening there are about two feet of dirty gravel under one and a half feet of alluvium. The gravel contains a large amount of sand, and sand underlies it. The latter is cross-bedded, and contains pockets and streaks of extremely fine, clean, sharp sand. Up to fifteen feet have been uncovered in this pit, but only six feet or so are now exposed above water. The indications are that up to fifteen acres in this bench might yield this material, but the depth is probably somewhat variable.

What are probably Wisconsin gravels are to be seen on the east side of the river, between it and the railroad, near the northwest corner of section 17, Beaver township. This material is coarse and somewhat dirty, and is buried under two to four feet of alluvium. The top of the gravel is about twenty feet above water. A few hundred yards farther north, in section 8, another opening shows practically the same material. The total area available at these two exposures will perhaps run as high as twenty-five or thirty acres. Chances for development at the latter opening are better than at the former because of a bank some fifty feet high, the only open road through which leads to the pit in section 8. A long stretch of the Humboldt-Fort Dodge road has been surfaced with gravel from this pit and is in excellent condition.

There is another pit in the same bench in the western part of section 5 of the same township. The gravel is more iron-stained than where observed farther south, and is being used on the roads.

From Humboldt to Livermore along the east branch of Des Moines river, bench gravels are a negligible quantity. The flood plain is narrow, and where benches are present they are composed of drift clay. It is reported that gravels are occasionally found in excavations in the river bottoms, but are covered so deeply with alluvium as to be almost unavailable.

Buchanan gravels.—The older gravels of the drift series constitute a quite important source of supply. South of Humboldt between the two forks of Des Moines river these are particularly well developed, and have been opened in several places. In sections 24, Corinth, and 19, Beaver, is a bench extending between the forks of the river which has an area of perhaps forty acres or more. Where this has been opened west of the road it shows four to five feet of coarse, rudely stratified, iron-stained gravel grading downward into fine gravel and sand. A little lower down the slope is another opening showing fine, iron-stained gravel underlying the sand. The total depth of gravel exposed is fifteen or sixteen feet, under some two feet of cover. Half a mile east of this pit the Minneapolis & St.

Louis Railroad formerly took gravel from the terrace, but this pit is now abandoned. In speaking of the area underlain by Buchanan gravels, Professor Williams says, "The extent of these deposits is very difficult to estimate. They probably underlie in considerable depth all the upland south of Humboldt and between the two forks of the Des Moines south to their union." And again from Williams, "In the particular case before us, the only natural outcrops of the Kansan occur along the river valleys, as already intimated, and here they seem to represent the drainage deposits left by the abundant south-flowing waters of the retreating glacier; they are the Buchanan gravels and alluvial sands. Exposures occur at several places along the river valley in Beaver township, as near the center of section 17, on the north side of Coon creek near its mouth, in the northwest quarter of section 20, and even on top of the hill in northwest 30. In all these cases we find the peculiar orange-brown color formed from decaying pebbles, which are today so near disintegration that they crumble in the fingers."

Reworked materials.—Sand and gravel bars, chiefly the former, occur in some abundance along both branches of Des Moines river all through the county. It will be mentioned in the Pocahontas report that sand bars are plentiful in the West Fork where it crosses the corner of that county. The same thing is true all the way down to Humboldt, and perhaps even more noticeable on the East Fork north of the latter place. Between Humboldt and Livermore this river wash sand is being removed in several places, notably on the Dunphy farm in section 15 and at the bridge in section 10, Grove township. The material is, on the whole, clean and white and serves nicely for concrete and cement work where fine sand is desirable; but the quality is quite variable within distances of a few feet.

Drift gravels.—Humboldt county lies within the area covered by the Wisconsin ice. While the depth of the drift over this county as a whole is quite thin when compared with others in this vicinity, yet the amount of available kame and knoll gravels is as great as in any of them. In southeast section 17, Grove township, and in north section 7, Humboldt township,

kames have been opened and the gravels used on roads and for concrete. Vernon township is reported to have "plenty of gravel" all of which is of the kame type, and there seems no doubt that the chances for finding it in other townships are just as good as in the ones named.

Stone.

The Kinderhook limestone beds outcrop near the Minneapolis and Saint Louis railway in the southern part of the city of Humboldt and present an almost continuous exposure on the river for more than a mile. The same beds outcrop near the Chicago and North Western railway north of the city, and near Rutland about five miles to the northwest. The section exposed below the dam in Humboldt is given below:

		FEET.
4.	Alluvial wash, variable in thickness; on top of terrace about	3
3.	Limestone, oölitic, rather coarse-grained, gray to white....	10
2.	Limestone, compact, gray-white, a gradation from No. 1, but fewer fossils present and apparently less brecciated..	2
1.	Limestone, brecciated and filled with casts of fossils, chiefly brachiopods, very compact and brittle in outcrop; bedding planes not apparent; exposed above low water.....	4

The section rises toward the town and the oölite probably shows a greater thickness than is indicated in the above section. All of the beds dip perceptibly up stream. An average sample was taken from the above section and analyzed. The result is given below:

Insoluble	0.50
Iron oxide and alumina	1.12
Calcium carbonate	97.20
Magnesium carbonate	2.00
Total	100.82

Analyzed by A. O. Anderson, from sample collected by C. M. Morgan.

At Rutland, along the south bank of the river, is one of the most conspicuous rock exposures in the county. The section exposed here is correlated by Macbride with the lower beds in the Humboldt section. The ledges are nearly in horizontal position, attain a maximum of twenty feet in thickness, and can be traced about one mile east where they disappear. Westward

they give place to the Saint Louis in section 23 in Avery township. Outcrops apparently referable to the same horizon are known at other points in Rutland township. The bedding planes in the Rutland limestone are not very apparent. The rock breaks up into irregular sharp angled spalls and is very hard.

The Saint Louis limestone appears at several points along both branches of Des Moines river and in Weaver township. It forms a solid foundation for a large portion of the city of Humboldt, as the cellars of many of the principal buildings were excavated in it, and, it is said, produced enough stone to build their own walls. The stripping or overburden of soil and drift is so thin in places that these limestone beds afford a natural pavement. The Saint Louis overlies the Kinderhook unconformably, although good natural exposures showing the contact are scarce. The most extensive section in the county appears along the east bank of the river, near the south line of the county. The beds are as follows:

		FEET.
9.	Drift of variable thickness.	
8.	Sandstone, probably Coal Measures	6- 7
7.	Limestone, in thin layers, arenaceous	6-10
6.	Limestone, heavy-bedded, containing angular fragments of lithographic stone	5- 7
5.	Shale, with pockets of clay; variable in thickness; a thin parting	1
4.	Limestone, hard and dense	4
3.	Limestone, regularly bedded, more or less arenaceous, about	2
2.	Talus to water level	4
1.	Limestone, soft, whitish or bluish in the bed of the river. On exposure turns brown or yellow and washes readily under rain. Occurs in layers six to eight inches thick, and is said to overlie blue shales.	

Number 1 has been quarried in the bed of the river for local use. Number 7 is the most characteristic and clearly defined member of the series. It occurs in layers three to four feet thick, is unevenly bedded, more or less brecciated and breaks off in large blocks as undermined by erosion of the thinner beds below. This particular horizon also outcrops in sections 31 and 32 in Grove township.

The Bull quarry near the center of Humboldt exposed the following section:

		FEET.
3.	Drift and soil	1-2
2.	Limestone, thin-bedded, with flinty layers, passing into beds of clay	2
1.	Limestone, blue, evenly bedded, of variable texture	6

Number 1 rests unconformably upon the subjacent limestone, which is supposed to belong to the Kinderhook. Other exposures of the Saint Louis limestone occur at the "Sandstone Quarry" in Rutland, and at several points in Avery and Weaver townships. The best beds usually available at all of these places, occur in medium to heavy ledges, are comparatively pure calcium carbonate, and yield a fair to superior grade of building stone, which has been used extensively in bridge piers and abutments, foundations and walls of some of the best buildings in the county. The entire assemblage is suitable for road and concrete work. The location of these outcrops should make them of especial importance for north-central Iowa.

IDA COUNTY.

Sand and Gravel.

The surface materials of Ida county are Kansan drift generally veneered with loess. Between these two formations is occasionally found a deposit of iron-stained sand and gravel called Buchanan by Professor Calvin.* An exposure of this material occurs in southeast section 27 of Corwin township, where in the valley of a small creek there are exposed some ten feet of gravelly sand under four feet of loess. The lower member in this section is composed of fine to medium sand mixed and interbedded with fine gravel. Gravel is reported to be present below the sand.

It seems not at all difficult to find these loess-covered gravels almost wherever a search is made, but the depth of the cover is usually so great as to render the cost of recovery prohibitive. While nothing but quicksand and silt are usually to be found along Maple river, yet some of its tributaries have small amounts of coarser material. In Ida Grove the Cement Products Company has a pit in which six to eight feet of sand are visible

*See report on Buchanan county in this volume.

above the water level. The sand is under ten or twelve feet of cover, most of which is used for the manufacture of brick. The upper part of the sand is interbedded with sandy clay, some of which is taken for sidewalk work. The sand as a rule is fine, clean quartz carrying a few pebbles variable in size, but occasionally bowlders up to several inches in diameter are found.

Just south of Odebolt creek in southeast section 14, Corwin township, Robert Hall has a pit which shows practically the same section as noted above. Here there are interbanded clay and sand seams which together with four or five feet of clay must be removed. The town is largely supplied from this pit.

There are gravel terraces along Little Sioux river where it touches the northwest corner of the county, and also on Ashton creek. These gravels are not easily available at present on account of the deep valley of the river. Lake View is the chief source of supply for Ida county. Gravel from the latter place is shipped in for all work of any importance, and the local products are used only for local purposes in a small way, such as sidewalks, plaster work, etc.

IOWA COUNTY.

Sand and Gravel.

The Aftonian gravels are widespread in Iowa county and constitute the leading water-bearing horizon for shallow wells. Outcrops are rare or unknown.

Small deposits of sand are found at the base of the loess and as flats and bars in some of the streams. The deposits carry more or less silt and clay and are of local importance only. Gravel used in the county is imported. It is possible that both sand and gravel might be pumped from Iowa river as in Johnson county.

Stone.

Small Coal Measure outliers occur in Iowa county, the most conspicuous member being the usual variable sandstone. Several decades ago these beds were developed quite extensively by the several villages belonging to the Amana Society. Some of the oldest and most important buildings in these communities

were constructed of these variable sandstones. The Amana store and the Amana church were built in 1862 and 1863 respectively, using the local stone, and both are in good repair. The store front was built of a red-brown sandstone obtained from a quarry about one and a half miles north of town, while a yellow-brown sandstone, said to have been obtained from a quarry equally distant northwest of town, was used in the sides and back walls. Other quarries were developed to the eastward and westward of these and used in the construction of the older buildings.

While some stone has been produced and used of late years for foundations and rough masonry purposes, no stone buildings have been constructed of the local material during the past quarter of a century. At the present time the old openings are much obscured by talus slopes. The stone available is very similar to that exposed in other border counties belonging to the same horizon. It is a sandstone, highly variable in color, texture, structure and state of induration. The prevailing colors are shades of yellow and brown combined with red; yellowish and reddish brown predominating. Texturally the stone is usually fine to medium grained, but occasionally shows a conglomeratic facies. Structurally the stone varies from a thinly bedded sandstone, with bedding planes fairly well defined, to a massive and imperfectly bedded deposit. False bedding is oftentimes very evident. As a rule it is imperfectly indurated, but appears to harden considerably on exposure. It varies from a very friable to a fairly compact stone. The deeper colored stone is usually the more highly indurated. The durability is sufficiently attested in the well-preserved buildings, where it has been exposed to the elements for half a century. As in the case of other Coal Measure sandstones, its color is not pleasing and its other properties are not sufficiently constant to commend it to the public. In quarrying the stripping increases rapidly from the natural outcrops and the percentage of usable stone is small, both of which factors contribute to the expense of production. While this variable sandstone has served a useful purpose in the early history of the communities, it has been displaced almost wholly by stone from other points, notably Stone City, which

can be more cheaply quarried. The materials are not well adapted for crushed stone products.

JACKSON COUNTY.

Sand and Gravel.

Remnants of gravel terraces still occur at various points along the Mississippi river valley in this county. According to Savage the age of these gravels is undetermined, although it seems probable that they belong to the period of flooded streams which was one of the features of the close of the Wisconsin stage of glaciation. One of the most important of these terraces extends from Bellevue north to section 24 of Tete de Mort township. Over the northern portion of this terrace the surface is covered with drifting dunes which are composed of fine sand heaped up by the winds. Elsewhere the sand is not piled into dunes but it still practically prevents the growth of vegetation. On the north edge of Bellevue the terrace has been opened up

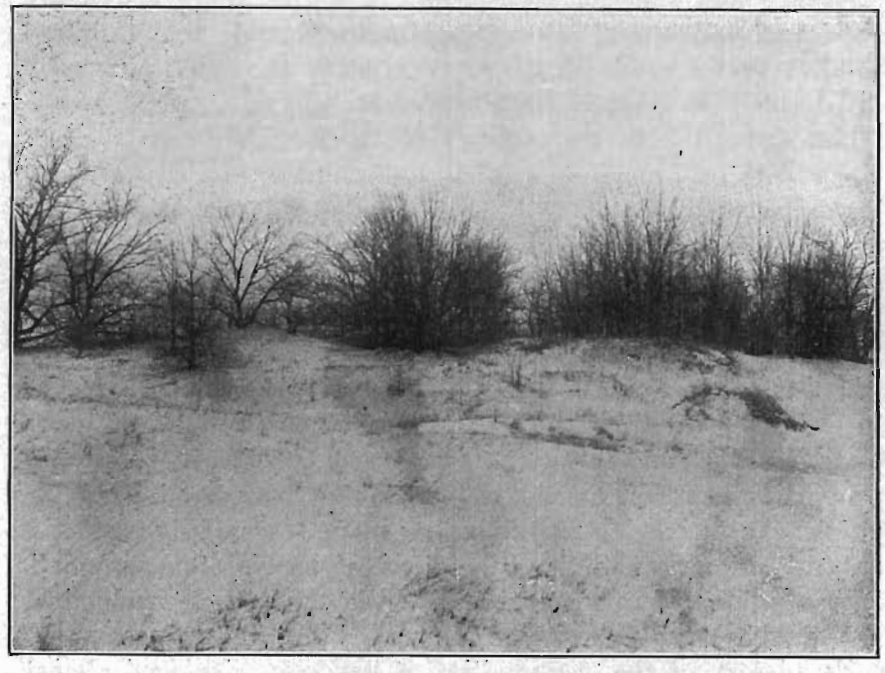


Fig. 43—Sand dune invading timber land northeast corner of Bellevue township, Jackson county.

to obtain sand and gravel for local use. The pit shows at the base ten feet of well rounded gravel with considerable sand. Above this layer are twenty feet of fine yellow sand resembling the dune sand. The division between these two phases is sharp and well marked. The terrace is forty feet high at Bellevue and seems to be underlain very largely by the coarser gravel. The gravel is also well exposed in the roadside near the southeast corner of section 1, Bellevue township.

Savage* mentions other terraces of similar composition between Sabula and Lainsville, and two and one-half miles east of Green Island, where the valley of a small creek has been filled to a height of twenty feet above the present flood plain.

At the north limits of the town of Maquoketa, on the South Fork of Maquoketa river about half a mile above the junction of the two branches, terraces are well developed on both sides of the stream. In the southeast quarter of section 13, South Fork township, several pits have been opened near the road leading to Hurstville. These show one or two feet of rather fine sand on top and below this a few feet of coarser sand and gravel, locally cross-bedded and iron-stained. Below are exposed six feet of medium coarse gravels to the bottom of the pits.

Stone.

A few outcrops of the Platteville stage of the Mohawkian series appear in Tete de Mort township from St. Donatus to Mississippi river and southward. Several small quarries have been opened but have not been operated extensively. Perhaps the largest quarry has been opened near the top of the bluff at Gordons Ferry station. A large amount of material has been taken from the bluff in the vicinity and used in the construction of wing dams along the river. The section exposed presents a massive dolomite in ledges from four to six feet in thickness. The beds are subcrystalline and quite free from chert. A small quarry near the village of St. Donatus shows the following beds:

*Geology of Jackson County; Iowa Geol. Surv., Vol. XVI, p. 582.

ST. DONATUS SECTION.

		FEET.
5.	Dolomite, grayish yellow, in layers three to eight inches in thickness, which are separated by narrow partings of shale; containing a number of fossils in the form of casts or molds	5½
4.	Dolomite, yellowish, similar to No. 5 above, and containing similar fossils	2
3.	Dolomite, yellow, two layers, each about eight inches in thickness, which are separated from each other and from those adjacent by two-inch bands of shale	1⅜
2.	Dolomite, rather hard, which is imperfectly separated into layers respectively 2, ¼, 2, ¾ and 1½ feet	6½
1.	Dolomite, yellow, fossiliferous and somewhat vesicular, consisting of layers 2, 3, 2½, ½ and 3 feet in thickness	11

Other quarries have been operated along Tete de Mort creek. A more extensive natural section may be viewed on the northeast quarter of section 24 in the same township. This exposure shows the following succession of beds:

		FEET.
8.	Dolomite, weathered ledge, hard, yellowish gray, indistinctly separated into layers and presenting a very rough surface	6
7.	Dolomite, hard, buff, in three layers, respectively 3, 3 and 1 feet in thickness, the surface showing numerous small cavities	7
6.	Dolomite in heavy layers, yellow, *Receptaculites oweni* abundant near the middle portion	5
5.	Limestone, hard, subcrystalline, yellow in color, showing numerous cavities, fossils few and poorly preserved	4
4.	Limestone similar in character to No. 5 above, weathering into indistinct layers three to six inches in thickness	5
3.	Limestone ledge consisting of two layers, each about two feet in thickness, containing a number of indistinct fossil remains	4
2.	Dolomite, hard, buff colored, similar to No. 3	3½
1.	Dolomite, hard, massive ledge, yellow, vesicular, down to level of water	4½

The upper layers of the Galena become thinner with numerous thin shale partings and the Galena cliffs are almost invariably overlain by Maquoketa slopes.

The Maquoketa beds are supposed to be responsible for the slopes which appear at the base of the massive Silurian limestone cliffs which face the Mississippi and its immediate tributaries and also appear in Fairfield and Van Buren townships. The Maquoketa beds are predominantly argillaceous but grade upward into thin layers of indurated limestone interbedded with thin shale layers. These transition beds have been quarried

locally at Bellevue and at a few other points in the northeastern portion of the county. The material breaks down rapidly when exposed to the weather and is not of a durable character. A representative section may be seen near the northeast corner of the town of Bellevue. The sequence is as follows:

		FEET.
8.	Dolomite, hard, massive, crystalline, in heavy layers three to six feet in thickness; indistinct remains of fossils not rare. Niagaran limestone	13
7.	Limestone, impure, yellowish gray, rather fine-grained, in even layers four to fourteen inches in thickness, weathering into bands of one to two inches; carrying a few fossils; without chert nodules	14
6.	Limestone, argillaceous, earthy, in layers two to six inches in thickness; containing a few fossils. On weathered faces thin partings of shale appear between the layers	19
5.	Stone, yellowish, argillaceous, bluish gray where not exposed to the action of the atmosphere; in layers one to three feet in thickness; weathering into narrow bands one to three inches thick. Occasional nodules of chert appear in lower part	15
4.	Shale, grayish blue, indurated, calcareous, weathers into thin bits; without fossils but carrying a few chert nodules	31⅓
3.	Limestone, impure, rather fine-grained, yellow colored, much decayed and showing numerous close lines of lamination	⅔
2.	Shale, bluish gray, somewhat indurated, weathering into small polygonal and irregular fragments, without fossils.	10
1.	Shale, blue, plastic, nonfossiliferous	30

In the above section number 8 represents the basal portion of the Niagaran limestone, which forms an overhanging cliff. Numbers 6 and 7 represent the transition phase of the Maquoketa, beds which have been quarried to a limited extent. The shales are a possible source of materials suitable for the manufacture of Portland cement.

The Niagaran limestone immediately underlies the drift over more than five-sixths of the surface of the county and supplies the chief rock quarried, for both lime and structural purposes. All of the beds developed, with the exception of a small area in Brandon township, belong to the Hopkinton stage. They consist, for the most part, of very heavy layers of subcrystalline dolomite ranging from two to eight feet in thickness and imperfectly stratified. The basal beds form an almost continuous outcrop along the Mississippi and appear in Van Buren and Fairfield townships. Good sections appear at numerous points along the principal streamways in the interior of the county.

From this wealth of outcrops only a few quarry sections are given, however, sufficient to give the general features of the beds and indicate their availability. The Hopkinton is represented by a basal yellow dolomite, which is nonfossiliferous and free from chert. It ranges from four or five to ten or twelve feet in thickness. These layers are overlain by the chert beds, which consist of an earthy yellow dolomite, thinly bedded and interstratified with bands of chert, and attain a thickness of from eighteen to twenty feet. The chert beds are followed by the massive, granular dolomite which constitutes the main portion of the Hopkinton. It attains a thickness of from fifty to eighty feet and is used extensively in the manufacture of lime. The following sections are fairly representative. A quarry located near the northeast corner of the southwest quarter of section 20, Iowa township, shows the following succession of layers:

		FEET.
7.	Dolomite, decayed, earthy, yellow, containing much chert; the bedding planes destroyed by the breaking down of the rocks on weathering	10
6.	Dolomite, yellow, very cherty, weathering into layers about one inch in thickness	3
5.	Dolomite, very cherty	2½
4.	Dolomite, earthy, with chert	2
3.	Dolomite, yellow, bearing, near the center, a band of chert two inches in thickness. Weathering into thin layers one to two inches thick	2⅓
2.	Dolomite, yellow, free from chert	1½
1.	Dolomite, yellow colored, rather fine-grained, without chert, in a single layer	2

On the northwest edge of Bellevue is the Ernest quarry, in the northeast corner of section 13, Bellevue township. It is located in the Niagaran above the thin transition beds at the summit of the Maquoketa. It shows eight feet of buff, finely granular dolomite at the base, in layers three to fourteen inches thick, some of them solid, some shelly. A thin band of chert extends across one of the upper beds. One of the lowest ledges shows blue cores in the center of the blocks. Above these is a two foot ledge then an eight foot layer. Only the thin beds below the two foot ledge are worked. The rock seems hard and durable and well adapted for road use. The quarry, however, is rather difficult of access, being well up on the hillside.

On the south side of Mill creek are several exposures of the transition beds from the Maquoketa to the Niagaran. They are thin, shelly, soft, probably too much so to be adaptable for macadamizing. In addition they are rather inaccessible.

The above sections illustrate the basal members of the Niagaran as developed in the county. Numbers 1 to 3 represent the non-cherty members, and numbers 4 to 7 represent the chert beds.

Hurst's lime quarry section east of the river at Hurstville, shows the upper member. The beds are as follows:

HURST'S LIME QUARRY SECTION.

		FEET.
3.	Dolomite, somewhat decayed, yellowish brown, weathered into layers from a few inches to three or four feet thick; containing Cerionites, crinoids and Pentamerus.....	15
2.	Dolomite, massive, yellow, imperfectly separated into layers six to eight feet in thickness, which contain crinoids and Halysites and Favosites besides numerous individuals of Pentamerus	30
1.	Dolomite, buff, crowded with rather small individuals of *Pentamerus oblongus*	8

The rock of the upper twenty feet of the section is harder than the lower part and is not burned, as it makes a brown lime. The lower portion is lighter colored, not so brown in color. The small waste from the quarry is used without crushing.

At the Pinhook quarry in section 23, South Fork township, on the South Fork, the upper twenty feet is used for road work, also the waste material, "gravel," from the lime rock. The upper rock is said to be harder than the corresponding ledges at Hurstville.

Niagaran dolomite ledges outcrop at several points along the road west of Maquoketa, as in sections 27 and 20, South Fork, and between Nashville and Millrock, and in the southwestern part of Monmouth township Bear creek has cut quite a deep gorge exposing the rock in numerous places.

Spalls from the quarry at the Keystone kiln, section 32, Monmouth, are used in concrete and macadam. All the rocks in this district crush up rather readily and make some dust, but are an improvement over dirt roads. The Niagaran has been

used extensively in Maquoketa but the work was not well done. The city hauls rock from Hurstville and crushes it with the city crusher.

JASPER COUNTY.

Sand and Gravel.

About the best that can be said for Jasper county is that good gravel is cheap and plentiful in adjoining counties. There are a number of sand and gravel deposits in the county, but they are small and usually of poor quality.

Kame deposits.—The only kame deposit in the county which has amounted to much is in the northern part of section 33, Poweshiek township. The sand and gravel used in building the concrete streets of Colfax came from here. From the appearance of the hill there is probably a good sized deposit of material suitable for road work. There are a few smaller kames in other parts of the township, but none are of much importance, unless the one in the northwestern part of section 18 proves to contain sand and gravel. Clear Creek township has a few undeveloped kames.

Reworked materials.—There is a considerable amount of rather fine sand in Skunk river between Reasnor and the south line of the county, but no evidence of gravel is to be seen. There is medium and coarse sand along Indian and Wolf creeks, but again gravel is absent.

Other sources.—There is some gravel and gravelly drift along North Skunk river. Gravel is exposed in a few places beneath drift or loess or both in a few places along this river as in section 35, Malaka township, and section 4, Poweshiek township. Sandy iron-stained Kansan drift is exposed in section 5, Richland township, and although covered with ten or twelve feet of loess it may prove of value.

Stone.

All of the Paleozoic rocks exposed in Jasper county belong to the Des Moines stage of the Upper Carboniferous series. They cover the entire county, with the exception of a small

triangular area of Kinderhook in the extreme northeast corner, and consist of interstratified shales, sandstones, coal and occasional thin beds of limestone. However, their character varies rapidly from place to place. The shales are prevailingly sandy and grade laterally into argillaceous sandstones. The sandstone layers are in places calcareous and, especially in connection with certain coal seams, pass into arenaceous limestone. Limestones of the darker colored variety occur as lenses and concretionary masses in some of the coal basins.

In Jasper county the rocks of the Des Moines stage are almost universally covered with drift. Exposures are not numerous as a rule, but are found fairly well distributed over the southern half of the county. Although the best sections are to be observed along stream ways, natural outcrops are not lacking over the uplands away from the streams.

Sandstone from the coal-bearing strata has been quarried at three known localities: section 34, Des Moines township; in a railroad cut in section 30, Fairview; and two miles above Lynnville, in the valley of North Skunk river. At the latter place only is quarrying at present carried on in the county. The exact location is the northeast quarter of the northeast quarter of section 34, Richland township. The quarry section at this point is as follows:

		FEET.
5.	Weathered shale	5
4.	White sandstone, soft, grading downwards into pink, brown and red	5½
3.	Plastic, white clay	⅚
2.	Sandstone, red to brown, compact; containing many small cavities lined with plastic clay, or containing pulverulent, red ocher. Micaceous, with fossil lepidodendrons	15
1.	Carbonaceous shale	1½

The total thickness of salable stone is in number 2, fifteen feet. It is evident that considerable stripping of the overlying shales is required. The quarry is worked by William Northcutt. Three hundred perches per year is the output. The stone is durable, and supplies the local demand for cellar and foundation walls.

RED ROCK SANDSTONE.

This formation is included in the Des Moines stage of the Upper Carboniferous, but it may be differentiated from the Coal Measures proper because of its uniformity, and the somewhat unique relation which it appears to bear to the other members of the series. In Jasper county it occupies a narrow elongated area coinciding in direction and corresponding in width with the territory covered by it in Marion county. The general trend is northeast-southwest, and in width it averages two and one-half to three miles, tapering to the northward.

Outcrops of this rock are to be seen at various points near Reasnor, on both sides of Skunk river; along Buck creek; on Elk creek near Murphy; along North Skunk river in the vicinity of Kellogg; and on Rock creek in sections 9, 16 and 17 of Rock Creek township.

Quarrying has been done at several points in the county in the belt of Red Rock sandstone, which affords the only extensive deposits of building stone in the county.

In section 17, Rock Creek township, the old Morgan quarry, on the land of G. M. Henning, was opened over forty years ago. A face twelve feet in height is exposed, consisting of a heavy bed of brown stone separated by two feet of shattered rock from a four foot stratum of compact, reddish brown sandstone. Similar strata have been worked both above and below this quarry in the valley of Rock creek and its branches.

One mile east of Kellogg the brown sandstone has been quarried quite extensively in the past by the Chicago, Rock Island and Pacific Railway Company. Fifteen feet of the sandstone are open to view. Large plans appear to have been made here for the development of these quarries, but no work has been done for years.

On the hill slope a short distance north of the town of Reasnor, fourteen feet of the sandstone may be observed in a small quarry; the prevailing color is brown, approaching a red in places. The sand grains are at times so coarse and irregular in size as to give the rock a finely conglomeratic texture. Many of the largest grains are of a jaspery nature, and some, ap-

proaching a pebble in size, appear to be fragments of an earlier sandstone. Cross-bedding is not uncommon. The base of this exposure is about sixty feet above the flood plain. In detail, this section is as follows:

		FEET.
7.	Loess, becoming fine sand on the hill-top	4
6.	Buff sandstone, micaceous	½
5.	Brown sandstone, cross-bedded	2
4.	Heavy-bedded sandstone, conglomeratic	2½
3.	Laminated, red and gray sandstone, cross-bedded	1½
2.	Heavy bed of brown sandstone, containing ferruginous, sometimes hollow nodules	4½
1.	Like No. 2, to base of quarry	3

In the northwest quarter of section 21, Buena Vista township, on Elk creek, there is exposed in two small quarries a maximum thickness of twenty-two feet of the sandstone. It exhibits the same characters as in former sections as to bedding and color. Some of the red is to be seen but the brown variety prevails. In the Lanphear quarry the jaspery, quartzitic bands are quite pronounced, as are also the spheroidal nodules. The latter frequently consist of concentric, ferruginous shells between which sandstone is intercalated. The greatest thickness of beds is found in the old Dooley quarry, where the ferruginous bands appear as firm crusts of siliceous limonite, separating the major beds of the section. The rock is coarse in texture, friable, and varies in color from gray to deep red. All the layers seem to be thoroughly impregnated with iron oxide.

One mile south of Reasnor, at "Stony Point," the brown sandstone has been quarried in the past.

The most extensive quarrying operations in the county were formerly carried on at the old Kemper quarry in section 8, Fairview township. The rock was quite widely known as the Monroe red sandstone, although both red and brown stone were taken out. John Reinhart took stone from here forty years ago, and worked the quarry for twenty-five years. E. G. Kemper produced, in seven or eight years of his possession, some cut and dressed stone, and at one time employed as many as twenty men. Considerable stone was shipped. The present owner, A. Herwehe, has put out very little stone in the last two years, although there is a fair demand locally.

Mr. B. L. Miller* has briefly described this quarry exposure as follows:

		FEET.
4.	Soil	1
3.	Weathered, brown sandstone	9
2.	Heavy beds, yellow-gray, variegated	10
1.	Dark red sandstone, heavy-bedded	8

Two small quarries are opened here and both the brown and the red stone have been taken out. Cross-bedding is very conspicuous in the upper part of the section. The change in color is gradual from the top downwards, and appears to be due to the degree of leaching and hydration which the rock has undergone. Chemical tests of the brown sandstone show a loss on ignition of 3.8 per cent, and 16.27 per cent of iron and aluminum oxides. The dark variety pulverizes to a deep red and ocherous powder, and analyzes 31.5 per cent Fe_2O_3. At one point in section 21 of Fairview township a weathered outcrop of the red stone occurs from which the resulting ocherous iron oxide has been taken for mineral paint. In places in both the red and brown sandstone, bands or nodules of a dense, flinty character occur, which appear to be quartzitic in nature and origin.

The following description of the sandstone points out its chief characteristics:†

"It is a moderately coarse-grained stone, with some range of color and texture and corresponds in general with the Red Rock stone which has been more widely marketed . . . As will be seen from the tests, it is an excellent stone and might be used to advantage in all structures similar to those in which brown stone has been used so extensively in the east. Under the microscope it seems to be made up of rather coarse and rounded grains of quartz cemented by a matrix of red-brown, iron-stained material which, judging from the analysis, is largely ferric oxides, but contains also some aluminous material. The sand grains are rarely in contact; the interstitial areas being usually as large as the cross-section of the individual grains."

The chemical analysis of this stone as given on page 412 of Dr. Bain's paper, is as follows:

*Geology of Marion county, Ann. Rep. Iowa Geol. Surv., Vol. XI, p. 159, 1900.
†H. F. Bain, Iowa Geol. Survey, Vol. VIII, p. 398.