IOWA

GEOLOGICAL SURVEY

VOLUME XXIV

ANNUAL REPORT, 1913

WITH

ACCOMPANYING PAPERS

GEO. F. KAY, STATE GEOLOGIST
JAMES H. LEES, ASSISTANT STATE GEOLOGIST

DES MOINES
PUBLISHED FOR IOWA GEOLOGICAL SURVEY
ROBERT HENDERSON, STATE PRINTER
J. M. JAMIESON, STATE BINDER
1914

GEOLOGICAL SURVEY ORGANIZATION

GEOLOGICAL BOARD

His Excellency, George W. Clarke	Governor of Iowa
Hon. John L. Bleakly	Auditor of State
John G. Bowman	President State University of Iowa
Raymond A. Pearson	President Iowa State College
C. N. Kinney	President Iowa Academy of Science

ADMINISTRATIVE OFFICERS

George F. Kay	State Geologist
James H. Lees	Assistant State Geologist
Nellie E. Newman	Secretary

GEOLOGICAL SECTION

George F. Kay	Geologist
James H. Lees	Geologist, Physiographic Geology
W. H. Norton	Geologist, Underground Waters
S. W. Beyer	Geologist, Road and Concrete Materials
T. H. Macbride	Geologist, Areal Geology
B. Shimek	Geologist, Pleistocene Geology
J. E. Carman	Geologist, Pleistocene Geology
M. F. Arey	Geologist, Areal Geology
John L. Tilton	Geologist, Areal Geology
A. O. Thomas	Geologist, Areal Geology
James E. Gow	Geologist, Areal Geology
O. P. Hay	Geologist, Pleistocene Mammals
F. M. Van Tuyl	Geologist, Areal Geology
Stuart Weller	Consulting Geologist, Areal Geology
George A. Gabriel	Assistant, Industrial Waters
Amos P. Potts	Field Assistant, Clay Working
A. W. Hixson	Chemist, Coal Analyses
Geo. T. Wright	Chemist, Industrial Waters

TOPOGRAPHIC SECTION

W. H. Herron	Geographer
W. L. Miller	Topographer
R. G. Clinite	Junior Topographer
Carl R. French	Junior Topographer

CONTENTS

ILLUSTRATIONS

FIGURES.

ADMINISTRATIVE REPORT

TWENTY-SECOND ANNUAL

Report of the State Geologist

IOWA GEOLOGICAL SURVEY,
DES MOINES, DECEMBER 31, 1913.

To Governor George W. Clarke and Members of the Geological Board:

GENTLEMEN:—I have the honor to report that during the year 1913 the Iowa Geological Survey successfully carried forward the investigations which were approved by you at the beginning of the field season. In accordance with the well established policy of the Survey each investigator was assigned the kind of work for which he was best fitted by training and experience. The work of the Survey for the year 1913 may be summarized as follows:

AREAL GEOLOGY.

Detailed areal work and geological mapping was carried forward in Audubon and Shelby counties by Bohumil Shimek, who had already done considerable work in this part of the state. As an aid in the interpretation of the Pleistocene geology of Audubon and Shelby counties, Professor Shimek made a detailed study of numerous deep cuts which, fortunately, had but recently been made, just north of Audubon and Shelby counties, between Coon Rapids and Manilla, by the Chicago, Milwaukee and St. Paul Railway Company.

The Director of the Survey continued his studies of the geology of Lucas county and also did some work in Union county. The Assistant State Geologist continued his work on the geology of Crawford county and also on the physiographic features of the Missouri slope of western Iowa.

The field work in Floyd county was completed by A. O. Thomas, in Clarke county by J. L. Tilton, in Cass county by J. E. Gow, and in Calhoun and Greene counties by T. H. Macbride. Reports on these counties are now being prepared for publication.

ROAD AND CONCRETE MATERIALS.

For several years S. W. Beyer, H. F. Wright and assistants have been making a detailed investigation of the road and concrete materials of the state. The field work and the laboratory tests were completed during the year, the latter having been made at the Experiment Station of Iowa State College. The manuscript is ready for publication. A preliminary report was prepared for the members of the last General Assembly. The complete report will constitute a large part of Volume XXIV of the publications of the Survey.

The information contained in this report will be of great value to the people of the state. There never was a time when the people were more interested than they now are in the subject of good roads. Only recently, for the first time, has a Highway Commission been created in this state. There is reason to believe that under the wise direction and supervision of efficient engineers the roads of Iowa will soon compare favorably with the best roads of the other states of the country. Road improvement and road building depend largely upon the availability of sand and gravel, clay, limestone, sandstone, glacial bowlders, and the manufactured products of clay and limestone. It is gratifying to know that the investigations of Doctor Beyer and his assistants have shown that the majority of the counties of Iowa are amply supplied with materials suitable for one or more types of road that are believed to be practical under existing conditions.

INDUSTRIAL WATERS.

During the summer of 1913 George A. Gabriel continued the investigations of the previous year on the surface waters of Iowa, to ascertain with definiteness their industrial applicability. The publication of the conclusions of these investigations will be of great value to many corporations and communities which have recently awakened to a realization of the great waste resulting from the use of unsuitable waters.

ARTESIAN WATERS.

Volume XXI of the Survey reports, on the Underground Waters of Iowa, was published last year. This report is proving to be of inestimable value to the people of Iowa in connection with the problem of water supply for domestic and other purposes. It has been most favorably reviewed in the geological journals of America and Europe. Since the publication of this volume the Survey has continued to keep records of the deep wells that have been sunk within the state, and from time to time it will publish information additional to that given in the published report. Professor Norton continues to be in charge of this work.

PLEISTOCENE PROBLEMS.

J. E. Carman of the University of Cincinnati has completed a detailed investigation of the drift sheets of northwestern Iowa. His work has made it possible to prepare a more accurate map than the present one of the soils and other surface features of this part of the state. Professor Carman's report will soon be ready for publication.

STRATIGRAPHIC GEOLOGY.

Many of the problems of geology are not limited to a single state but embrace several adjoining states. In the investigation of such problems it is of great advantage from every standpoint to have close coöperation among the various geological surveys concerned. At the present time several of the state surveys, including those of Oklahoma, Kentucky, Ohio, Illinois, Missouri and Iowa, are interested in a thorough study of the Mississippian rocks which occur in these states. During the summer of 1913 the surveys of Illinois, Missouri and Iowa employed Professor Stuart Weller of the University of Chicago, who has been for many years a student of the stratigraphy and paleontology of the Mississippian series, to act in an advisory capacity in the study of the Mississippian rocks of their respective states. Under the supervision of Professor Weller field work in Iowa was done by Francis M. Van Tuyl, who made detailed sections of the rocks in the southeastern part of the state and collected numerous fossils which will be of great service in correlating the Mississippian rocks of Iowa with those of adjacent states.

A. O. Thomas began a detailed investigation of the stratigraphy and paleontology of the Devonian rocks of the state.

THE STREAMS OF THE STATE.

In connection with the study of the flow, floods and waterpower of the streams of the state gaging stations have been established for some time on the Des Moines, Cedar, Wapsipinicon and Iowa rivers. During the summer of 1913 additional stations were established on some of the above streams, and also on Upper Iowa, Maquoketa, Turkey and Skunk rivers. At these stations gage readings are systematically being made. Discharge measurements also are being made at low and high water stages of the streams. The work is being done by the Iowa Geological Survey in coöperation with the Water Resources Branch of the United States Geological Survey, each survey bearing half the expense.

COOPERATIVE TOPOGRAPHIC MAPPING.

The Iowa Geological Survey continued to coöperate with the United States Geological Survey in making topographic maps of areas selected by the Director of the Iowa Survey. The Iowa Geological Survey spent $1,750 in this work, and the United States Geological Survey spent an equal amount for field work. As in former years the Iowa Survey paid half the expenses of the field whereas the United States Geological Survey paid half the expenses of the field and all other costs connected with drawing, engraving and publishing the maps.

The field work was done under the supervision of R. B. Marshall, Chief Geographer of the United States Geological Survey, on the Boone, Attica, Chariton and New Virginia sheets. The drafting of the Ames topographic map was completed and the map was transmitted for engraving.

The topographic maps of Iowa already issued are proving to be of great value, and it is strongly recommended that the next legislature be urged to appropriate to the Survey a much larger amount than is now available for this important work. The state of Illinois is spending $10,000 a year for topographic work, in which state the United States Geological Survey spends an equal amount. In Ohio about $45,000 a year is being expended, in Minnesota $20,000 yearly, and in Missouri $12,000. The Iowa Geological Survey should have at least $10,000 a year for topographic mapping. If this amount were duplicated, as it probably would be, by the United States Geological Survey it would be possible to complete the topographic map of the state in a much shorter time than can be done with our present small appropriation.

The development of the state in connection with a highway system, drainage projects, steam and interurban railways and in many other ways demands the preparation of topographic maps as rapidly as possible. Further delay will but add to the great financial loss that the state has already suffered through a lack of such maps. At the last meeting of the Iowa Engineering Society, and also at a recent meeting of the Iowa Academy of Science, resolutions were adopted urging that efforts be made to secure for the Iowa Geological Survey increased appropriations for this important work.

ANALYSES OF IOWA COALS.

The Survey has already published much valuable information about the coals of the state. It now has ready to be published an additional report that will be of great value to all persons who are interested in the coal industry of Iowa. The report has been prepared by A. W. Hixson. It consists of proximate and ultimate analyses of sixteen representative coals of Iowa, accompanied by a thorough discussion of these analyses. The investigation has shown that Iowa coals have a low heat value on account of their high sulphur and moisture content; that the high sulphur content, moreover, renders the coals unsuitable for the manufacture of coal or water gas, and causes them to be destructive to grates and fire boxes. The coals weather somewhat rapidly, which is an unfavorable feature in connection with long storage of the coals. The characters of Iowa coals with regard to the manufacture of producer gas and coke, the probable effect of washing the coals, and many other features are interestingly discussed. It is stated that the Iowa coals compare favorably with those of northern Illinois and Missouri. In the closing pages of the report is a discussion of the purchase of coal under specification. Professor Hixson's report will be published as a part of Volume XXIV of the Survey.

THE CLAY PLANTS OF THE STATE.

During the summer of 1913 A. P. Potts of Iowa State College collected samples of clay from the various plants of the state which are using the shales of the Des Moines stage. In the laboratory, Professor Potts will subject these clays to detailed tests in order to secure information which may be of value to the industrial users of clays.

MINERAL STATISTICS.

Early in 1913 the Iowa Geological Survey in coöperation with the United States Geological Survey compiled the statistics of mineral production in Iowa for the year 1912. The value of the output was $22,910,066, which is higher than any previous figure of record. The year 1910 previously held the record, the value of the output for that year having been $22,744,572, which output exceeded that for 1911 by $1,790,955. Coal was in 1912, as in previous years, the leading mineral product. Its value at the mines was $13,152,088, which was fifty-seven per cent of the total value of the mineral industry of the state. The five leading coal producing counties in order of rank were Monroe, Polk, Appanoose, Mahaska and Dallas. These same counties held similar rank in 1911. The average price of coal at the mine was $1.80 a ton, which is the highest average price on record in Iowa. The average number of men employed in coal mining was 16,370.

The value of clay and clay products was $4,524,492, which exceeded the figure for 1911 but was less than that for 1910 when the record value of $5,335,036 was reached. Of the total value drain tile contributed $2,293,084 and common brick $1,017,097. In the production of clay and clay products, Webster county with ten producers ranked first, Cerro Gordo county with seven producers, second, Polk county with eleven producers, third, and Woodbury county with three producers, fourth. These four counties contributed sixty per cent of the total value of the clay industry.

The value of cement sold in 1912 reached the figure of $2,790,396. This was an increase of nearly fifty per cent over the value of 1911, which was $1,881,253. With three modern plants of large capacity, and with an abundance of excellent raw material available, larger and larger productions of cement may be expected.

The figures for stone and lime and for sand and gravel were larger for 1912 than for any previous year. The value of the stone and lime was $998,236 and of the sand and gravel $563,409. A large part of the stone was used for concrete and railroad ballast. Lee county produced more than one-third of the total output. This was due to a considerable extent, to the large amount of limestone used by the Mississippi Power Company in the construction of the Keokuk dam.

The value of the gypsum output was less in 1912 than in 1911. Decreases were also shown in the values of mineral waters and sand lime brick.

Some months ago the mineral statistics for 1911 and 1912 were published and distributed to the mineral producers of the state. These statistics will be published also in Volume XXIV of the Survey.

THE CENTERVILLE GYPSUM DEPOSIT.

A brief reference was made to the Centerville gypsum deposit in Volume XXI of the reports of the Survey. Recently, a somewhat detailed account of the deposit was written by the Director of the Iowa Geological Survey for publication by the United States Geological Survey.*

The discovery of a deposit of gypsum in the Mississippian rocks of southern Iowa is of scientific interest. Whether or not this gypsum will prove to be of economic importance has yet to be determined. The evidence indicates that the deposit may be extensive and the gypsum is of good quality. The presence of anhydrite decreases the value of the deposit for making wall plaster and related products. The relation of the anhydrite to the gypsum and the relative amounts of the two minerals will have an important bearing on the commercial value of the deposit. However, anhydrite is considered by some manufacturers of Portland cement to be practically as serviceable as gypsum.

The fact that the deposit is more than five hundred feet below the surface and the presence of large amounts of artesian water are factors unfavorable to the mining of the gypsum. On the other hand, the deposit is well located with regard to fuel and transportation, and it is fair to assume that if gypsum products were made in this part of the state a good market for such products could soon be developed.

PUBLICATIONS OF THE SURVEY.

During the year 1913 the Iowa Geological Survey published and distributed to the people of the state a Bibliography of

*Kay, George F., A New Gypsum Deposit in Iowa: Bull. U. S. Geol. Survey, No. 580-E.

Iowa Geology and Mining and a bulletin on the Weed Flora of Iowa. The former which is Volume XXII of the Survey is a complete bibliography of all that has been written with regard to the geology of the state. The author of the volume was Dr. Charles Keyes, a former Assistant State Geologist of the Survey. Preceding the bibliography proper are chapters on Geographic Exploration of Iowa-Land, Geologic Reconnaissance in Iowa, Historical Sketch of Mining in Iowa, and Systematic Geologic Surveying in Iowa. In these chapters some exceedingly interesting facts are presented. The discussion of geographic exploration covers a period of three centuries. Reference is made to the influence that early trade routes had upon settlement and the establishment of commercial enterprises. In the chapter on geological reconnaissance it is pointed out that some of the earliest geological work in America was done within the limits of our own state. The chapter on the history of mining in Iowa brings out the fact that the first discovery of lead and zinc in America was in the Dubuque region; that mineral coal was used by the Iowa Indians before the advent of Europeans in the region; and that coal was mined here one hundred and fifty years previous to its discovery in Pennsylvania. The first practical experiment in the conservation of our mineral resources was tried out seventy-five years ago in Iowa by the Federal Government, and proved a dismal failure. At one time the Dubuque region produced nine-tenths of the lead of the United States, and one-tenth of the world's supply. This bibliography will serve the very useful purpose of making available and accessible the extensive and widely scattered literature of the geology of the state.

The Weed Flora of Iowa is a bulletin of 900 pages and constitutes Bulletin No. 4 of the publications of the Iowa Geological Survey. The need of such a volume had long been felt by all who are familiar with the enormous damage caused to the crops of Iowa by weeds. A conservative estimate places the injury at $25,000,000 annually. The publication of concise information with regard to weeds, such as is given in this bulletin, should do much to decrease this great loss. If the unexcelled resources of our soil could be conserved by the extermination of weeds the farmers would be greatly benefited in a financial way.

Each kind of weed is described in detail, its geographical distribution within the state is shown on a small state map, and methods of extermination are given. Excellent illustrations of the weeds described will be of great assistance to those who are not familiar with the different weeds but who wish to identify them.

Among the most interesting chapters are those dealing with the general characters of seeds, the scattering of weeds, weed migration, the injuriousness of weeds, and weeds for medicinal purposes. A chapter on weed laws gives a summary of the laws of various states in the Mississippi valley.

This bulletin, which will be of great service to the agricultural and related interests of the state, was prepared by Dr. L. H. Pammel and collaborators.

OFFICE WORK.

The Des Moines office has been in charge of James H. Lees, Assistant State Geologist, and Miss Nellie Newman, the Secretary. Mr. Lees cannot be commended too highly for his thorough and painstaking work in connection with the preparation and publication of the reports that have been issued during the year.

From the office have gone out hundreds of letters giving reliable information with regard to the geological features of the different sections of the state. In response to the continued demand for the publications of the Survey many volumes of our reports have been distributed during the year, not only to the citizens of Iowa, but to many persons in other parts of the country who are interested in the possibilities for investment within the state.

Herewith I submit the following papers with the recommendation that they be published as Volume XXIV, which is the Twenty-second Annual Report of the Iowa Geological Survey:

The Road and Concrete Materials of Iowa, by S. W. Beyer and H. F. Wright.

Analyses of Iowa Coals, by A. W. Hixson.

Mineral Production in Iowa for 1911 and 1912, by George F. Kay.

Respectfully submitted,

GEORGE F. KAY.

MINERAL PRODUCTION IN IOWA

IN 1911 AND 1912

By

GEORGE F. KAY

MINERAL PRODUCTION IN IOWA FOR 1911 AND 1912[1]

BY GEORGE F. KAY.

VALUE OF MINERAL PRODUCTION.

1910.

Coal	$13,903,913
Clay and clay products	5,335,036
Stone and lime	639,831
Gypsum	943,849
Lead and zinc	12,128
Sand-lime brick	31,269
Mineral waters	27,175
Sand and gravel	464,863
Other products	1,386,508
Total	$22,744,572

1911.

Coal	$12,663,507
Clay and clay products	4,436,839
Stone and lime	817,121
Gypsum	871,752
Lead and zinc	5,400
Sand-lime brick	25,300
Mineral waters	20,500
Sand and gravel	393,649
Cement	1,881,253
Other products	3,790
Total	$21,119,111

1912

Coal	$13,152,088
Clay and clay products	4,524,492
Stone and lime	998,236
Gypsum	845,628
Lead and zinc	5,670
Sand-lime brick	*
Mineral waters	11,325
Sand and gravel	563,409
Cement	2,790,396
Other products	18,822
Total	$22,910,066

The total value of the mineral production in Iowa in 1911 was $21,119,111 and in 1912 $22,910,066. The value in 1912 was

[1]The mineral statistics were compiled by the Iowa Geological Survey in co-operation with the United States Geological Survey.

*Included in other products.

higher than any previous figure of record. The following table shows the value of Iowa's mineral output during each of the past ten years.

VALUE OF MINERAL PRODUCTION IN IOWA FOR THE YEARS 1903 TO 1912 INCLUSIVE.

1903	$14,637,480
1904	14,955,000
1905	15,103,046
1906	16,414,447
1907	17,627,925
1908	18,090,447
1909	20,365,721
1910	22,744,572
1911	21,119,111
1912	22,910,066

Previous to 1912, the year 1910 held the record, the value of the output for that year having been $22,744,572. In 1912 there was an increase over 1911 in the value of all mineral products except gypsum, sand-lime brick and mineral waters. The most marked increase was in connection with the cement industry, the value of the output of 1912 exceeding that of 1911 by nearly 50 per cent.

The number of mineral producers in Iowa was 726 in 1911 and 665 in 1912.

The total production, by counties, for 1911 and 1912 is given in Table I.

TABLE I.

VALUE OF TOTAL MINERAL PRODUCTION, BY COUNTIES, FOR 1911.

Counties	No. of Producers	Coal	Clay and Clay Products	Stone and Lime	Sand and Gravel	Other Products	Total
Adair	1		*				
Adams	7	$ 18,779	*				$ 18,779
Allamakee	4			$ 5,572			5,572
Appanoose	69	2,102,485	*	*	*		2,134,037
Audubon	7		*		$ 10,648		10,648
Benton	7		$ 16,050	12,316			28,366
Black Hawk	12			10,898	20,990	*	31,888
Boone	10	413,548	81,294				494,842
Bremer	4				4,917		4,917
Buchanan	1			*			
Buena Vista	5		20,010		*		20,010
Butler	3		*		*		898
Calhoun	1		*				
Carroll	2		*		*		
Cass	2		*				
Cedar	3		*	*			13,735
Cerro Gordo	13		731,834	50,598		*	782,432
Cherokee	5				14,554		14,554
Clarke	1		*				
Clay	1		*				
Clayton	9		*	1,964	*		9,264
Clinton	15		21,600	*	19,251	*	52,604
Crawford	2		*				
Dallas	9	731,805	180,994				912,799
Decatur	2		*	*			
Delaware	5		7,840	*			7,840
Des Moines	4		*	*	*		21,608
Dickinson	1				*		
Dubuque	19		41,000	70,951	21,439	$ 5,400	138,790
Emmet	6				6,175		6,175
Fayette	7		*	*	5,202		24,052
Floyd	7		*	1,867	*		1,867
Franklin	1		*				
Fremont	2		*				
Greene	7	30,400	*		*		72,826
Grundy	3		*		*		24,419
Guthrie	11	29,570	9,420				38,990
Hamilton	1		*				
Hancock	1		*				
Hardin	10		55,450	28,301	765		84,516
Harrison	1		*				
Henry	4		23,920	*			23,920
Howard	6		*	3,880	*		3,880
Humboldt	2		*	*			
Ida	4				1,609		1,609
Iowa	3		19,600				19,600
Jackson	4		*	*			68,658
Jasper	14	672,532	17,553			*	690,085
Jefferson	8	11,236	36,340			*	47,576
Johnson	9		28,150	*	6,750		34,900
Jones	11		*	40,343	*		47,080

TABLE I—Continued

Counties	No. of Producers	Coal	Clay and Clay Products	Stone and Lime	Sand and Gravel	Other Products	Total
Keokuk	17	23,978	30,202	*	----	----	54,180
Kossuth	1	----	*	----	----	----	----
Lee	15	----	*	119,654	*	----	125,574
Linn	16	----	19,234	62,855	22,884	----	104,973
Louisa	7	----	*	*	*	*	11,885
Lucas	4	24,004	*	----	----	----	24,004
Lyon	3	----	----	----	8,445	----	8,445
Madison	7	----	----	60,224	----	----	60,224
Mahaska	26	1,200,117	33,001	*	----	----	1,233,118
Marion	18	265,303	38,280	----	*	----	303,583
Marshall	10	----	16,716	*	*	----	144,211
Mills	4	----	5,500	----	----	----	5,500
Mitchell	3	----	----	658	----	----	658
Monona	1	----	----	----	*	----	----
Monroe	14	3,402,743	----	----	----	----	3,402,743
Muscatine	8	----	14,253	----	*	----	14,253
O'Brien	4	----	----	----	6,868	----	6,868
Osceola	2	----	----	----	*	----	----
Page	6	36,189	*	----	*	----	55,110
Palo Alto	4	----	*	----	5,839	----	5,839
Plymouth	10	----	*	----	15,198	----	15,198
Pocahontas	2	----	*	*	----	----	----
Polk	47	2,729,625	587,356	----	84,058	*	3,401,039
Pottawattamie	4	----	32,209	----	----	----	32,209
Poweshiek	4	----	25,498	----	----	----	25,498
Sac	3	----	*	----	*	----	82,464
Scott	13	----	32,230	121,080	*	*	185,310
Shelby	1	----	*	----	----	----	----
Sioux	6	----	----	----	3,747	----	3,747
Story	10	----	*	----	6,803	----	6,803
Tama	7	----	59,585	*	----	----	59,585
Taylor	7	22,979	*	----	----	----	22,979
Union	1	----	*	----	----	----	----
Van Buren	7	20,340	*	*	*	----	22,370
Wapello	22	523,535	70,570	11,474	*	*	619,197
Warren	4	*	69,210	----	----	----	69,210
Washington	9	----	42,522	112	----	----	42,634
Wayne	8	234,761	*	----	----	----	234,761
Webster	22	101,949	1,100,237	----	2,201	875,472	2,079,859
Winnebago	2	----	*	----	*	----	----
Winneshiek	5	----	*	*	*	----	9,729
Woodbury	9	----	300,886	----	5,895	----	306,781
Worth	1	----	*	----	----	----	----
Wright	6	----	31,400	----	5,354	----	36,754
County values representing less than three producers, and small coal mines	----	67,629	636,895	214,374	114,057	1,927,123	2,408,080
Total	726	$ 12,663,507	$ 4,436,839	$817,121	$393,649	$ 2,807,995	$21,119,111

*Included in "county values" and totals.

TABLE I—Continued

VALUE OF TOTAL MINERAL PRODUCTION, BY COUNTIES, FOR 1912.

Counties	No. of Producers	Coal	Clay and Clay Products	Stone and Lime	Sand and Gravel	Other Products	Total Value
Adair	1		*				
Adams	6	$ 24,690	*				$ 24,690
Allamakee	4		*	$ 24,277			24,277
Appanoose	66	2,506,844	*	*	*		2,534,142
Audubon	5		*		$ 500		500
Benton	6		$ 48,892	*			48,892
Black Hawk	14			11,389	22,590	*	33,979
Boone	8	454,731	67,096				521,827
Bremer	3				3,283		3,283
Buchanan	1			*			
Buena Vista	6		15,064		1,088		16,152
Butler	3		*		*		19,894
Calhoun	1		*				
Carroll	1		*				
Cass	1		*				
Cedar	1		*				
Cerro Gordo	11		884,337	*		*	3,205,546
Cherokee	4				16,700		16,700
Clarke	1		*				
Clay	2		*				
Clayton	18		*	3,255	24,865		28,120
Clinton	4		16,720			*	16,720
Crawford	1		*				
Dallas	10	810,532	153,340				963,872
Decatur	1			*			
Delaware	6		8,140	*			8,140
Des Moines	7		*	10,562	*		23,261
Dickinson	1					*	
Dubuque	17		48,500	73,333	17,973	$ 5,670	145,476
Fayette	8		*	*	5,414		29,759
Floyd	4		*	*	*		51,587
Franklin	2		*				
Fremont	1		*				
Greene	6	24,250	*		*		36,052
Grundy	3		*		*		24,600
Guthrie	7	16,191	11,256				27,447
Hamilton	1		*				
Hancock	1		*				
Hardin	9		55,166	*	3,533		58,699
Harrison	1			*			
Henry	3		*	*			35,893
Howard	3		*	*	*		12,820
Ida	2				*		
Iowa	2		*				
Jackson	2		*	*			
Jasper	17	669,936	17,305			*	687,241
Jefferson	8	9,170	34,305			*	43,475
Johnson	8		17,600	*	8,428		26,028
Jones	10		*	91,205	*		106,929
Keokuk	17	26,733	32,819	*			59,552
Kossuth	1		*				

TABLE I—Continued

Counties	No. of Producers	Coal	Clay and Clay Products	Stone and Lime	Sand and Gravel	Other Products	Total Value
Lee	15		7,250	327,917	5,452		340,619
Linn	15		27,489	55,576	18,680		101,745
Louisa	8		*	*	*	120	9,360
Lucas	3	*	*				32,070
Lyon	6				19,237		19,237
Madison	5		*	42,361			42,361
Mahaska	19	944,156	41,310	*			985,466
Marion	18	315,260	41,800		17,288		374,348
Marshall	11		93,971	*	*		207,008
Mills	4		6,550				6,550
Mitchell	1			*			
Monroe	15	3,757,856					3,757,856
Muscatine	8		13,503		*		13,503
O'Brien	2				*		
Osceola	2				*		
Page	4	*	*				22,600
Palo Alto	4		*		9,943		9,943
Plymouth	9		*		19,707		19,707
Pocahontas	2		*	*			
Polk	48	2,761,723	582,878		148,302	*	3,492,903
Pottawattamie	3		32,172				32,172
Poweshiek	4		29,004				29,004
Sac	4		*		27,722		27,722
Scott	16	*	44,071	128,823	*	*	216,089
Shelby	1		*				
Sioux	6				24,650		24,650
Story	7		*		5,530		5,530
Tama	7		59,619	*			59,619
Taylor	4	12,700	*				12,700
Union	1		*				
Van Buren	7	18,785	*	*	*		28,628
Wapello	20	345,324	68,096	8,900	22,522	*	444,842
Warren	3	*	*				75,602
Washington	5		32,587				32,587
Wayne	6	205,182					2,051,182
Webster	27	107,088	947,748		*	854,178	1,909,014
Winnebago	2		*		*		
Winneshiek	5		*	*	*		10,606
Woodbury	8		309,466		16,120		325,586
Worth	1		*				
Wright	3		*		*		8,400
County values representing less than three producers, and small coal mines		140,937	776,438	220,638	123,882	2,811,923	1,191,354
Total	665	$ 13,152,088	$ 4,524,492	$998,236	$563,409	$ 3,671,891	$22,910,116

COAL.

As in previous years, coal was in 1911 and 1912 the leading mineral produced in Iowa. Its value at the mines, in 1911, was $12,663,507 and in 1912, $13,152,088. Although the value of the coal was greater in 1912 than in 1911, the total tonnage in 1912 was less than in 1911. The value of the coal mined in 1912 has been exceeded only in 1910 when the value of the coal output was $13,903,913. There were twenty-one producing counties in 1911 and twenty-two in 1912. In both years the five leading coal producing counties, in order of rank, were Monroe, Polk, Appanoose, Mahaska, and Dallas.

In 1911, the average price of coal at the mine was $1.73 a ton, and in 1912 the average price was $1.80 a ton, the latter figure being the highest average price on record in Iowa. In 1911, there were 16,599 men employed in coal mining in Iowa; in 1912 there were 16,370.

The table below gives the tonnage, value, average price per ton, average number of days worked, and average number of men employed, in Iowa, during the past decade, according to the United States Geological Survey:

Year	Total Tons	Value	Average Price	Average Number of days worked	Average Number of Men Employed
1903	6,419,811	$10,563,910	$1.65	226	14,162
1904	6,519,933	10,504,406	1.61	213	15,629
1905	6,798,609	10,586,381	1.56	209	15,113
1906	7,266,224	11,619,455	1.60	224	15,260
1907	7,574,322	12,258,012	1.62	230	15,585
1908	7,161,310	11,706,402	1.63	214	16,021
1909	7,757,762	12,793,628	1.65	---	17,286
1910	7,928,120	13,903,913	1.75	218	16,666
1911	7,331,648	12,663,507	1.73	203	16,599
1912	7,289,529	13,152,088	1.80	188	16,370

In 1912, during the month of April and a considerable part of May, many of the coal mines were shut down pending the settlement of the wage scale. When the mines were again opened, it was found that many of the miners had left the state and that, furthermore, there was a great shortage in cars to handle the coal. The railway companies had diverted the cars which were available before the shut-down for the hauling of coal to other lines of traffic. Never, in the history of the state, has there been a greater car shortage than in 1912.

The output, disposition of product, value, average price per ton, average number of days worked and average number of men employed in 1911 and 1912 are given, tabulated by counties, in Table II.

TABLE II.

COAL PRODUCTION FOR IOWA IN 1911, BY COUNTIES, IN SHORT TONS.

Counties	Loaded at Mine for Shipment	Sold to local trade and used by Employees	Used at Mine for Steam and Heat	Total Quantity	Total Value	Average Price per Ton	Average Number Days Active	Average Number of Employees
Adams				7,472	$ 18,779	$ 2.51	120	52
Appanoose	1,023,405	55,051	26,267	1,104,723	2,102,485	1.90	163	4,066
Boone	174,932	26,388	13,120	214,440	413,548	1.93	206	653
Dallas	371,794	7,204	6,590	385,588	731,805	1.90	257	707
Greene				11,800	30,400	2.58	160	43
Guthrie		10,390		10,390	29,570	2.84	142	59
Jasper				292,427	672,532	2.30	219	648
Jefferson				5,129	11,236	2.19	192	22
Keokuk		11,697	815	12,512	23,978	1.92	188	29
Lucas				13,337	24,004	1.80	184	43
Mahaska	733,178	22,152	21,859	777,189	1,200,117	1.54	213	1,425
Marion	149,803	15,446	6,080	171,329	265,303	1.55	225	327
Monroe	2,140,265	55,181	63,793	2,259,239	3,402,743	1.51	217	4,266
Page		12,396		12,396	36,189	2.92	126	62
Polk	1,302,029	173,288	56,693	1,532,010	2,729,625	1.78	217	2,995
Taylor	4,565	5,385		9,950	22,979	2.32	135	58
Van Buren				8,656	20,340	2.35	208	15
Wapello	268,784	38,690	4,858	312,332	523,535	1.68	226	572
Wayne				116,382	234,761	2.00	203	379
Webster	37,749	6,425	1,852	46,026	101,949	2.13	173	169
Counties with less than three producers and small mines	388,395	92,826	2,303	28,321	67,629			9
Total	6,594,899	532,519	204,230	7,331,648	$ 12,663,507	$ 1.73	203	16,599

COAL PRODUCTION FOR IOWA IN 1912, BY COUNTIES, IN SHORT TONS.

Counties	No. of Producers	Loaded at Mine for Shipment	Sold to Local Trade and Used by Employees	Used at Mine for Steam and Heat	Total Quantity	Total Value	Average Price per Ton	Average Number Days Active	Average Number of Employees
Adams	5		9,868		9,868	$ 24,690			55
Appanoose	63	1,168,776	65,969	17,921	1,252,666	2,506,844			4,166
Boone	5	172,585	35,683	3,900	212,168	454,731			776
Dallas	5	420,990	8,969	6,247	436,206	810,532			957
Greene	3				9,590	24,250			32
Guthrie	4		5,870		5,870	16,191			28
Jasper	10	237,221	19,530	14,550	271,301	669,936			584
Jefferson	3		4,248		4,248	9,170			16
Keokuk	5		14,240		14,290	26,733			31
Mahaska	15	546,100	20,669	12,074	578,843	944,156			983
Marion	12	161,655	16,434	3,979	182,068	315,260			428
Monroe	15	2,272,658	48,297	72,457	2,393,412	3,757,856			4,281
Polk	22	1,226,294	221,240	38,519	1,486,053	2,761,723			2,912
Taylor	3		2,520		5,120	12,700			31
Van Buren	3		3,529		9,154	18,785			14
Wapello	9	175,031	25,877	5,194	206,102	345,324			488
Wayne	6		10,631		99,168	205,182			377
Webster	5	42,320	3,054	2,700	48,074	107,088			151
Counties with less than three producers[1] and small mines		95,677	73,578	2,475	65,328	140,937			60
Total		6,519,307	590,206	180,016	7,289,529	$ 13,152,088	$ 1.80	188	16,370

[1]Lucas, Page, Scott and Warren.

Iowa's rank as a coal producing state, in 1912, is given in the table which follows. It will be seen that Iowa ranked eleventh in tonnage and ninth in value. In 1911, Iowa ranked ninth in tonnage and ninth in value.

RANK OF LEADING COAL-PRODUCING STATES IN 1912, WITH QUANTITY AND VALUE OF PRODUCT AND PERCENTAGE OF EACH.[1]

Production.

Rank	State	Quantity (Short Tons)	Percentage of Total Production
1	Pennsylvania:		
	Anthracite	84,361,598	15.8
	Bituminous	161,865,488	30.3
2	West Virginia	66,786,687	12.5
3	Illinois	59,885,226	11.2
4	Ohio	34,528,727	6.4
5	Kentucky	16,490,521	3.1
6	Alabama	16,100,600	3.0
7	Indiana	15,285,718	2.8
8	Colorado	10,977,824	2.0
9	Virginia	7,846,638	1.5
10	Wyoming	7,368,124	1.4
11	Iowa	7,289,529	1.4
	Total for United States	534,466,580	100.0

Value.

Rank	State	Value	Percentage of Total Value
1	Pennsylvania:		
	Anthracite	$177,622,626	25.6
	Bituminous	169,370,497	24.4
2	Illinois	70,294,338	10.1
3	West Virginia	62,792,234	9.0
4	Ohio	37,083,363	5.3
5	Alabama	20,829,252	3.0
6	Indiana	17,480,546	2.5
7	Kentucky	16,854,207	2.4
8	Colorado	16,345,336	2.4
9	Iowa	13,152,088	1.9
10	Wyoming	11,648,088	1.7
11	Kansas	11,324,130	1.6
	Total for United States	$ 695,606,071	100.0

[1]From Advance Chapters of Mineral Resources of the United States for 1912.

CLAY AND CLAY PRODUCTS.

The value of clay and clay products in Iowa in 1911 was $4,436,839 and in 1912, $4,524,492. In both years the value fell below the record value of 1910, which was $5,335,036.

The output of clay products during 1911 and 1912 was distributed as follows:

Product	1911		1912	
	Quantity in Thousands	Value	Quantity in Thousands	Value
Common brick	154,434	$1,025,011	148,472	$1,017,097
Paving brick	8,879	103,384	15,033	197,035
Face brick	9,241	114,178	11,912	142,637
Drain tile	------	2,468,962	------	2,293,084
Sewer pipe	------	284,817	------	291,672
Fireproofing, terra cotta lumber, hollow building block or tile	------	374,628	------	535,254
Pottery	------	36,319	------	30,141
Other products	------	25,575	------	15,406
Clay	------	3,965	------	2,166
Total	------	$4,436,839	------	$4,524,492

In the production of clay products in 1912, Webster county with ten producers, ranked first; Cerro Gordo county with seven producers, second; Polk county with eleven producers, third, and Woodbury county with three producers, fourth. These four counties contributed 60 per cent of the total value of the clay industry. Iowa continues to be the premier state in the manufacture of drain tile, the value of this product in 1911 having been $2,468,962 and in 1912, $2,293,084. The two leading producers of drain tile are Cerro Gordo and Webster counties. In 1912, there was a marked increase over 1911 in the quantity produced and the value of paving or vitrified brick.

The clay product is tabulated by counties, in Table III in which the distribution of the leading products is given:

TABLE III.

VALUE OF IOWA CLAY AND CLAY PRODUCTS FOR 1911, TABULATED BY COUNTIES.

Counties	No. of Producers	Common Brick	Paving Brick or Block	Face Brick	Drain Tile	Other Products†	Total Value
Adair	1	*			*		
Adams	2	*			*	*	
Appanoose	2	*			*		
Audubon	2	*			*	*	
Benton	4	$ 4,450			$ 11,600		$ 16,050
Boone	3	40,685	*	*	*	*	81,294
Buena Vista	3	*			*		20,010
Butler	1	*					
Calhoun	1	*			*		
Carroll	1	*			*		
Cass	2	*		*	*	*	
Cedar	1	*			*		
Cerro Gordo	7	52,090			603,891	$ 75,853	731,834
Clarke	1	*					
Clay	1	*			*		
Clayton	2	*			*	*	
Clinton	3	*			*		21,600
Crawford	2	*					
Dallas	5	8,512			167,512	4,970	180,994
Decatur	1	*			*		
Delaware	3	*			*		5,620
Des Moines	1	*			*		
Dubuque	3	41,000					41,000
Fayette	1	*					
Floyd	1	*			*	*	
Franklin	1	*			*		
Fremont	2	*					
Greene	2	*			*		
Grundy	2	*		*	*		
Guthrie	3	1,519			*	*	9,420
Hamilton	1	*			*		
Hancock	1				*		
Harrison	1	*			*		
Hardin	2	*	*		*		
Henry	3	*			*		23,920
Howard	1	*			*		
Humboldt	1				*		
Iowa	3	*			*		19,600
Jackson	2	*			*		
Jasper	6	*			*		17,553
Jefferson	4	*			27,712	*	36,340
Johnson	4	*			*		28,150
Jones	2	*			*		
Keokuk	10	*			23,591	*	30,202
Kossuth	1				*	*	
Lee	2	*		*			
Linn	5	*			*		19,234
Louisa	2	*			*		
Lucas	1	*					

TABLE III—Continued

Counties	No. of Producers	Common Brick	Paving Brick or Block	Face Brick	Drain Tile	Other Products†	Total Value
Mahaska	3	10,101	*	*	13,100	*	33,001
Marion	3	*	----------	--------	13,340	*	38,280
Marshall	6	7,224	----------	*	*	--------	16,716
Mills	4	*	----------	--------	*	--------	5,500
Muscatine	4	*	----------	--------	*	--------	7,537
Page	2	*	----------	--------	*	*	----------
Palo Alto	1	----------	----------	--------	*	*	----------
Plymouth	1	*	----------	--------	--------	--------	----------
Pocahontas	1	----------	----------	--------	*	--------	----------
Polk	11	167,983	*	*	153,174	155,255	587,356
Pottawattamie	3	32,209	----------	--------	--------	--------	32,209
Poweshiek	4	*	----------	--------	23,099	*	25,498
Sac	1	*	----------	--------	*	--------	----------
Scott	3	7,194	*	--------	*	*	32,230
Shelby	1	*	----------	--------	--------	--------	----------
Story	2	*	----------	*	*	*	34,262
Tama	6	19,839	----------	*	*	--------	59,585
Taylor	1	*	----------	--------	--------	--------	----------
Union	1	*	----------	--------	*	*	----------
Van Buren	1	*	----------	--------	--------	--------	----------
Wapello	3	*	----------	*	*	*	43,187
Warren	3	2,110	----------	--------	*	*	69,210
Washington	6	14,350	----------	--------	23,522	*	42,522
Wayne	1	*	----------	--------	--------	--------	----------
Webster	11	61,320	*	--------	708,287	319,990	1,096,297
Winnebago	1	*	----------	--------	*	--------	----------
Winneshiek	1	*	----------	--------	--------	--------	----------
Woodbury	4	234,472	----------	*	*	*	300,886
Worth	1	----------	----------	*	--------	--------	----------
Wright	3	*	----------	--------	*	--------	31,400
**Pottery	5	----------	----------	--------	--------	--------	36,319
***Clay sold	3	----------	----------	--------	--------	--------	3,965
Counties with less than three producers	----	319,953	103,384	114,178	700,134	128,952	658,058
Total	217	$ 1,025,011	$ 103,384	$114,178	$ 2,468,962	$685,020	$ 4,436,839

†Includes fancy brick, sewer pipe, fireproofing, etc.
**Includes Delaware, Muscatine and Wapello counties.
***Includes Hardin and Webster counties.

TABLE III—Continued

VALUE OF IOWA CLAY AND CLAY PRODUCTS FOR 1912, TABULATED BY COUNTIES.

Counties	No. of Producers	Common Brick	Paving Brick or Block	Face Brick	Drain Tile	Other Products	Total Value
Adair	1	*					
Adams	1	*			*		
Allamakee	1	*			*	*	
Appanoose	1	*			*		
Audubon	2	*			*		
Benton	5	$ 18,498			$ 19,044	*	$ 48,892
Boone	3	33,807	*	*	*	*	67,096
Buena Vista	3	*			12,664		15,064
Butler	1	*			*		
Calhoun	1	*			*	*	
Carroll	1	*					
Cass	1	*			*	*	
Cedar	1	*			*		
Cerro Gordo	7	82,282			621,224	$180,831	884,337
Clarke	1	*			*		
Clay	2	*			*		
Clayton	1	*					16,720
Clinton	3	*			*		
Crawford	1	*					
Dallas	5	2,007			141,145	10,188	153,340
Delaware	3	2,880			*	*	6,800
Des Moines	1	*			*		
Dubuque	3	48,500					48,500
Fayette	1	*				*	
Floyd	1	*			*	*	
Franklin	2	*			*	*	
Fremont	1	*					
Greene	2	*			*	*	
Grundy	2	*		*	*		
Guthrie	3	*			7,993	*	11,256
Hamilton	1	*			*	*	
Hancock	1				*		
Hardin	2	*			*		
Henry	2	*			*	*	
Howard	1	*			*	*	
Iowa	2	*			*		
Jackson	1	*			9,850	*	17,305
Jasper	6	*					
Jefferson	4	*			23,434	4,608	34,305
Johnson	3	*			*		17,600
Jones	2	*			*	*	
Keokuk	10	5,578			26,228	*	32,819
Kossuth	1	*		*	*		
Lee	3	*		*			7,250
Linn	6	21,169			6,320		27,489
Louisa	2	*			*	*	
Lucas	1	*					
Madison	1	*			*		
Mahaska	3	15,710	*		17,300	*	41,310

TABLE III—Continued

Counties	No. of Producers	Common Brick	Paving Brick or Block	Face Brick	Drain Tile	Other Products	Total Value
Marion	3	*	----------	--------	9,500	*	41,800
Marshall	7	9,311	----------	*	55,360	*	93,971
Mills	4	6,550	----------	--------	----------	--------	6,550
Muscatine	4	*	----------	--------	*	--------	8,191
Page	2	*	----------	--------	----------	--------	----------
Palo Alto	1	----------	----------	--------	*	*	----------
Plymouth	1	*	----------	--------	----------	--------	----------
Pocahontas	1	----------	----------	--------	*	--------	----------
Polk	11	135,891	*	*	*	161,697	582,878
Pottawattamie	3	32,172	----------	--------	----------	--------	32,172
Poweshiek	4	*	----------	--------	24,974	*	29,004
Sac	1	*	----------	--------	*	*	----------
Scott	4	16,518	----------	--------	*	*	44,071
Shelby	1	*	----------	--------	----------	--------	----------
Story	2	*	----------	*	*	*	----------
Tama	6	*	----------	*	25,857	--------	59,619
Taylor	1	*	----------	--------	----------	--------	----------
Union	1	*	----------	--------	*	*	----------
Van Buren	2	*	----------	--------	*	--------	----------
Wapello	3	28,486	*	*	*	*	44,607
Warren	2	*	----------	--------	*	*	----------
Washington	5	*	----------	--------	20,292	*	32,587
Winnebago	1	*	----------	--------	*	--------	----------
Winneshiek	1	*	----------	--------	----------	--------	----------
Webster	10	90,334	*	--------	587,808	257,917	946,058
Woodbury	3	*	*	*	*	*	309,466
Worth	1	----------	----------	*	----------	--------	----------
Wright	1	*	----------	--------	*	--------	----------
**Pottery	4	----------	----------	--------	----------	--------	30,141
***Clay sold	4	----------	----------	--------	----------	--------	2,166
Counties with less than three producers	----	467,404	197,035	$142,637	684,091	227,091	831,128
Total	207	$ 1,017,097	$ 197,035	142,637	684,091	227,091	831,128

†Includes fancy brick, sewer pipe, fireproofing, etc.
**Includes Delaware, Muscatine and Wapello counties.
***Includes Hardin and Webster counties.

The following table shows the rank of the ten leading states in value of clay products in 1911 and 1912. It includes, also, the number of operating firms and the percentage of the total value produced by each of the ten states:

TEN LEADING STATES IN VALUE OF CLAY PRODUCTION IN 1911 AND 1912.[1]

1911.

State	Rank	Number of Operating Firms Report'g	Value not including raw clay sold	Percentage of Total Product
Ohio	1	633	$ 32,663,895	20.13
Pennsylvania	2	423	20,270,033	12.49
New Jersey	3	162	18,178,228	11.21
Illinois	4	330	14,333,011	8.83
New York	5	222	10,184,376	6.28
Indiana	6	302	7,000,771	4.32
Missouri	7	122	6,274,353	3.87
California	8	92	4,915,866	3.03
West Virginia	10	55	4,333,420	2.67
Iowa	9	214	4,432,874	2.73
Total for United States	------	4,628	$ 162,236,181	100.00

1912.

State	Rank	No. of Operat'g Firms Report'g	Value not including raw clay sold	Percentage of Total Product
Ohio	1	596	$ 34,811,508	20.14
Pennsylvania	2	393	21,537,221	12.46
New Jersey	3	155	19,838,553	11.48
Illinois	4	301	15,210,990	8.80
New York	5	219	12,058,858	6.98
Indiana	6	278	7,935,251	4.59
Missouri	7	110	6,412,861	3.71
California	8	91	5,912,450	3.42
West Virginia	9	54	4,775,874	2.76
Iowa	10	200	4,522,326	2.62
Total for United States	------	4,284	$ 172,811,275	100.00

It will be seen from this table that in 1911 Iowa ranked ninth and in 1912, tenth.

[1]Advance chapter from Mineral Resources of the United States for 1912.

STONE AND LIME.

The quarry production for 1911 and 1912 showed a marked increase over 1910. The value of the output in 1910 was $639,831, in 1911 the value reached $817,121, and in 1912 the record figure of $998,236 was reached. The output for 1911 and 1912 was distributed as follows:

	1911	1912
Limestone—		
Building	$ 39,350	$ 54,809
Riprap and rubble	118,471	155,945
Crushed stone—		
Road making	39,496	30,821
Railroad ballast	162,704	235,326
Concrete	267,936	404,302
*Other purposes	51,938	63,682
Lime	80,914	51,800
Total limestone and lime	$760,809	$996,685
Sandstone	$ 56,312	$ 1,551
Total stone and lime	$817,121	$998,236

*Paving, curbing, flagging, etc.

The distribution of limestone and lime is given, by counties, in Table IV.

TABLE IV.

PRODUCTION OF LIMESTONE AND LIME IN 1911.

Counties	No. of Producers	Building Stone	Riprap and Rubble	Crushed Stone			Lime	Other Uses	Total Value
				Road-making	Railroad Ballast	Concrete			
Allamakee	4	$ 1,159	*			*			$ 5,572
Appanoose	1	*				*			
Benton	3	*	*			*		$ 12,200	12,316
Black Hawk	3	*		*		*			10,763
Buchanan	1	*							
Cedar	2		*		*	*		*	
Cerro Gordo	3	*	*			$ 29,309	*		50,598
Clayton	4	749					*		1,814
Clinton	2	*	*					*	
Delaware	1	*	*						
Des Moines	1	*							
Dubuque	10	6,350	$ 35,925	$ 8,100	*	4,830	*	1,070	70,951
Fayette	2	*							1,867
Floyd	5	1,691	*					*	
Hardin	3	*				*			
Henry	1					*			
Howard	4	1,235	*			*		*	3,880
Humboldt	1	*							
Jackson	1		*				*		
Johnson	1	*	*	*		*			
Jones	8	2,199	21,598	*	*	8,983		*	40,343
Keokuk	2	*	*	*		*			
Lee	9	*	20,935	17,475	*	75,734		*	119,054
Linn	4	*		*	*	11,458			62,855
Louisa	2	*	*			*			
Madison	7	*		*		46,557		10,153	60,224
Mahaska	1	*	*	*		*		*	
Marshall	1		*		*				
Mitchell	3	*				*		*	

TABLE IV—Continued

Counties	No. of Producers	Building Stone	Riprap and Rubble	Crushed Stone			Lime	Other Uses	Total Value
				Road-making	Railroad Ballast	Concrete			
Pocahontas	1					*			
Scott	6	428	16,394	4,130	$ 39,538	39,327		20,860	120,677
Tama	1		*						
Van Buren	1	*							
Wapello	3		5,230						
Washington	3	87				*		*	
Winneshiek	2	*							
Counties with less than three producers		25,452	18,389	9,791	123,166	51,738	80,914	8,725	199,895
Total		$ 39,350	$ 118,471	$ 39,496	$ 162,704	$ 267,936	$ 80,914	$ 51,938	$ 760,809

TABLE IV—Continued

PRODUCTION OF LIMESTONE AND LIME IN 1912.

Counties	No. of Producers	Building Stone	Riprap and Rubble	Crushed Stone			Lime	Other Uses	Total Value
				Road-making	Railroad Ballast	Concrete			
Allamakee	3		*			*			$ 24,277
Appanoose	1			*					
Benton	1			*					
Black Hawk	4	$ 1,664		*	*	*		*	11,289
Buchanan	1	*							
(Cedar)	0								
Cerro Gordo	2	*	*			*		*	
Clayton	6	1,471	*	*		*	*		3,056
Delaware	2	*	*						
Des Moines	4	*	*	*				*	10,562
Dubuque	9	10,700	$ 37,673	$ 12,460	*	*	*	*	73,333
Fayette	2	*							
Floyd	2	*	*					*	
Hardin	2	*				*			
Harrison	1							*	
Henry	1	*				*			
Howard	1	*				*			
Jackson	1						*		
Johnson	1	*	*			*			
Jones	7	22,827	18,533	*	*	$ 41,839			91,205
Keokuk	2	*	*			*			
Lee	9	*	24,662	8,920		245,550		*	327,917
Linn	4			*	*	*			55,576
Louisa	2		*			*			
Madison	4	*				38,868		*	42,361
Mahaska	1		*	*					
Marshall	2				*	*			
Mitchell	1	*							
Pocahontas	1			*		*		*	

TABLE IV—Continued

Counties	No. of Producers	Building Stone	Riprap and Rubble	Crushed Stone			Lime	Other Uses	Total Value
				Road-making	Railroad Ballast	Concrete			
Scott	6	*	33,233	*	*	21,200	----------	*	127,661
Tama	1	----------	*	----------	----------	----------	----------	----------	----------
Van Buren	1	*	*	----------	----------	*	----------	----------	----------
Wapello	3	*	*	----------	----------	*	----------	----------	8,900
Winneshiek	2	*	----------	----------	----------	----------	----------	----------	----------
Counties with less than three producers	----	18,147	41,844	9,441	235,326	56,845	----------	63,682	220,548
Total	----	$ 54,809	$ 155,945	$ 30,821	$ 235,326	$ 404,302	$ 51,800	$ 63,682	$ 996,685

The tables show that a large part of the stone was used for concrete and railroad ballast. Lee county produced, in 1912, more than one-third of the total output. This was due, to a considerable extent, to the large amount of limestone used by the Mississippi Power Company in the construction of the Keokuk dam.

SAND AND GRAVEL.

The value of the sand and gravel industry in 1911 was $393,649 and in 1912, $563,409, the latter figure being higher than that of any previous year on record.

The sand and gravel sold during 1911 and 1912 may be classified as follows:

Kind—	1911	1912
	Value	Value
Sand used for—		
Molding	$ 4,582	$ 3,572
Building	226,675	328,882
Engine	5,527	4,556
Other sand	31,842	68,543
Gravel	125,023	157,856
Total sand and gravel	$393,649	$563,409

Table V shows the distribution of sand and gravel by counties:

TABLE V.

VALUE OF SAND AND GRAVEL PRODUCED IN IOWA IN 1911.

County	No. of Producers	Molding Sand	Building Sand	Engine Sand	Other Sand	Gravel	Total
Appanoose	1	*					
Audubon	5		$ 10,525		*	*	$ 10,648
Black Hawk	7	$ 950	13,340		$ 6,700		20,990
Bremer	4		*		*	$ 3,709	4,917
Buena Vista	2					*	
Butler	2		*			*	
Carroll	1		*	*		*	
Cherokee	5		3,440	*	1,741	9,355	14,554
Clayton	1				*		
Clinton	9		2,998	*	*	15,405	19,251
Des Moines	2		*		*	*	
Dickinson	1		*				
Dubuque	5	*	8,601	*	*	*	21,439
Emmet	5	*	5,425		*	*	6,175
Fayette	4		4,855	*		*	5,202
Floyd	1					*	
Greene	1					*	
Grundy	1		*				
Hardin	3		*	*	*		
Howard	1		*				
Ida	4		*		*		1,609
Johnson	4		5,202			*	
Jones	1		*				
Lee	2		*	*			
Linn	7		17,034	*	*	5,575	22,884
Louisa	1		*				
Lyon	3		5,445		*		8,445
Marion	2		*		*	*	
Marshall	2	*				*	
Monona	1		*				
Muscatine	1		*		*	*	
O'Brien	4		6,840			*	6,868
Osceola	2		*			*	
Page	1		*		*		
Palo Alto	3		*			*	5,839
Plymouth	9		13,686		*	*	15,198
Polk	13	*	55,096	$ 939	*	23,070	84,058
Sac	2		*	*	*	*	
Scott	2		*		*	*	
Sioux	6		3,060		*	*	3,747
Story	8		5,122		*	1,531	6,803
Van Buren	1		*				
Wapello	2	*	*	*	*	*	
Webster	4	*	1,624		*	*	2,201
Winnebago	1				*		
Winneshiek	2	*	*			*	
Woodbury	5		4,995		*	*	5,895
Wright	3		*	*		*	5,354

TABLE V—Continued

County	No. of Producers	Molding Sand	Building Sand	Engine Sand	Other Sand	Gravel	Total
Counties with less than three producers ----	----	3,632	59,387	4,588	23,401	66,378	121,572
Total ------	157	$ 4,582	$ 226,675	$ 5,527	$ 31,842	$125,023	$ 393,649

TABLE V—Continued

VALUE OF SAND AND GRAVEL PRODUCED IN IOWA IN 1912.

County	No. of Producers	Molding Sand	Building Sand	Engine Sand	Other Sand	Gravel	Total
Appanoose	1	*	*	-------	-------	*	-------
Audubon	3	-------	*	-------	-------	*	-------
Black Hawk	8	*	$ 14,900	-------	$ 6,940	*	$ 22,590
Bremer	3	-------	-------	-------	-------	$ 3,283	3,283
Buena Vista	3	-------	*	-------	*	*	1,088
Butler	2	-------	-------	-------	*	*	-------
Cherokee	4	-------	7,900	-------	2,970	5,830	16,700
Clayton	8	-------	*	*	*	17,158	24,865
Des Moines	2	-------	*	-------	-------	*	-------
Dubuque	4	-------	*	*	-------	10,081	17,973
Fayette	5	-------	5,125	-------	-------	289	5,414
Floyd	1	-------	-------	-------	-------	*	-------
Greene	1	-------	-------	-------	-------	*	-------
Grundy	1	-------	-------	-------	*	-------	-------
Hardin	3	-------	*	-------	*	*	3,533
Howard	1	-------	-------	-------	*	*	-------
Ida	2	-------	*	-------	-------	-------	-------
Johnson	4	-------	*	-------	-------	*	8,428
Jones	1	-------	*	-------	-------	-------	-------
Lee	3	-------	*	*	-------	-------	5,452
Linn	5	-------	15,290	*	-------	*	18,680
Louisa	1	-------	-------	-------	-------	*	-------
Lyon	6	-------	13,175	*	*	5,324	19,237
Marion	3	-------	*	-------	*	*	17,288
Marshall	2	*	*	*	*	*	-------
Muscatine	2	-------	*	-------	*	*	-------
O'Brien	2	-------	*	-------	-------	-------	-------
Osceola	2	-------	*	-------	-------	*	-------
Palo Alto	3	-------	-------	-------	-------	9,943	9,943
Plymouth	8	-------	15,257	-------	*	*	19,707
Polk	14	*	105,172	*	*	29,359	148,302
Sac	3	-------	*	*	*	*	27,722
Scott	2	-------	*	-------	*	*	-------
Sioux	6	-------	16,725	-------	-------	7,925	24,650
Story	5	-------	2,033	-------	*	*	5,530
Van Buren	1	-------	*	-------	-------	-------	-------
Wapello	3	*	*	-------	-------	-------	22,522
Webster	2	-------	*	-------	-------	*	-------
Winnebago	1	-------	-------	-------	*	-------	-------
Winneshiek	2	-------	*	-------	*	*	-------
Woodbury	5	-------	12,650	-------	*	*	16,120
Wright	2	-------	-------	-------	*	-------	-------
Counties with less than three producers	----	$ 3,572	120,655	$ 4,556	58,633	68.664	124,382
Total	140	$ 3,572	$ 328,882	$ 4,556	$ 68,543	$157,856	$ 563,409

GYPSUM.

The value of the gypsum industry in Iowa, in 1911, was $871,752 and in 1912, $845,628. The figures for both of these years are smaller than for 1910 when the value of the output of gypsum was $943,849, the largest figure in the history of the industry in the state.

The principal items of production and distribution were as follows:

	1911		1912	
	Short tons	Value	Short tons	Value
Crude gypsum mined	354,204	----------	411,186	----------
Distributed as follows—				
Sold crude—				
To Portland cement mills, paint mills, plaster mills, and as land plaster	11,032	$ 14,465	42,443	$ 40,824
Sold calcined—				
As hard wall plaster	195,274	777,095	223,756	708,198
As plaster of Paris, etc.	26,501	60,546	1,282	4,575
Other purposes	8,115	19,646	48,078	92,031
Total sold calcined	229,890	$857,287	273,116	$804,804
Total sold	240,922	$871,752	315,559	$845,628

In both years, 1911 and 1912, there were seven mines and six mills in operation. No gypsum has yet been mined from the deposit at Centerville which was found in 1910, by the Scandinavian Coal Company while prospecting for coal. A company has been formed and a shaft is being sunk of sufficient size to be used in hoisting the gypsum to the surface.

LEAD AND ZINC.

During 1911 and 1912 there was little activity in the lead and zinc region in the vicinity of Dubuque. The Avenue Top mine which was in operation in 1910 was closed during 1911 and 1912. The lead derived from lead concentrates obtained from small mines, as a result of development work, was sixty tons, valued at $5,400, in 1911, and sixty-three tons, valued at $5,670, in 1912.

The outlook for any marked improvement in the lead and zinc industry in Iowa, in the near future, is not promising.

MINERAL WATERS.

The value of mineral waters sold in 1911 was $20,500, and in 1912, $11,325. These figures show a decrease when compared with 1910, when the value of mineral water was $27,175. In 1911 the total quantity sold was 176,000 gallons, and in 1912, 84,300 gallons. About one-fifth of the output was sold for medicinal purposes, the remainder for table use. The Crystal Spring, at Estherville, reported for the first time in 1911, and in 1912 the Egralharve, on the west shore of Lake Okoboji, began to produce. The six reporting springs in 1912 were as follows:

Crystal Spring, Estherville, Emmet County.
Egralharve Spring, Montgomery, Dickinson County.
Fry's Spring, Colfax, Jasper County.
Heston's Spring, Fairfield, Jefferson County.
Red Mineral Springs, Eddyville, Wapello County.
White Sulphur Spring, Davenport, Scott County.

PORTLAND CEMENT.

Iowa now has three up-to-date Portland cement plants, two of which are at Mason City and the third at Des Moines. The Lehigh Portland Cement Company, of Mason City, first began to produce in 1911. The output of the three plants in 1911 was 1,952,590 barrels with a value of $1,881,253. In 1912 these same plants shipped 3,190,354 barrels with a value of $2,790,396, which is an increase of nearly 50 per cent over the value of 1911. Iowa has an abundance of raw material for Portland cement and hence, year by year, larger and larger productions may be confidently expected.

The growth of the Portland cement industry in the United States has been exceedingly rapid. The figures for the quantity and value of the Portland cement shipped by the ten leading states in 1912 are as follows:

SHIPMENT OF PORTLAND CEMENT BY STATES, 1912.[1]

State	Shipping Plants	Quantity (Barrels)	Value	Average Price per Barrel
Pennsylvania	26	27,539,076	$18,918,165	$0.687
Indiana	5	9,634,582	7,237,591	.751
California	8	6,093,790	8,215,894	1.348
Missouri	5	4,614,547	3,700,776	.802
Illinois	5	4,602,617	3,444,085	.748
New York	7	4,543,060	3,448,735	.759
New Jersey	3	4,490,645	3,052,098	.680
Michigan	10	3,651,094	3,145,001	.861
Kansas	12	3,592,148	2,815,113	.784
Iowa	3	3,190,354	2,790,396	.875
Total (ten states)		71,951,913	$56,767,854	
Total (other states)		13,060,643	$12,341,946	
Total, United States		85,012,556	$69,109,800	

SAND-LIME BRICK.

The production of sand-lime brick in Iowa has declined rapidly during the past few years. In 1909 the value of the output was $48,210, in 1910 it had decreased to $31,269. In 1911 and in 1912 there were only two producers and during each of these years the production was considerably less than in 1910.

NATURAL GAS.

In Louisa county small amounts of gas continue to be obtained from pockets of sand in the drift. This gas is used for illuminating purposes. In 1911, the total value of the gas was $70 and in 1912, $120.

[1]From advance chapter of Mineral Resources for 1912.

IRON ORE.

Although the Missouri Iron Company has been carrying forward experimental work on an extensive scale in connection with the Waukon iron ore, no ore has yet been mined for commercial purposes.

The Road and Concrete Materials of Iowa

BY

S. W. Beyer and H. F. Wright

CONTENTS

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 STREAKS 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			(40)	LIMESTONE, MOSTLY BRACHIOPOD COQUINA
		Lime Creek			(120)	MOSTLY SHALES (LOCALLY DEVELOPED FEATURES EACH LYING UNCOMFORMABLY ON THE MIDDLE DEVONIAN.)
		Sweetland Creek			(20)	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
			New Richmond		20	SANDSTONE.
			Oneota		150	DOLOMITE.
CAMBRIAN	POTSDAMIAN OR SARATOGAN	St. Croix	Jordan		100	COARSE SANDSTONE
			St. Lawrence		50	DOLOMITE MORE OR LESS ARENACEOUS.
			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 aggregate 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 post-glacial 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 concentrated 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	$1\frac{1}{6}$
8.	Limestone like No. 9 with two inch cherty clay residue below....	$\frac{1}{2}$
7.	Limestone, firm ledge somewhat broken by weathering; marked tendency to separation into blocks by vertical joints	$\frac{3}{4}$
6.	Shaly limestone, chert bearing, by weathering forms a reëntrant in the quarry face	$1\frac{1}{12}$
5.	Limestone ledge, persistent	$\frac{1}{2}$
4.	Limestone, shaly, blue to gray where unweathered, but iron-stained at crop; persistent and forms a conspicuous reëntrant	$1\frac{1}{4}$
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	$\frac{7}{12}$
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	$2\frac{1}{8}$
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..........	1/3
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 demonstrate 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	$1\frac{1}{2}$
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 Auburn 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 Fayette 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	$1^2/_3$
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,

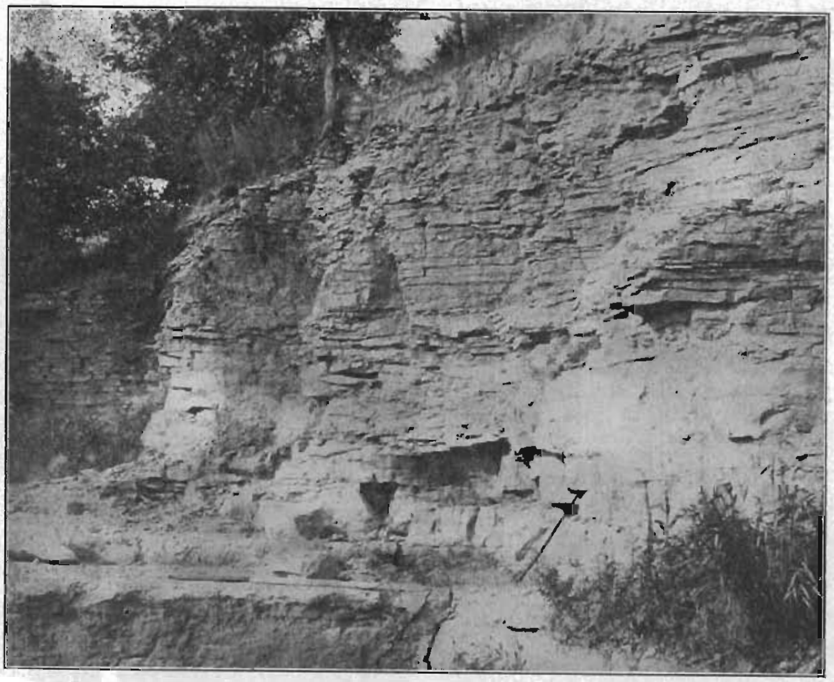


FIG. 1—Long's quarry in the east bank of Cedar river, Section 4, Harrison township, Benton county.

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	$1^1/_3$
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	$^5/_6$

		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

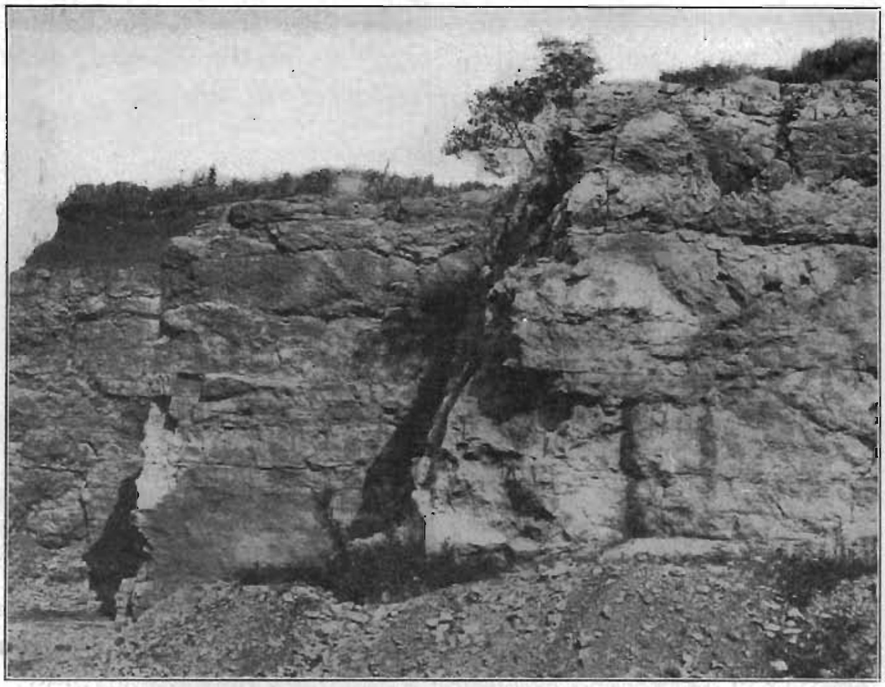


FIG. 2—Abandoned quarry on Hinkle creek near Garrison, Benton county.

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 operation 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

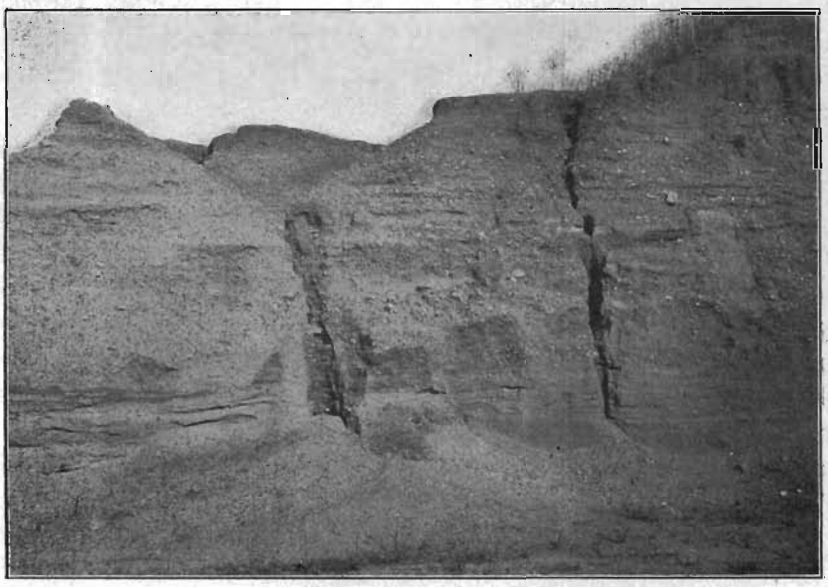


Fig. 3—Buchanan gravel east of Teachers College, Cedar Falls, Black Hawk county.

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....	1 1/3
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....	5/6
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....	1 1/3
4.	Limestone, fine-grained, more or less streaked or banded..	1 2/3
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	1⅙
7.	Limestone, drab	¾
6.	Limestone, buff, earthy, finely streaked with yellow lines	2⅙
5.	Shaly partings with very wavy lines of contact above and below	¼
4.	Limestone, hard, brittle, drab, middle portion developing layers	3⅙

		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 produced 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.

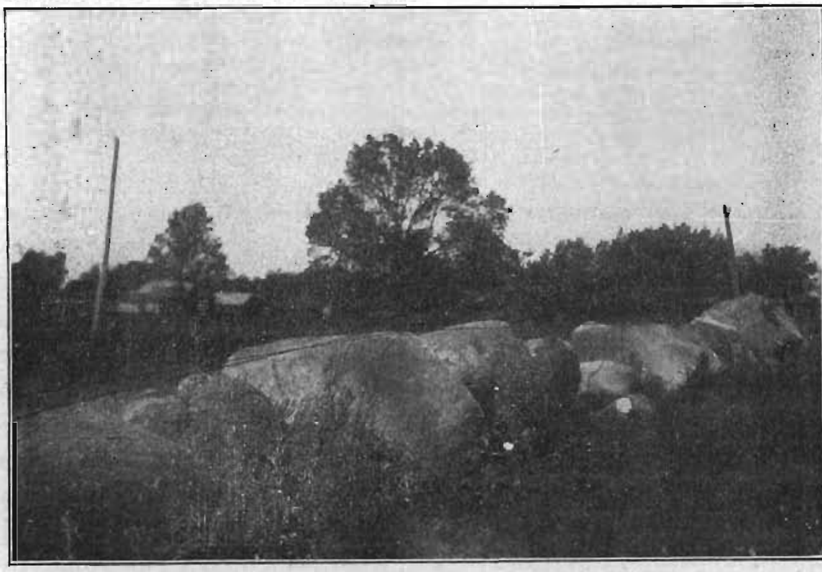


FIG. 4—Iowan bowlder fence near Horton, Bremer county.

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.

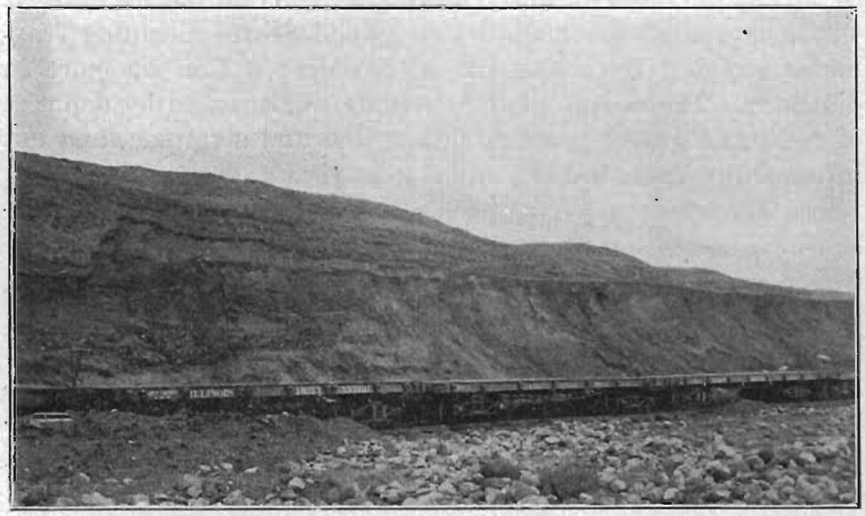


FIG. 5—Buchanan gravels, Illinois Central Railway pit east of Independence, Buchanan county.

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.

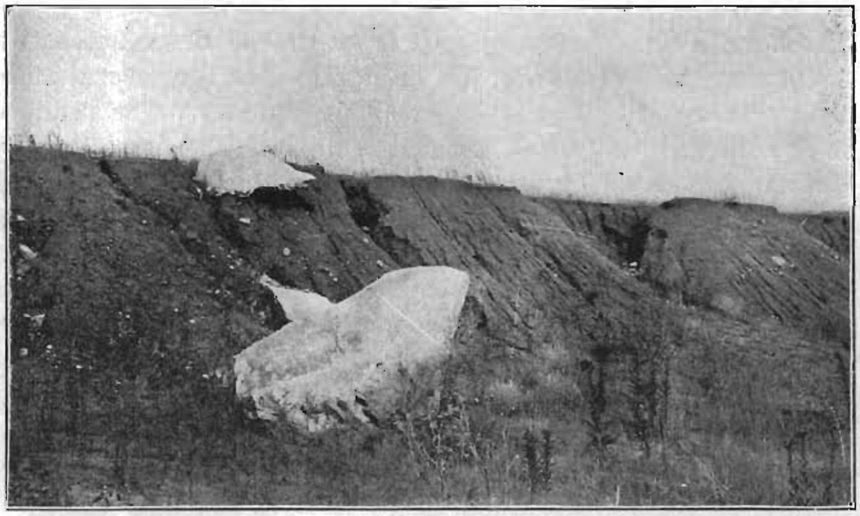


FIG. 6—An abandoned part of Illinois Central gravel pit showing Iowan bowlders, east of Independence.

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.

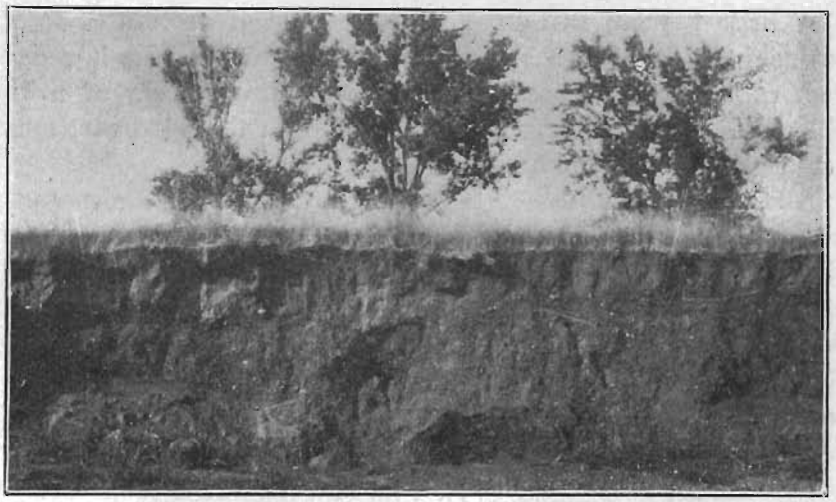


FIG. 7—Pit showing Buchanan gravel overlain by Iowan drift about two miles west of Winthrop, Buchanan county.

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:

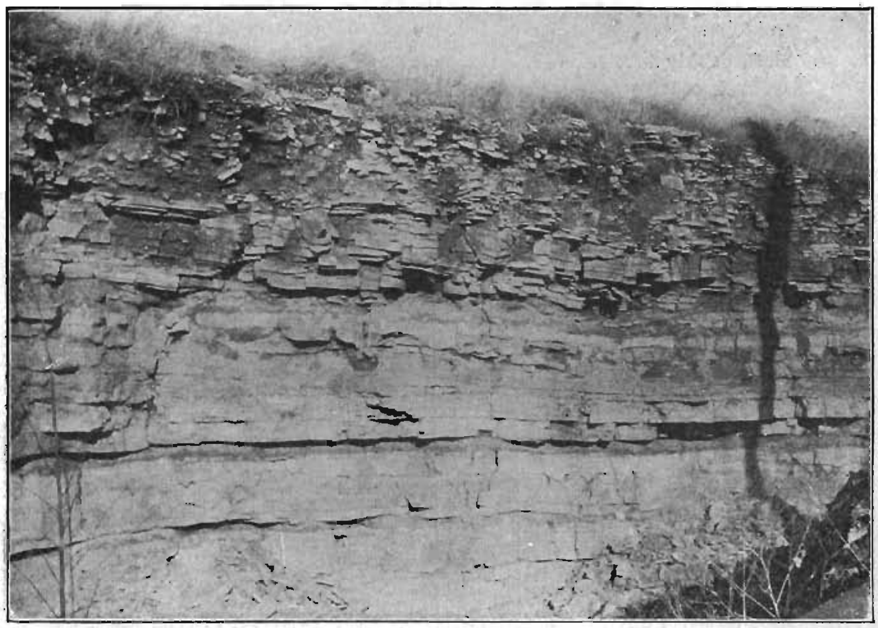


Fig. 14—Schrader quarry, Clarksville, Butler county, showing the flaggy, lithographic facies of the Cedar Valley.

		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.

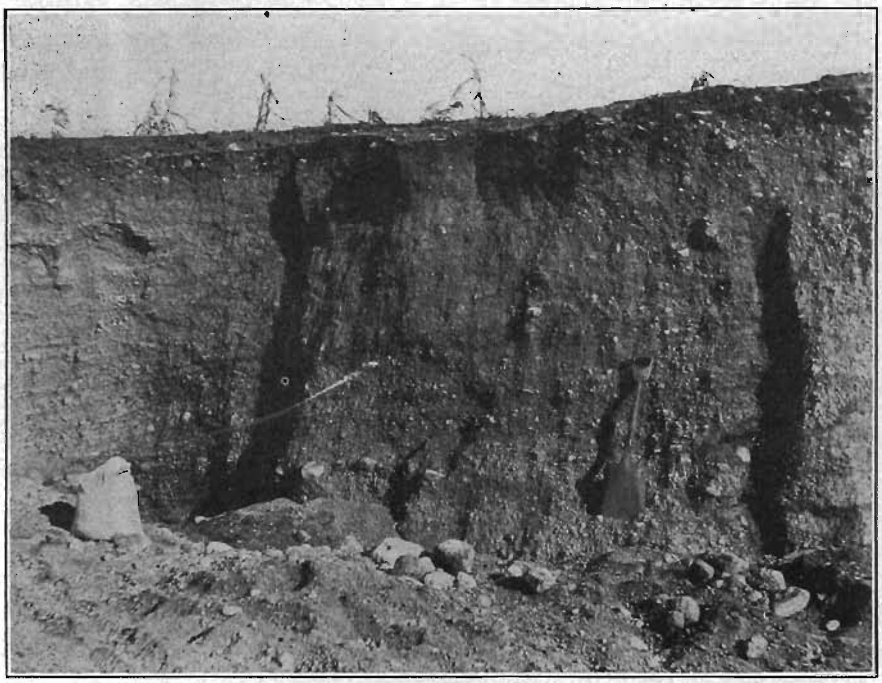


FIG. 15—Gravel pit near Lake City, Calhoun county.

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	$1\frac{1}{2}$
4.	Limestone, dark gray, coarse textured	$\frac{3}{4}$
3.	Shale, buff to gray, fossiliferous	$1^1/_3$
2.	Shale, variegated, lower part carbonaceous, micaceous, and splits into conchoidal fragments	$2\frac{1}{2}$
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

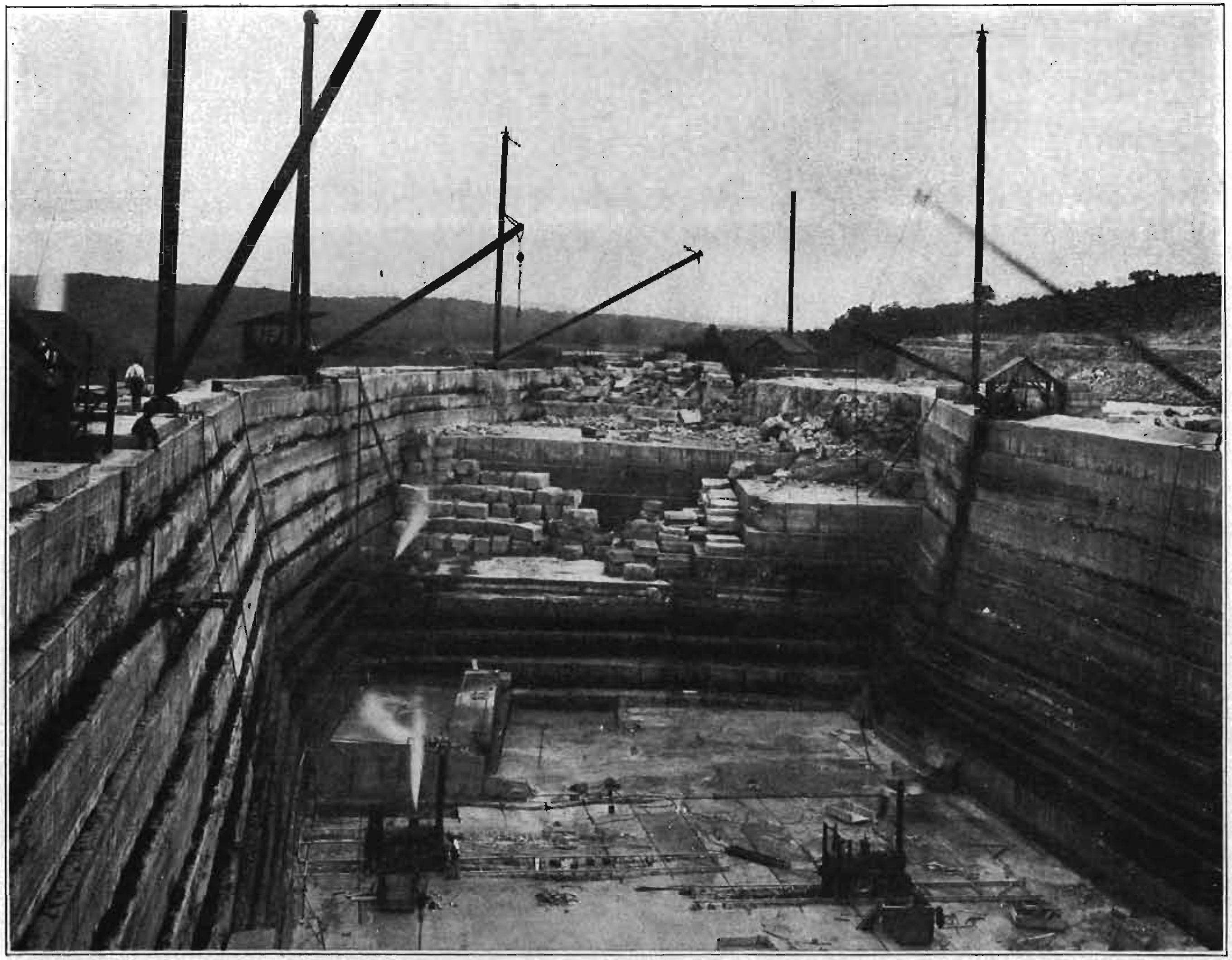


PLATE II—Main pit of Bealer quarry showing channelers in foreground. Cedar Valley, Cedar county. The chief output of the quarry at present is crushed stone and quarry methods have changed very materially.

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 several 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.

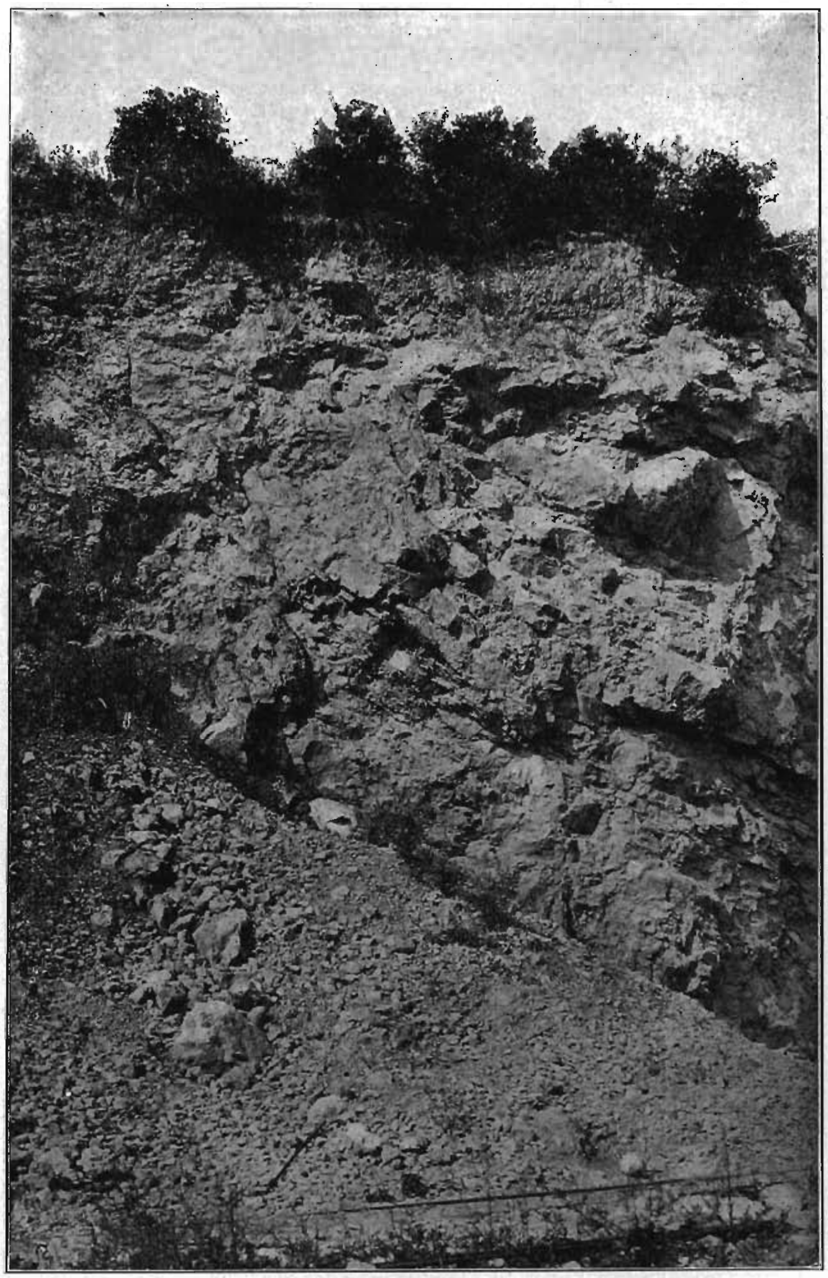


PLATE III—Quarry section showing irregularly bedded Gower limestone of Cedar county.

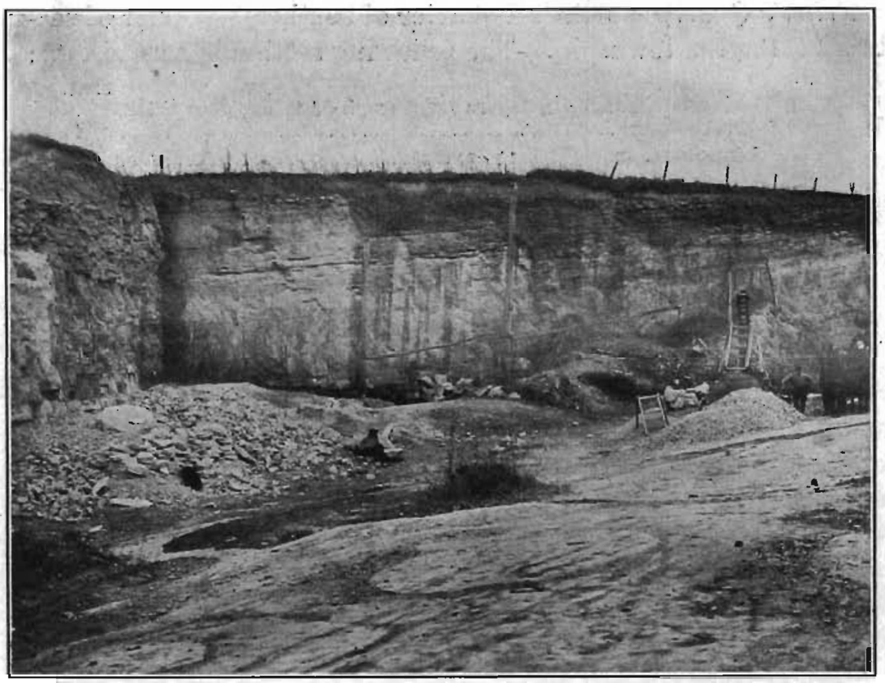


FIG. 16—Weathered face of Miller quarry showing beds dipping to the northeast. Lowden, Cedar county.

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 laminated, 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.	$11\frac{5}{6}$

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	$1\frac{1}{6}$
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	$6\frac{1}{2}$

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

P. [139]

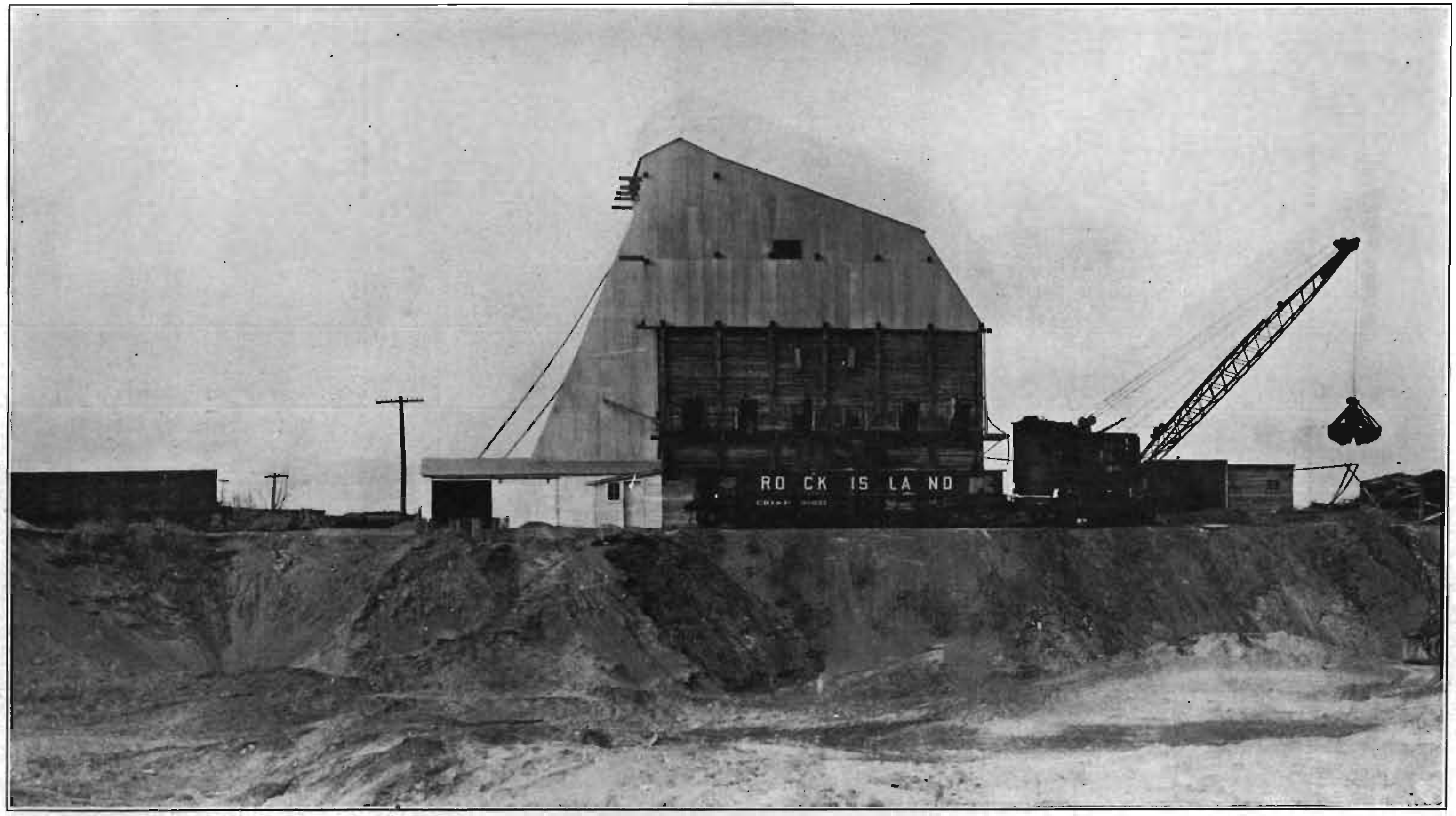


Plate IV—Pit and Plant of Mason City Sand Company, Mason City, Iowa, showing dipper so mounted that it is used for stripping, loading cars at pit and transferring gravel from cars to screening plant.

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.

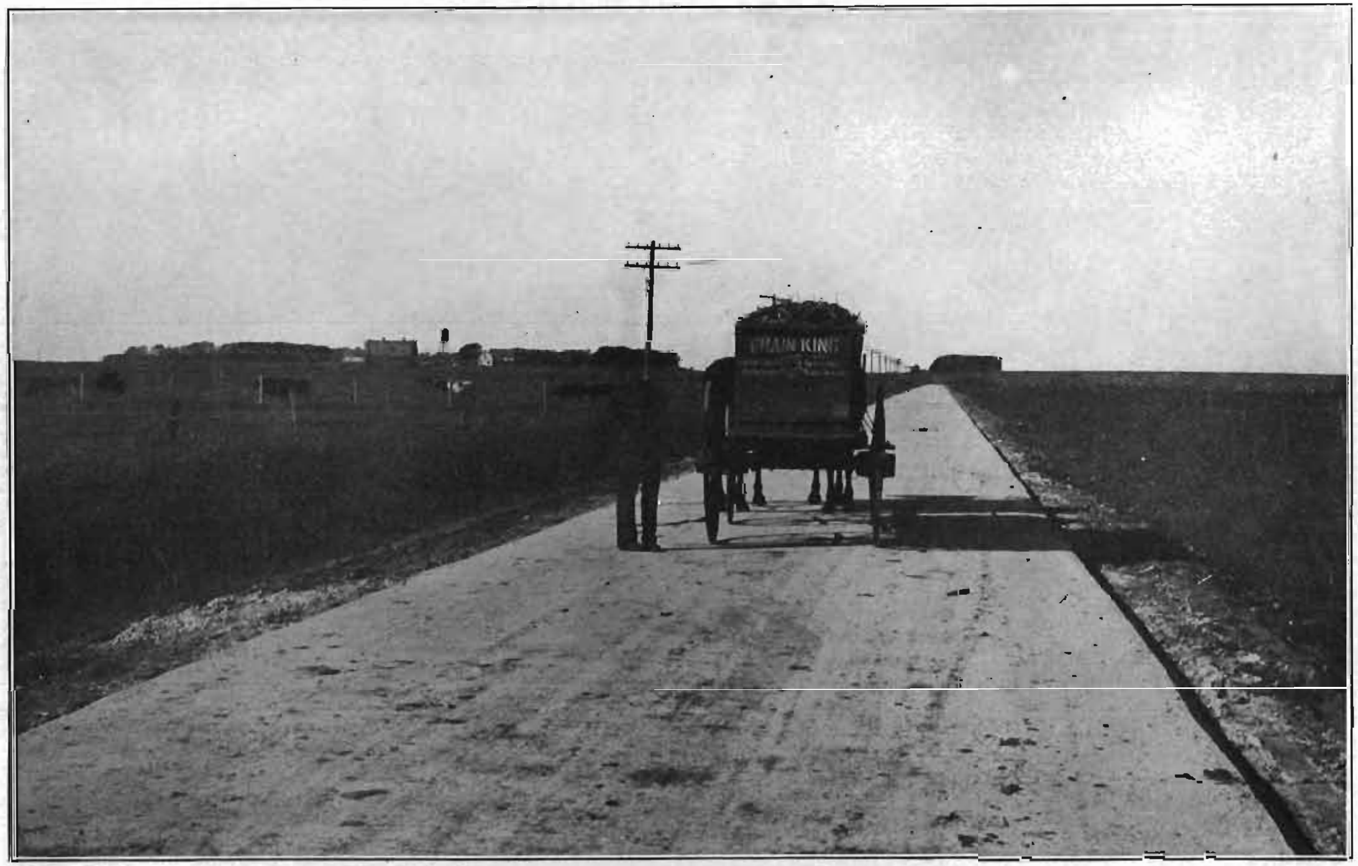
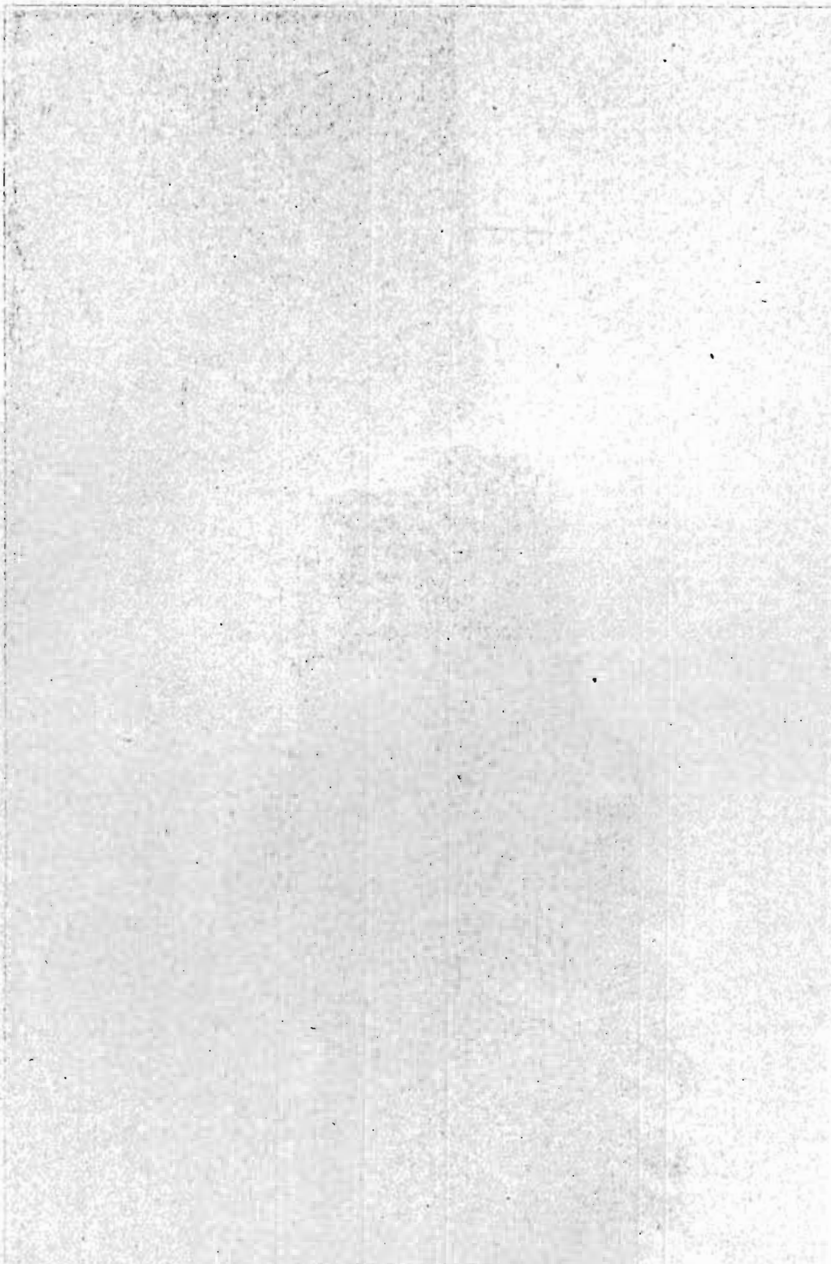


PLATE VII—Mason City-Clear Lake road after laying the concrete but before bank is done. Cerro Gordo county.

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.

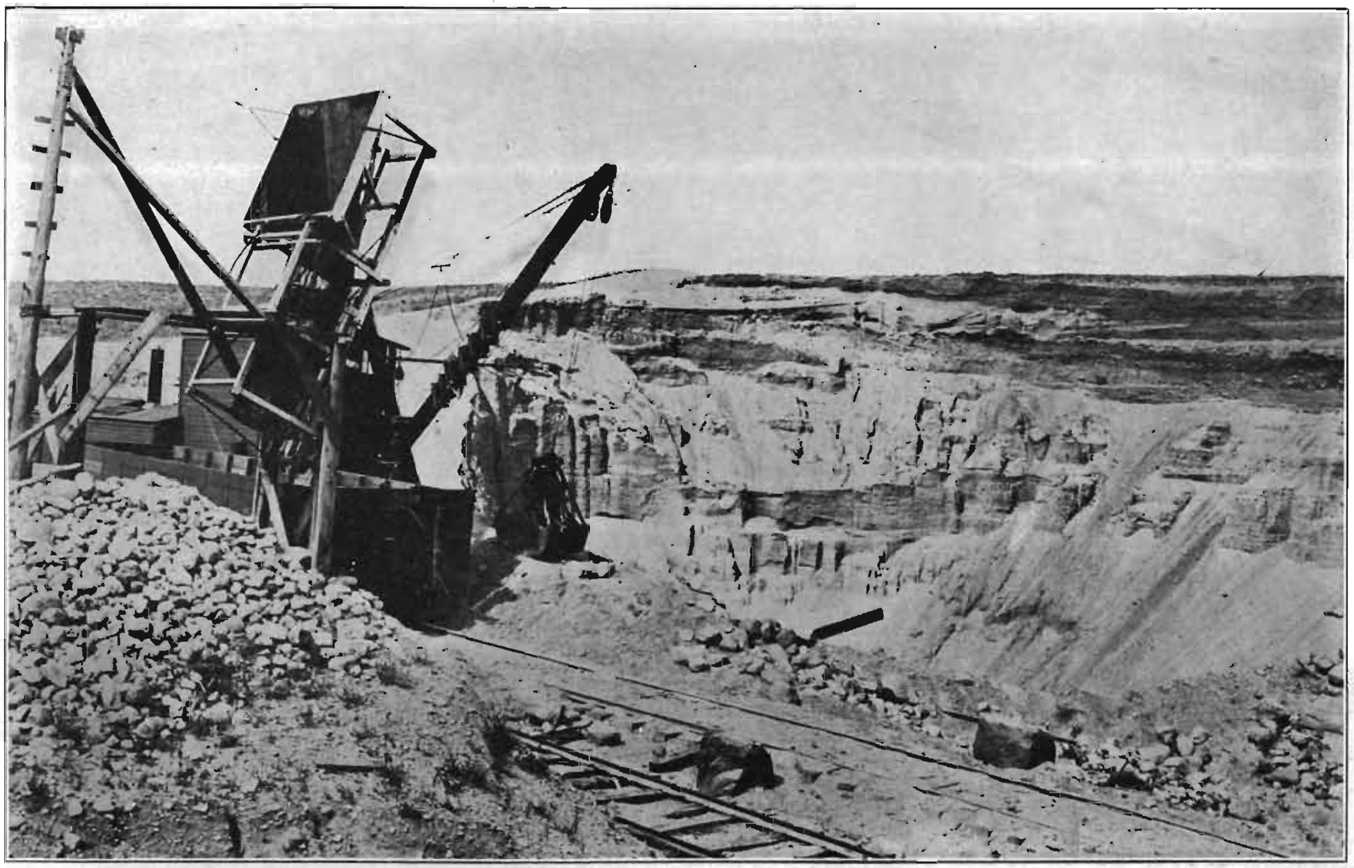


PLATE IX—Gilleas pit showing steam clam dipper working on a sixty foot face, Cherokee, Cherokee county.

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-

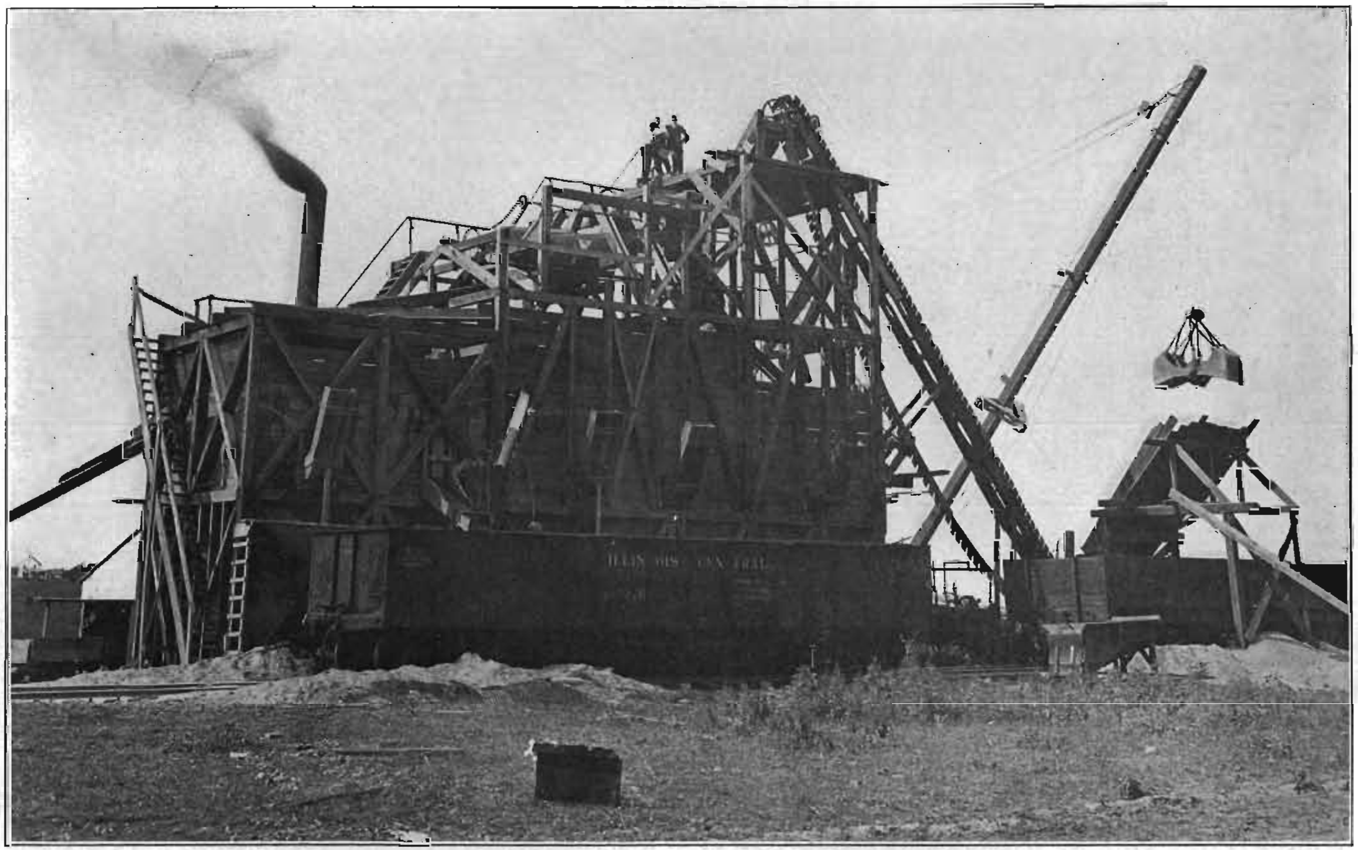


PLATE X—Washing plant of the Cherokee Sand and Gravel Company, Cherokee.

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

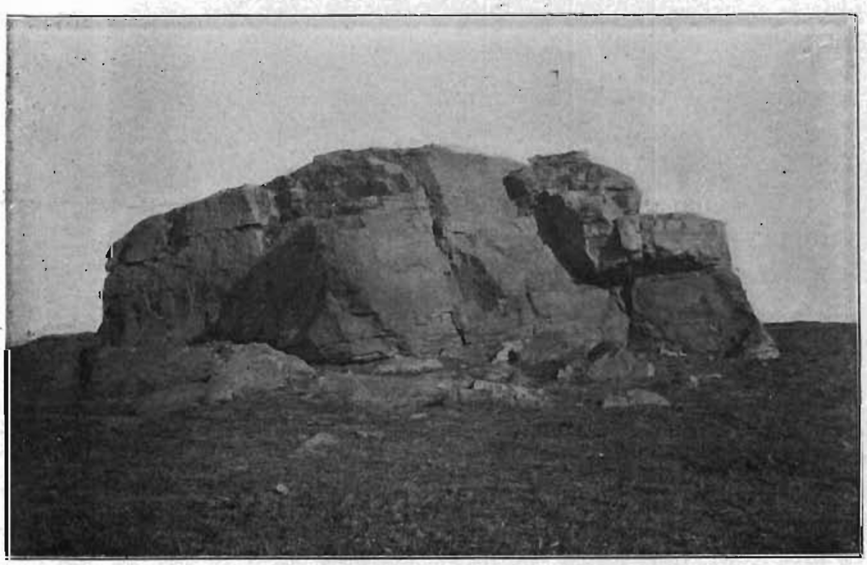


FIG. 17—Pilot Rock, a Sioux quartzite bowlder four miles south of Cherokee.

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	2/3
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	$3\frac{3}{4}$
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 appears 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

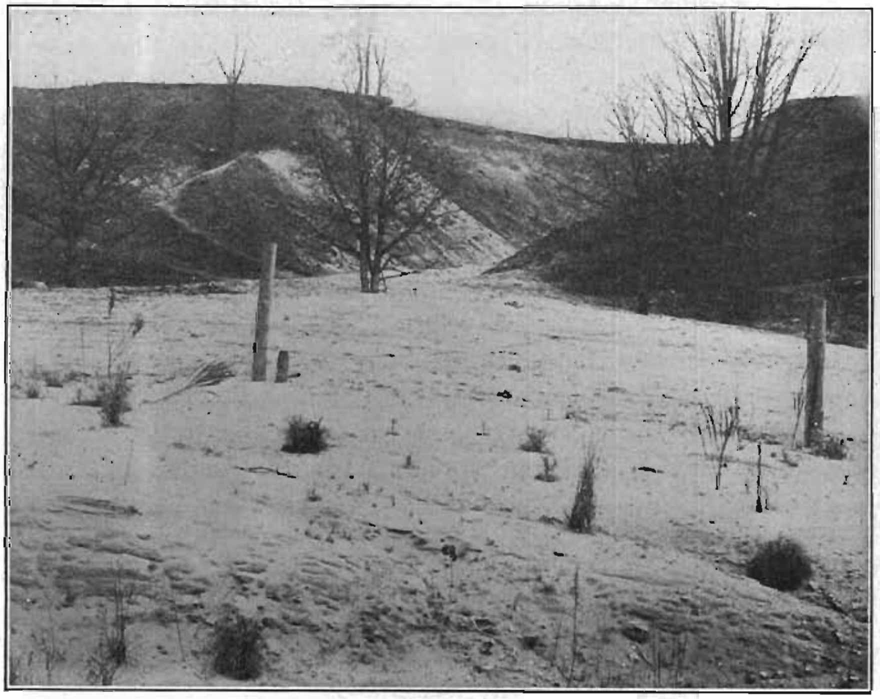


FIG. 20—Sand and gravel wash from terrace near Littleport, Clayton county.

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 nondolomitic, 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 calcareous 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	1²/₃

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.

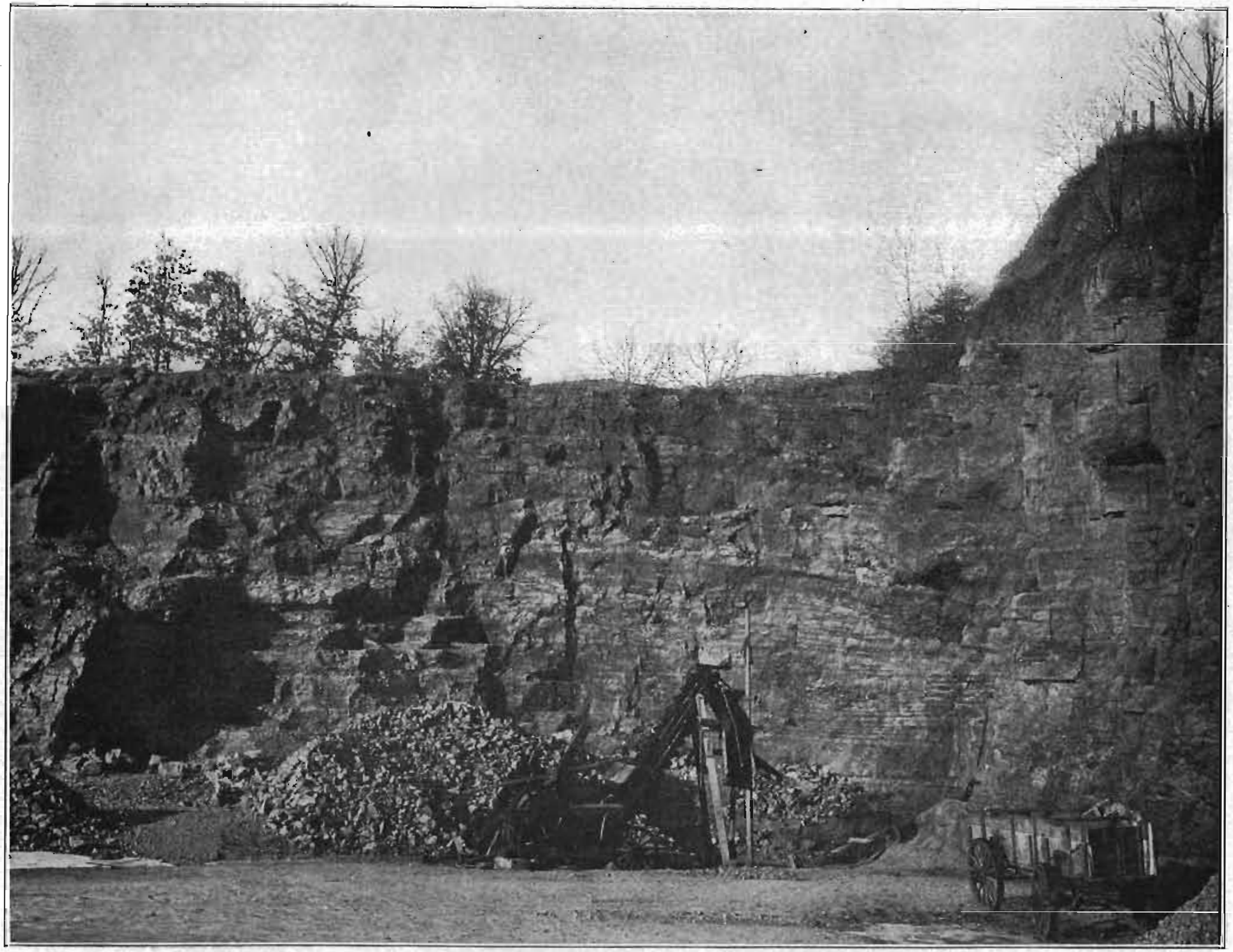


PLATE XII—Thomas Carey quarry section showing the general character of the Niagaran beds of the region. The chert beds are rather prominent in the middle section. Clinton, Clinton county.

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 yellowish 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.

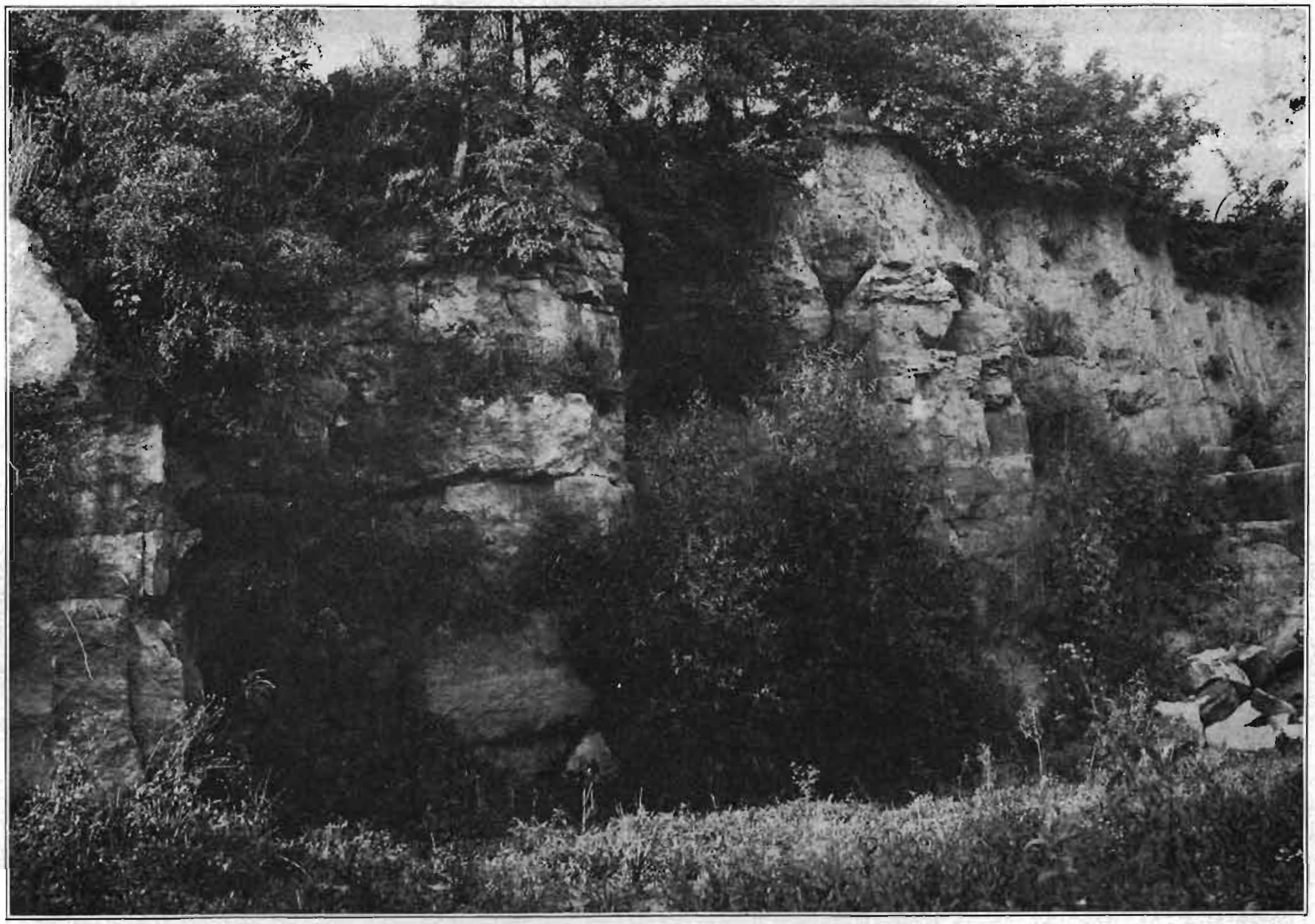


PLATE XIII—Old Randall quarry near Big Rock, Clinton county, showing heavy

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 exposures 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	2/3
4.	Limestone	3/4
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	2/3
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 suggest 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.

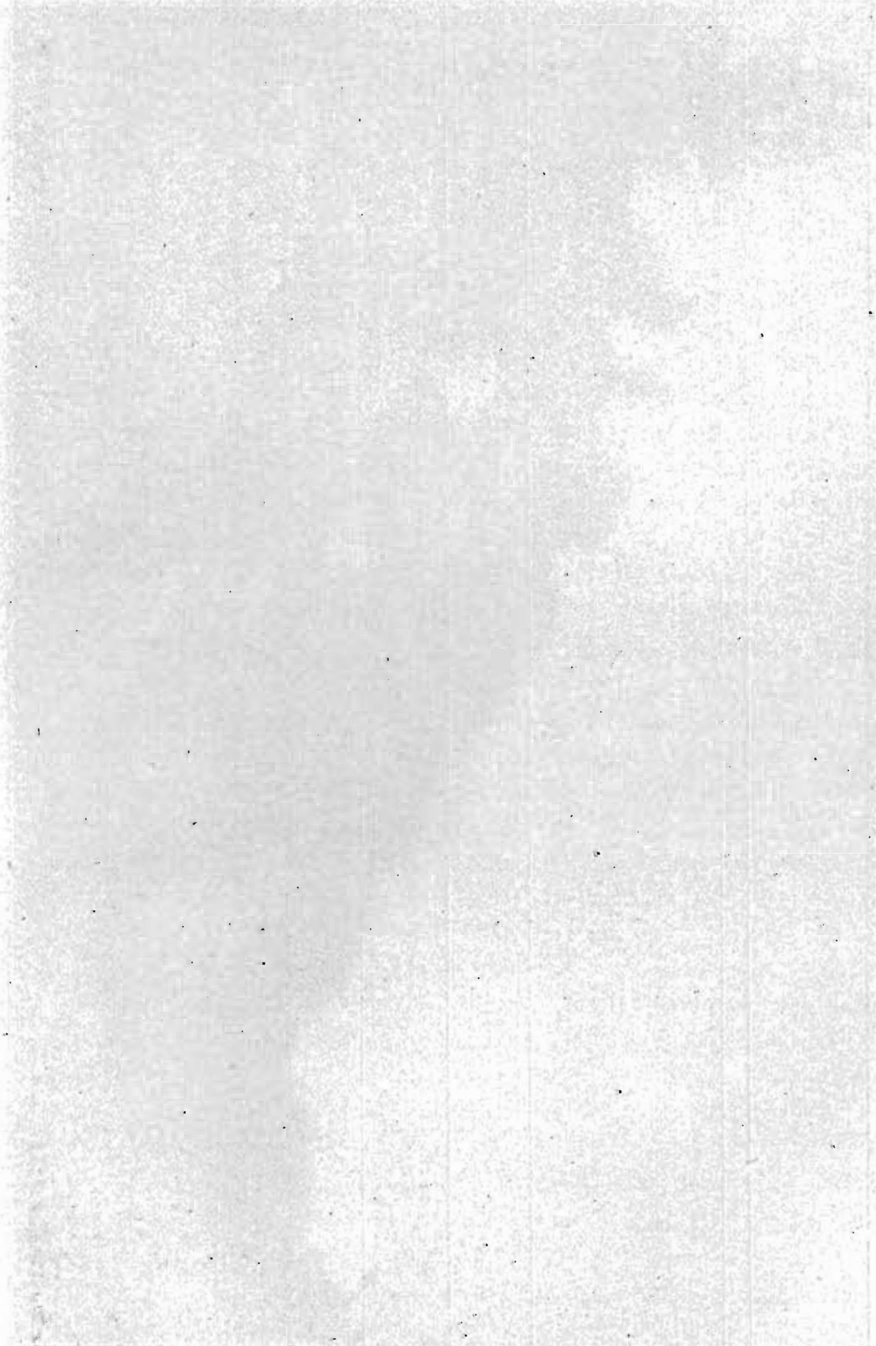
DECATUR COUNTY.

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:

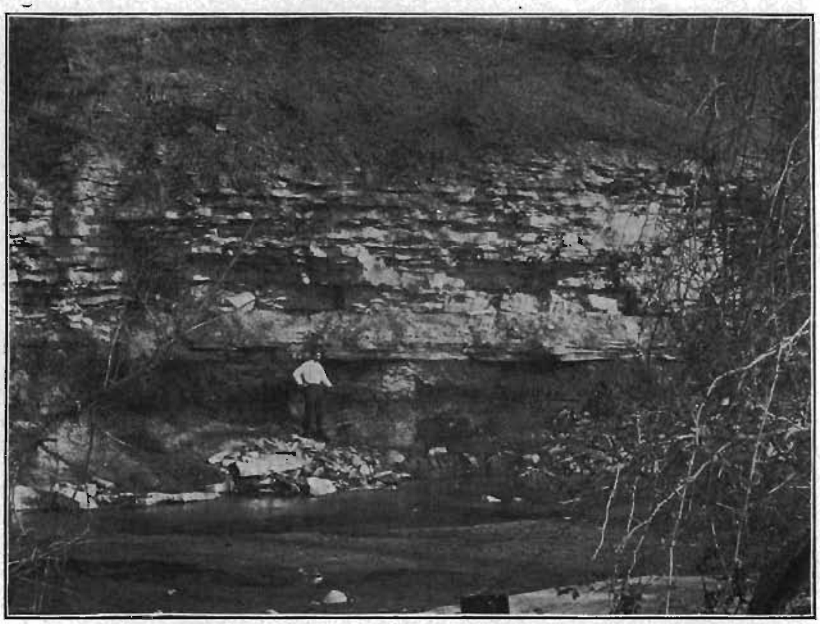


FIG. 23—Winterset limestone on Pot Hole creek with shales below extending down to the Earlham limestone. Decatur county.

		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	1/6
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	1/3
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 engine 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	$2\frac{1}{3}$
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	$1\frac{1}{4}$
7.	Even-grained rock, cleavable	$\frac{5}{6}$
6.	Good quarry stone in several layers	3
5.	Compact layer with large, flat Pentamerus	2
4.	Lowest layer worked	$\frac{5}{6}$
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:

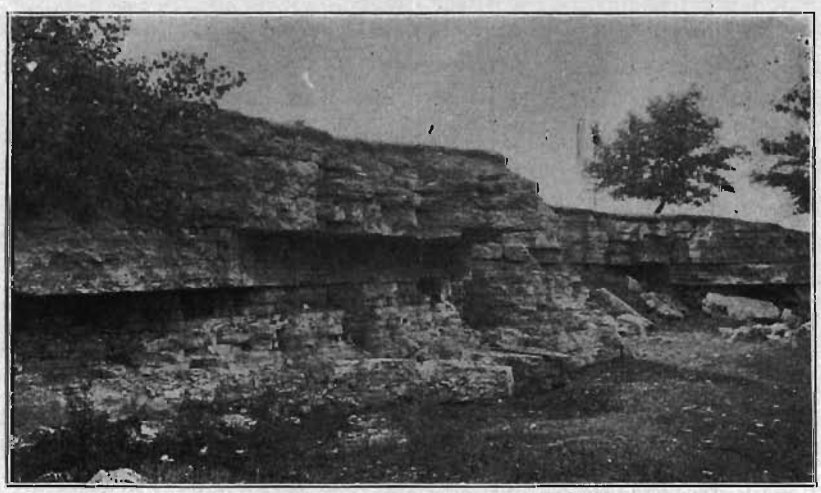


FIG. 25—Regularly bedded Pentamerus-bearing limestone in section 31, Bremen township, one mile east of Earlville, Delaware county.

		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

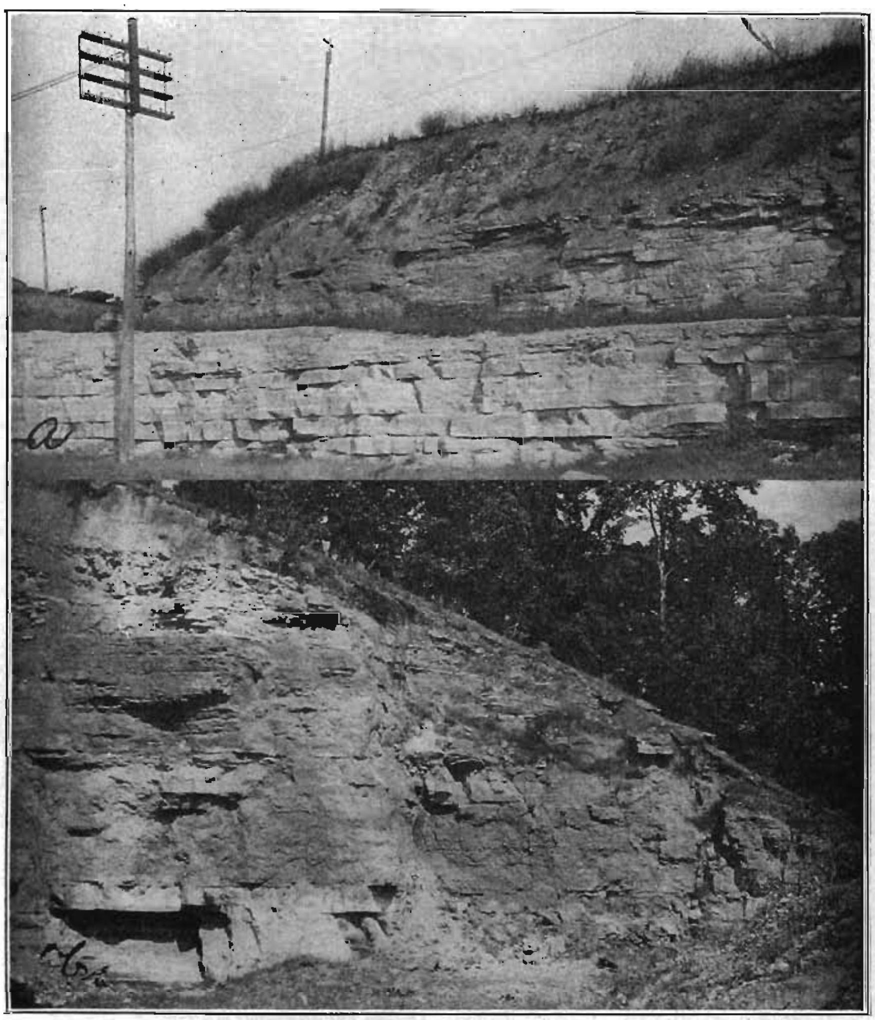


PLATE XV—a. Section at Union Depot in Keokuk, Lee county, showing chert beds.

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

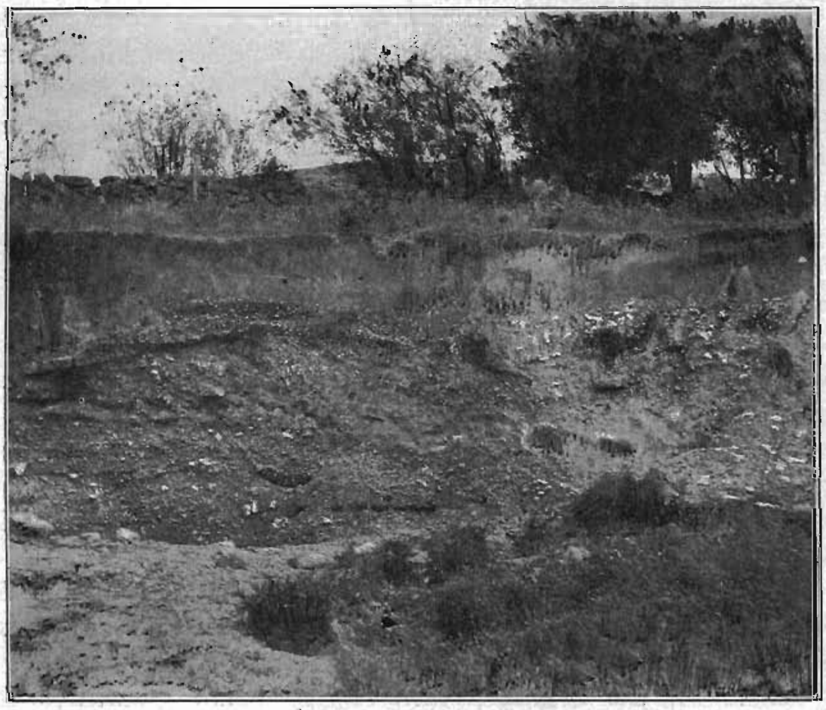


Fig. 26—Gravel terrace of Catfish creek, showing an abundance of residual cherts. Dubuque county.

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

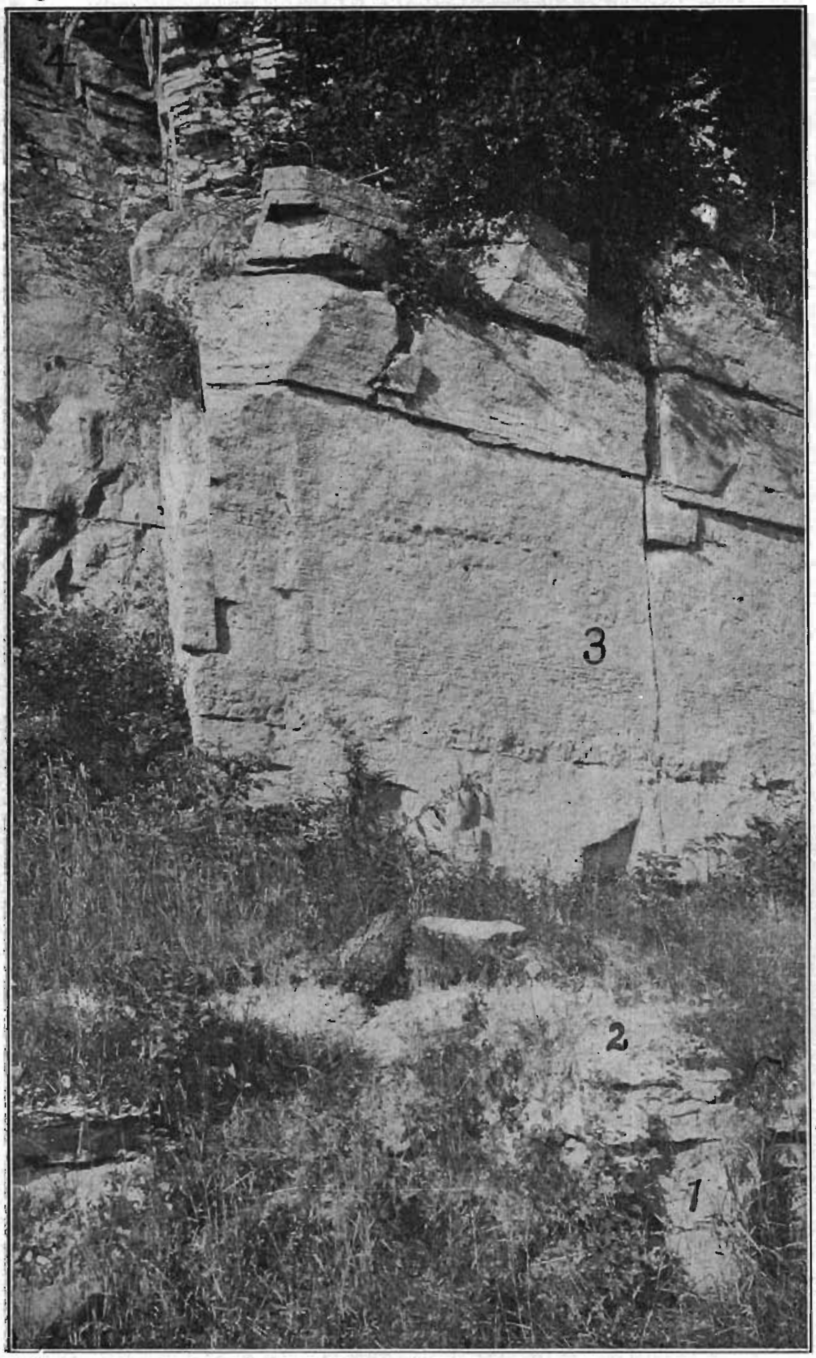


PLATE XVI—View three-fourths of a mile below Spechts Ferry, showing in ascending order: 1. Saint Peter sandstone. 2. Basal shale. 3. Lower Buff beds. 4. Thin, brittle, blue beds.

		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

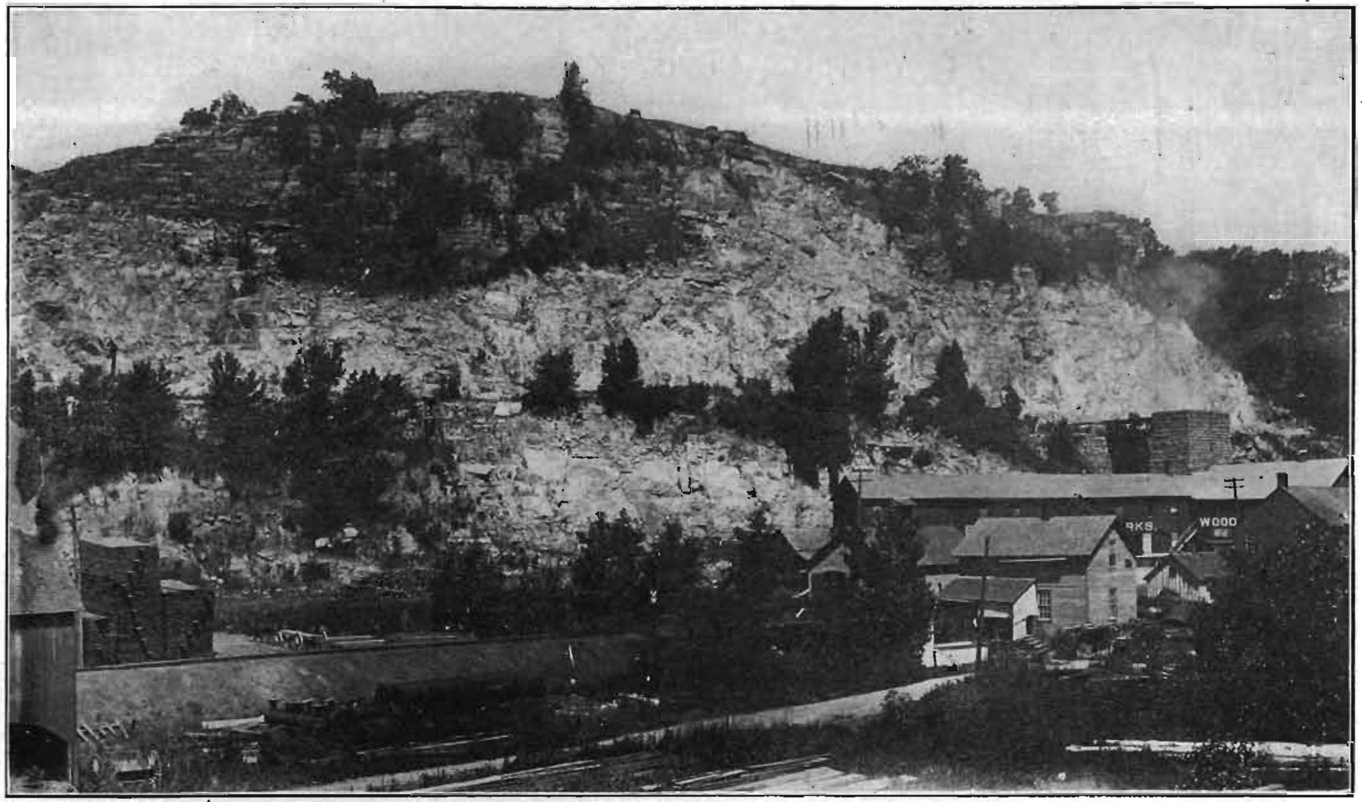


PLATE XVII—Quarry and plant of Eagle Point Lime Company, Eagle Point, Dubuque county.

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.

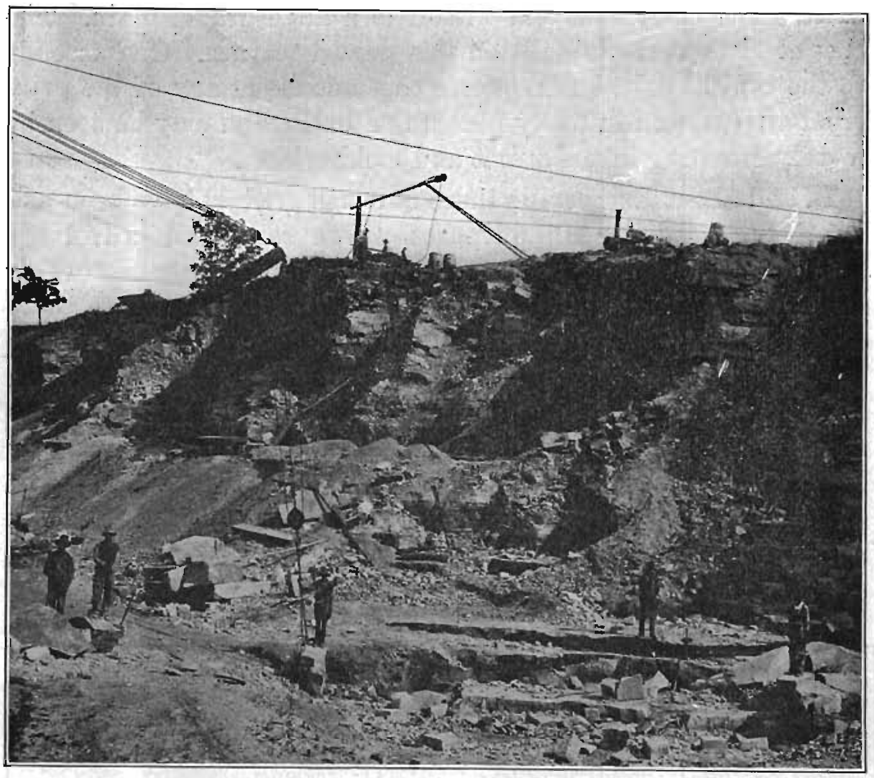


FIG. 27—Arquitt quarry, somewhat obscured by an excessive amount of talus. North Farley, Dubuque county.

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 terraces 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

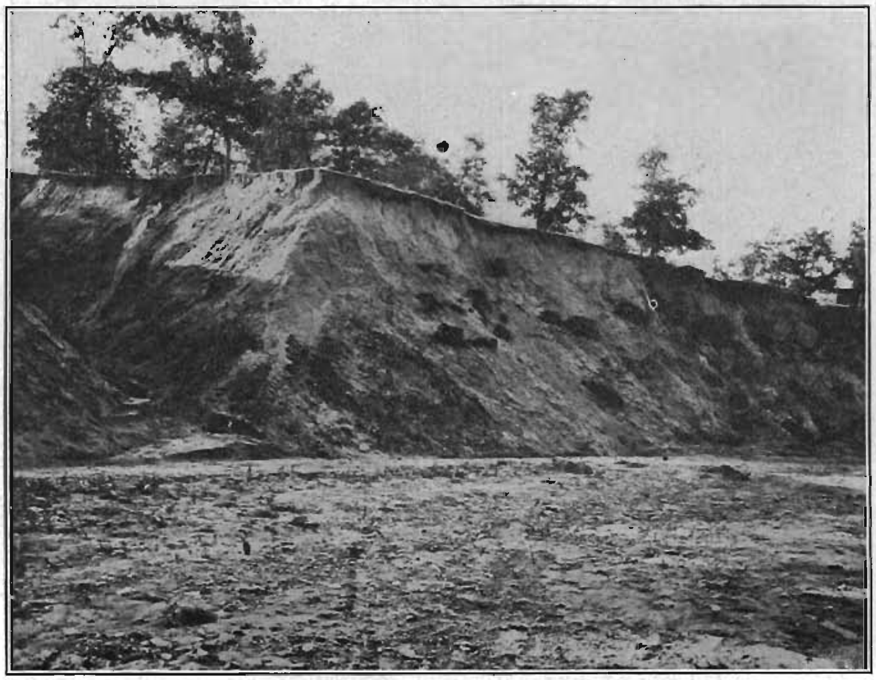


FIG. 30—General view at the same locality as Figure 29.

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

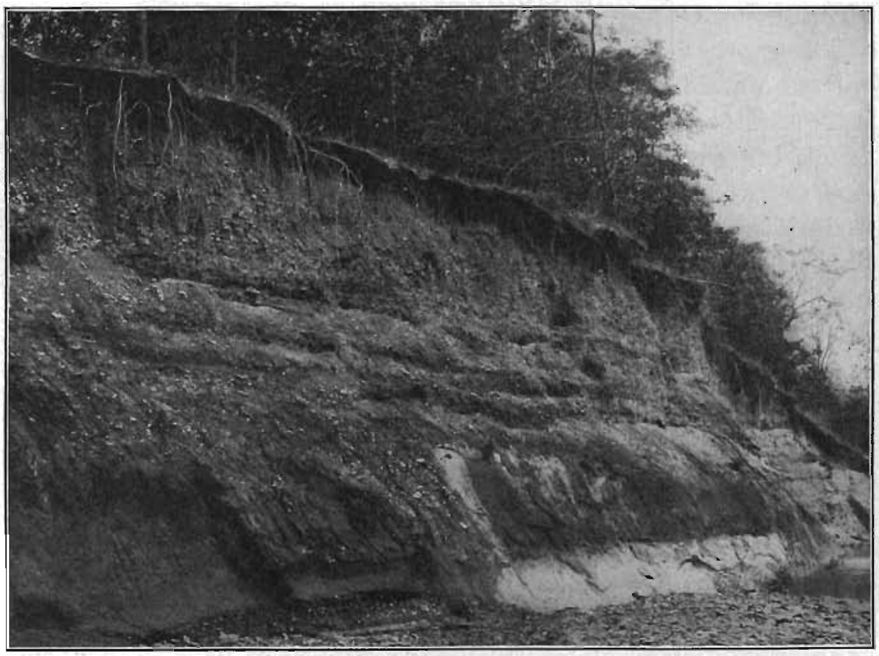


FIG. 31—Gravel terrace along the Turkey river near the old Huntsinger bridge two and one-half miles east of Eldorado, Fayette county.

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.

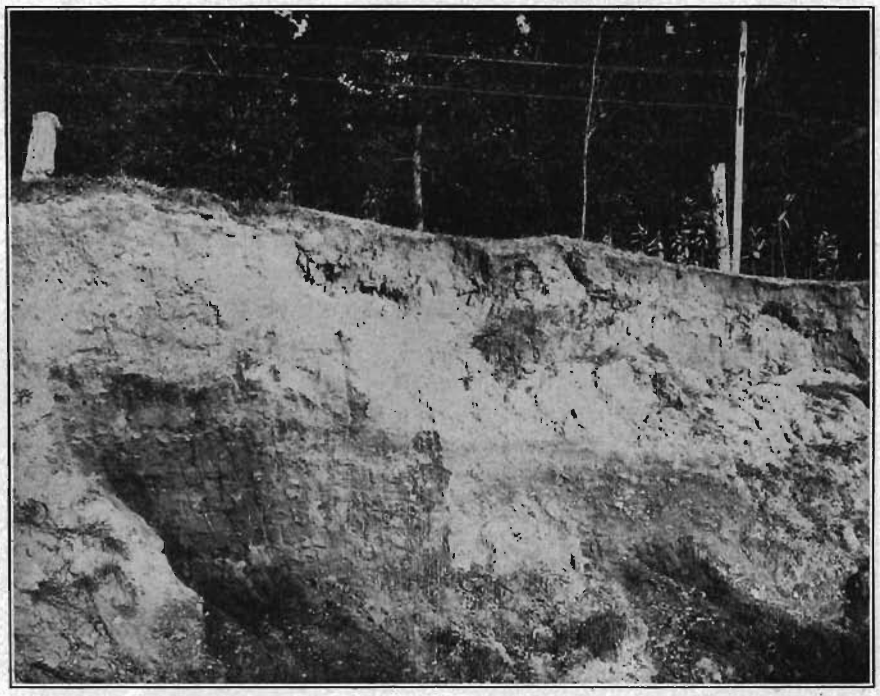


FIG. 32—Gravel pit showing fresher gravels above and more weathered ones below. Waucoma, Fayette county.

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.

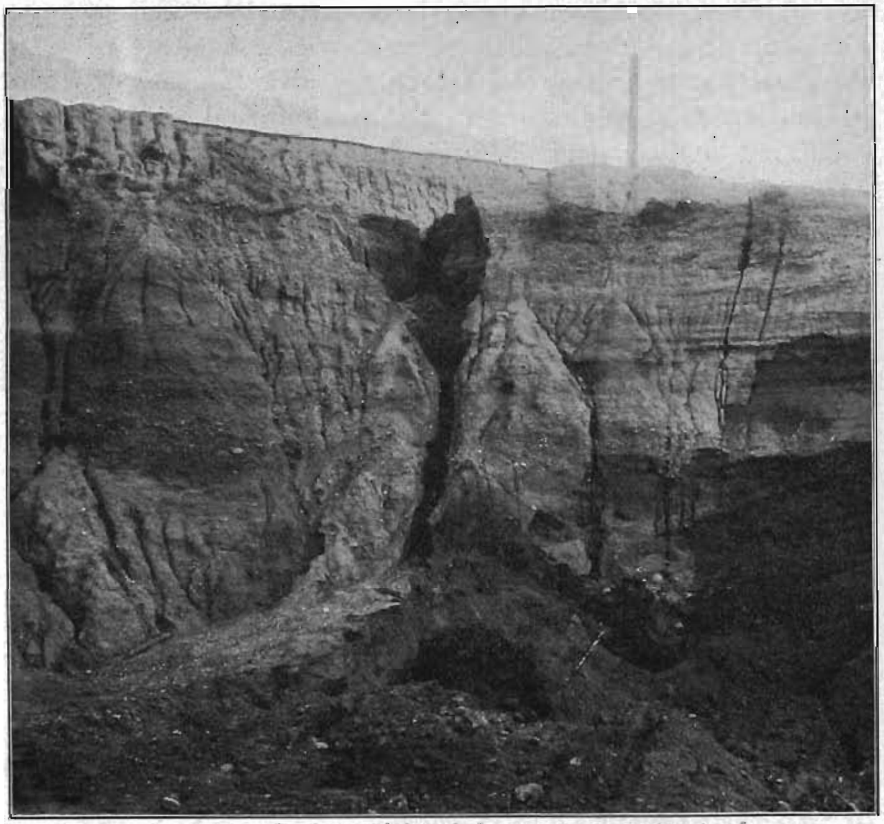


FIG. 33—Buchanan gravels, West Union, Fayette county.

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.

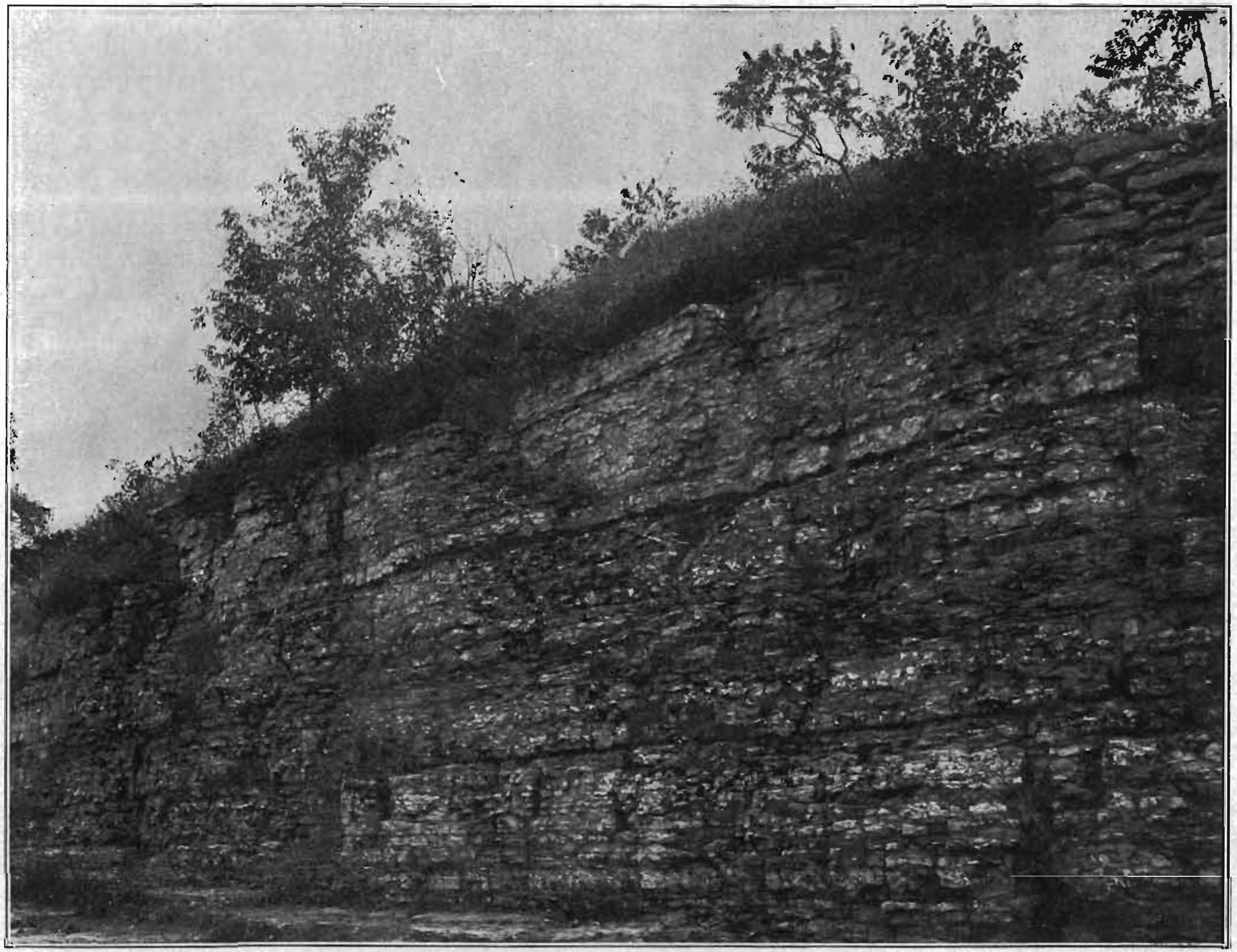


PLATE XIX—The chert beds of the Maquoketa afford excellent material for road work. Clermont, Fayette county.

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:

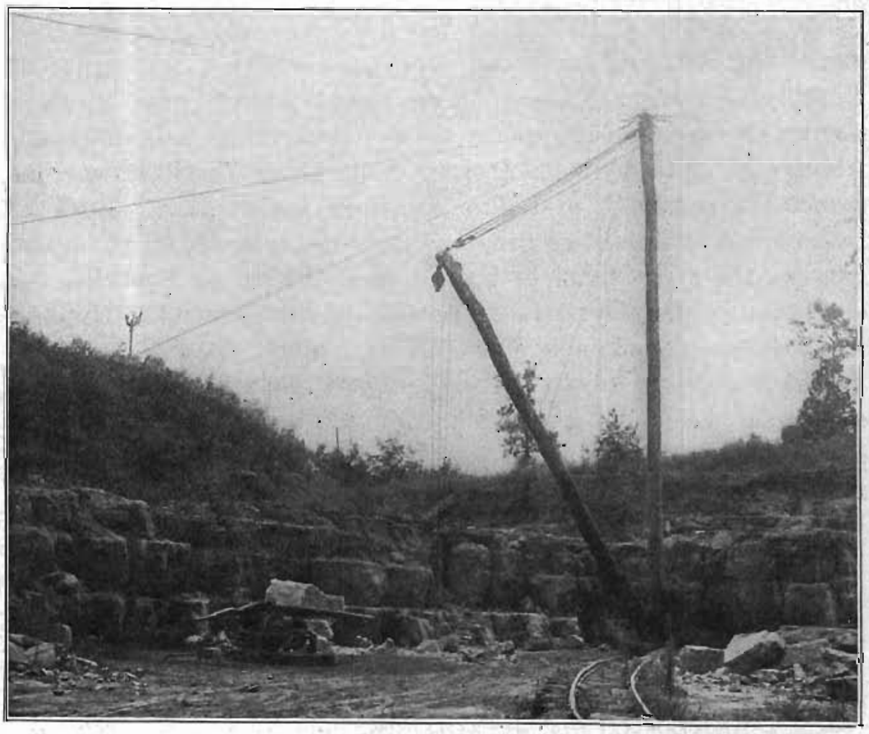


FIG. 34—Wilkes Williams quarry showing the rough, heavy bedded facies of the Niagaran, section 24, Clermont township, Fayette county.

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	$1\frac{5}{6}$
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 townships 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	$1^2/_3$

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.

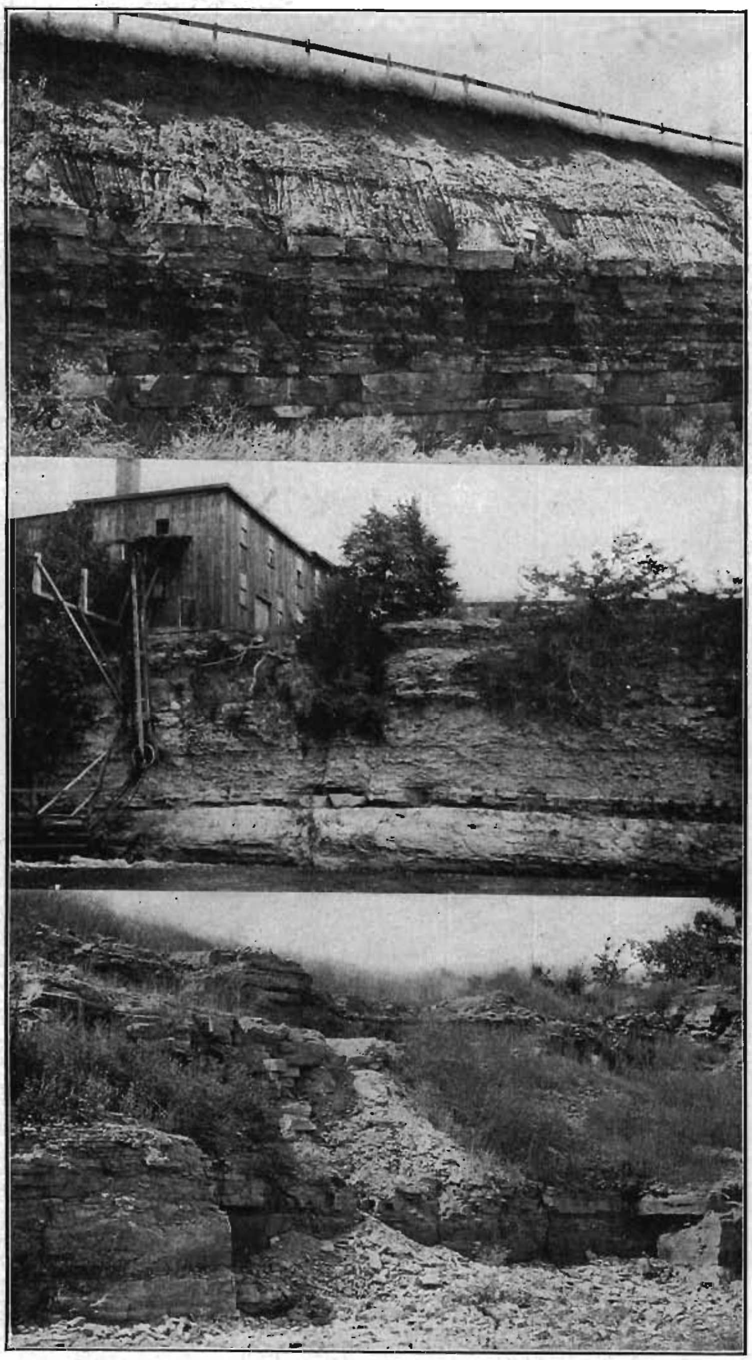


PLATE XX—a. City quarry, Charles City, Floyd county.
b. Shell Rock river, Nora Springs, Floyd county.
c. Floyd quarry section.

		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-

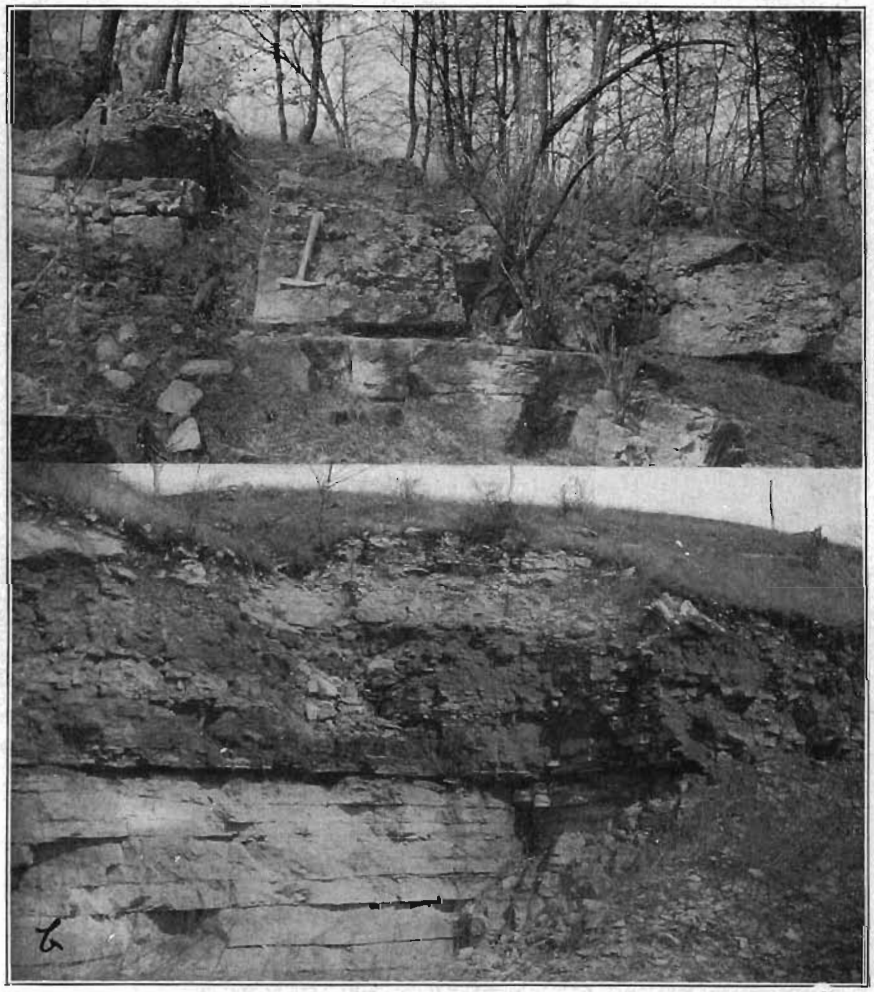


PLATE XXI—a. Old lime quarry above Marble Rock, Floyd county, showing Stromatopora zone and brecciated zone.
b. Marble Rock quarry showing evenly bedded, lithographic beds below, and Stromatopora and brecciated zone above.

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 1/6
7.	Limestone, lithographic, thinly bedded, where weathered, separating into thin plates	1 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:

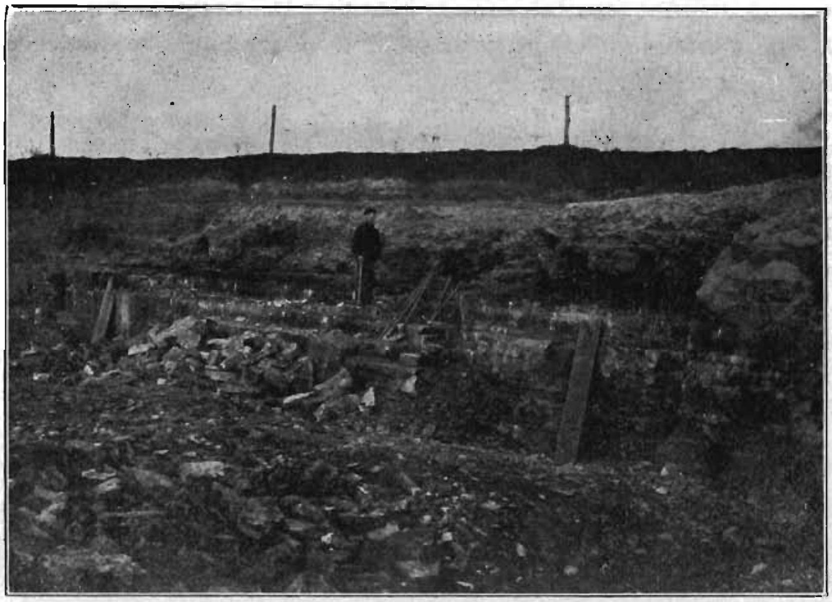


FIG. 35—Kinderhook limestone quarry one mile west of Chapin, Franklin county.

		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 hill-side 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 quality 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 lime-rock 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.

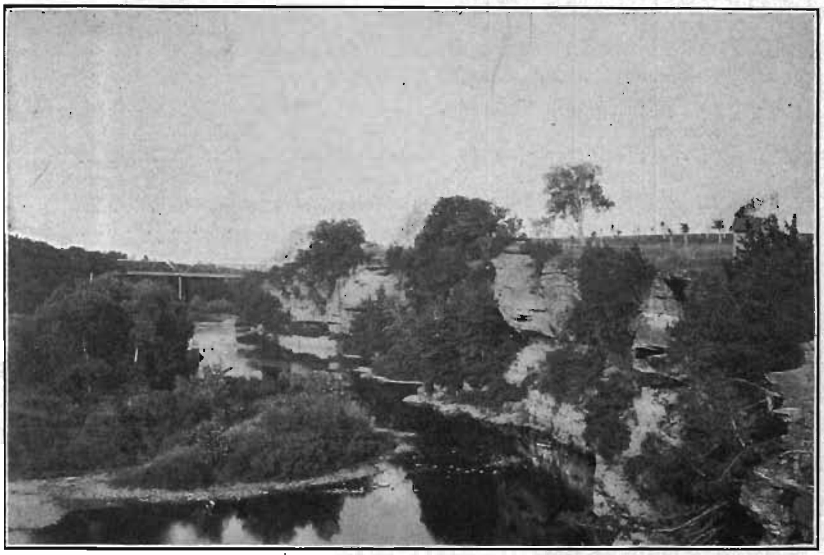


FIG. 37—Iowa river gorge, Iowa Falls, showing the Kinderhook limestone, Hardin county.

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-

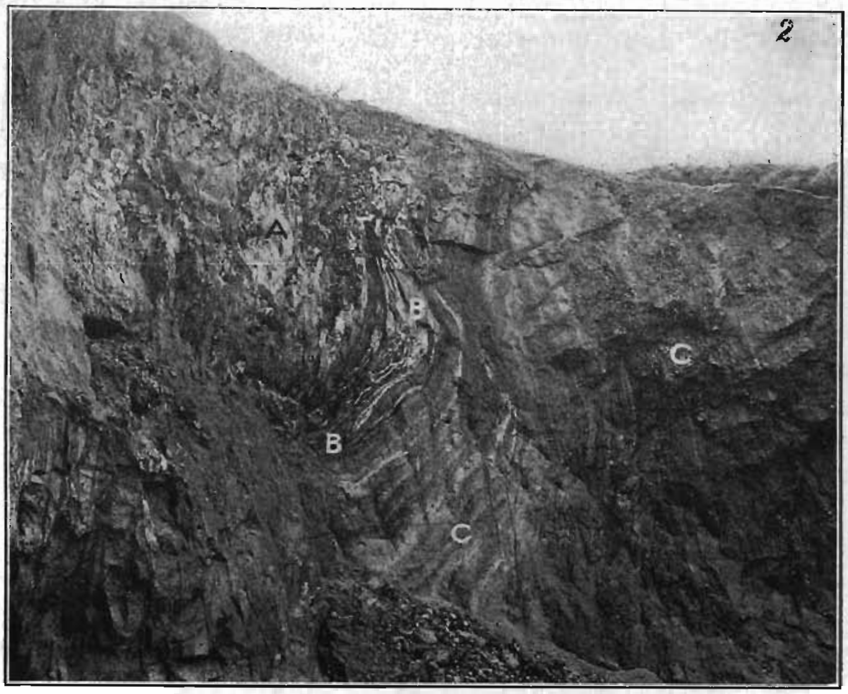


FIG. 38—McGavern pit, showing variability of the Aftonian gravels, Missouri Valley, Harrison county.

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 divisions 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.

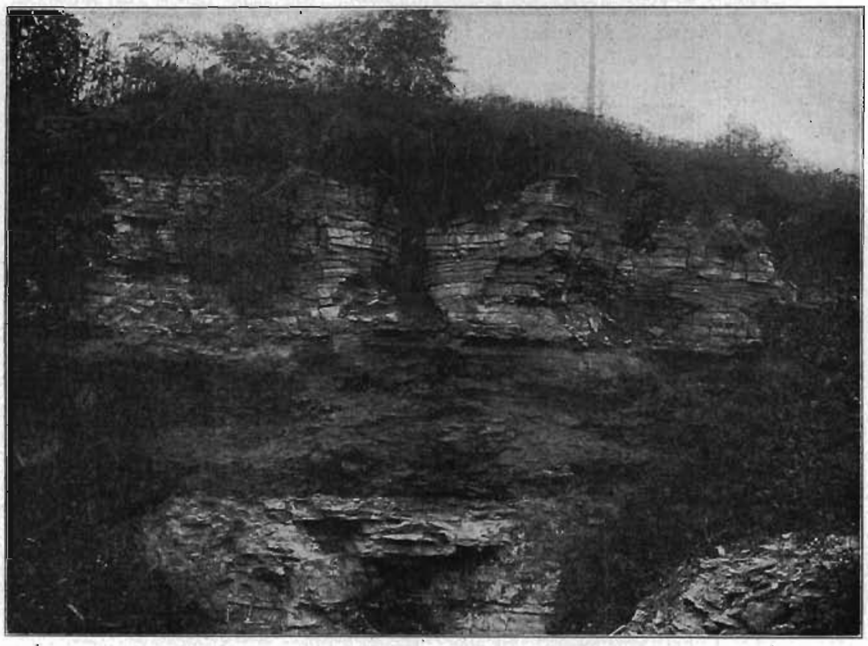


FIG. 41—St. Louis limestone near Winfield, Henry county.

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

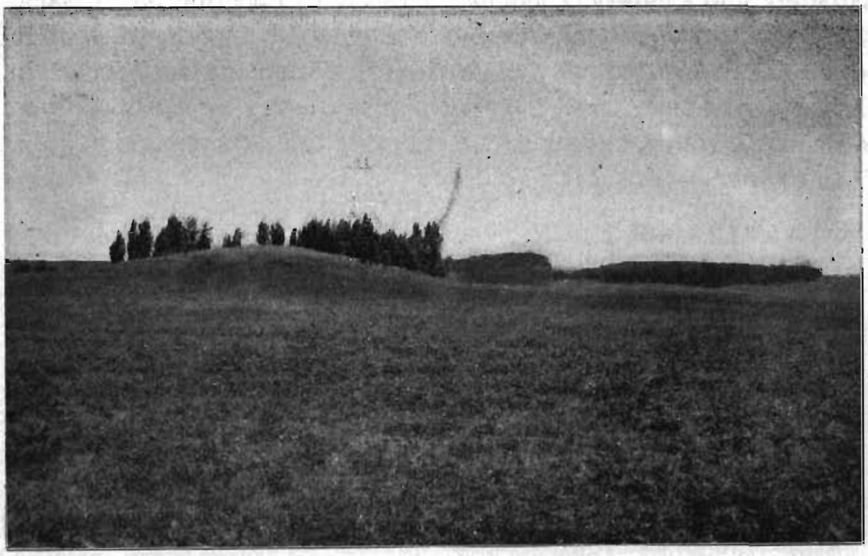


FIG. 42—Esker of Buchanan gravel in the southwest quarter of section 27, Albion township, Howard county.

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	4¹/₃
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

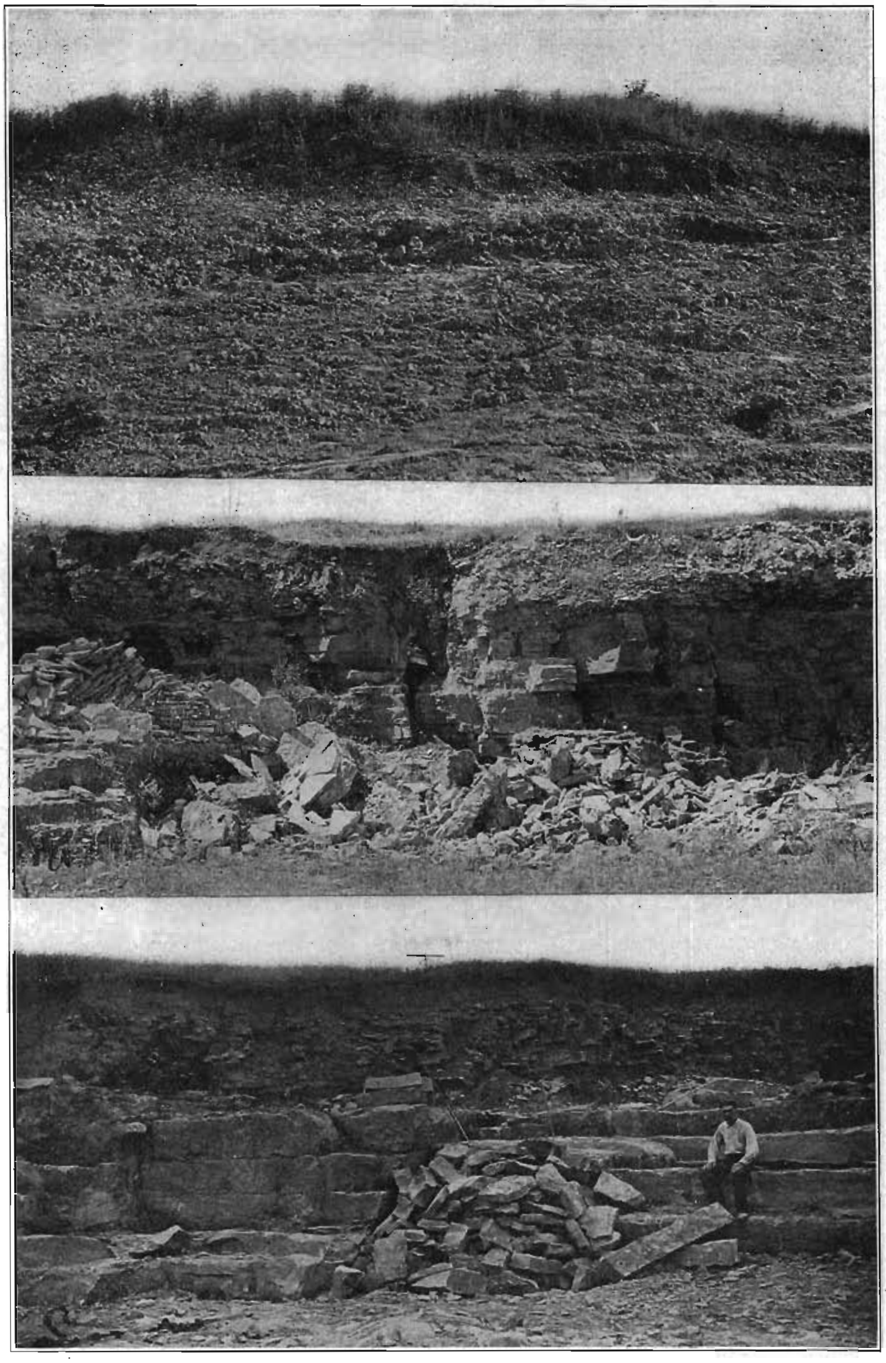


PLATE XXIII—a. City quarry about one and one-half miles north of Cresco. The product is a natural macadam.
b. Quarry northeast of Elma showing flaggy character of beds.
c. Hallman quarry showing principal quarry beds. Cresco, Howard county.

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

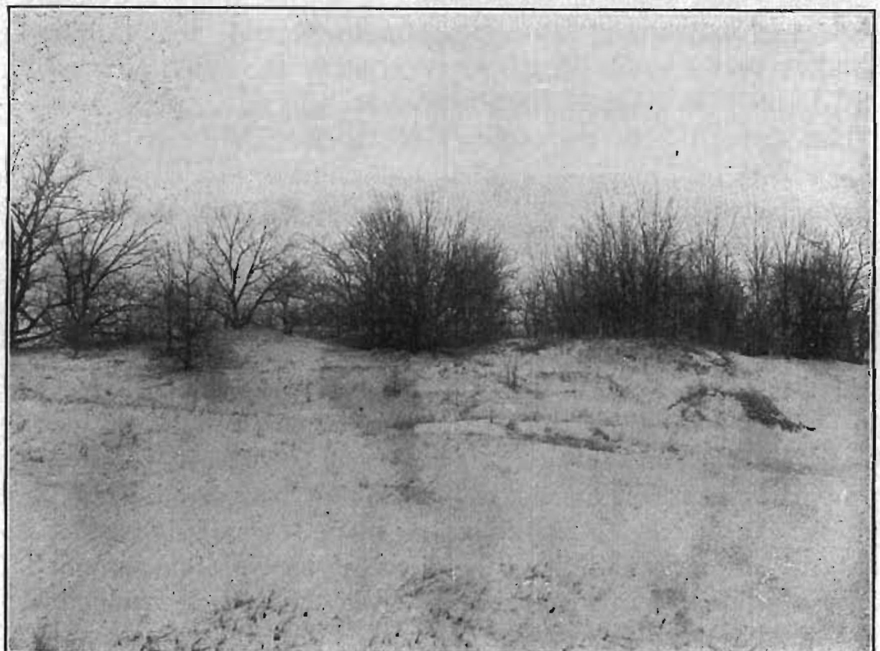


Fig. 43—Sand dune invading timber land northeast corner of Bellevue township, Jackson county.

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	3⅓
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, approaching 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.

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

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

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

JEFFERSON COUNTY.

Sand and Gravel.

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

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

*Iowa Geological Survey, Volume XII.

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

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

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

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

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

Stone.

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

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

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

		Feet.
4.	Soil and drift of variable thickness.	
3.	Clay and marl, yellow	3½
2.	Limestone, dark gray, porous, somewhat cherty in places	7
1.	Limestone, grayish yellow, exposed	5

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

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

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

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

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

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

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

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

JOHNSON COUNTY.

Sand and Gravel.

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

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

Stone.

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

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

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

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

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

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

TERRILL MILL SECTION.

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

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

CORALVILLE SECTION.

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

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

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

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

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

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

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

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

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

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

JONES COUNTY.

Sand and Gravel.

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

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

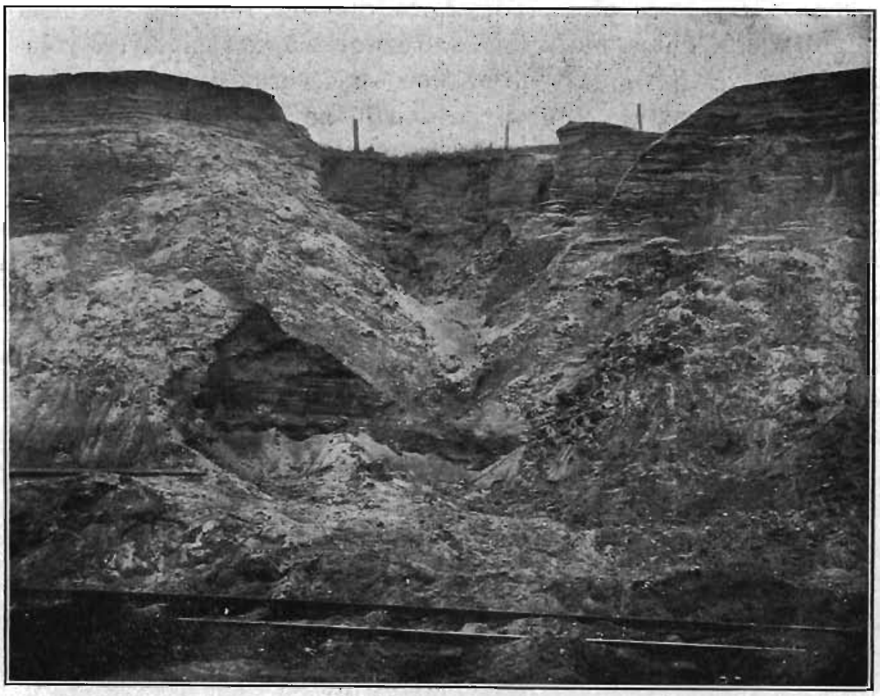


FIG. 44—Chicago, Milwaukee & St. Paul Railway sand and gravel pit. Monticello, Jones county.

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

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

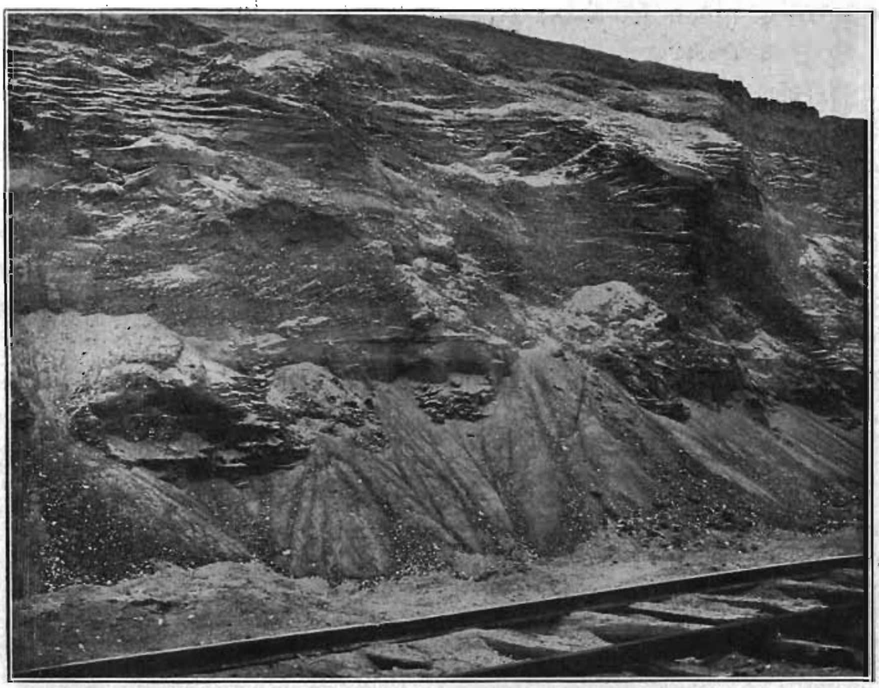


FIG. 45—Chicago, Milwaukee & St. Paul sand pit, Monticello, Jones county.

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

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

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

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

Stone.

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

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

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

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

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

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

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

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

STONE CITY.

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

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

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

CHAMPION QUARRY No. 1. SECTION.

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

11.	Solid ledge of good building stone................	1	4
10.	Compact ledge, best quality afforded by the quarry	1	2
9.	"Wavy ledge" good for ordinary masonry; the laminæ are more or less undulated...............	2½-3	....
8.	Good building ledge	..	11
7.	"Flint ledge," compact limestone, breaking into angular fragments on exposure to weather....	½-1	4
6.	Flagging ledge, easily split......................	1	4
5.	Ledge containing cavities lined with crystals......	1	....
4.	Ledge of good building stone.....................	..	11
3.	Lower flagging ledge..............................	2	....
2.	Lower bridge stone ledge, very durable, though occasionally containing cavities lined with crystals	2	4
1.	Ledge that may again be split into blocks convenient for building purposes......................	3	....

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

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

STONE CITY QUARRIES.

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

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

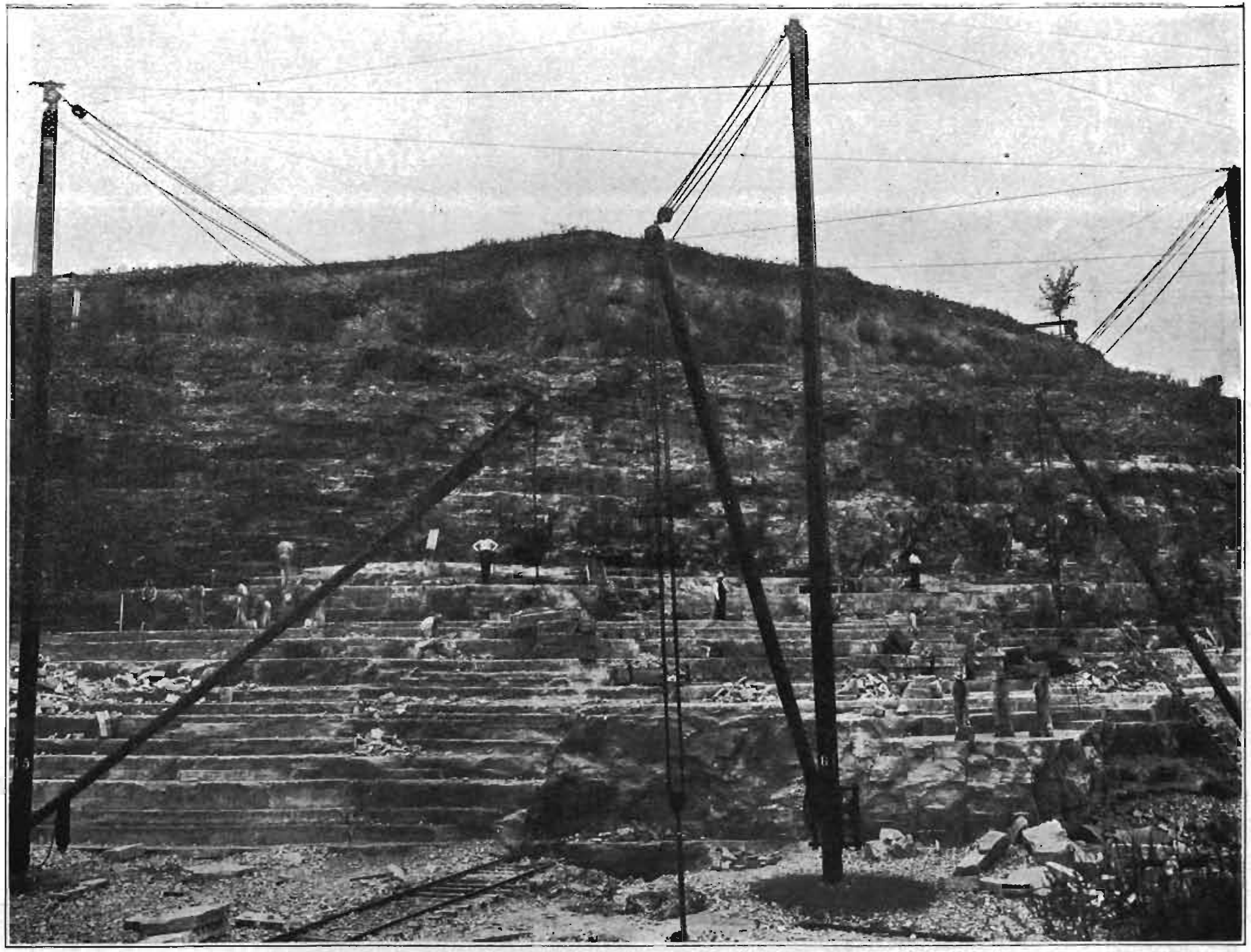


PLATE XXVII—State quarry, Anamosa, Jones county. This quarry is unique among the larger quarries of the state in the absence of improved machinery. All power is hand power.

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

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

ANAMOSA QUARRY.

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

STATE QUARRY.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

KEOKUK COUNTY.

Sand and Gravel.

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

STONE.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

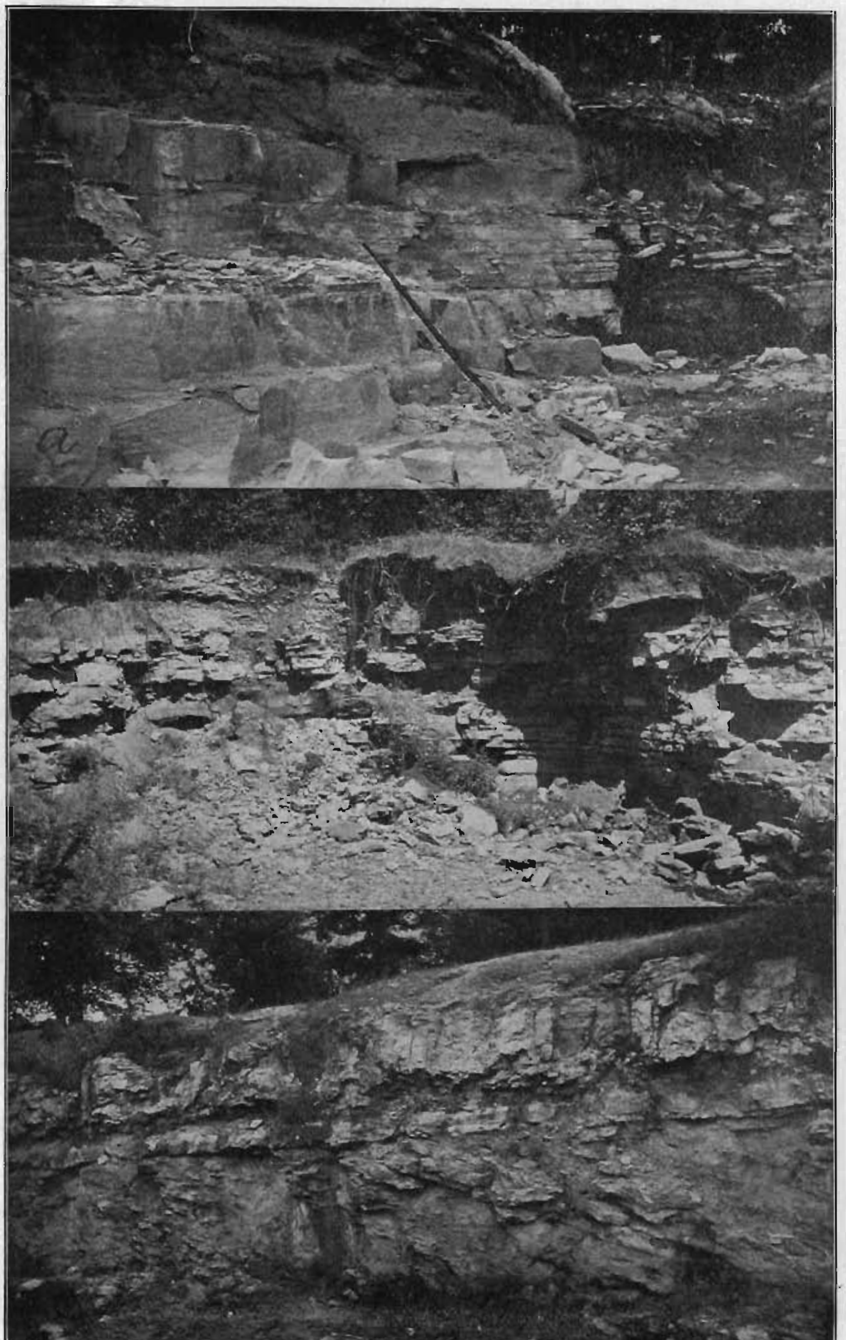


PLATE XXVIII—a. Near view of quarry face, Tracy, Marion county, showing Pella beds.
b. Miller quarry, about two miles north of Sigourney, Keokuk county, showing Pella beds.
c. Local unconformity in Verdi beds, near Showman station, Keokuk county.

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

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

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

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

KOSSUTH COUNTY.

SAND AND GRAVEL.

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

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

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

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

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

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

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

LEE COUNTY.

SAND AND GRAVEL.

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

STONE.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

BELFAST SECTION.

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

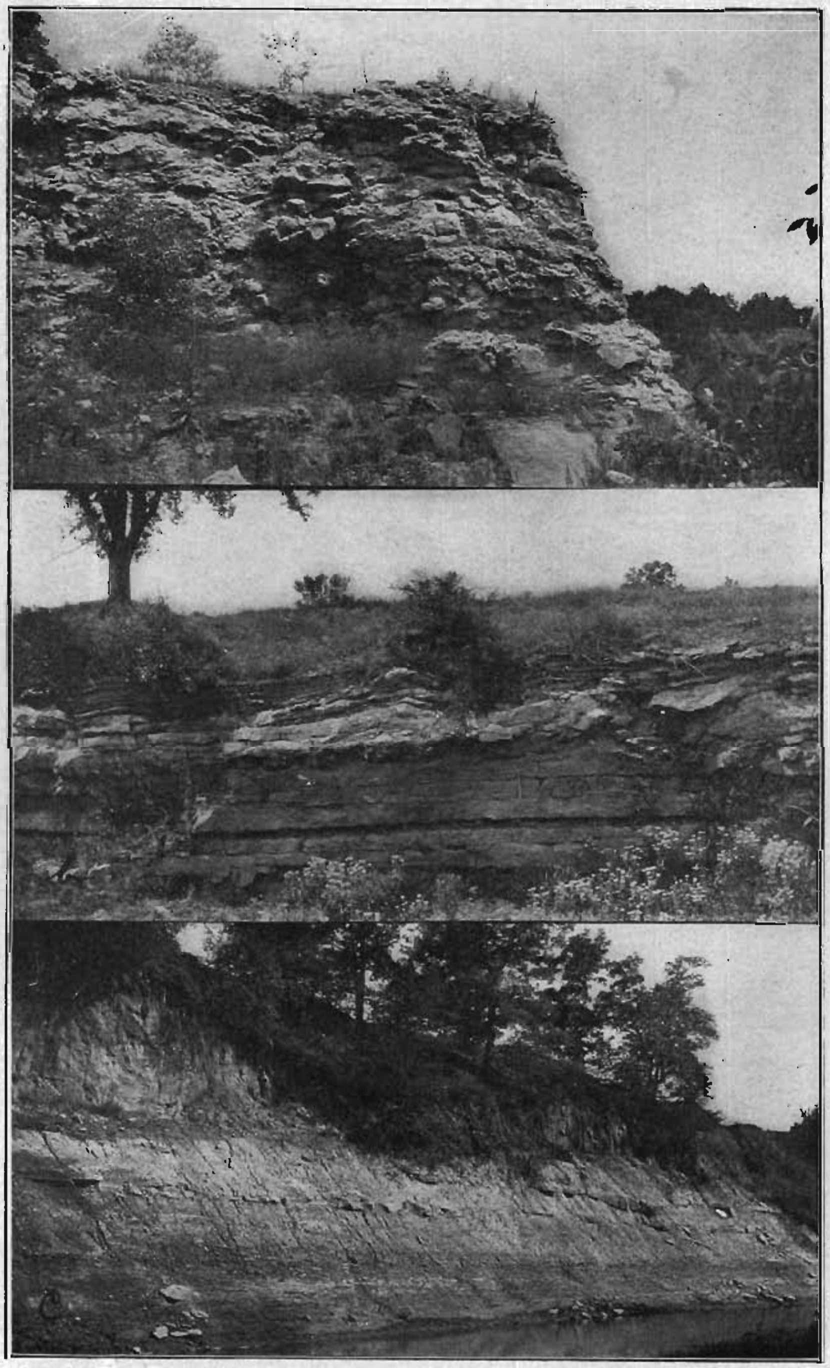


PLATE XXIX—a. Abandoned Santa Fe quarry east of Belfast.
b. Principal quarry section southwest of Mt. Pleasant.
c. Geode bearing shale, west of Farmington, Van Buren county.

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

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

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

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

GRANER QUARRY.

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

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

LINN COUNTY.

Sand and Gravel.

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

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

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

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

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

STONE.

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

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

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

MOUNT VERNON SECTION.

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

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

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

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

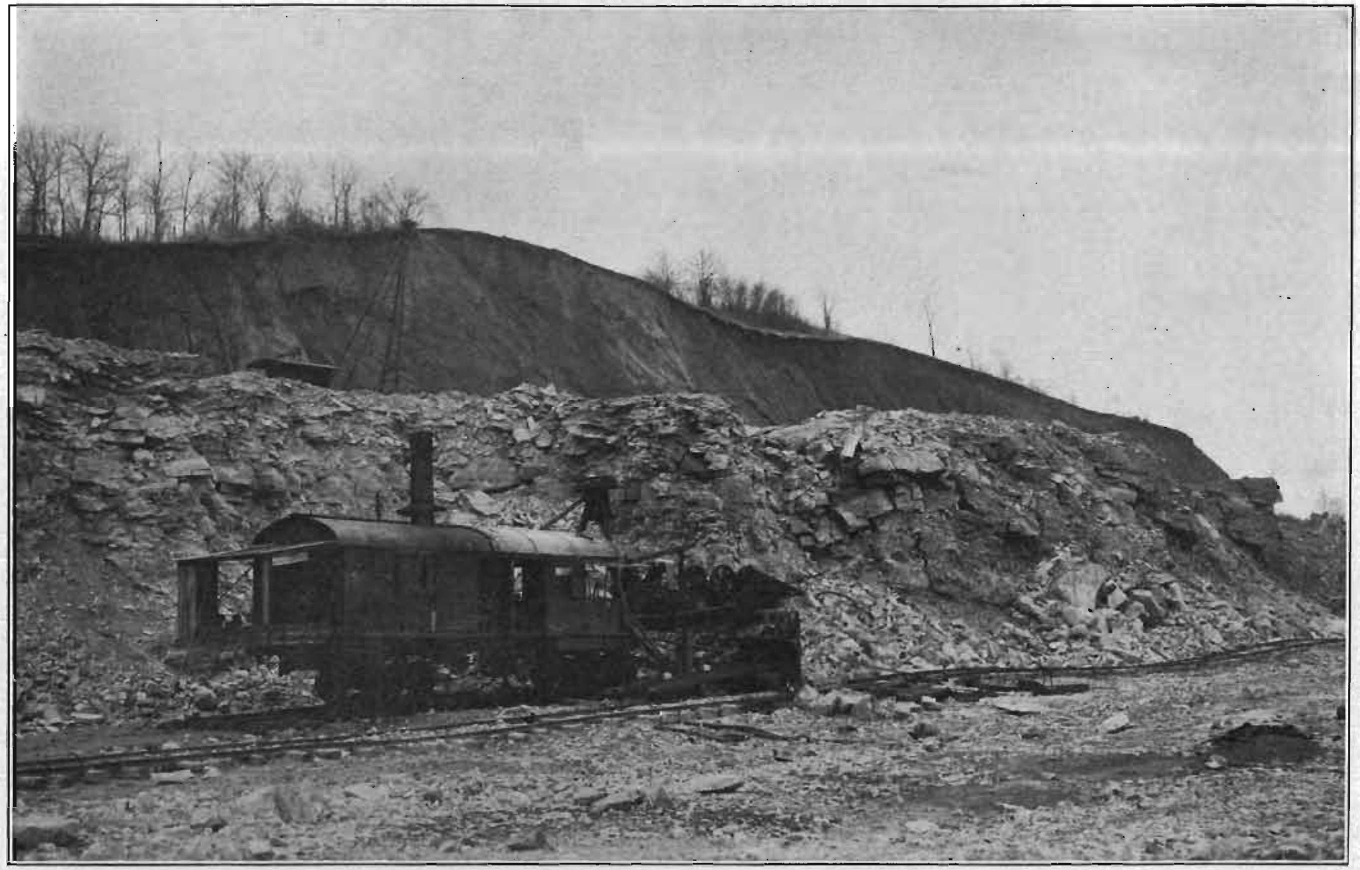


PLATE XXX—Quarry of the Chicago and North Western Railway, Cedar Rapids, showing steam shovel, drill rig and broken stone.

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

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

COGGAN SECTION.

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

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

CENTRAL CITY SECTION.

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

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

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

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

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

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

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

LOUISA COUNTY.

Sand and Gravel.

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

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

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

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

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

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

Stone.

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

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

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

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

		FEET.
6.	Disintegrated crinoidal limestone, brown to yellow........	3½
5.	Partially weathered crinoidal limestone containing some chert; ledges 4 to 6 inches thick, fair stone..............	2⅔
4.	White chert, nearly fails in places	½
3.	Yellowish crinoidal limestone with chert above and containing fossils	4
2.	Yellowish fine-grained limestone, containing open pockets often lined with botryoidal calcite or quartz crystals, soft and can usually be crumbled to a powder in the fingers..	1-3
1.	Coarsely crystalline pure limestone, light brown to bluish white; in ledges from one foot above to massive three-foot ledges below; stylolitic jointing very common; free from chert	6

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

LUCAS COUNTY.

Sand and Gravel.

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

Stone.

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

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

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

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

LYON COUNTY.

Sand and Gravel.

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

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

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

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

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

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

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

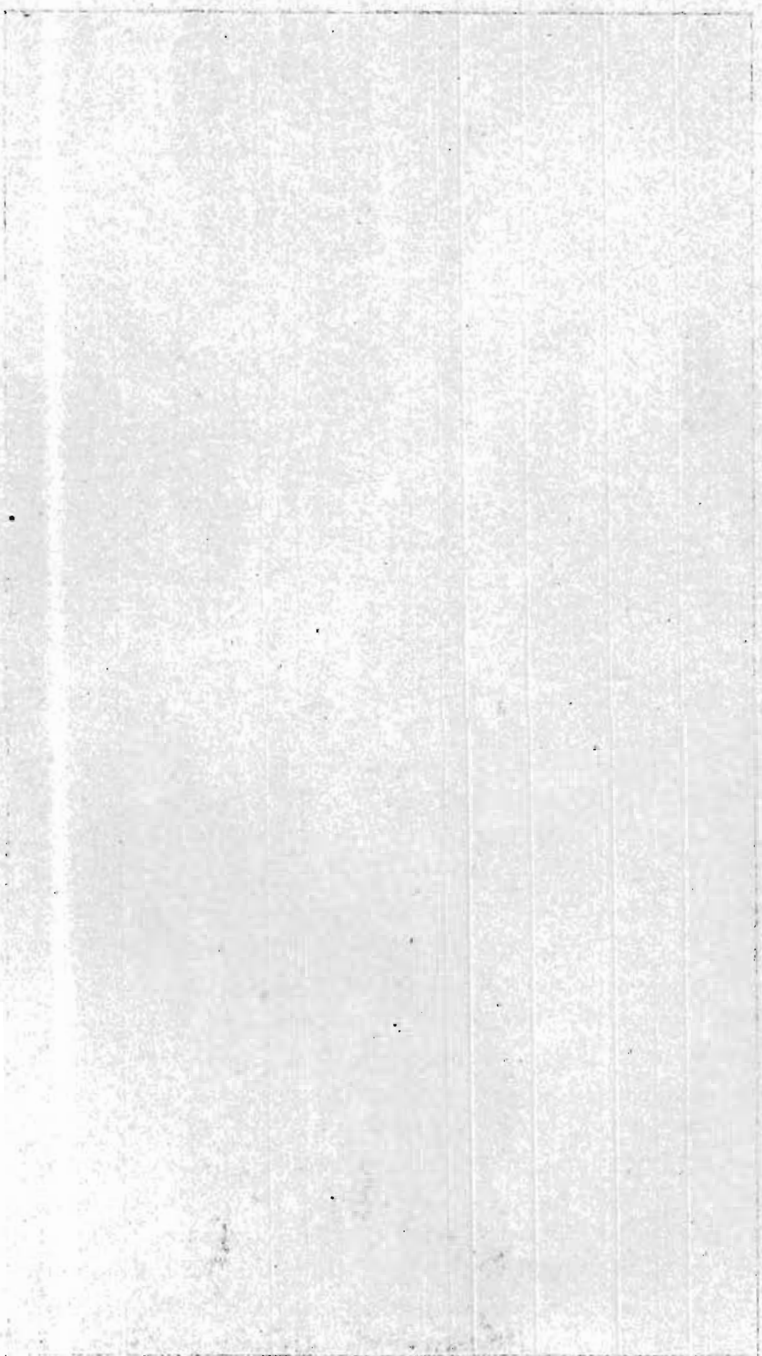


PLATE XXXI—The Miller-Montgomery pit showing pit methods. Doon, Lyon county.

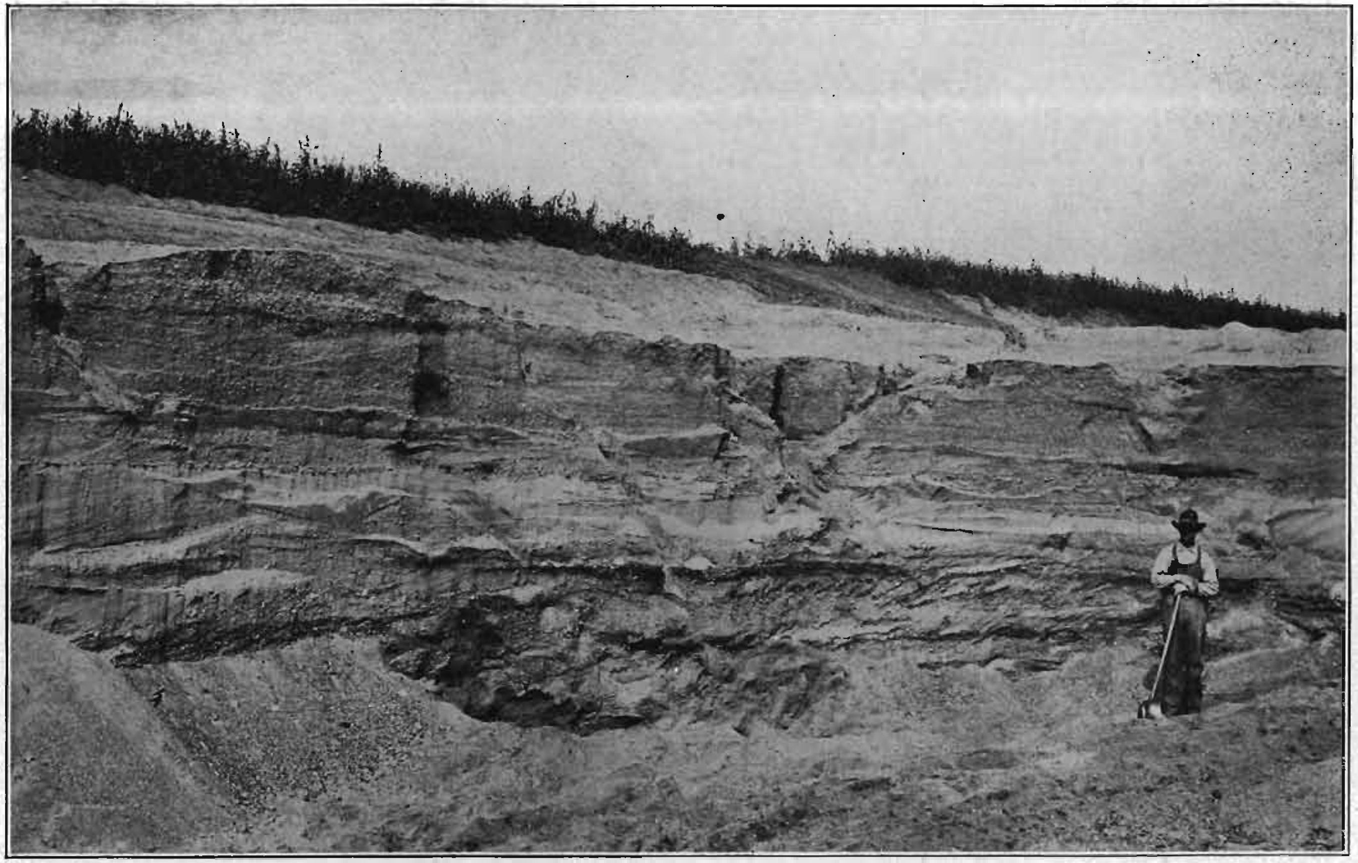


PLATE XXXII—Lehatchka and Pattengill pit which shows great irregularity in bedding. Rock Rapids, Lyon county.

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

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

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

	FEET.
Stripping	2-4
Gravel, fine and clean, with lenses of sand	3-4
Sand, silty in streaks, and having some fine gravel	1-2
Pebble band	¼-⅓
Sand, cross-bedded, and with streaks and lenses of gravel	2-3
Gravel, cross-bedded, iron-stained in part	2
Sand and fine gravel	2
To water line (not exposed)	2

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

STONE.

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

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

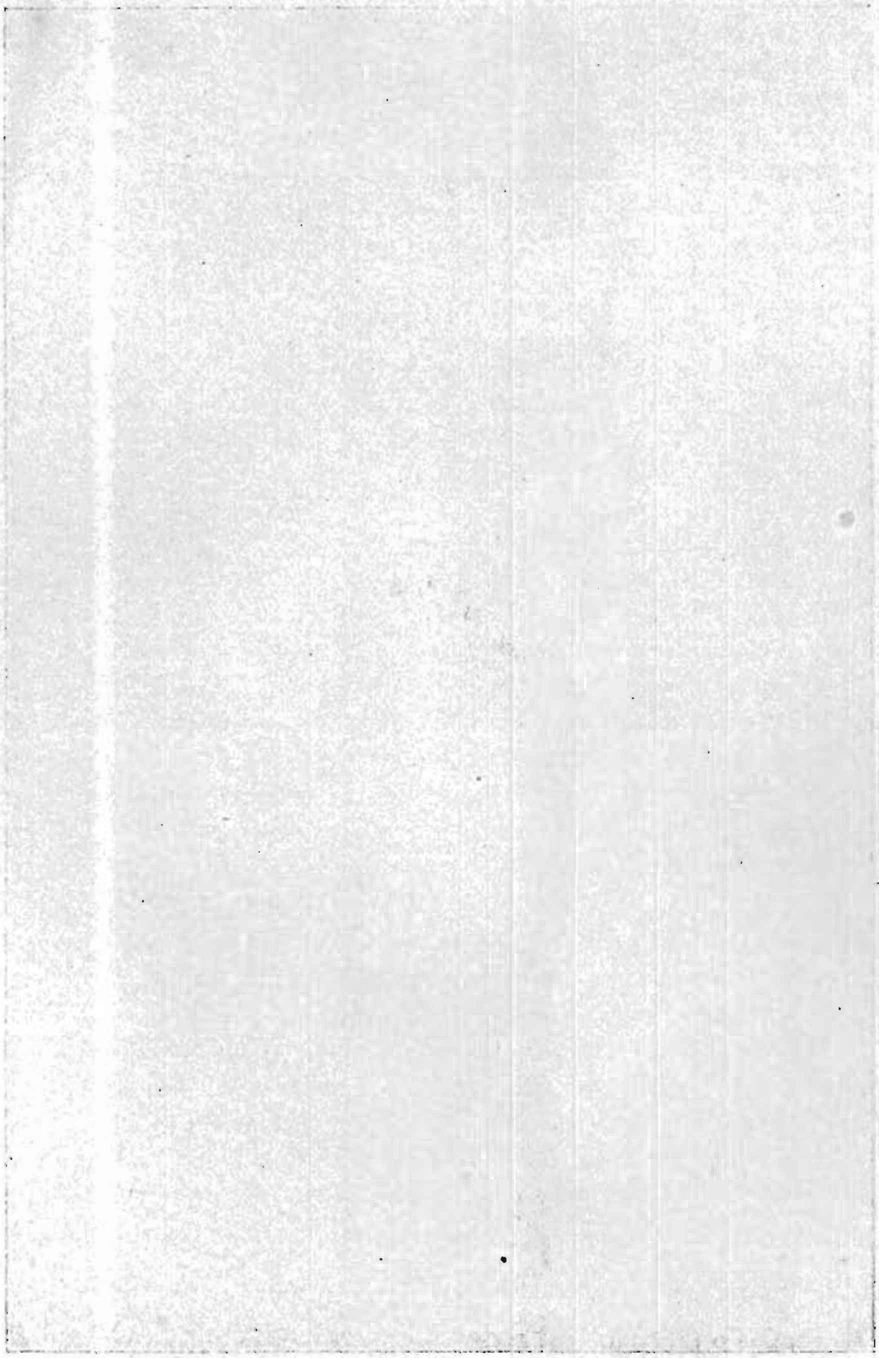
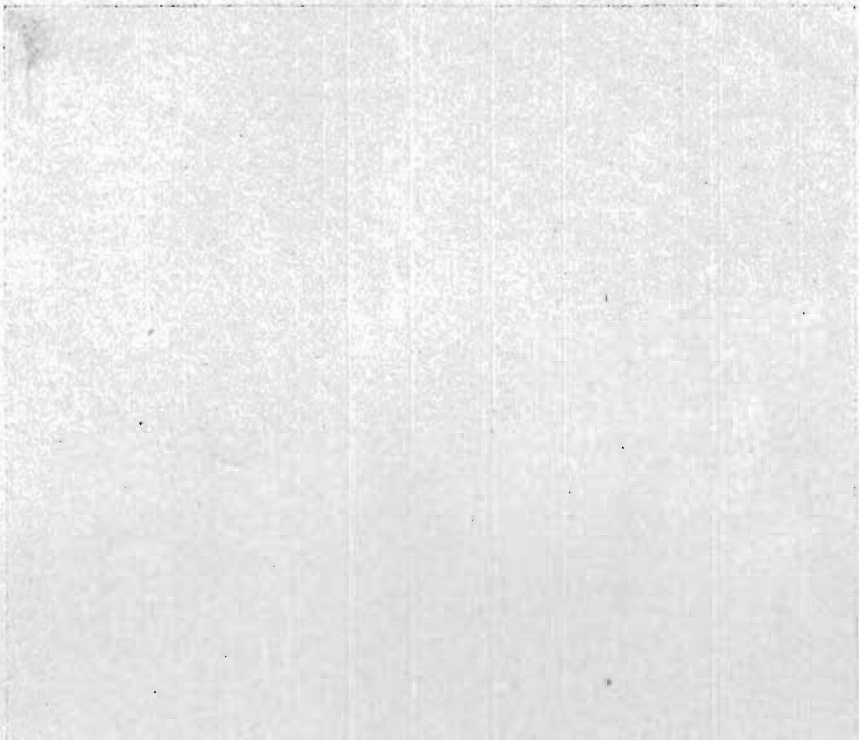


PLATE XXXIII—Sioux quartzite escarpment along Big Sioux river in the extreme northwest corner of Iowa; the best material in Iowa for crushed stone products.

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



MADISON COUNTY.

SAND AND GRAVEL.

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

STONE.

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

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

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

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

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

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

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

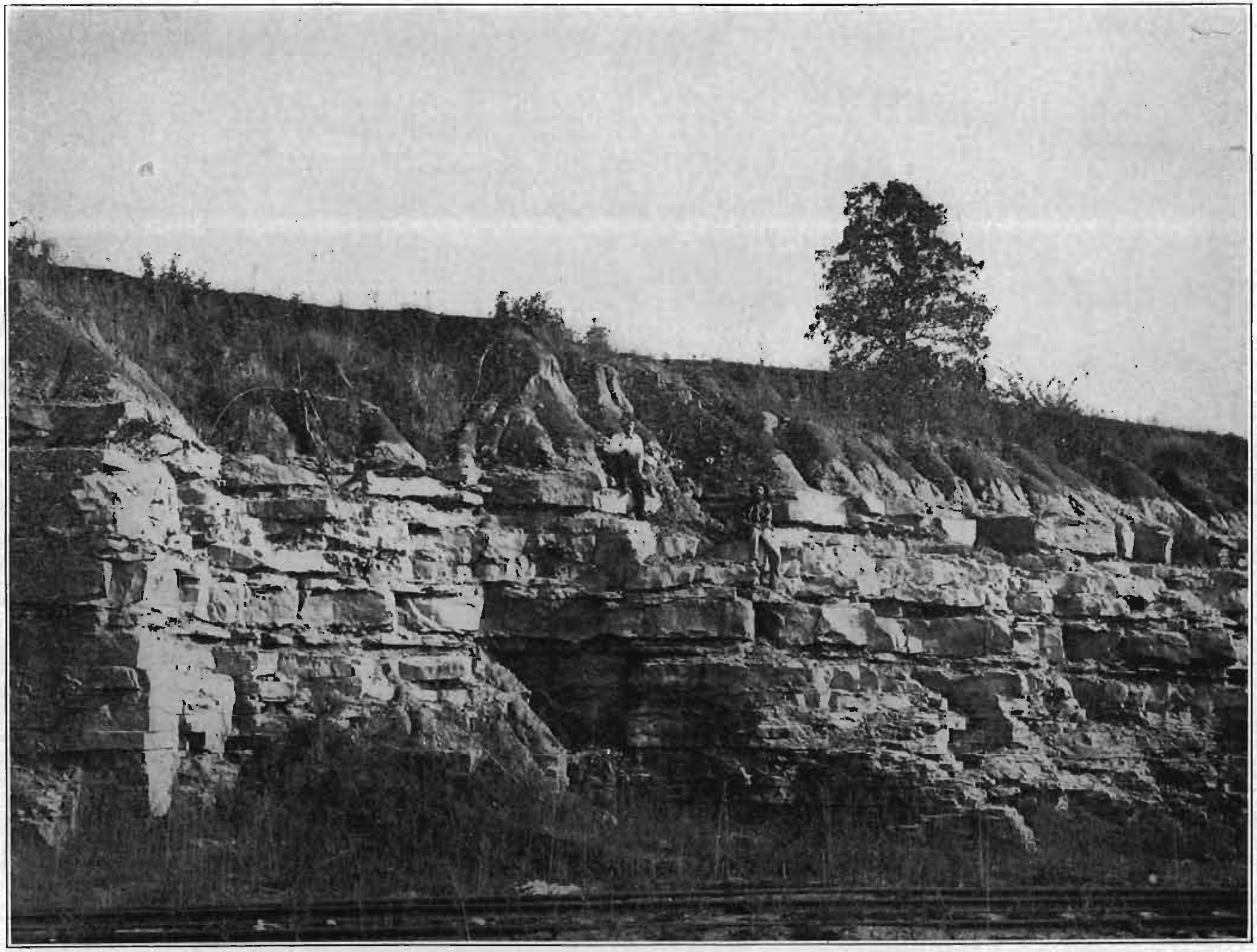


PLATE XXXV—Iowa Portland Cement Company quarry, Earlham, Madison county, showing the principal limestone beds with their characteristic clay partings.

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

EARLHAM LAND COMPANY QUARRY SECTION.

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

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

IOWA PORTLAND CEMENT COMPANY QUARRY SECTION.

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

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

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

L. G. MICHAEL, Analyst.

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

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

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

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

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

		Feet.
7.	Drift and soil (thickens greatly in the bluffs)	3
6.	Limestone, disintegrated, uneven on the upper surface and probably thickens toward the bluffs, exposed	3
5.	Limestone, gray, heavy-bedded, somewhat porous and fossiliferous	3
4.	Limestone, fossiliferous and presents a concretionary facies; decidedly argillaceous	1⅓
3.	Limestone, gray to buff, hard, brittle and fossiliferous; unevenly bedded, top and bottom layers thickest, slightly concretionary	8
2.	Limestone, shaly, gray to yellow, highly fossiliferous	1½
1.	Limestone, buff to gray, somewhat unevenly bedded and slightly clayey; massive in unweathered sections, exposed	4

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

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

Analysis of Winterset limestone selected from City quarry.

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

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

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

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

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

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

Analyzed by L. G. MICHAEL.

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

MAHASKA COUNTY.

Sand and Gravel.

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

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

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

Stone.

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

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

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

MARION COUNTY.

Sand and Gravel.

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

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

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

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

STONE.

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

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

TRACY SECTION.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

CRUSHING TEST.

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

ABSORPTION TEST.

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

CHEMICAL COMPOSITION.

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

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

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

MARSHALL COUNTY.

SAND AND GRAVEL.

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

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

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

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

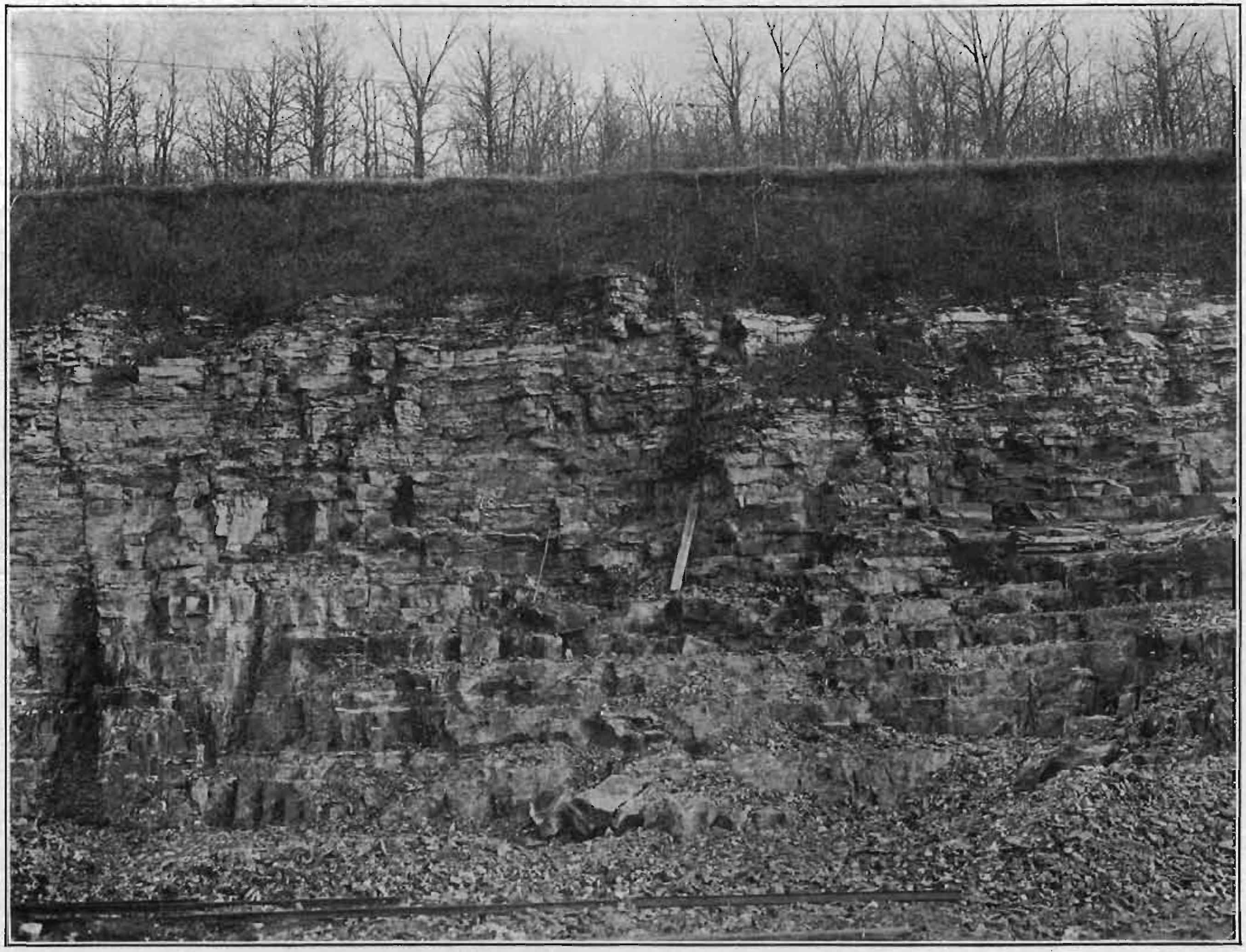


PLATE XXXVI—Typical section in quarry of LeGrand Quarry Company, Quarry, Marshall county. The entire assemblage of beds are suitable for road and concrete materials.

STONE.

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

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

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

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

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

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

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

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

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

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

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

Quarry Industry.

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

LE GRAND QUARRY COMPANY.

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

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

At present only the southeast quarry is being operated.

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

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

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

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

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

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

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

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

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

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

MILLS COUNTY.

Sand and Gravel.

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

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

STONE.

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

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

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

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

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

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

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

Section in the quarry at Henton:

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

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

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

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

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

MITCHELL COUNTY.

Sand and Gravel.

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

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

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

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

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

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

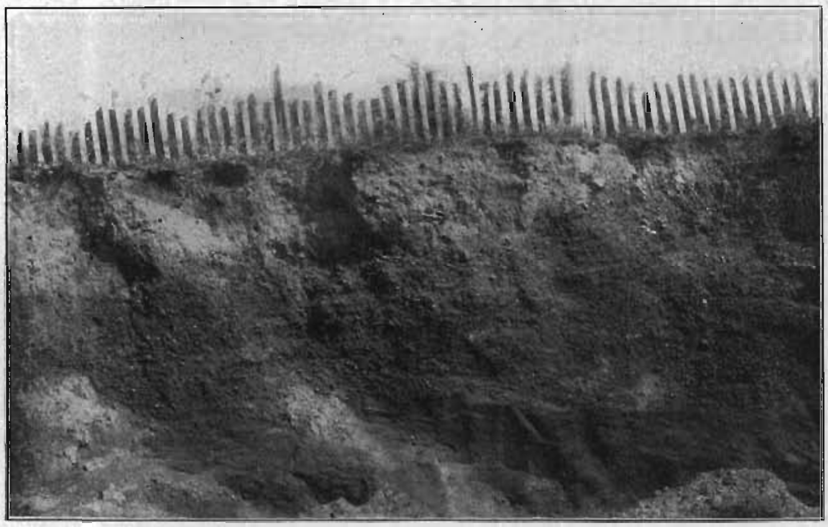


FIG. 49—Buchanan gravels overlain by Iowan loess, in the northwest quarter of section 35, Cedar township, Mitchell county.

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

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

STONE.

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

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

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

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

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

GENERALIZED DEVONIAN SECTION.

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

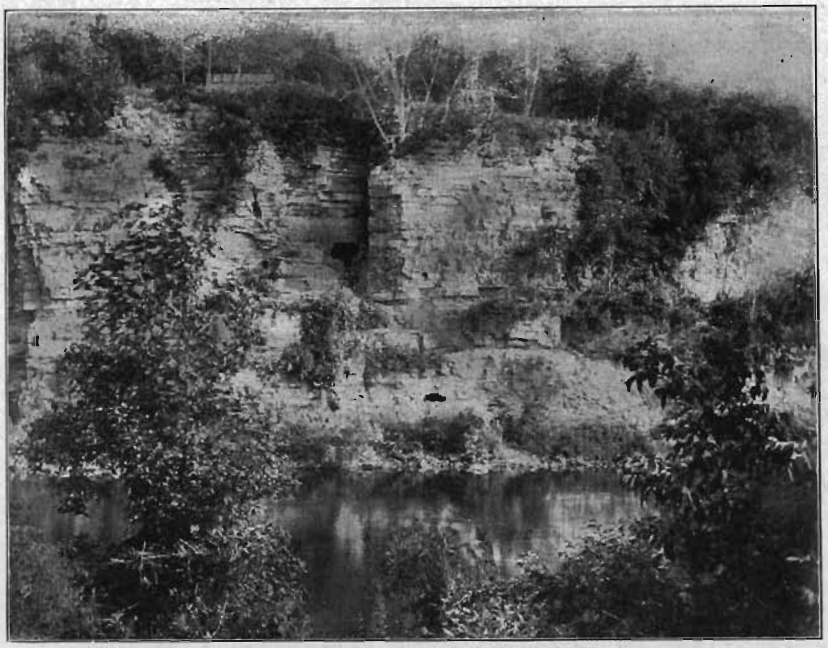


FIG. 50—Cliff below the wagon bridge in the northeast quarter of section 28, Osage township, Mitchell county. There are folded and brecciated beds at the base of the cliff; the lithographic limestone appears at the top.

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

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

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

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

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

LEWIS LIME QUARRY.

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

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

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

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

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

A. O. ANDERSON, Analyst.

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

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

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

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

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

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

MONONA COUNTY.

Sand and Gravel.

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

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

Belvidere Township.

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

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

Kennebec Township.

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

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

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

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

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

MONROE COUNTY.

Sand and Gravel.

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

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

Stone.

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

MONTGOMERY COUNTY.

SAND AND GRAVEL.

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

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

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

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

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

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

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

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

STONE.

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

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

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

*Iowa Geological Survey, Vol. IV, 1894.

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

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

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

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

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

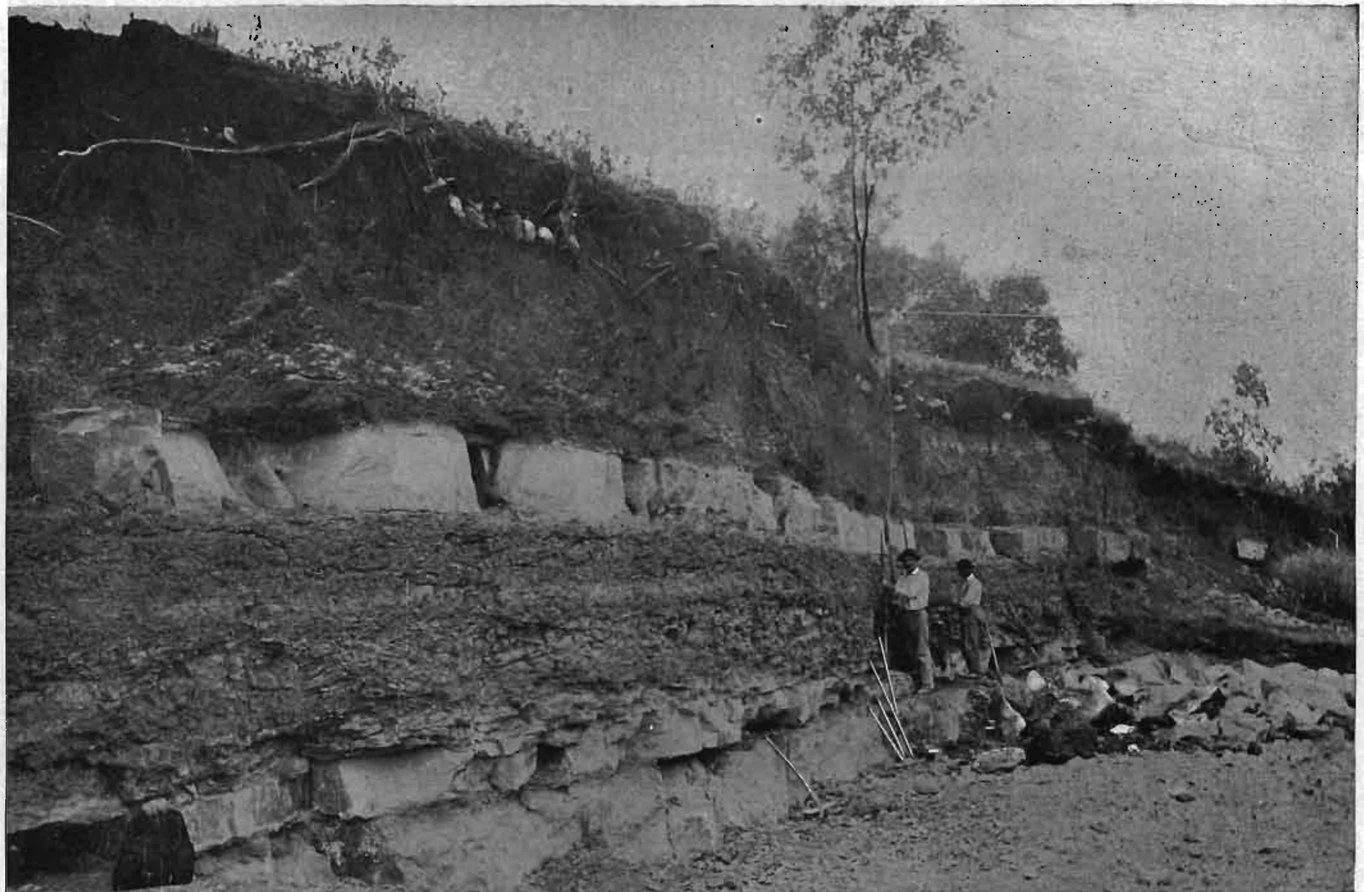


PLATE XXXIX—Typical exposure of the Missouri stage of the Coal Measures. Fate quarry, Stennett, Montgomery county. The stripping and interbedded shales and clays make quarrying unprofitable.

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

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

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

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

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

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

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

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

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

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

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

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

MUSCATINE COUNTY.

SAND AND GRAVEL.

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

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

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

STONE.

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

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

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

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

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

		FEET.
7.	Drift and soil, of variable thickness.	
6.	Limestone, weathered ledges, with scattered casts of cup corals	2⅓
5.	Limestone, black, carbonaceous, with Stromatopora	¼
4.	Limestone, bluish, dolomitic, thick-bedded, with fossil casts	9
3.	Shale, soft, fossiliferous	1
2.	Limestone, in thin hard ledges, with small, kidney-shaped or cakelike Stromatopora	2
1.	Limestone, dolomitic, bluish, finely granular; fossiliferous, exposed	4

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

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

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

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

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

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

CARPENTER QUARRY SECTION.

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

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

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

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

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

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

O'BRIEN COUNTY.

Sand and Gravel.

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

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

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

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

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

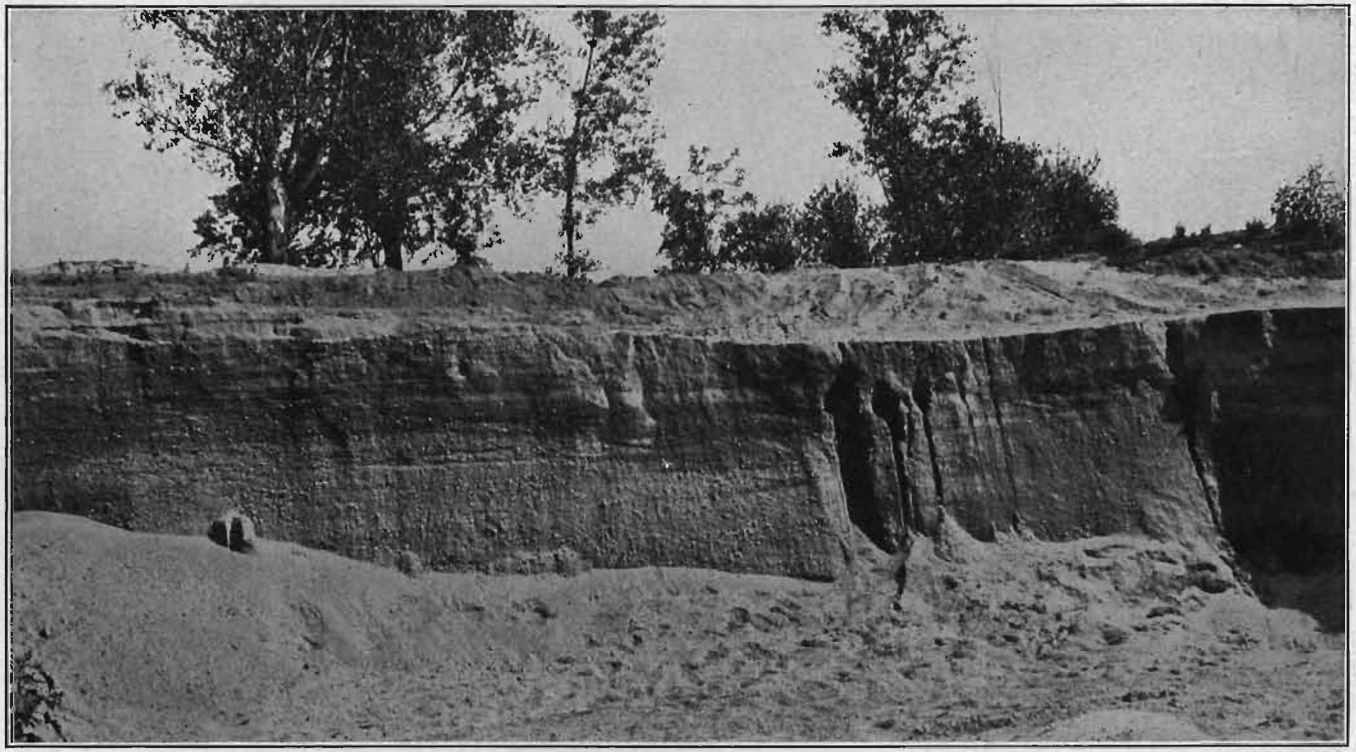


PLATE XL—Griffen pit, Sheldon, O'Brien county.

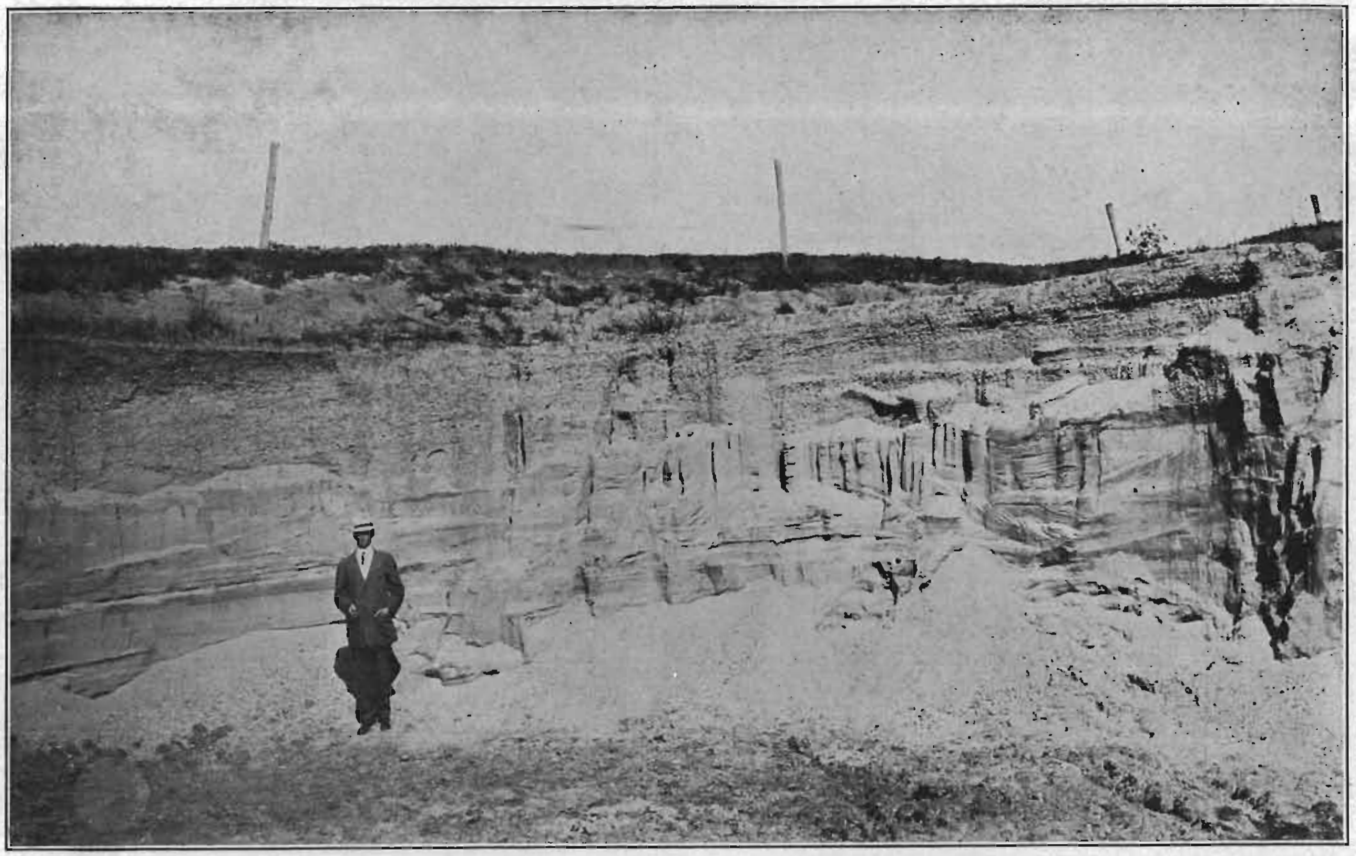
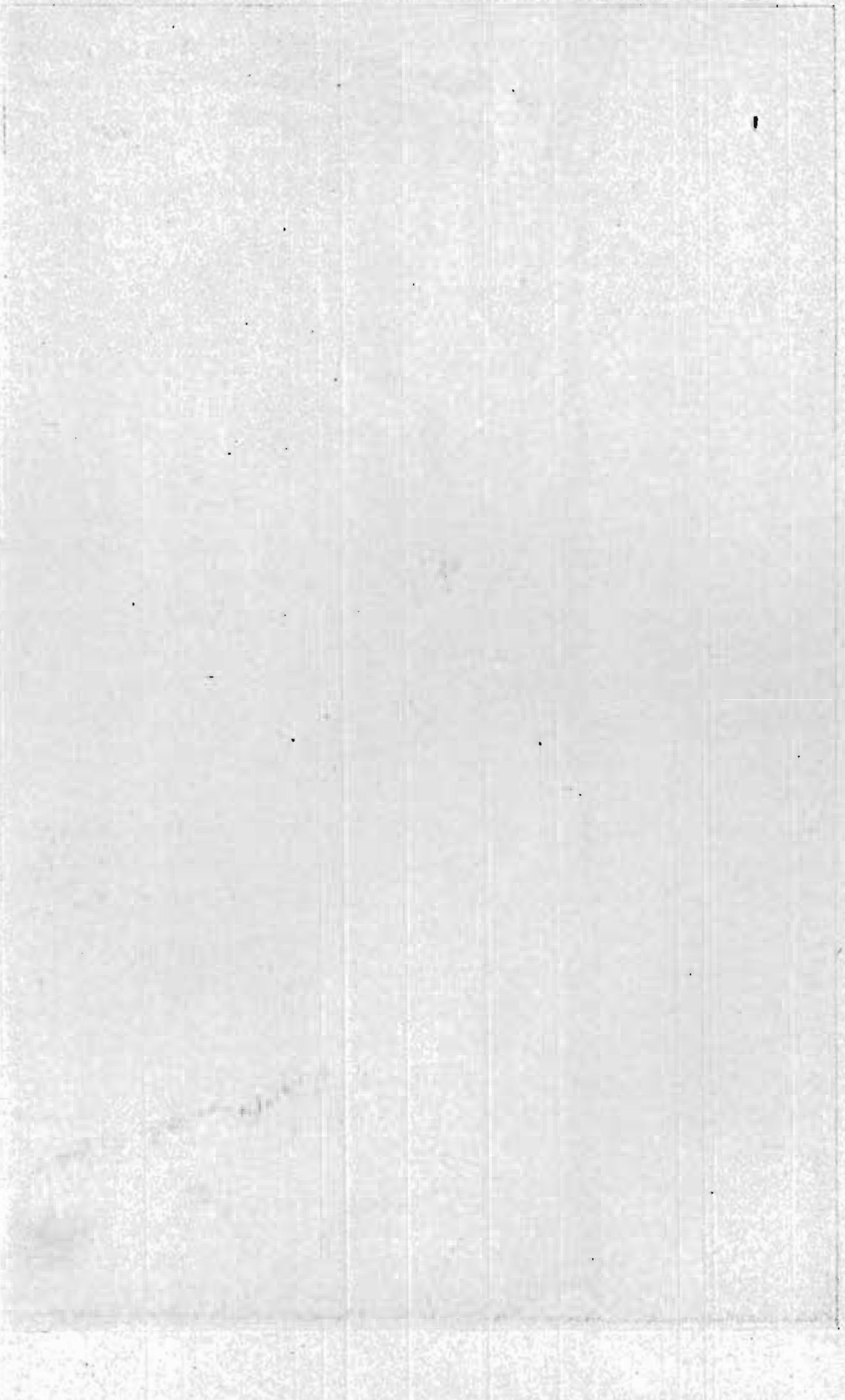


PLATE XLI—McCracken pit, showing gravel above and sand below, Paullina, O'Brien county.



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

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

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

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

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

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

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

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

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

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

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

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

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

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

OSCEOLA COUNTY.

Sand and Gravel.

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

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

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

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

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

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

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

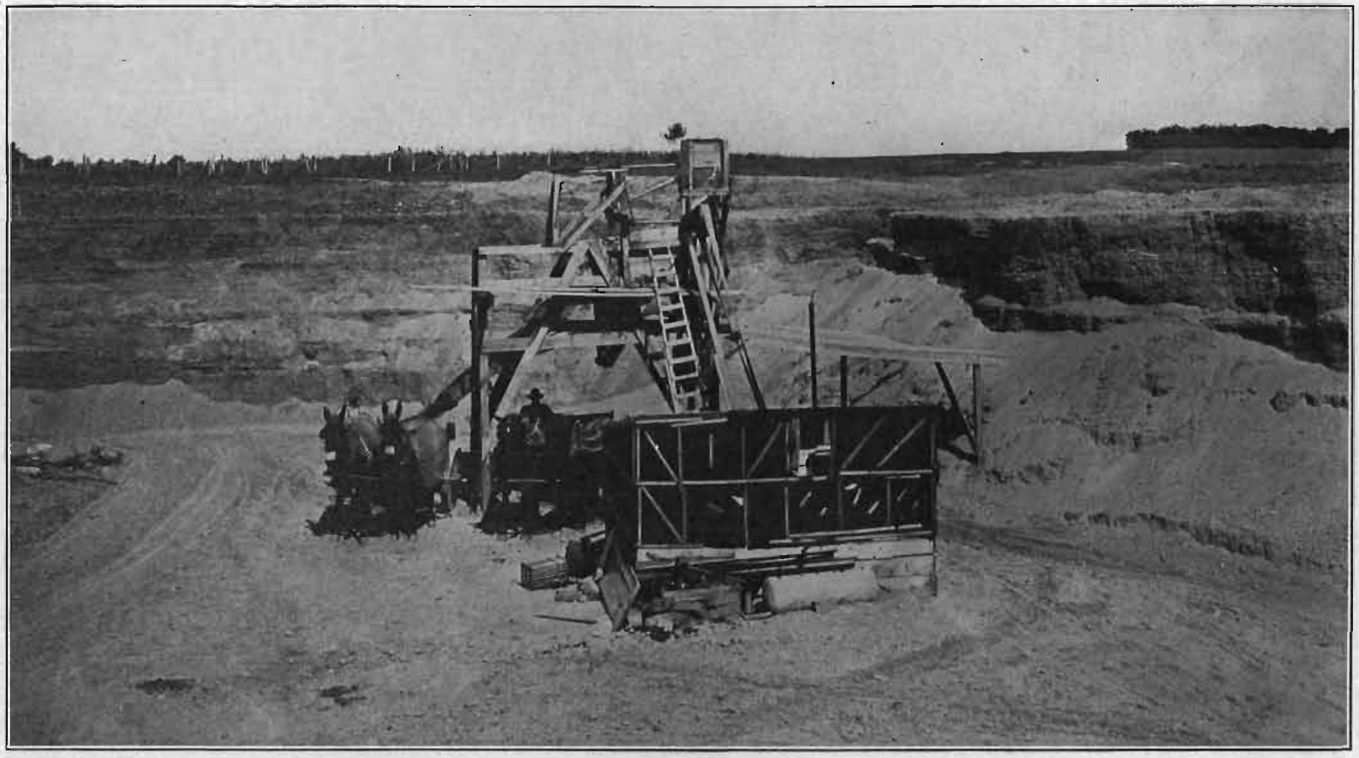


PLATE XLII—City gravel pit showing elevator and loading chute. Sibley, Osceola county.

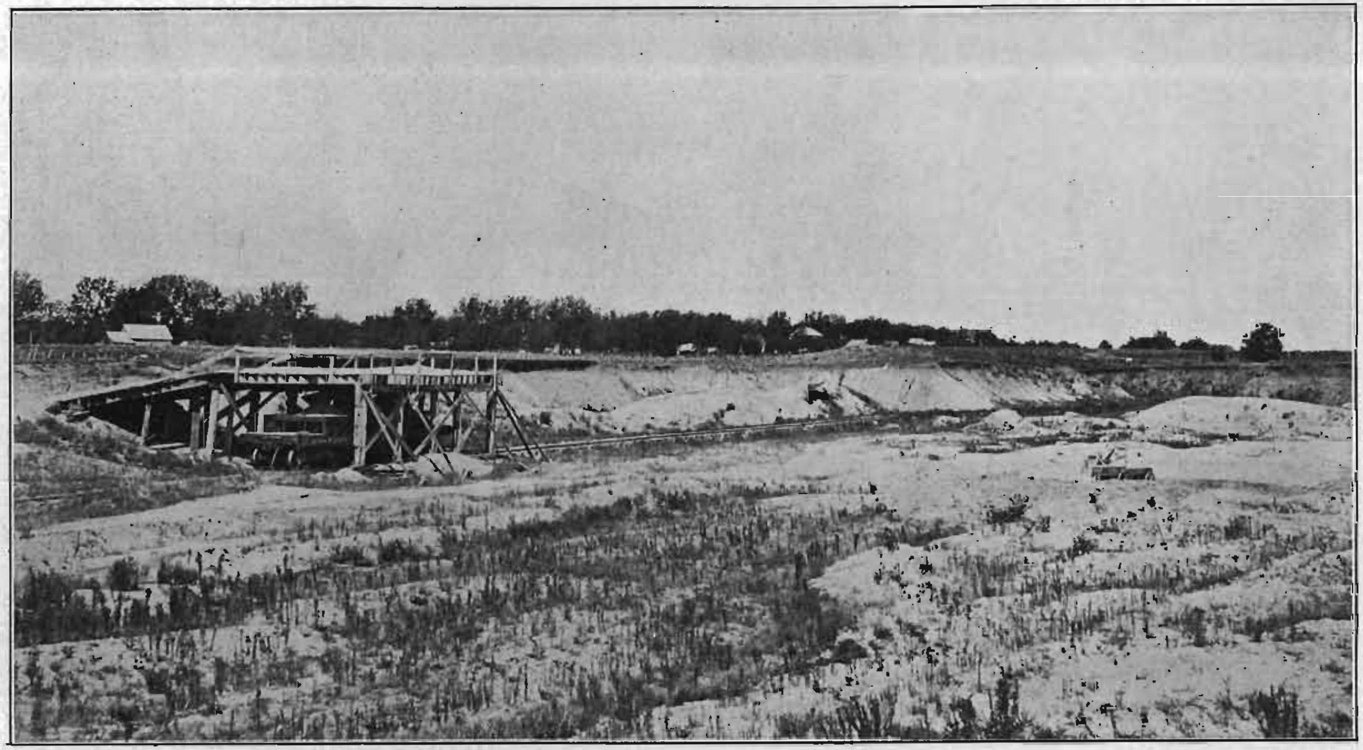


PLATE XLIII—Chicago, Rock Island and Pacific Railway pit showing loading trap. Sibley, Osceola county.

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

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

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

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

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

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

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

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

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

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

PAGE COUNTY.

Sand and Gravel.

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

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

Stone.

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

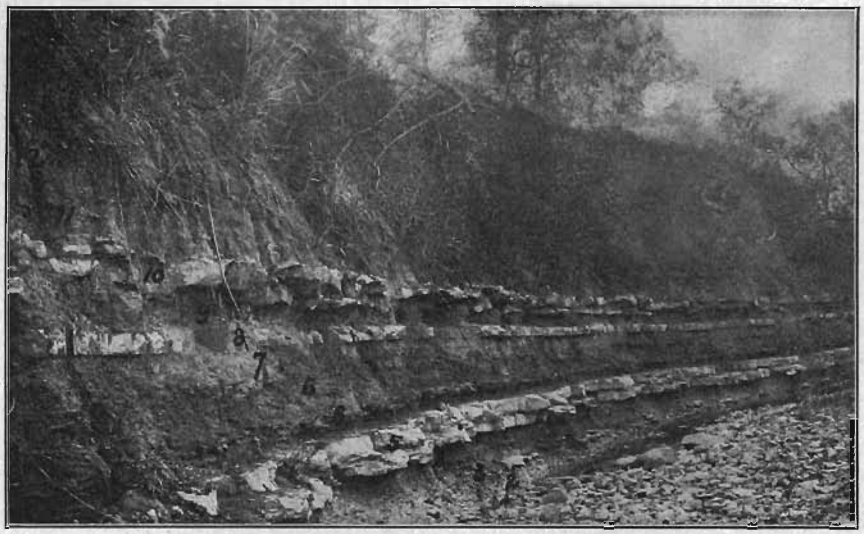


Fig. 52—Exposure of the Forbes limestone near Hawleyville, Page county.

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

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

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

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

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

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

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

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

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

		FEET.
5.	Drift, maximum of	20
4.	Fusulina limestone cap above quarry ledge	⅔
3.	"Blue ledge" limestone, No. 1 of Burns' quarry section	1+
2.	Calcareous and fossiliferous bluish shale	7
1.	Yellow, marly clay, apparently weathered limestone	1¼

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

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

PALO ALTO COUNTY.

Sand and Gravel.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

PLYMOUTH COUNTY.

SAND AND GRAVEL.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

STONE.

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

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

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

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

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

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

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

POCAHONTAS COUNTY.

Sand and Gravel.

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

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

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

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

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

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

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

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

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

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

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

STONE.

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

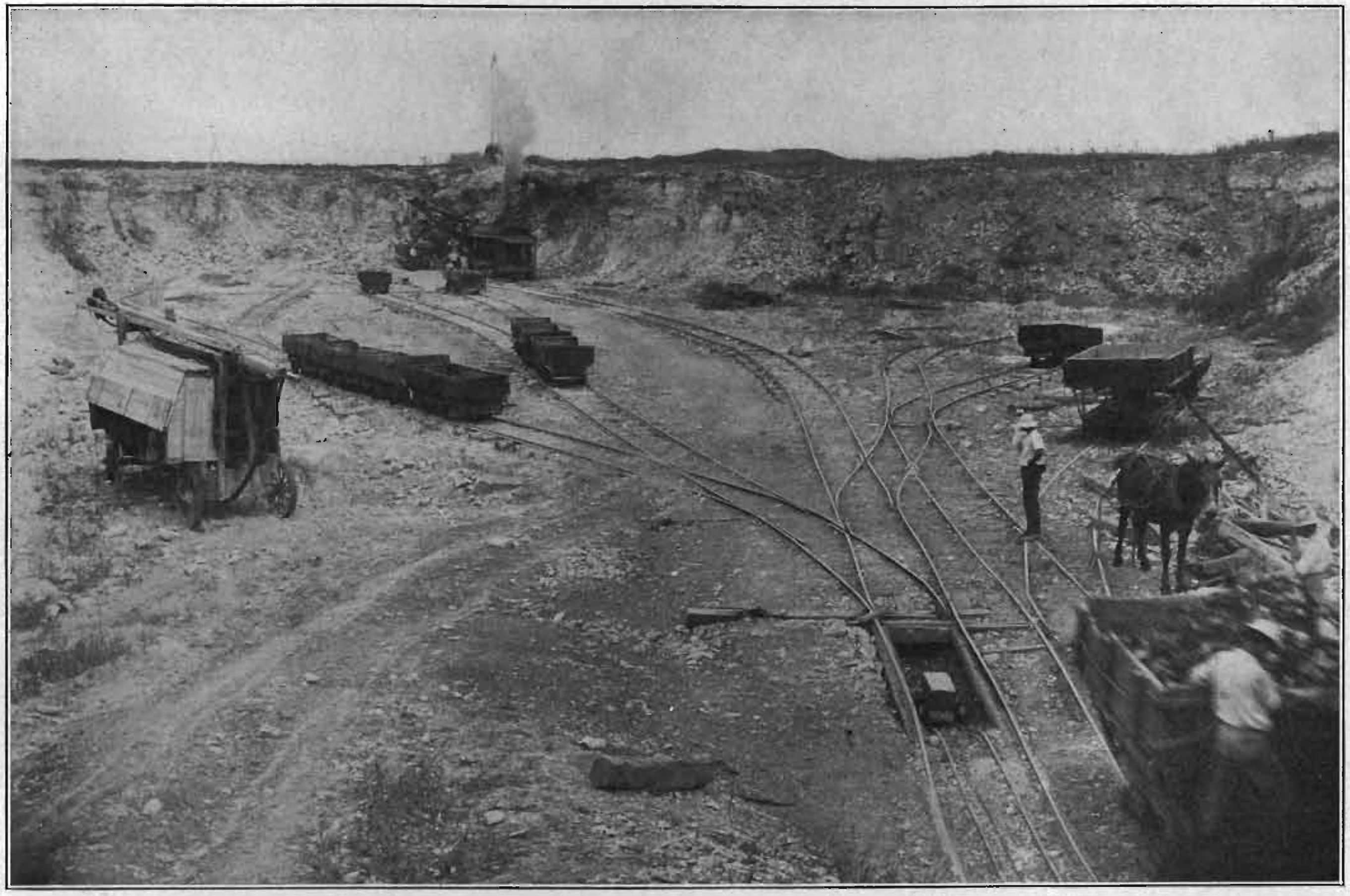


PLATE XLVI—Fort Dodge Portland Cement Company quarry showing steam shovel, drill rigs and track arrangement. This quarry supplies one of the largest crusher plants in the state. Gilmore City, Pocahontas county.

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

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

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

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

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

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

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

J. B. WEEMS, analyst.

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

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

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

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

POLK COUNTY.

SAND AND GRAVEL.

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

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

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

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

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

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

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

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

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

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

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

Stone.

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

POTTAWATTAMIE COUNTY.

Sand and Gravel.

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

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

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

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

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

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

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

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

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

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

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

STONE.

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

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

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

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

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

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

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

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

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

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

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

POWESHIEK COUNTY.

Sand and Gravel.

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

RINGGOLD COUNTY.

Sand and Gravel.

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

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

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

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

SAC COUNTY.

Sand and Gravel.

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

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

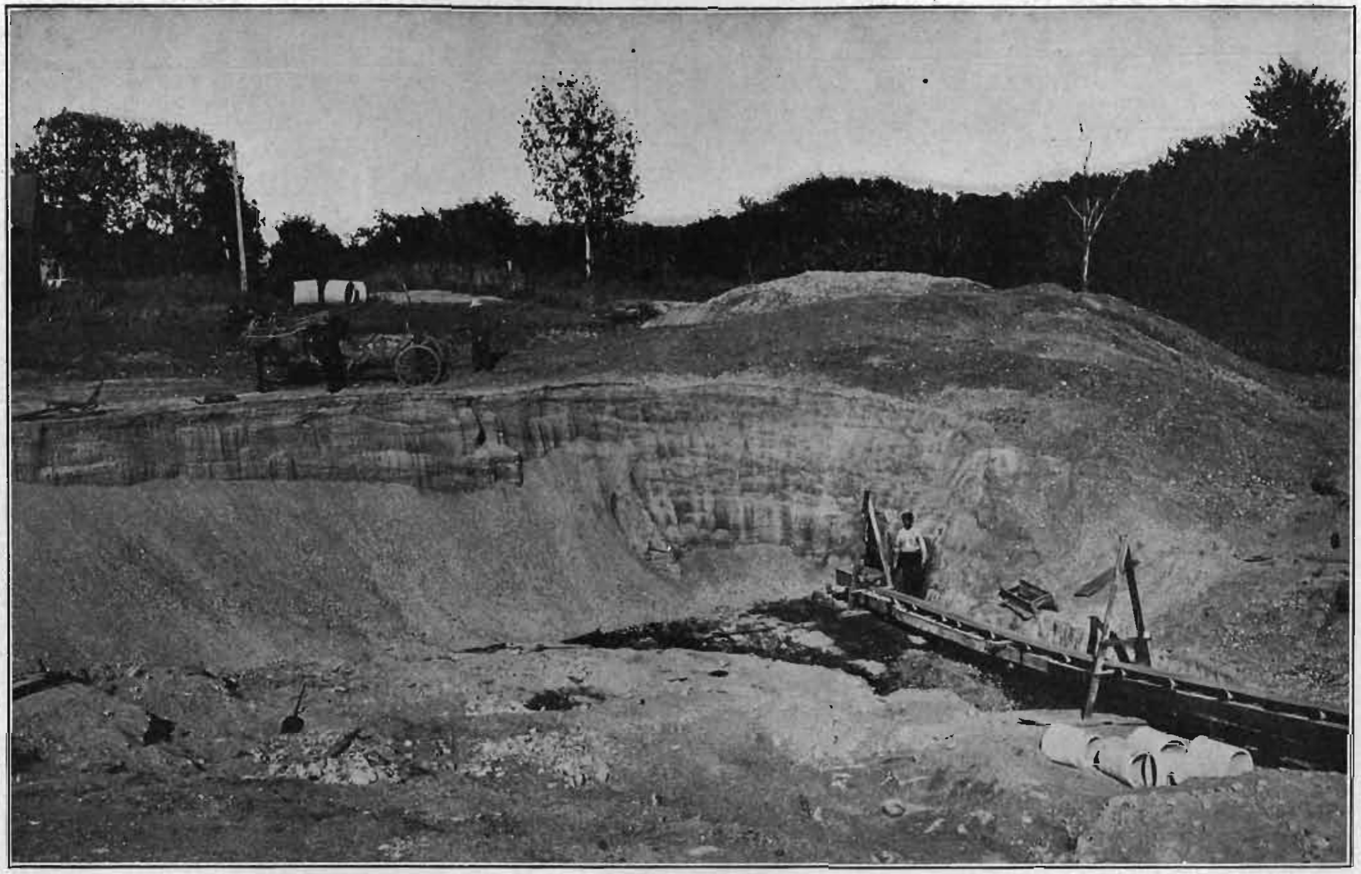


PLATE XLVIII—Hammen pit showing pit end of conveyor and rear view of pit, Sac City Cement Pipe Company, Sac City, Sac county.

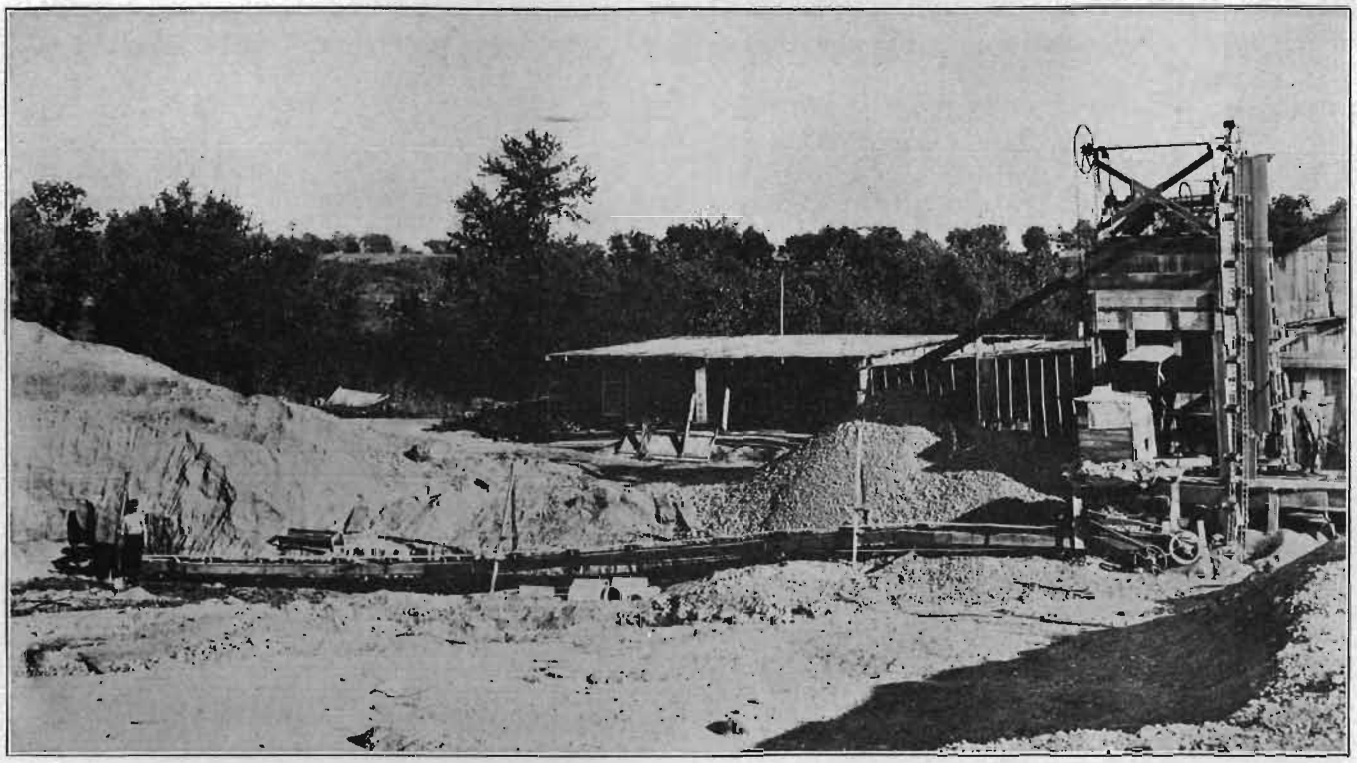


PLATE XLIX—Hammen pit showing belt conveyor, elevator and screen, Sac City Cement Pipe Company, Sac City, Sac county.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Stone.

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

SCOTT COUNTY.

Sand and Gravel.

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

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

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

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

STONE.

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

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

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

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

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

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

The beds exposed are as follows:

LE CLAIRE SECTION.

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

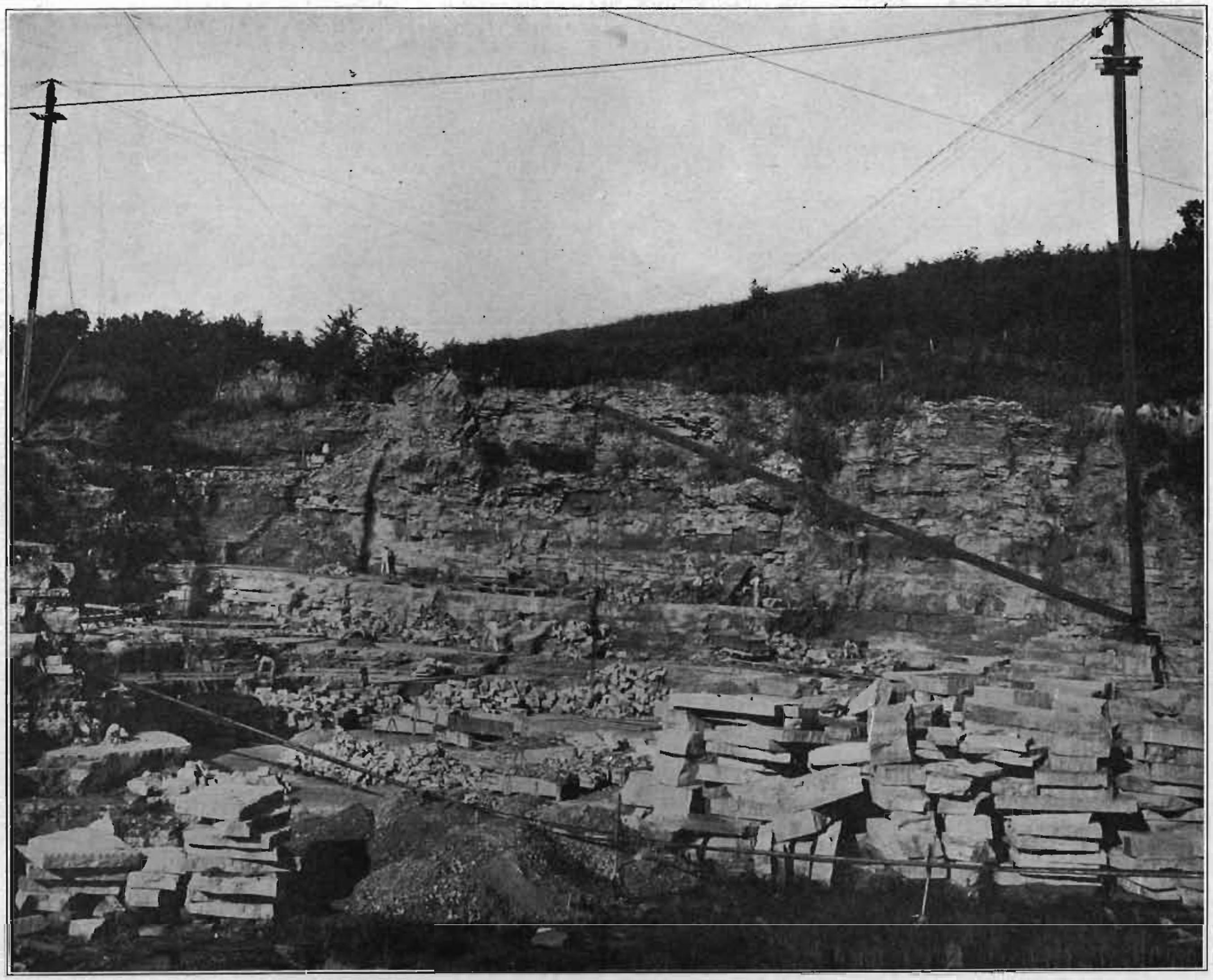


PLATE LI—General view of LeClaire Stone Company quarry, near LeClaire, Scott county. The handling of material is done by derricks alone.

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

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

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

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

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

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

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

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

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

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

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

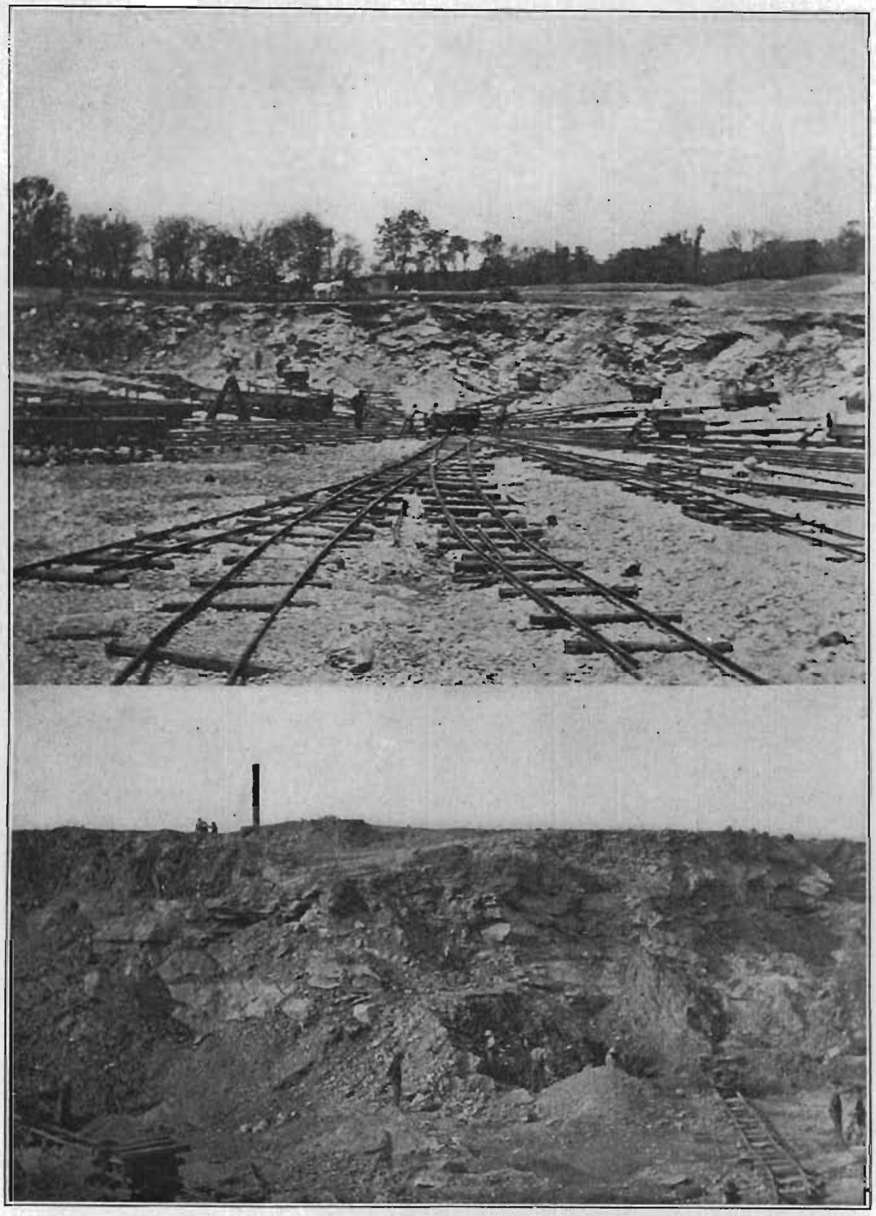


PLATE LII—Clark quarry, near Buffalo, Scott county; upper view showing trackage arrangements leading to incline, lower view showing irregular beds and large amount of shaly talus.

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

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

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

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

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

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

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

SHELBY COUNTY.

Sand and Gravel.

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

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

SIOUX COUNTY.

SAND AND GRAVEL.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

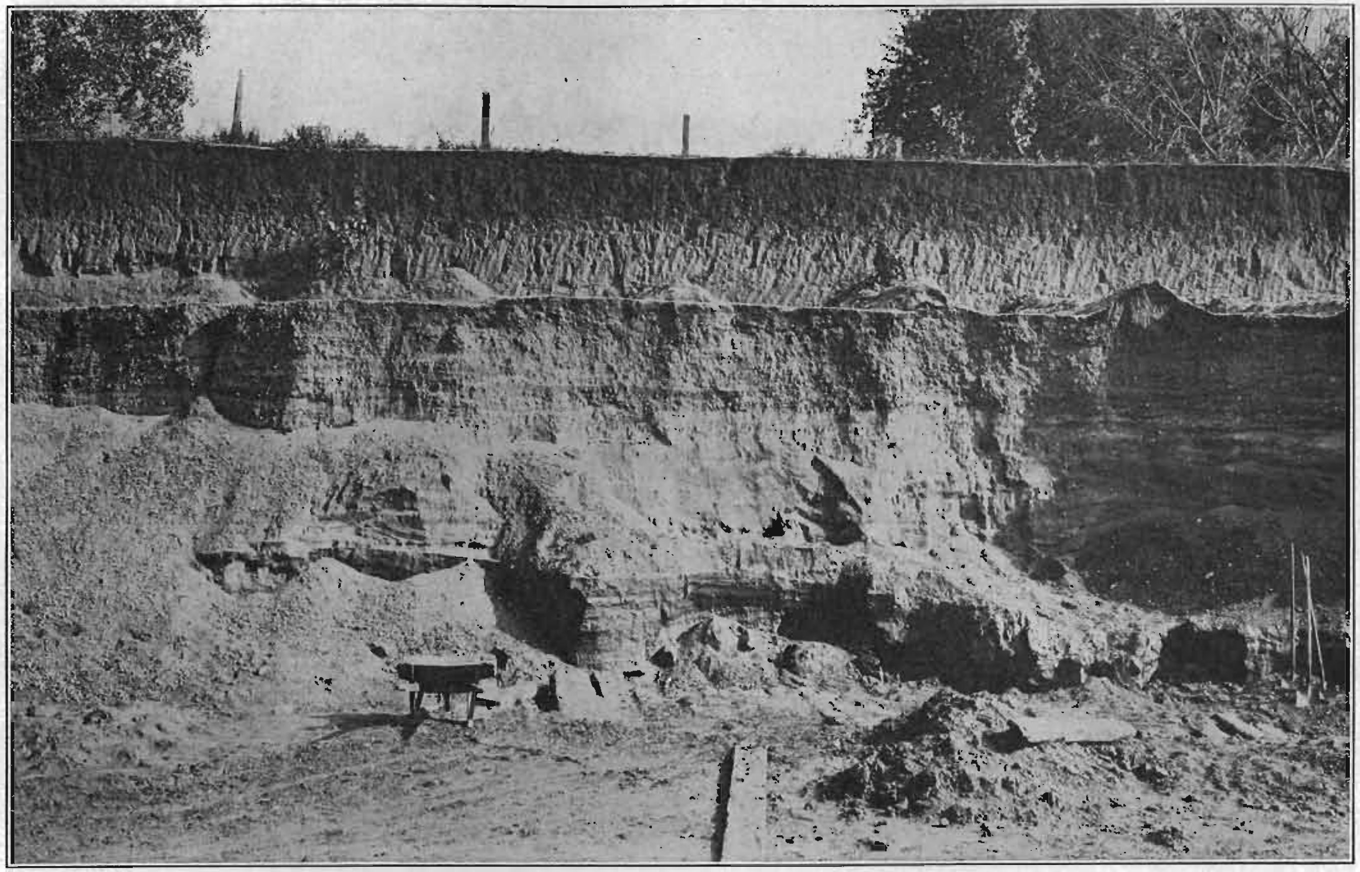


Plate LIII—Hyink pit showing rather heavy stripping. Alton, Sioux county.

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

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

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

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

STORY COUNTY.

Sand and Gravel.

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

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

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

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

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

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

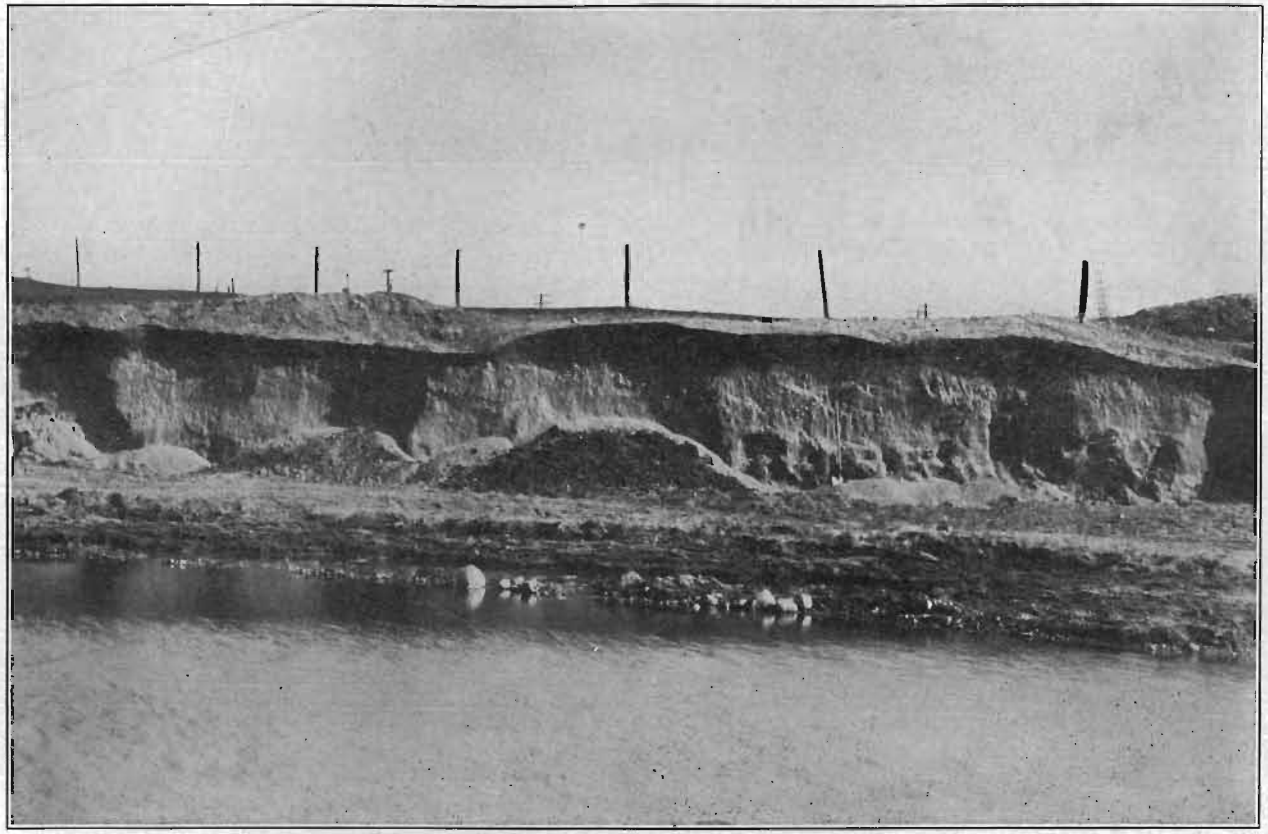


PLATE LIV—Iowa State College gravel pit located on the Squaw creek terrace, Ames, Story county.

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

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

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

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

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

Stone.

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

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

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

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

At the Bloomington quarries more of number 1 is exposed.

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

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

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

TAMA COUNTY.

Sand and Gravel.

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

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

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

Stone.

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

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

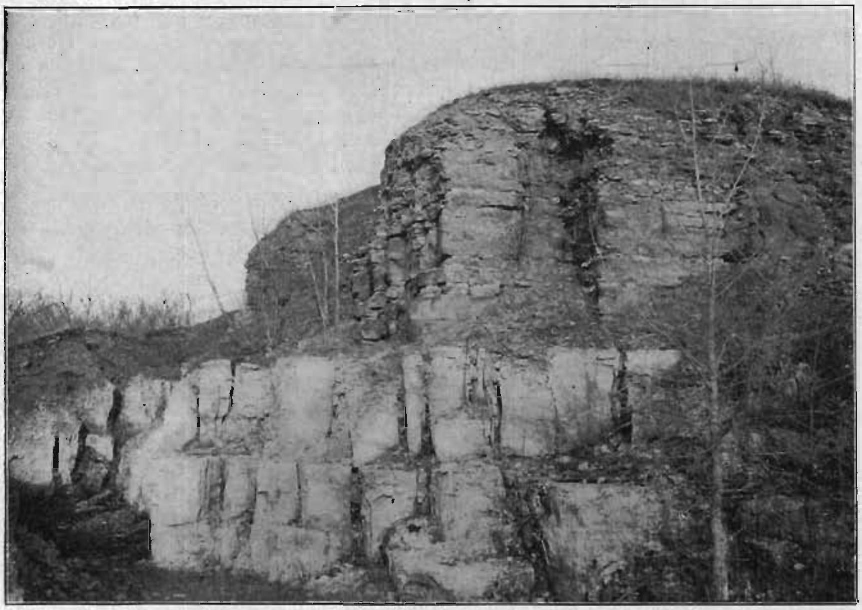


FIG. 56—View in the Stevens quarry in section 8, Indian Village township, Tama county. The thin layers at the very top are limestone and admirably adapted for road and concrete work. The white, massive beds below comprise the oolite.

STEVENS QUARRY SECTION, BUTLERVILLE.

		FEET.
15.	Gray crinoidal limestone which weathers into thin pieces..	1
14.	Crinoidal limestone, gray in color, with numerous fossil fragments	⅔
13.	Fissile limestone in thin layers, few fossils	4
12.	Brown magnesian limestone with layer of chert nodules two inches in thickness at the top	¾
11.	Bed of rather soft, friable sandstone, much water-seamed and containing numerous chert nodules, fossils few	7
10.	Arenaceo-magnesian limestone, fine-grained and quite hard, brown in color, layers 8 to 12 inches in thickness; containing casts of a species of Chonetes, Productus, Rhynchonella and Spirifer	4
9.	Bed of incoherent, brown, fine-grained sand	1⅙
8.	Band made up of chert nodules	⅓
7.	Impure arenaceo-magnesian limestone, few fossils	$1\frac{1}{12}$
6.	Bed composed largely of nodules of chert carrying a layer of sand, 3 inches in thickness	1
5.	Magnesian limestone containing some fine-grained yellow sand	1⅔
4.	Bed similar to number 5 above	1½

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

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

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

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

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

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

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

TAYLOR COUNTY.

Sand and Gravel.

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

STONE.

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

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

UNION COUNTY.

SAND AND GRAVEL.

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

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

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

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

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

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

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

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

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

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

VAN BUREN COUNTY.

Sand and Gravel.

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

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

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

STONE.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

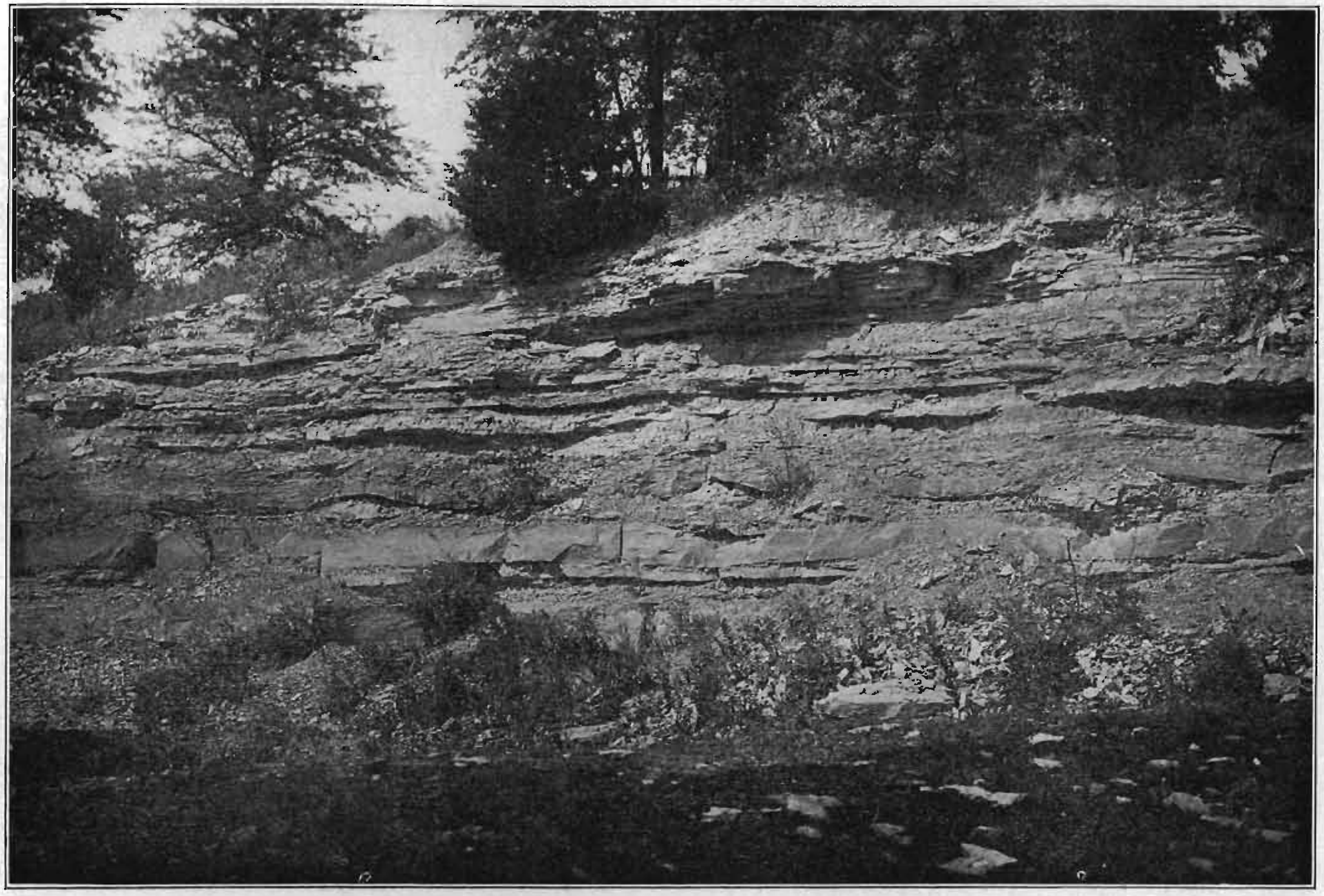


PLATE LV—Old quarry opening in Bentonsport, Van Buren county.

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

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

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

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

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

Quoting again from Gordon:

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

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

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

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

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

ROCK CREEK SECTION.

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

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

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

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

FIG. 57—Davis quarry, west of Bentonsport, Van Buren county. Heavy beds of magnesian sandstone (Warsaw Sandstone).

		FEET.
7.	Drift, sand and gravel	2½-10
6.	Blue-gray "soapstone" shale with thin limestone layers in lower portion	6
5.	Arenaceous limestone, light brown to bluish	2½
4.	Sandy blue magnesian limestone, "sandstone", solid ledge which splits readily with chisel parallel to bedding; some chert near base	5
3.	Irregularly bedded gray to blue, coarse-grained limestone, fossiliferous (bryozoan abundant)	5+
2.	"Soapstone," containing chert, to water in creek	1½
1.	White limestone reported to unknown depth	1½

Number 6 is plastic and appears free from concretionary matter. The maximum amount of stripping, about fifteen feet, is indicated in the section. Stone is shipped from this quarry but must be hauled to the railroad at Bentonsport. The sandstone gives good satisfaction in walls, and dresses well for use in more conspicuous and exposed parts of buildings. John Gaston has a small opening in the same beds one-fifth of a mile south on the opposite side of Bear creek.

A good development of the "sandstone" occurs also in the Price quarry on a tributary of Chequest creek in the southwest quarter of section 20, Van Buren township.

Section six miles northwest of Keosauqua along a small tributary of Chequest which enters the larger stream from the southwest:

		Feet.
7.	Drift and loess of variable thickness.	
6.	Limestone, much weathered and siliceous, certain layers weather shaly and are stained red to yellowish brown....	2-4
5.	Limestone, blue-gray, evenly bedded and of uniform texture; very hard and tough, beds up to thirty inches in thickness	4
4.	Talus slope.	
3.	Limestone, gray, vesicular, coarser textured than number 5 and fossiliferous, partially obscured by talus slope; thickness not determined.	
2.	Sandstone in heavy ledges, evenly bedded though beds are somewhat undulating; layers smooth enough to be used for dimension stone without tooling....................	10-12
1.	Shale, calcareous to arenaceous, blue-gray, yellow where weathered; said to become more shaly below the bed of the stream; exposed..................................	3

The sandstone beds range up to three feet in thickness, although blocks more than two feet thick were not seen in any of the sections exposed. It has been used extensively for bridge work and other heavy masonry. This stone was used for the piers which support the wagon bridge across Des Moines river. It yields to any kind of stone dressing, is strong and withstands weathering influences well. Blocks put in walls or piers more than a half century ago still retain the tool marks, which appear to be as fresh as when the blocks were laid. On account of lack of transportation facilities almost no stone is quarried at the present time.

The Saint Louis limestone is well exposed all along Chequest creek from the middle of Chequest township to Pittsburgh. As indicated in the above two sections the lower portion of the magnesian limestone grades locally into a sandstone.

The large proportion of the stone used in the southern part of the county has come from the Indian creek quarries west of Farmington. Outcrops occur along this stream from near its mouth to the quarries on the line between sections 5 and 32 of Farmington township. The quarry in section 5 is now

FIG. 58—Saint Louis limestone exposed along creek about three miles west of Farmington, Van Buren county.

worked by Cyrus Falker and Mark Hornbaker. Lime burning was formerly done here. The strata now visible are given:

	FEET.
8. Loess and drift	10+
7. Limestone, gray, coarsely subcrystalline, weathering to a friable condition; thin shaly layer at base	2½
6. Limestone, homogeneous and fine-grained, with conchoidal fracture above; coarser and more impure below; separated into heavy ledges, the upper one 18 inches thick; stone traversed by seams of crystalline calcite which in general run vertically	5⅚
5. Obscured	3½
4. Soft shale, gray	4
3. Limestone, heavy ledge; gray, compact, fracture conchoidal, irregularly shattered by weathering	2½
2. Alternating bands of light blue to brown limestone and slaty shale	2
1. Thin-bedded limestone, to water	3⅚

Only the members above No. 5 have been used. The upper three feet of No. 6 make a fair building rock. It is hard and weathers slowly. There is a considerable area on both sides of the creek where the stone is available without an excessive amount of stripping. The beds would afford a good product if crushed. The Chicago, Burlington and Quincy railroad follows Indian creek and would afford good transportation facilities.

Section one and a half miles west of Farmington, south of coal chute of Chicago, Burlington and Quincy Railroad:

		FEET.
6.	Loess and wash, rather sandy and iron-stained and mottled throughout	5-20
5.	Shale, clayey, blue-gray	3
4.	Shale, arenaceous, hard, projecting ledge; variable	1-2
3.	Shale as above	3
2.	Shale, arenaceous, forms a projecting ledge similar to 4, variable	1-2
1.	Shale, somewhat variable in texture, varying from plastic and gritless to slightly arenaceous; as a rule becomes highly plastic on weathering; evidently fissile, blue-gray to dark blue; occasional concretions and geodes present. Exposed above creek channel about	8

About one-half mile farther west a massive sandstone appears in a cut along the railroad and below the railroad bridge the heavy-bedded sandstone may be seen resting on the shales. The undercutting of the creek has produced and is maintaining an escarpment. The bedding planes in the sandstone are not apparent and the beds in the railway cut appear to be disturbed. The sandstone and shales appear to be the equivalents of those exposed along Des Moines river below Belfast. (See plate XXIX, c, page 401.)

Van Buren county is unusually rich in hard, compact limestone suitable for crushed stone products. The county is not, however, very well equipped with transportation facilities, especially near the important stone crops.

WAPELLO COUNTY.

Sand and Gravel.

The gravel and sand deposits of Wapello county are of two kinds, viz., the Aftonian gravels which underlie the Kansan drift, and bars and beds of sand in the channels of the principal streams.

Aftonian Gravels.—A few exposures of Aftonian gravels are present in the county. As a source of gravel supply this formation is not commercially important, but it will doubtless furnish limited amounts for local use. This ferruginous and much weathered gravel, often partially cemented into a conglomerate (described in some detail in the report on Union county), occurs at the base of the drift of the district and rests directly upon the Coal Measures. It is well shown near the northwest corner of section 6, Cass township, along a tributary of South Avery creek. Here the black shales are overlain by a very ferruginous gravel and coarse, cross-bedded sand. In places the iron is sufficiently abundant to serve as a cementing material, and a firm conglomerate or coarse sandstone is formed. The pebbles are mostly quartz and sandstone, but some are igneous in character, such as greenstone and granite. On North Avery creek in the southwest quarter of section 26, the ferruginous gravel is again exposed at the base of the drift, which here has a thickness of six to fifteen feet. Still another locality where this deposit occurs is on Des Moines river just above Eldon. The gravel and sand at this place have a thickness of ten feet. They rest upon the Coal Measure shales and are overlain by fifty feet of drift.

Sand and some gravel is taken from Des Moines river in Ottumwa and vicinity. The sand plants are located from one-fourth mile south of the Milwaukee railway bridge to the principal pit just below the west end of the Vine street bridge. The gravel is fine-grained, mostly sand, and the supply is renewed by the river.

The Ottumwa Sand Company is operating a pumping plant one-third of a mile below the Milwaukee railway bridge. A 75 H. P. motor is placed on a dredge in the river. The capacity of the plant is about 500 tons per day. The sand bed varies from three to five feet in depth. The quality is not quite so good as at the Vine street bridge. About one-fourth of a mile below the pumping plant considerable gravel is obtained for local use.

Large amounts of sand and gravel are being accumulated near Chillicothe and considerable quantities of sand have been accumulated by the river between Chillicothe and Eldon but these deposits are of less importance below Cliffland. At Eldon there is a large sand and gravel bar.

There is a sand pit on the flood plain of the river in section 14, Keokuk township. The small creeks emptying into Des Moines river between Chillicothe and Eldon deposit sand only in small amounts. The sand is considered too fine-grained for commercial purposes though it is used to some extent by the county. Village creek is accumulating some sand in section 9, Keokuk township. Soap creek, which enters Des Moines river at Eldon, deposits a considerable amount of good sand, though mostly in Davis county. This sand bar is about 75 to 100 feet in width and one-half mile in length. The quality is probably inferior to that at Ottumwa.

Stone.

In Wapello county the representatives of the Saint Louis stage that are of economic importance belong to the Pella beds, the upper division of the formation. Exposures are practically confined to the northwestern part of the county where the beds outcrop along the Des Moines valley from Eddyville to Ottumwa, and on North and South Avery creeks in the vicinity of Dudley.

Limestone was formerly quarried at a number of openings south of Eddyville, near the mouth of Miller creek. The John Lafferty quarry is the only one now in operation. It is located on Miller creek in the southwest quarter of section 7, Columbia township. The section exposed here for a distance of eight to ten rods, is as follows:

		Feet.
7.	Loess and river silt	5
6.	Residual clay, deep red, plastic	3½
5.	Residual clay, greenish, calcareous, grading into argillaceous limestone	3
4.	Compact limestone of lithographic texture and separated by marly partings; on exposure it becomes badly shattered by weathering of partings and vertical jointing	2⅓
3.	Heavy limestone bed, highly fossiliferous, upper portion contains cavities lined with calcite and abundant iron pyrite concretions; two ledges, respectively 14 and 22 inches	3
2.	Shell marl, a few inches.	
1.	Close-textured bluish limestone in 4 to 6 inch layers, to base of quarry	2½

Number 3 shapes readily and affords excellent stone for building purposes and for heavy masonry.

This quarry supplies stone which is used in bridge abutments in this and adjoining counties. The stone is handled by derrick and loaded on wagons. Considerable quantities have been shipped from Eddyville. There is a triangular terrace area here of considerable extent lying between Des Moines river and Miller creek around the borders of which the stone outcrops. The overburden is probably not more than ten or twelve feet at any place, and an unlimited supply is thus available.

At Dudley large quantities of rock have been removed just west of the Chicago, Burlington and Quincy station, both north and south of the tracks. Stone is now quarried by Andrew Lames on the south side of the railroad. The following strata are shown in the quarry face:

		FEET.
5.	Loesslike silt, underlain with a thin bed of iron-stained gravel	18
4.	Bluish shale in places.	
3.	Limestone, compact but shatters readily on exposure, separates in 2- to 3-inch laminæ	2½
2.	Limestone, compact, light brown to blue, fossiliferous in upper portion, and contains much iron pyrites	9½
1.	Blue limestone in thin layers	18-20

Only number 2 is used for building purposes and it furnishes good dimension stone, although not so heavy as the corresponding layer in the Eddyville section. Much crushed stone is produced, the railroad company using the major portion of the output. All work in the quarry is by hand. Stone for the crusher is loaded on small flat cars and drawn by one horse. Stripping is done by means of scrapers.

The T. L. Stevens opening is located on Middle Avery creek one-half mile south of Dudley. The same strata are to be seen as given in the section above. They are covered with loess and gravel. The iron sulphide concretions are more conspicuous and numerous than in the Lames section.

The Saint Louis beds in this vicinity afford a fair grade of crushed stone for ballast. The presence of iron pyrite, which rapidly weathers and leaves blotches, streaks of iron rust,

PLATE LVI—Andrew Lames quarry, Dudley, Wapello county. The section shows the hard, compact beds of the Saint Louis limestone under the usual heavy stripping of the district.

and small cavities in the stone, is a drawback to the extensive use of number 2, which is otherwise suitable for building purposes. Without question there is more and better stone available in the vicinity of Eddyville than at Dudley, but it is in a less accessible location at present for railroad transportation.

Limestone has been quarried at several points in Ottumwa and vicinity. It has for many years been taken from the bed of the river at Ottumwa during low water. A new place is opened up and worked out each season. That portion of the bed of the stream which is to be quarried during the summer is enclosed by an embankment to keep out the water. This is constructed of barrels filled with clay against which are piled broken stone, gravel and sand, until a substantial barrier is built up. About six feet of limestone are removed, the upper layers being thin-bedded and the lower ledges three to eight inches thick. All of the Saint Louis beds exposed here and at other places in the county are suitable for crushed stone products.

WARREN COUNTY.

Sand and Gravel.

Warren county as a whole presents an unbroken loess-Kansan drift surface. Des Moines river forms the northeastern boundary for some half dozen miles and the river here as elsewhere in central Iowa is margined with sand flats and contains sand and gravel bars of sufficient volume to supply a large portion of the county. These natural resources have not been developed to any extent in Warren county. The interior streams, while important as drainage lines, are of little importance as sources of sand and gravel. The interglacial sands and gravels are of no importance in the county. At the present time Des Moines and vicinity is the chief source of supply.

WASHINGTON COUNTY.

Sand and Gravel.

The usual interglacial sand and gravel terraces are poorly developed or almost wholly concealed in Washington county. Deposits occur in varying quantity here and there throughout the drift, but at only a few points is there a sufficient quantity of the right quality easily available. These points are, in general, along the larger streams. At Coppock, just over the line in Henry county, there is a gravel terrace margining Skunk river from which considerable amounts of material have been taken by the Chicago, Burlington and Quincy Railroad. The gravel is fine and is mixed with sand.

South of Riverside, on Goose creek, the following section was observed by Bain:*

		FEET.
3.	Sand, coarse, yellow, alternating with fine gravel	25
2.	Clay, yellow, with pebbles	½
1.	Clay, blue, plastic, few small pebbles	12

Sand and gravel in small quantities and of rather inferior quality occur in the present streams. These as well as the drift pockets are of local interest only.

Clay of good quality, such as has been burned elsewhere for ballast and road materials, is everywhere present.

STONE.

The upper magnesian layers of the Kinderhook outcrop along South English river and its immediate tributaries, but they have little to commend them for structural purposes. They have been developed, however, to a limited extent near Riverside and Wassonville, and have been used for rough foundation work, well curbing and even for bridge stone, ordinary dimension stone and caps and sills. The stone is rather soft and not pleasing in appearance.

Limestone beds referable to the Osage outcrop at numerous points in a belt which crosses the middle portion of the county in an east and west direction. Quarries have been opened northwest of Washington and north of Wellman. The Eckels quarry, located on the southwest quarter of section 2, Franklin township, presents one of the best sections between Washington and West Chester and is given below.

*Iowa Geological Survey, Vol. V, p. 153.

ECKELS QUARRY.

		FEET.
3.	Loess	12
2.	Drift	6
1.	Limestone, coarsely subcrystalline, blue, gray and white in color, running in ledges from 3 to 20 inches in thickness	20

Other quarries in the neighborhood display less extensive sections and present no new features of importance. Chert bands are quite common in all of the quarries and in one of the quarries an earthy to arenaceous bed carrying calcareous geodes may be viewed. North of Wellman, near Dayton, an old quarry shows the following indurated beds:

		FEET.
3.	Limestone, buff, arenaceous	5
2.	Limestone, brown, coarse, subcrystalline, fossiliferous	½
1.	Limestone, blue to gray, finely subcrystalline, fossiliferous	4

The stone very closely resembles that quarried in the Washington district. Openings have been made at other points, but are of local interest only.

The Saint Louis limestone occurs over a large area in the southern portion of the county, comprising a strip ranging from about five miles in width, on the east boundary, to eleven miles on the west. The most important exposures occur along Skunk river and near vicinity, in Brighton and Clay townships. The principal quarries are located in the immediate vicinity of the town of Brighton. The most valuable ledges quarried here, as well as at other points, belong to the upper member or Pella beds. The overburden is usually heavy, ranging from a few feet at the face in natural outcrops to fifteen or twenty feet a short distance toward the bluffs. There are two main ledges especially suitable for bridge stone which range from sixteen inches to two feet in thickness and rest upon two layers of flagstone. The flagstone layers are in turn underlain by heavy beds which were at one time worked by the Chicago, Rock Island and Pacific Railway Company near Brighton. These lower ledges are more or less water-coursed, and the quarry has been abandoned. On the west side of the Rock Island tracks, immediately north of town, the following layers were formerly exposed and quarried:

		FEET.
7.	Soil and drift, variable, thickening rapidly in the bluff	5-15
6.	Marl	2-4
5.	Limestone, in thin layers	⅔
4.	Limestone ledge, bridge stone	1¾
3.	Limestone ledge, bridge stone	$1^{11}/_{12}$
2.	Limestone, flagging and rubble	¼
1.	Limestone, flagging and rubble	¼

Other quarries opened in the immediate neighborhood show essentially the same beds but in slightly different thicknesses.

About two miles northwest of Brighton, a quarry is being operated on the Whitmore place. The beds developed are as follows:

		FEET.
2.	Loess and drift up to	20
1.	Limestone, gray-blue, compact, tough, somewhat fossiliferous; in ledges as follows:	
	Top ledge, 8 inches Bridge stone, 20 inches Bridge stone, 20 inches Flagstone, 6 inches Flagstone, 6 inches	5

The upper ledges are very much weathered along the joint planes, and in places the blocks are reduced to rounded cores practically valueless though they appear to be as tough and of the same color as the unweathered blocks. The ledges work readily by the feather and wedge method. The flags are somewhat rough but appear to be durable.

The Chicago, Rock Island and Pacific Railway has used much of the stone of the district for bridge purposes. The stone has been generally used in the town and county and has been shipped in large quantities to adjoining counties.

The stone quarried in this region is fine-grained, compact, breaks with an even to conchoidal fracture, and is of a pleasing ash-gray color. It is of good quality, but limited in quantity, as only a few ledges are workable, and can be obtained only at great expense on account of the excessive overburden. Below are the disturbed beds of the Verdi which are of little value for quarry purposes. Small quarries have been opened in these beds near Verdi, but have long since been abandoned.

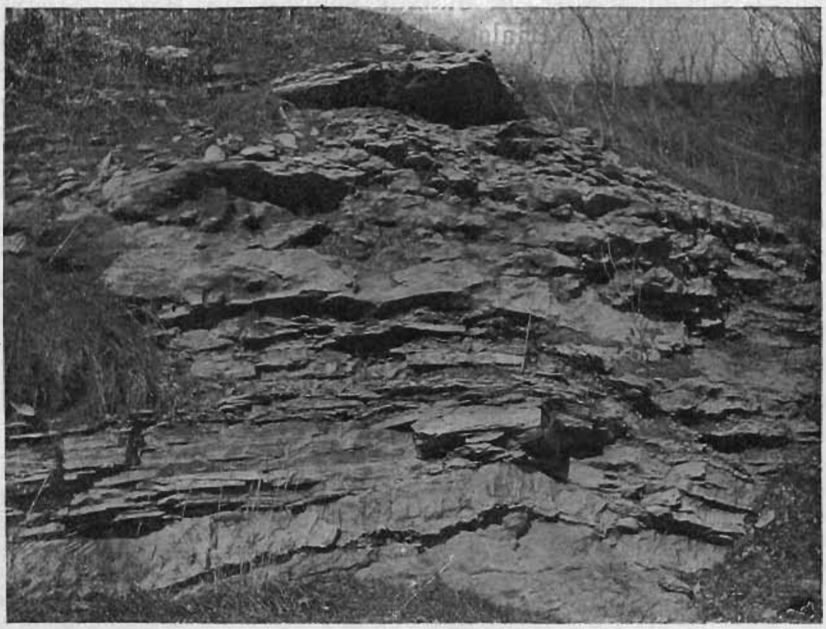


FIG. 59—Irregular beds of limestone in the Saint Louis, Verdi quarry, Washington county.

About three miles south of Washington on Crooked creek, a small quarry has developed the lower magnesian portion of the Saint Louis, but it is of local importance only.

With the exception of layers in the Kinderhook, all of the limestones available in the county are well adapted for road and concrete materials.

WAYNE COUNTY.

SAND AND GRAVEL.

Wayne county lies wholly within the loess-Kansan area and contains no large streams. The northern portion of the county is drained by Chariton river and its tributaries, but none of these have accumulated any considerable deposits of sand and practically no gravel. Some sand and gravel is obtained from the vicinity of Morgan in Decatur county for use in and about Lineville. The interglacial gravels, while probably present in the county, are not known to be available. The county is dependent almost wholly on outside sources for its supply of road and concrete materials.

STONE.

Exposures of the underlying rocks are very scarce in Wayne county. The Des Moines stage of the Coal Measures occupies the major portion of its area. Stone suitable for quarrying is known to occur only along the south fork of Chariton river near the east edge of the county. A small amount of rock has been taken out on the farm of Mr. Talkington in the northeast quarter of the southwest quarter of section 36, Wright township. Four feet of gray fossiliferous limestone are exposed, overlain with fifteen to twenty feet of drift. The stone is traversed by veinlets of calcite and separates into thin laminæ on exposure. The same bed has been worked at a few points farther up the river and over the line in Appanoose county. It can be of little importance even locally.

WEBSTER COUNTY.

SAND AND GRAVEL.

The chief source of sand and gravel is Des Moines river and its immediate tributaries. Lesser quantities are found in the knoblike hillocks of the drift.

Des Moines river has cut a deep trench from north to east of south across the entire county. The sands and gravels occur in two well-marked terraces about twenty to seventy feet respectively above the level of the water in the river. Fragments of higher terraces appear occasionally and are gravel-bearing. Sand bars and flats in the present stream are of some importance. Remnants of the terraces may be viewed in and near Fort Dodge; e. g., on Soldier creek at Miller's quarry; near the stone bridge in Fort Dodge; back of the city hospital and on the bank of the river in west Fort Dodge; and on section 30, Cooper township.

Near the north line of Douglass township the terraces are especially well marked and are separated by a drift terrace about fifty feet above water level. Similar terraces, not so well developed, are found along some of the leading tributaries.

Kame and esker gravels are somewhat erratically distributed over the Wisconsin upland drift plain. One of the most prominent of these occurs on section 9, Lost Grove township, and is locally known as Coon Mound. The mound is an esker which rises to a height of some fifty feet above the level country surrounding it, and is composed of more or less classified material—largely sand and gravel. Similar hillocks occur in other parts of the county. A sample of gravel was taken from a pit located in a knob near the middle of section 10 in Cedar Creek township.

STONE.

In Webster county the outcrops of the Saint Louis limestone worthy of mention are confined to Des Moines river and immediate tributaries, from the north line of the county to Fort Dodge. A few detached areas are known south of this point along the river, and one or two small patches occur in the interior of the county. The beds comprising the Saint Louis are decidedly heterogeneous in character, varying from a hard, compact limestone in well developed ledges to a structureless, clayey marl, and from a pure calcium carbonate to a highly magnesian limestone. In places a calcareous sandstone appears. The beds are usually too deeply buried under the Coal Measures and glacial debris to be of interest economically, but in the vicinity of Fort Dodge and northward along the river and along Soldier creek, considerable areas have been partially stripped of their overburden and quarrying has been thus made possible. On account of the lack of persistence and rather indifferent quality of the beds, quarrying has not been, and is not likely to become, an important industry in the county. The stone has been developed at a number of points, and a considerable quantity has been used for foundations and retaining walls in and about Fort Dodge. A few representative sections are given herewith.

Section at Miller's quarry, near the stone bridge over Soldier creek in Fort Dodge:

		Feet.
7.	Soil	2
6.	Gravel, fresh, cross-bedded	10
5.	Clay, yellow, not jointed, unleached, many limestone pebbles	15
4.	Soil and clay mingled, both unleached, soil dark and containing many wood fragments	15
3.	Sand, uncemented, containing lumps of coal and large pieces of wood, in layers varying greatly in color from white to gray	8
2.	Calcareous sandstone, a single layer, very firm	1½
1.	Limestone, layers coarse, often two feet thick, stone of fine, even texture, no fossils	25

In the creek bed at the foot of this exposure the limestone gives place again to calcareous sandstone, the thickness of which could not be determined.

Number 1 in the above section is variable, the beds ranging from limestone more or less pure, to limestone more or less magnesian. The texture also lacks constancy. The terrace on the west side of the river from the mouth of Lizard creek northward for about two miles is supported by the Saint Louis limestone. South of the center of section 7 in Cooper township, a good section may be viewed. The beds are as follows:

		Feet.
5.	Sand and silt	5
4.	Limestone, rather heavy-bedded, variable, with persistent chert band near the top	12
3.	Sandstone, cherty in places	½
2.	Limestone ledge	1½
1.	Sandstone, to water level	1½

While the limestones continue to the county line, they are as a rule too deeply covered and too far removed from transportation lines, to merit consideration. Below Fort Dodge, limestone outcrops are unimportant.

Des Moines river and its immediate tributaries have exposed heavy beds of sandstone at several points in the county. As a rule these beds are composed of massive, friable sandstone oftentimes strongly pyritic or marcasitic. The presence of these ingredients causes the stone to disintegrate rapidly on exposure while their presence in small quantity in a finely divided state produces discoloration of the exposed surface.

Several quarries have been opened and operated at various times. The most important one is located in the northwest quarter of the northeast quarter of section 14, Pleasant Valley township. The quarry is located in a small ravine where the rock is naturally exposed. An average section through the quarry face shows the following beds:

	FEET.
3. Soil and drift	10-15
2. Shale	2-3
1. Sandstone	15

The sandstone is probably much thicker, but it has not been quarried below the bottom of the ravine. It is ferruginous and contains many selenite scales which look like mica. Even in a given layer the stone varies often in color and hardness. The colors are various shades of red. Some layers are practically useless for building purposes because they contain many small iron concretions. At certain points in the quarry the rock attains a fair degree of hardness. The layers are of a desirable thickness, varying from six inches to two feet. Jointing is imperfect, but sufficiently well developed to render quarrying easy. Some years ago the quarry was well equipped with steam derricks, and a side track gave good shipping facilities, but at present it is not operated. The product is known commercially as the Albee sandstone, and at one time this was the most extensive sandstone quarry in the state.

Sandstone quarries have been opened at other points in the county. In Fort Dodge some stone of fair quality has been taken out. North of the city the sandstone layers appear to be better cemented but have not been developed to any extent. Neither the Coal Measures sandstones nor the Saint Louis limestones as developed in Webster county are promising sources of supply for crushed stone products.

WINNEBAGO COUNTY.

SAND AND GRAVEL.

Winnebago county lies wholly within the Wisconsin drift area. While this youngest ice sheet extends well into Worth and Cerro Gordo counties, the morainal belt which marks the rather unstable ice front continues back over the eastern one-half of Winnebago county. The "knobby drift" of Owen, now known as the Altamont moraine, contains occasional sand and gravel domes and ridges, and these are the chief sources of road and concrete materials in the county. While the sand and gravel hillocks are more common in the morainal belt they are generally, though not numerously, distributed over the Wisconsin drift plain. The kame sands and gravels are as usual poorly classified and generally carry considerable percentages of undersize (clay and silt) and oversize (cobbles and bowlders) materials.

Unlike many another county within the Wisconsin area, the streams of Winnebago exhibit practically no traces of gravel trains. What streams may have transported glacial debris in their flood waters carried it out beyond the limits of the county.

WINNESHIEK COUNTY.

Sand and Gravel.

The valley of Oneota or Upper Iowa river is plentifully strewn with beds and banks of sand and gravel of various ages and characteristics. These comprise fine, fresh, clean sands, beds of coarse pebbles and old, rusty, weathered gravels. The character of these deposits serves in many instances as a fair index of their relative ages, although the evidence is not conclusive for some of them. Thus there are at intervals from the county line westward to a point a short distance beyond Decorah banks composed chiefly of pebbles of limestone with some chert, foreign pebbles and sand. Such a deposit is described by Calvin from section 36, Pleasant township; and in section 35 of the same township test holes sunk by the Upper Iowa Power Company at the site of their dam showed:

	FEET.
Black dirt (alluvium)	2-10
Gravel	1-6
Sand, clean, fresh, in streaks and pockets	7+
Clay in streaks.	
Bowlders and gravel mixed.	
Bed rock.	

The materials form a broad flat terrace reaching as high as thirty feet above the stream. The coarser elements are largely limestone, with some foreign pebbles. They were used in making the concrete dam and other structures of the company's power plant.

Again in section 3, Glenwood township, is a similar terrace which shows about thirty feet of alternating sands and coarse gravel below eight feet of yellow Iowan loess. This latter is weathered above but fresh below, and at the contact the gravels are iron-stained. One exposure shows two feet of ferruginous

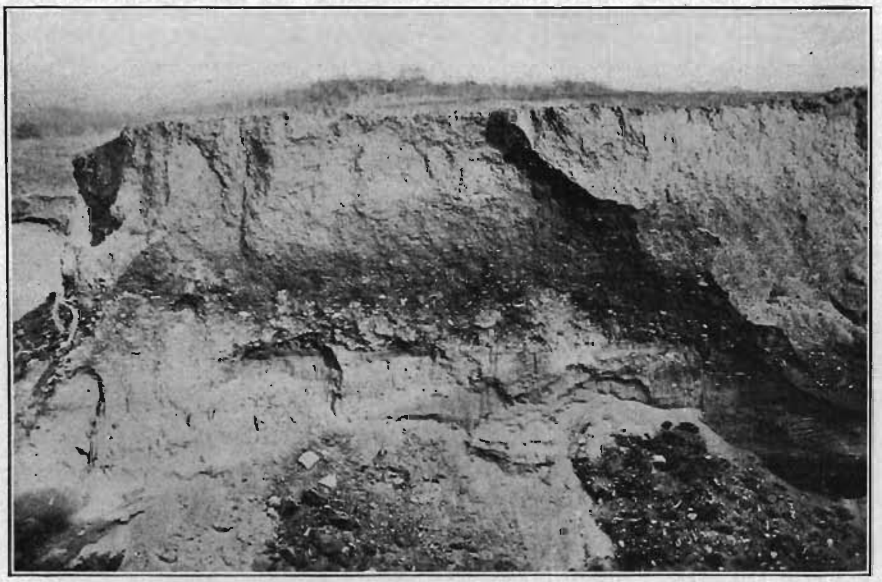


FIG. 60—Old weathered gravels over fresher sand, section 9, Glenwood township, Winneshiek county.

gravel immediately below the yellow soil. Other terraces of like nature are also seen in sections 4 and 9 of the same township, and on the north bank of the river opposite Decorah similar deposits are bound into a firm conglomerate by a calcareous cement. This conglomerate is discussed by Calvin in his report on Winneshiek county* where the probable origin of the materials here mentioned is treated.

*Iowa Geological Survey, Vol. XVI, p. 37.

Above Decorah there are no terraces, but in the river banks there are exposed beds of gravel and sand at a few localities. In the southwest quarter of section 8, Decorah township, about two miles above the town, the river impinges upon its left bank and has cut into a bed of coarse gravel, chiefly local, with some fresh sand intermingled. This bed is similar to those below Freeport. Six feet of this material are exposed and overlain by finer, much more weathered sand with some coarse material, about equally divided between local and foreign pebbles. The material from this bank has been used on the roads in the immediate vicinity with excellent results, as it cements well and forms a firm roadbed. Other deposits in similar situations and doubtless laid down under like conditions are exposed at the bridge near the north line of section 6, Decorah township, and in the northeast quarter of section 10, Bluffton township.

The beds at these different localities may be classified as of undetermined, but probably Kansan age. Their character does not in all cases permit of an accurate determination of their geologic position. But there are other deposits about which there is not such uncertainty. A notable instance is in section 7 of Glenwood and section 13 of Decorah townships, where a broad sheet of gravels is spread over the bottom lands in the vicinity of Freeport. These gravels bear unmistakable evidence of their relationships with the Buchanan gravels in their weathered and rusty condition. They are rather fine, like the typical valley phase of the Buchanan gravels, and are overlain by fresh, clean Iowan sand. The road leading northeast from Freeport is cut through these beds and exposes a good section. Similar beds occur for some miles up and down the river. They are of excellent character for use on the roads and should be used where the newer incoherent sands make the roads of the neighborhood very heavy.

In the northwest quarter of section 30, Canoe township, is an extensive deposit of dark red, weathered sand somewhat indurated, bearing very little coarse material. It extends 200 yards back from the flood plain in the form of a sloping terrace, and grades up to a sandy soil twenty to forty feet above the plain.

Sands of Iowan age also occur at various points in the Oneota valley. In sections 7 and 8 of Glenwood and 13 of Decorah townships are large bodies of fresh sand. About the middle of the section last mentioned, on the east side of the road, is an immense bed of clean, white sand with darker layers beneath. These latter are in some cases quite hard, are for the most part quite fine, and may be Buchanan in age. In section 23 of Decorah township is another bank of similar clean fresh sand of Iowan age.

In sections 11 and 14 of Bluffton township is an extensive area which lies comparatively level, with the exception of several hills of circumdenudation. Considerable amounts of fresh sand, apparently of Iowan age, are exposed here along the plain and covering the hills. In places, however, the rocky core of these latter is exposed.

Aside from the main drainage course of the county, there are numerous bodies of Buchanan gravels. Calvin has mentioned several of these; as in section 22, Hesper township, section 36, Madison, and section 15, Decorah township, all of which are related to the upland phase.

The valley phase of these gravels is represented by beds seen in the southwest quarter of section 35, in the northeast quarter of section 28, and in the northwest quarter of section 20, all in Washington township. All of these beds consist for the most part of rather fine, rusty gravels and sands with some associated coarser layers. At the last locality mentioned there is quite a large bench which seems to be underlain by the gravels.

A considerable part of the town of Fort Atkinson is built upon a bench of coarse, rusty Buchanan gravels. These extend from the margin of the flood plain of Goddard creek northward beyond the railroad tracks where they are probably banked against the hills of Fort Atkinson dolomite. Where they have been exposed by street grading in the southern edge of the village a thickness of four feet is exposed. The basement of the Catholic school was sunk into them to a depth of five feet and the railroad pit opposite the depot, whence large quan-

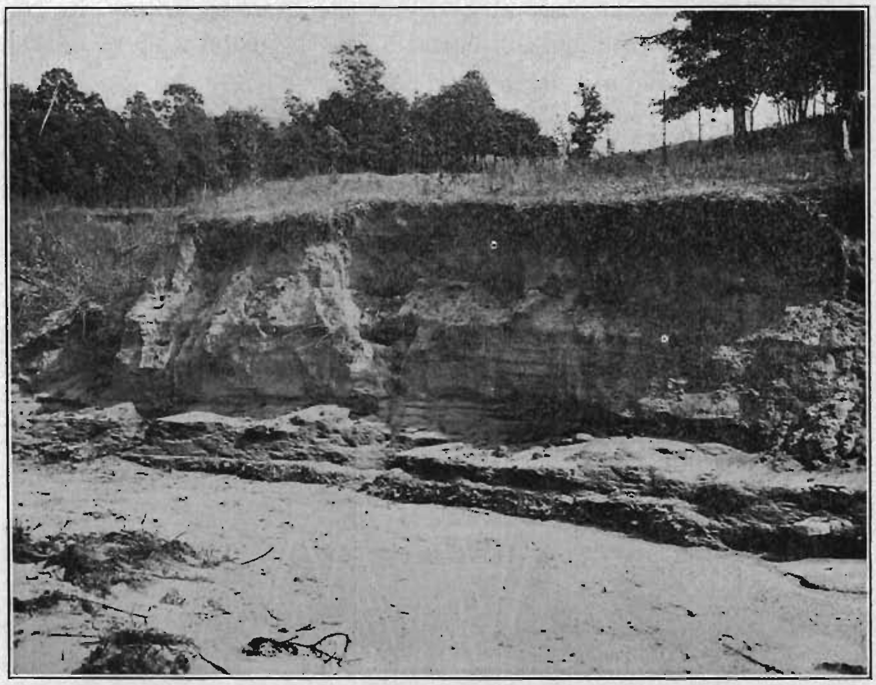


FIG. 61—Buchanan gravels overlain by fresher sands, southwest quarter of section 35, Washington township, Winneshiek county.

tities have been removed, shows a section ten feet in depth, above which are ten feet of Iowan loess. These gravels have been used on the roads with good results except that they are a little soft.

Another quite extensive deposit is cut into by a small creek in the northeast quarter of section 1, Jackson township, and the northwest quarter of section 6, Washington township. Where the road crosses the creek about six feet of hard, ferruginous gravels are exposed and the bench extends to the river plain 200 yards or more distant. About one-half mile farther north, along the same road, eight feet of fine, ferruginous, red to yellow sands, alternating with fine gravel and coarser material of mingled native and foreign derivation, are exposed. A few rods south of the bridge crossing the creek on the south edge of Spillville is a bank of gravel which has been opened up to some extent. This bank shows a section as follows:

	FEET.
Soil, sandy, fine, gray	1
Soil, with coarse red sand	1
Gravel, hard, oxidized, breaks up with difficulty	1
Sand, fine, yellowish, incoherent	½
Gravel, hard, red, with some layers of fine sand	1½
Gravel and sand in alternating layers, coarse material both local and foreign; all fairly fresh and incoherent	3

One-half mile east of here the fine phase of the Buchanan gravels is shown by the roadside at the top of a flat bench which extends from the steep bluffs on the north side of the river to the lower level of the flood plain.

STONE.

Good quarry stone is available at a number of horizons in the Ordovician as developed in Winneshiek county. The lowest beds eminently suitable for structural purposes occur near the base of the Oneota limestone in Highland and Pleasant townships. The lower thirty or forty feet, resting directly on the Jordan sandstone, is a light buff, evenly bedded dolomite, fairly uniform in texture and obtainable in blocks of almost any dimensions up to thirty inches in thickness and easily dressed. The outcrops are practically limited to the bluffs facing Bear creek from Highlandville to the county line, and limited outcrops on sections 23, 24, 25 and 26 in Pleasant township. These beds are almost wholly undeveloped in the county on account of the absence of transportation facilities. The upper beds of the Oneota are less desirable for structural purposes on account of their more drusy character, absence of regular bedding planes and general lack of uniformity in texture, structure and composition. At the present time none of the beds belonging to the Oneota are quarried in Winneshiek county.

The Galena-Platteville limestone, as in adjoining counties, affords several well-defined quarry horizons. The three divisions recognized by the Minnesota and Wisconsin geologists are very marked here. The lowest division or Platteville limestone is again divisible in three parts, "Lower Buff Beds," "Thin, Brittle Beds," and "Thicker Quarry Beds" in ascending order.

As a whole the Platteville thickens southward and as a consequence is much thicker in Dubuque than in Winneshiek county. The Lower Buff Beds do not exceed five or six feet in the latter county, with eight inch layers, and have been developed at but few points and then in a small way. The heaviest ledges of the Lower Buff Beds occur in the valley of the Upper Iowa in the vicinity of Freeport and east. The Thin, Brittle Beds were quarried formerly to a limited extent, and while apparently in heavy beds where protected, they break down when exposed to weathering influences and are of little economic importance. The uppermost member or Thicker Quarry Bed attains a thickness of from four to eight feet and is evenly bedded. The stone is hard and compact, fine-grained, nondolomitic limestone, and is of a bluish color. The individual layers range from six to eight inches in thickness, are remarkably uniform and can be obtained in sheets or tablets of almost any desired dimensions. This horizon has been quarried extensively in the vicinity of Decorah and Hesper. The beds are composed chiefly of finely comminuted and firmly cemented brachiopod shells. From one of the quarries north of the river at Decorah attempts were made to produce an ornamental stone by sawing into thin slabs and polishing by machinery. The product possessed a rather pleasing appearance and was used to a limited extent for table tops and interior decoration.

A number of quarries have been opened in the Galena limestone, above the level of the Decorah shale. Many are small and were operated only temporarily to supply some immediate local need. At no point does quarrying in the Galena assume commercial importance. The upper quarry of Mr. Halloran is worked at the level of the lower Receptaculites zone, about fifty feet above the Decorah shales. The quality of the stone is not as good as that from the upper part of the Platteville. The bedding is not so regular; the texture is less uniform; much of the stone is liable to split into small chips on long exposure to the weather.

Several quarries have been opened in the blue ledges of the Platteville on the north valley wall of the river, opposite Decorah. One between the Ice Cave and Mill Spring ravine shows about fifteen feet of these beds. There are also great quantities of rock washed out from the Galena beds in the ravine through which the road enters Decorah from the northwest. These have been used on this road, as has similar material from the river bed in section 8, Decorah township, and all these give excellent results. The road leading southeast from Decorah across section 22 to Trout run has also been macadamized with limestone as well as with gravels from the river terraces. This road is firm and smooth, an excellent example of what may be accomplished with the materials so abundantly at hand.

In the neighborhood of Nasset, in the southwest quarter of the southwest quarter of section 22, Glenwood, is a small quarry opened in the hillside in the blue ledges of the Platteville, just below the Decorah shales. The rock is hard and firm and the location is favorable for getting out road material. Along the east-west road across section 26, Glenwood, are several exposures of geest, dark rust-red, with much chert. While this is not present in great quantity it would make excellent material for road work as far as it goes. There is a large quarry at Nordness which is opened in the upper beds of the Galena. The Maquoketa begins only a few feet above the exposure. The upper beds are badly checked and weathered, but below these there are some quite firm ledges varying from ten to fourteen inches in thickness, with which there is associated a ten inch band of shale. About the middle of the quarry face there is a belt of irregularly bedded concretionary limestone, three feet in thickness, altogether lacking in the homogeneity requisite for good quarry stone. Below this belt there are six feet of more regular and more homogeneous beds, with some of the individual courses fully ten inches in thickness. Another quarry at the same horizon as that at Nordness is opened on the south side of Yellow river in the north half of the northeast quarter of section 13, Bloomfield township, on land belonging to the estate of Mr. Melvin Green. The characteristics are the same as at Nordness except that there are several bands of shale, ranging from two or three to ten inches in thickness, interstratified with the limestone. Another quarry which includes the uppermost beds of the Galena is located on the south side of the diagonal road in the southwest quarter of section 17, Bluffton township. There are other small quarries, worked temporarily or intermittently to supply the purely local demands, near Kendallville, Plymouth Rock and Burr Oak. In the southeast quarter of section 7, Fremont township, are some small quarries opened in beds of dolomitized Galena, a phase of the formation resembling that at Dubuque. Dolomitization here is local, being restricted to an area of three or four square miles. The many other small openings in the Galena limestone are too numerous to be individually noted.

Much of the Galena limestone is very unreliable. When quarrying has been carried into the hillside beyond the zone of weathering, the ledges may appear to be thick, firm, durable, suitable for any kind of construction; but after being placed in

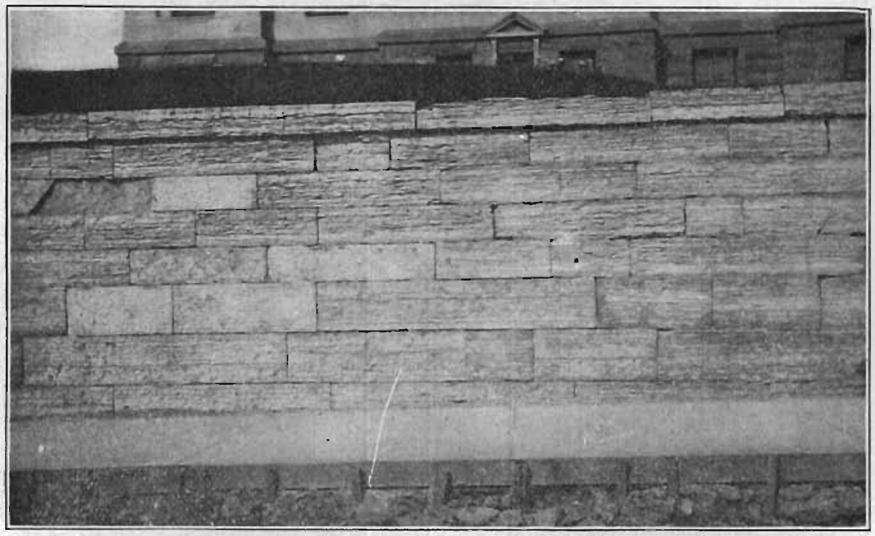


FIG. 62—Portion of retaining wall around Court House Square in Decorah, Winneshiek county, showing unreliable character of Galena limestone.

walls and exposed to alternations of temperature and the chemical effects of air and moisture they split into thin laminæ and eventually break up into small, irregular chips. The effect is well shown in the portions of the old retaining wall still standing around the court house square at Decorah.

Quite an amount of quarrying has been done in the Maquoketa formation. The Isotelus zone is very regularly and evenly bedded, and in a few instances it is firm enough to serve for building stone. One quarry at this horizon, located in the northwest quarter of section 18, Springfield township, is noted by Calvin in connection with the general discussion of the Maquoketa beds of this county.* In some cases the strata lying between the Isotelus zone and the Clermont shale are capable of furnishing a fair grade of building material for rough walls and foundations; but the principal quarry horizon in the Maquoketa is that of the Fort Atkinson limestone. This, not infrequently, is a hard, granular, crystalline dolomite, comparable to some phases of the Galena limestone in Dubuque county. At Fort Atkinson quarries have been worked in this formation for many years, and one of these, located a few yards west of the

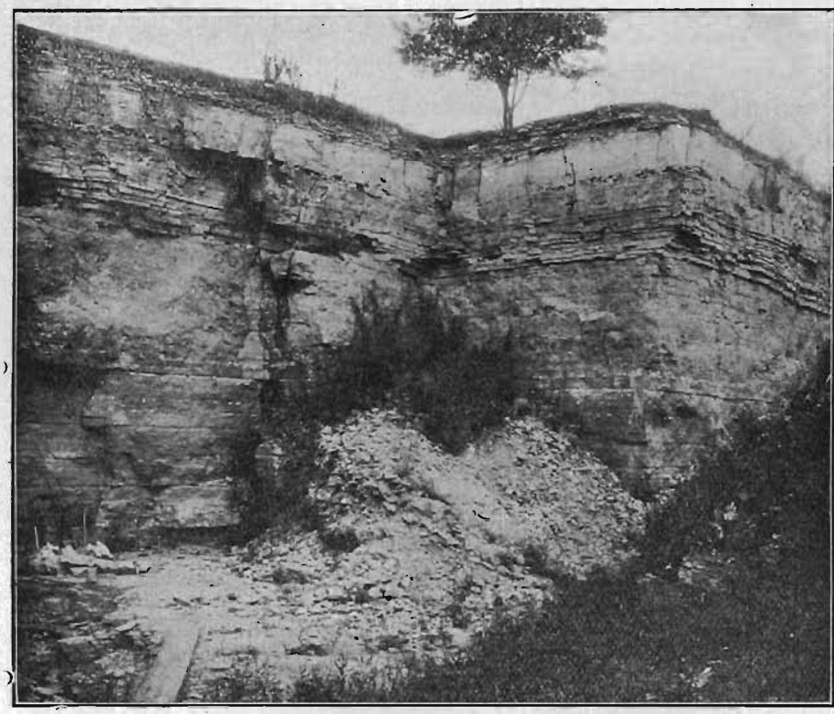


FIG. 63—Fort Atkinson limestone as seen in quarry a few rods west of the old fort, Fort Atkinson, Winneshiek county.

*Iowa Geological Survey, Vol. XVI, p. 101.

old fort (Fig. 63), is capable of yielding blocks of any desired dimensions up to three feet in thickness. Another quarry in the same limestone, on the east side of the fort, has been operated intermittently for some time and has furnished quite an amount of fairly good material. In the southwest part of Military township there are many quarries and natural exposures in the Fort Atkinson beds. The small quarry near the center of the southwest quarter of section 33, and that near Ossian in the northwest quarter of section 15, will be found noted with some detail in the part of the report on Winneshiek county which treats of the Fort Atkinson limestone.*

About a mile south of Calmar, in the southeast quarter of section 35, Calmar township, is a quarry of Mr. Gallaman. This is opened in the Fort Atkinson beds and shows eight to ten feet of yellow, flinty, thin-bedded layers overlying yellow beds free from chert, the beds two to eight inches thick. Of these lower beds four feet are exposed. On top is one to two feet of waste rock, then one foot of soil. The quarry has been well opened and is easy of access from the road. The beds shown here are also exposed on both sides of the ravine which runs past the quarry and a considerable amount of rock is available. Similar beds are exposed in the ravines and road-cuts just north of Festina.

On the north side of the Cresco-Calmar ridge the Fort Atkinson formation comes to the surface and is quarried near the center of the southwest quarter of section 27, Springfield township, and about sixty rods south of the northwest corner of section 5, Bloomfield. At the point last named the rock is yellower, softer, less crystalline than at Fort Atkinson. The rocks of this horizon become more earthy or shaly toward the northeast, and gradually lose the qualities of a pure dolomite which distinguish them at the type localities in Fort Atkinson and Clermont.

Several small outliers of the Niagaran limestone appear in Washington township and are believed to be the northernmost outcrops of that formation in the state. The stone commonly representing the Niagaran here is a yellow-buff, dolomitic lime-

*Iowa Geological Survey, Vol. XVI, p. 101.

stone. Some of the layers exposed in an old quarry west of Festina comprise a hard, buff, subcrystalline dolomite comparable with typical Niagaran dolomites exposed farther south. The beds are of small importance and have been but little developed in Winneshiek county.

The Chicago, Rock Island and Pacific Railway has a large quarry near the station at Nordness. This shows at the base fifteen feet of heavy blue-gray ledges of fine texture which weather to gray or buff. The ledges are six inches to a foot in thickness. The upper ones show a conchoidal fracture. Above these heavy beds is a layer of slaty shale, drab or slate color, eight to ten inches thick, which breaks into very thin spalls. Overlying this layer is a heavy ten-inch ledge, then thinner ledges for fifteen feet. These are separated by thin shale bands of one to two inches thickness and are nodular and of uneven thickness. They are capped by a five-foot bed of yellowish gray calcareous shale which breaks up into small angular bits. At the top of the section are five feet or more of gray iron-stained loess with the lower part strongly impregnated with iron. There is no drift present here.

A sample was collected from the heavy beds below the shale band, also from the thinner beds above. Several quarries are opened in this vicinity in the heavy beds below the shaly layers of the Galena. The yellow shale beds are the basal layers of the Elgin Shaly Limestones, the lowermost division of the Maquoketa stage. Forty feet of these are exposed in the roadside one-half mile east of Nordness. Below the quarry beds are exposed layers which appear hard and solid, as if suitable for road work.

At the time samples were being collected the quarry of E. H. Weber, one-fourth mile south of Hesper, was not being used. Considerable quantities of stone have been removed, however. The beds used are the blue layers of the Platteville. Only a few feet are removed and these are just below the Decorah shales. On the northeast edge of town is a smaller quarry which is opened in the same ledges as the Weber quarry, but the location is not so advantageous as is that of the latter.

A little rock is taken out near Locust from these same blue layers.

On the south slopes of the hills in section 35 of Washington township the Niagaran is exposed in steep scarps and in the road bed. It is fine-grained, subcrystalline and responds readily to the acid. On the top of the hill where the road descends to the river plain some rock has been taken out and this pit reveals thin shelly layers on top of thicker ones. The heavy massive beds seen in the scarps are not here exposed.

The type exposure of the Fort Atkinson dolomite is the quarry west of the old fort at the town of Fort Atkinson. This is well described by Calvin. The flinty beds of this formation are also exposed in the road in the northwest quarter of section 7, Washington. These and also the quarry are convenient for obtaining road metal of which they should furnish an excellent quality in abundance. Numerous exposures occur on the road from Fort Atkinson to Spillville and also on the road from the latter village to Calmar. Considerable rock waste is uncovered here and this would yield a supply very easily obtained.

In the town of Ossian a little macadamizing has been done, the cherty layers of the Fort Atkinson beds being the material used. So far as noted the stone gives good results except that as insufficient fine material was used the surfacing was not good. The stone was taken from a quarry in the northern part of section 15, Military. This is described in some detail by Calvin in his report on Winneshiek county.

WOODBURY COUNTY.

Sand and Gravel.

The terraces along Little Sioux river and its tributaries furnish the principal supplies of sand and gravel for Woodbury county. Gravels which occur under the loess are opened in a few places along Missouri river, but these are of minor importance.

Stream Terraces.—The benches along Little Sioux river which are so prominent in Cherokee county continue southward, the lower one being conspicuous across the corner of Ida and on into Woodbury county. It is sometimes as much as a mile in width, and it seems to be composed almost entirely of gravel. It has been opened by the Illinois Central Railway in section 23 of Union township, and from a pit in the northeastern part of section 35, same township, much is being hauled to Correctionville. In the latter place there is only a small amount of cover. The usable material is coarse, rusty, impure gravel at the top, but becomes cleaner and more evenly bedded toward the bottom.

As a rule the higher terrace seen in Cherokee county is not prominent, but appears at many points as jutting headlands which are often capped with gravel. Such occurrences may be seen in sections 14 and 23, Union township, and also in section 27 west of the river. These headlands stand sixty to eighty feet above the river. In Ida county they appear east of the river in the northwest sections and also on Ashton creek.

The high terraces increase in importance as they are traced up Pierson creek and its tributaries. They appear as a low bench in northeast section 17, Union township, where a pit is open along the creek, and continue southward along Pierson creek all the way to Correctionville. This terrace is always prominent—sometimes drift, sometimes merely capped with gravel, again all gravel—but always capped with or leading back beneath the loess which covers all the hills. On the creek at the middle of the south side of section 17, Union township, is a most excellent erosion exposure which shows some twenty-five feet of clean gravel under ten feet of loess. Gravels show in the roads at many places, *e. g.*, southwest 21, southeast 28, south 27 and north 34, Union township. The outcrop last mentioned is owned by John Fleming, is the largest opening and contains the best and most accessible materials. The sand and gravel are usually clean and moderately fine, with few bowlders, but contain streaks of almost quicksand, and lenses of very fine sand with clay are not uncommon. These latter are, however, easily wasted. There are not over three feet of stripping at the most, resting on fully thirty feet of usable gravel followed by a very ferruginous red coarse gravel which grades downward into an unusually clayey material. Apparently there is an unlimited quantity available, and it is readily accessible to the Chicago and North Western railroad.

Along Pierson creek there is also a lower bench noticeable south of the stream in section 28, Union township, where its exact relation to the Little Sioux benches is not clear. It seems, however, to be composed almost entirely of gravel and sand. In southwest Union township there are enormous quantities of gravel and sand along the creek. Far up on the hillside near the northeast corner of section 14 is a large pit which shows a few feet of sand over clean stratified gravel.

Above Correctionville, and especially to the west of the Sioux and north of Pierson creek the gravels form a conspicuous platform fully fifty feet above both streams. There is practically no covering over the gravel, which crops out in prominent escarpments and is so near the surface that there is scarcely sufficient soil for tillage.

Two pits, those of Welch Bros., in southeast 28, and of Moran and Hempel in northeast 20, Union township, have been opened quite recently. The first is a clean exposure with very light stripping on the valley end of a ridge. Fifteen to eighteen feet of gravel are open, finer and with more sand and cross-bedding at top, but coarser below. Moran and Hempel have a large opening, but except at the very point of the hill the depth of cover runs up to six or eight feet. They have confined their development work to the edge of the hill where the cover is thin. As a rule, the gravel seems coarser here, running coarse at top and fine below. There are about eighteen feet of gravel resting upon blue till with an iron-stained band at the top.

South of Correctionville the lower terrace is of wide expanse, at the town east of the river and on the concave sides of curves all the way to section 8, Miller township, south of Anthon. The latter town is on a terrace which seems to be not over fifteen to eighteen feet above water.

At Anthon, in west section 33 of Kedron township, there are three feet of black alluvium to strip. Below this are three and a half feet of coarse iron-stained clayey gravel with little sand,

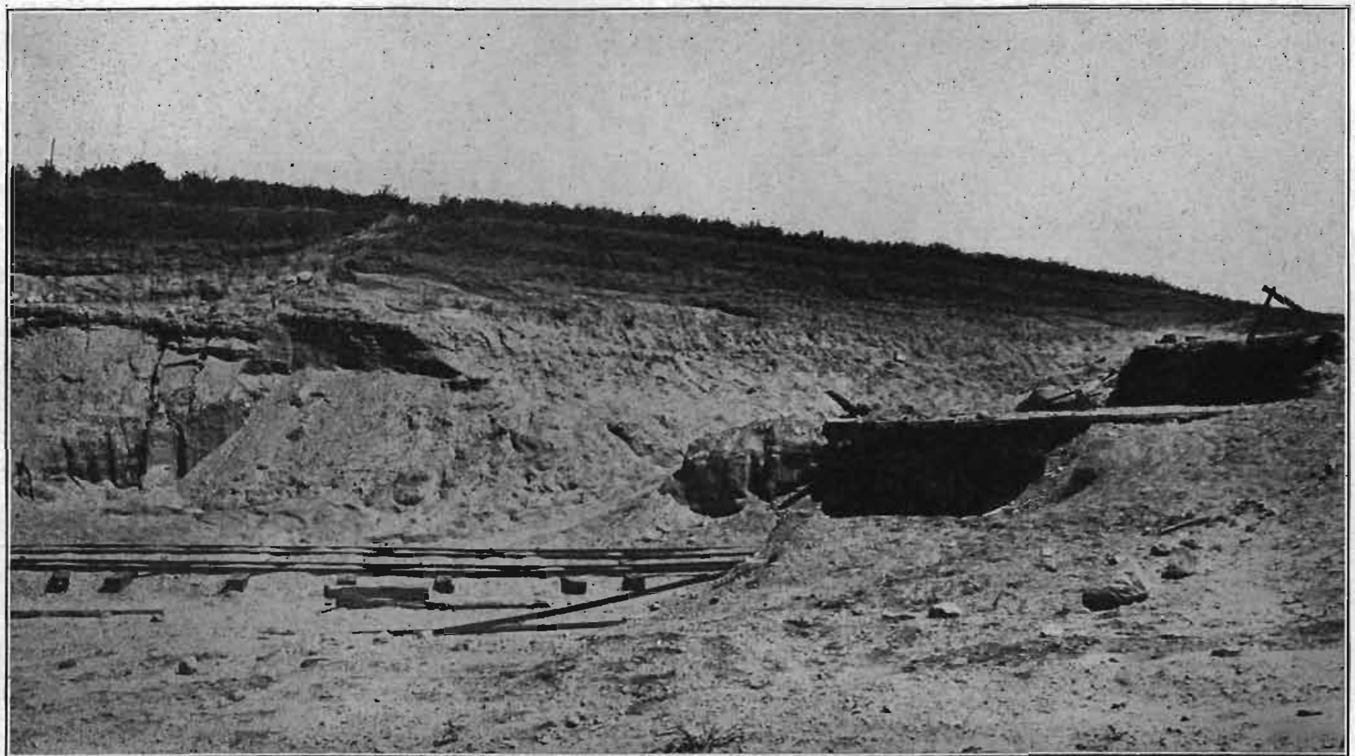


PLATE LVII—Moran and Hempel pit showing loading trap, Correctionville, Woodbury county.

and then four feet of cross-bedded, nicely banded clean gravel with coarse sand, the largest pebbles being not over an inch or so in diameter. Underlying this are five feet of clean gravel down to talus and perhaps to six or eight feet above water. At the Gilleas opening on the railway in southwest 15, Kedron township, there are fully twenty feet of good material available under but little cover.

Farther south than this the lower gravels do not appear conspicuously, but the bench blends gradually into the flood plain of the river. It is likely, however, that fragments of this bench occur to the south county line or farther although not noticeable.

The upper (sixty to seventy-foot) terrace is evident as jutting promontories at many places on both sides of the stream. These are particularly noticeable in sections 21, 28 and 34 of Kedron township and in section 4, Miller township, on Wright creek. These benches are sometimes gravelly, but not invariably so.

Reworked Materials.—Missouri river has immense beds and bars of sand (mostly quicksand) in its channel the whole way across the county. Although there are enormous quantities of material in these beds they are unimportant from a practical standpoint, as there are many conditions which prevent their economical removal.

Sand bars also occur along Little Sioux in varying quantities, but the presence of so much more reliable deposits in the terraces renders them of little importance.

Miscellaneous Deposits.—It is not uncommon in parts of the county where erosion forms are abrupt, as near the mouths of all streams coming into Little Sioux, to find outcropping at the base of the loess a very coarse quartzitic bowlder bed, sometimes resting on drift and again on top of beds of red gravel or sand. Such may be noted in section 17 of Union township, and at other points along branches of Pierson creek. They are also seen in the lower courses of Bacon, Wright and Plumb creeks and at many points along the west side of the valley. These are different from the high terrace gravels. At many points along the bluffs on the east side of Missouri river gravel and sand are to be seen outcropping from under the loess. As a rule, this material is available in only small quantities, if at all. Where attempts are made to recover it a sort of crude mining system is used. The gravel is removed from under the loess, which varies in depth up to forty or fifty feet in places, and work usually stops when the loess caves down. Sometimes timbering is done, but this is not commonly the case.

In the vicinity of Sioux City the upland is covered with a thick veneer of loess. The loess here, as in adjoining counties, seems to be quite generally underlain by sand, which is rarely exposed except artificially and is not worked to any extent because of the great expense of stripping. This is the only local source of sand, so most of what is used is shipped from Correctionville. In speaking of the subloessial sands and gravels, Mr. H. F. Bain, in his report* on Woodbury county in 1896, says, "At some time in the period between the retreat of the Cretaceous sea and the advent of glacial conditions, at least a part of Woodbury county was covered by a shallow lake. The deposits made at this time are shown under the later glacial deposits in the pits at Riverside:

	FEET.
Loess, usual character, variable thickness	30
Clay, plastic, brown, weathering yellow along joints, usually free from grit; pebbles rarely found	6
Gravel, erratic drift pebbles	½
Sand, fine, white and even-grained, with small granitic pebbles; no distinctly northern gravel	12

"The lake deposits consist of fine to coarse white sand containing occasional small pebbles, in the main granitic with chips of wood and a few fossils. The pebbles found are of small size, water-worn, and of such type that they might readily come from either the west or the north. There are, as far as careful search reveals, no distinctively northern rocks present, and certainly no rocks showing ice action. The general character of the sand is much like that of the Miocene or Pliocene beds found a few miles west in Nebraska and South Dakota." In the beds, of

*Iowa Geological Survey, Vol. V, p. 243.

which the section given by Bain is typical, the sand and gravel are usually mixed together so that neither can be used without screening.

Along the loess escarpment stretching southeast from Sargent Bluff there are occasional exposures of gravelly drift cropping out from beneath the loess. Gravel was once taken from the bluff at this latter place, but the pit was abandoned when the loess cover reached a thickness of twenty feet. East of Hornick the beds have been opened up at one or two places and sand and gravel for local consumption are being removed.

A very old and quite coarse gravel appears about 150 feet above the Missouri bottoms in sections 24 and 25, Orange township. The gravel is much iron-stained, and some of the pebbles can be crushed in the hand. A lower and finer gravel outcrops in section 31, Westfork township. This material has a newer appearance and is entirely different from the high gravel mentioned above. There may possibly be as much as twenty-five feet of the gravel under two feet of loess at the outcrop, but the cover rapidly becomes much deeper. It would seem, however, that several hundred yards of gravel suitable for roads could be removed before the cost for stripping would become prohibitive.

Stone.

(For notes on stone see Plymouth County.)

WORTH COUNTY.

Sand and Gravel.

The Wisconsin drift covers the northwest two-fifths of Worth county. The Altamont moraine, with its knobs and hillocks, stretches diagonally from Fertile to Northwood township. Sands and gravels in abundance occur along Lime creek and its immediate tributaries, Willow and Winans creeks. The gravel terrace rises from ten to twenty feet above the bottom land, reaches about a mile in width, and rests on a limestone bench, which rises a few feet above the water level in the creeks.

The terrace appears only in the north bank of Lime creek and continues up Winans and Willow creeks a distance of one and a half to two miles. These terraces are composed of fairly coarse materials. The granitoid bowlders are more or less weathered and break down readily on exposure. Pits have been opened at numerous points for road and concrete materials, but none are being worked on a large scale at present. The gravel varies from ten to twenty feet in thickness and covers most of sections 29, 30, 32 and 33 in Danville township and considerable portions of sections 25, 26, 35 and 36 in Fertile township. The alluvial wash covering over the gravel varies from almost nothing on the breaks to three to five feet on the bench some distance back from the escarpment.

Terrace gravels are also found along Elk creek outside the Wisconsin drift area. Here, as in the case of Lime creek, the terrace is most prominent on the north bank.

Occasional sand banks are found along Shell Rock river, but well-marked gravel terraces are unimportant, if not absent.

Sand flats and bars are present occasionally in nearly all of the streams in the county, but are of interest only locally.

In the morainal tract kame and esker sands and gravels are available as usual and have been developed to meet the local demand, especially for road work. Occasional sand knobs are found in the upland Wisconsin plain.

Stone.

Limestones of the Mason City substage of the Cedar Valley stage outcrop in the banks of both Shell Rock river and Lime creek and their chief tributaries. The strata are similar in every way to their equivalents in the Mason City sections in Cerro Gordo county.

On the Shell Rock a maximum thickness of twenty feet of the limestone beds may be observed at the railroad bridge in section 1 of Lincoln township.

The following section at Foster's mill in the northeast corner of section 30, Union township, is typical for the Cedar Valley beds:

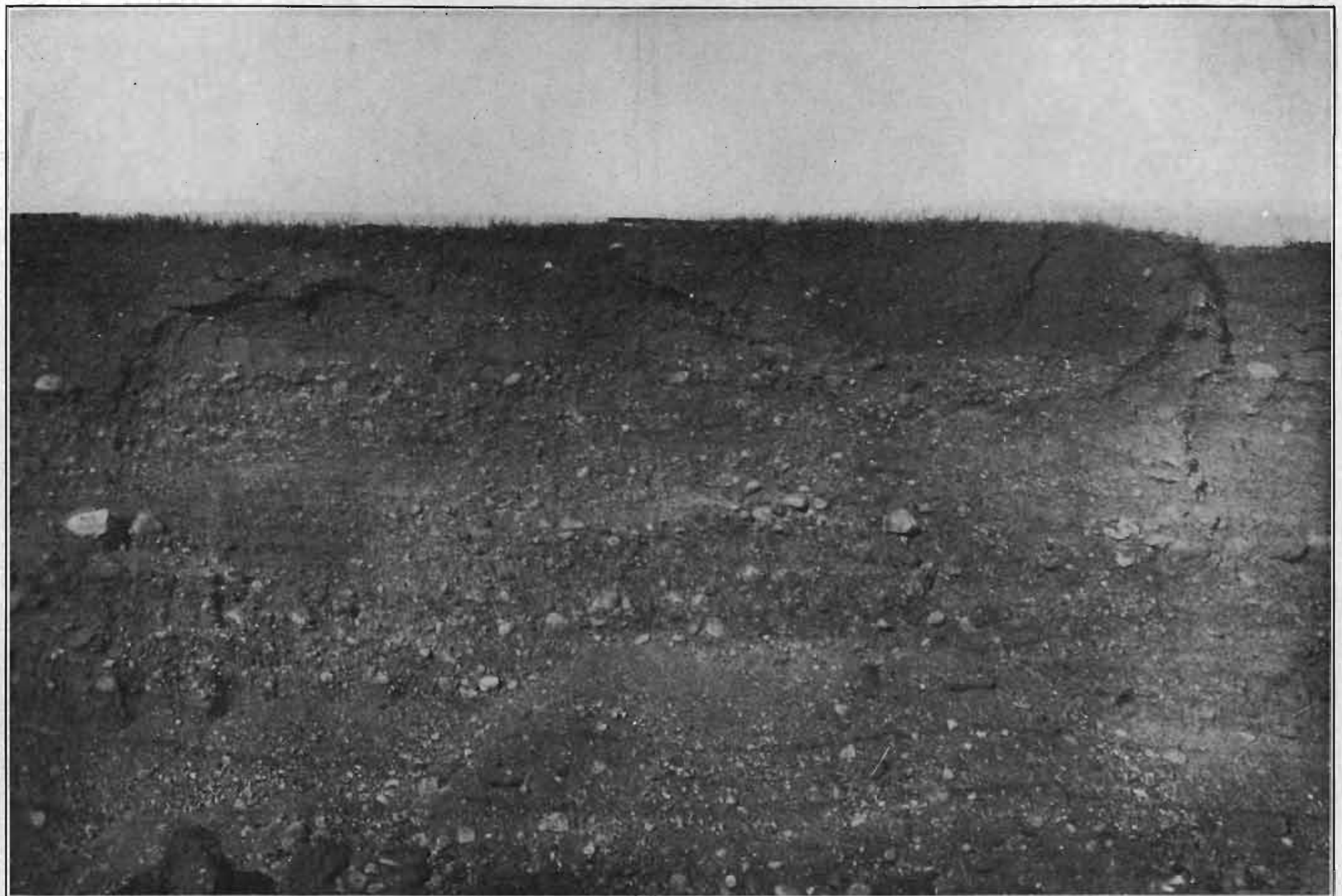


PLATE LVIII—Lime creek terrace gravels, one and a fourth miles east of Hanlontown, Worth county.

	FEET.
4. Weathered limestone, crystalline, and containing numerous calcite cavities	10
3. Compact, light colored, dolomitic limestone, heavy-bedded..	4
2. Very close textured limestone, lithographic in appearance, hard and breaking with conchoidal fracture. Has a very characteristic ring when struck with the hammer	3
1. Argillaceous, bluish dolomite layer, exposed to water below dam	1

No. 4 is the Stromatopora zone which characterizes this stage at nearly every exposure. It is the equivalent of the beds that are employed for the manufacture of Portland cement at the Mason City plant, in the adjoining county to the south.

Near the south edge of section 12, Lincoln township, is a small quarry from which crushed stone has been taken for road material. The middle layer of the Foster mill section is the one used.

FIG. 64—Quarry in northern Lincoln township, Worth county, showing excellent material for road and concrete work.

Beginning in the northwest quarter of section 1, Lincoln township, is a continuous outcrop for about one-third of a mile where Shell Rock river flows close to the west edge of its valley and at the foot of the exposure. From a short distance below the railroad bridge it extends northward across the line into Kensett township. The following is the somewhat generalized section:

		FEET.
5.	Bowldery drift	2
4.	Badly weathered limestone, rusty red in color, no fossils, nodular in appearance, bedding obscure on account of disintegration	6
3.	Fine-textured limestone of light color, nonfossiliferous and containing much interstitial crystalline calcite, heavy-bedded	3
2.	Slightly argillaceous magnesian limestone, grading downward into the darker variety, breaks with earthy fracture, but is very hard, bedding 8 to 12 inches	2-3
1.	Argillaceous dolomite, that portion not adjacent to joint or bedding planes a dark blue, good building stone, to water	6

No. 4 of this section is the equivalent of the upper member in the Foster mill section. Below the railroad bridge a layer of calcareous sandstone eight inches thick appears between Nos. 3 and 2. This is very susceptible to the weathering agencies, and its breaking down forms a reëntrant in the quarry face.

A small quarry has been opened in the northern part of section 14, Kensett township, and some stone removed to supply a local demand for the purpose of rough masonry. The argillaceous dolomite has here been quarried to a depth of six feet. A thin layer of sandy, shaly and weathered limestone occurs between strata of the dolomite. All the layers shown at this exposure have suffered more or less from weathering and are of little value as building material.

At Fertile an outcrop in the south bank of the stream, below the wagon bridge, gives the following section:

		FEET.
3.	Hard limestone, badly shattered into small blocks by weathering	4½
2.	Arenaceous shaly limestone, very slight effervescence with dilute HCl	8
1.	Heavy-bedded, subcrystalline, dolomitic limestone, to water level	5

Bed No. 2 gives way much more readily to weathering than the other members and is conspicuous as a reëntrant along the face of the exposure. A small amount of stone has been quarried at the east edge of the town in a low terrace to the north of Lime creek.

Limestone outcrops along Willow creek along the roadway between sections 29 and 30, Danville township. A considerable area is available here under light stripping. Both the white and the brown limestone are of excellent quality for crushed stone products.

The quarry industry of Worth county has been developed only to the extent of supplying a local demand in the immediate vicinities of the exposures of the limestone beds. Practically all that has been used for building purposes has been from the compact, light colored stratum and the underlying dark magnesian layer given in the sections along the Shell Rock. The former is well suited for road material and concrete work, while the latter, which is the equivalent of the Mason City dolomite, is considered one of the best and most durable building stones taken from the several quarries in Cerro Gordo county. This stone is well exposed to a thickness of ten to twelve feet in the northern part of Lincoln township, where the Chicago Great Western crosses Shell Rock river, and in a location where conditions are favorable for development.

FIG. 65—Iowan bowlder field in northwestern Lincoln township, Worth county.

WRIGHT COUNTY.

SAND AND GRAVEL.

Wright county lies wholly within the Wisconsin drift area. Two drainage systems are represented in the county: Iowa river in the eastern portion, and Boone river, the most important tributary of Des Moines river, which drains the western two-thirds of the county. The former stream is the more important as a source of sand and gravel. Iowa river and its largest tributary in the county, West Branch, have well marked terraces almost throughout their courses within the confines of the county. The terraces are best developed in the vicinity of Belmond, where extensive pits have been opened by all of the railways entering the town. The principal terrace varies from fifteen to thirty feet above the water in the river. The terrace rises up stream. At Belmond it is about twenty feet above the river level. The usual terrace section is:

	FEET.
Alluvium	1- 3
Sand and gravel	12-15
Bowlder clay, exposed at, or about 3 to 5 feet above water level.	

Pebbles above two inches in diameter are relatively rare, although occasional cobbles up to six inches in diameter are present. Limestone pebbles are conspicuous. Sand as a rule predominates. Cross-bedding is common and prevails below, while more or less horizontal bedding is the rule above. The terrace attains a width up to three-fourths of a mile or more, and is persistent on one or both sides of the river. The grade of the present river is low and the terrace rises up stream, the materials becoming coarser. The town of Belmond is in large part built on the terrace. While the terrace rises relatively up stream when compared with the present grade of the river, the gravels do not thicken appreciably as the bog line below the gravels also rises.

The terrace on West Branch is almost identical with the Iowa river terrace but rises more rapidly up stream and is not so well developed. In section 12, Belmond township, the terrace rises some forty feet on the west side of the branch, while the bog line is about fifteen feet above the water level. Between the top of the bog line and the stream channel large bowlders are strewn over the surface in some abundance. Near the channel the bowlders are less conspicuous on account of

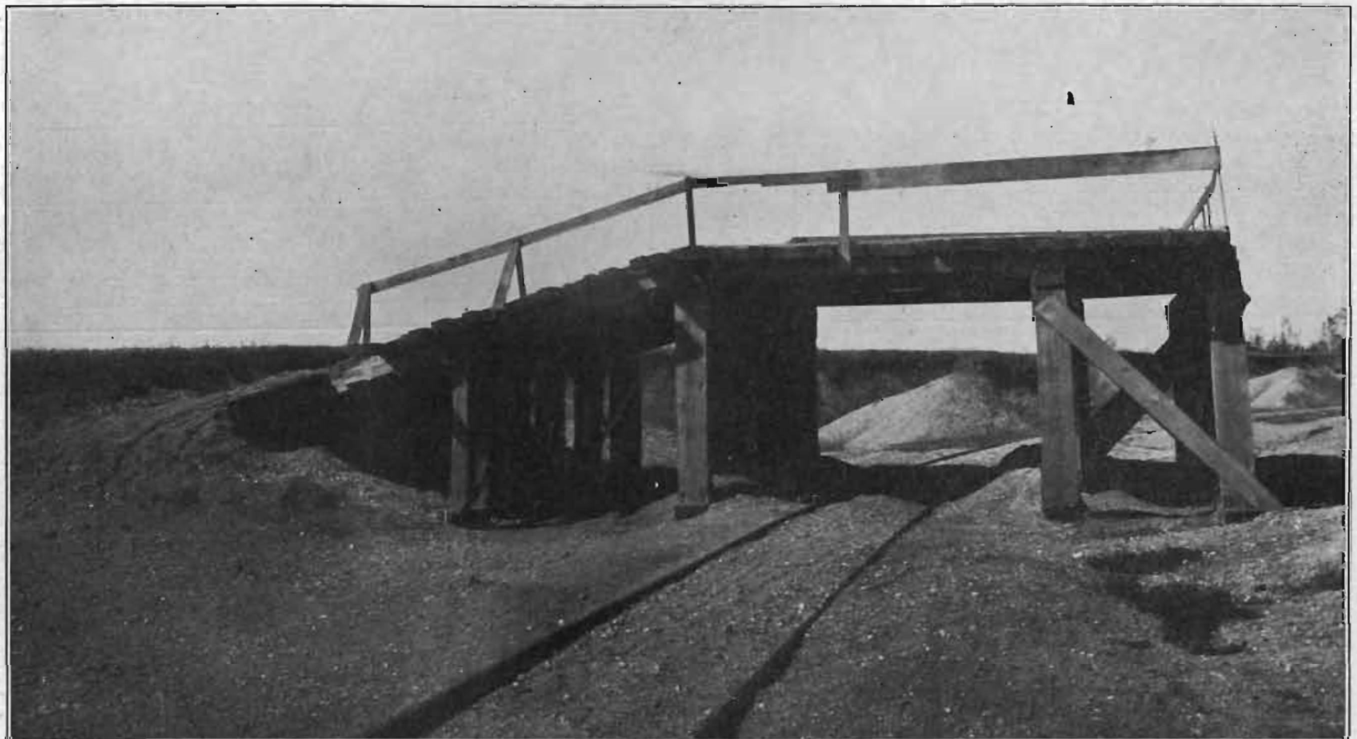


PLATE LIX—Pit of the Chicago, Rock Island & Pacific Railway showing loading trap. Belmond, Wright county.

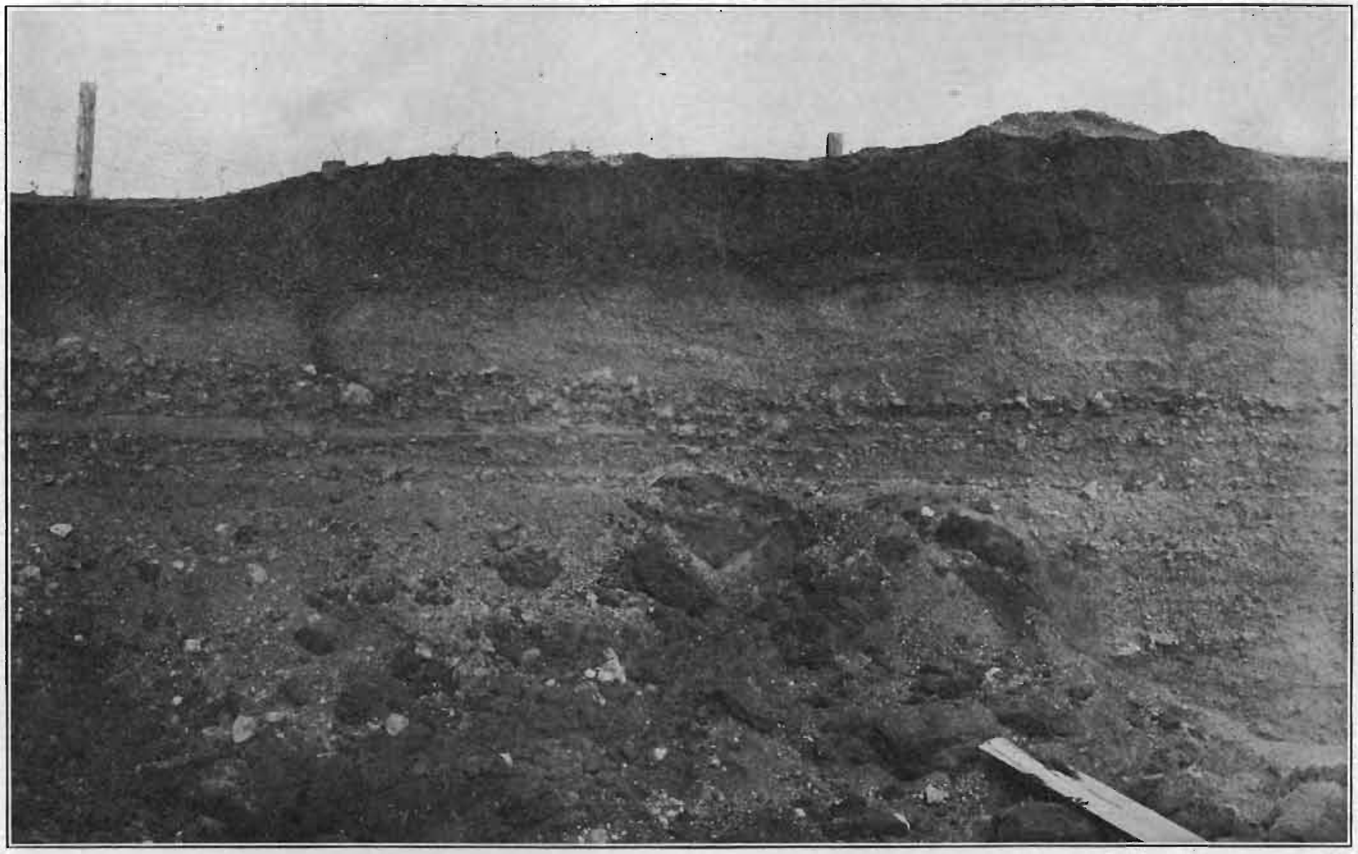


PLATE LX—Country pit about two and a half miles northwest of Belmond, Wright county.

natural levees of alluvium. West Branch has a steep grade—much steeper than the river itself. There is a pit opened in the extreme northwest corner of Belmond township. The gravel is coarser here than in the pits farther down stream. The section exposed is about as follows:

		FEET.
4.	Alluvium	1-3
3.	Gravel and sand, more or less evenly bedded	2-4
2.	Gravel, coarse cobbles up to four or five inches in diameter	2-3
1.	Gravel and sand, variable in texture and bedding	6

Cross-bedding is evident in number 1 of the above section. The section as a whole affords material excellently adapted for road work and all save the alluvium may be used for concrete.

The leading railway pits are at present located in sections 19 and 30, Pleasant township, and 12 in Belmond township.

Crude methods are used for loading the material, the commonest of which are the team and scraper with the incline and platform with trap.

Boone river is also terraced but the terraces are less well developed than those along Iowa river. Pits have been opened in section 32, Eagle Grove township. The material is sand and some gravel and occasional cobbles, and contains considerable clayey and silty material. The terrace here is from twenty-five to thirty feet above the river. Seven to ten feet of sand and gravel under from two to three feet of stripping are available. Much coarser material appears along the roadway in sections 18 and 19 in the same township, but little development work has been done. The most extensive pit in this neighborhood is located in the northeast quarter of section 7 on a small tributary just above its junction with Boone river. The gravel runs from five to seven feet in depth on a terrace some fifteen feet above the river level. The gravel is fairly coarse and much iron-stained. Limestone pebbles prevail. A few bowlders are present but few of the pebbles are over an inch in diameter. Similar deposits are available both north and south of Eagle Grove township. Occasional bars and sand flats occur in the channel of the river, but so far as known gravel is scarce or wanting in such deposits.

The Boone river terraces afford a sufficient supply of material suitable for road work to meet the local demand. The deposits as a rule are not being utilized extensively. The local supply is not so well suited for concrete work on account of high percentage of silt, clay and fine sand. Most of the gravel used for city work in Eagle Grove is shipped in from Mason City and Belmond.

In addition to terrace and stream sand and gravel, some material for road work may be obtained from kame deposits in the morainal tracts. Such tracts are best developed near Dows, through Vernon and Blaine townships, a belt east of Cornelia in Grant and Belmond townships and a less important belt northwest of Wall lake in Wall Lake township. The kame gravels are much more variable in every way than are the stream and terrace materials.

Wright county has enough sand and gravel not only for home use but for export to less favored counties. Pits could be opened in the Iowa river terrace near Belmond where road and concrete material could be produced by the train load at small cost.

TESTS AND ANALYSES OF IOWA LIMESTONES, SANDS AND GRAVELS.

Among the various properties of stone or gravel that is to be used for road construction, three are of such importance as to determine, in most cases, the value of the materials for the purpose. These three are: cementing value, toughness, and hardness.

In order to determine the relative value of various materials for road construction, numerous tests have been proposed for these three properties and finally standard methods of testing have been adopted. The tests in themselves determine the degree of the various properties possessed by a certain stone, yet the value of the determination, so far as the suitability of the material for road construction is concerned, is that it forms a basis for comparing the material with other materials that have been satisfactory in service. That is to say, by a careful study of the records of tests that have been made upon materials which have been used for road purposes, approximate limits may be determined for the various properties of the stone.

Cementing Value.—By "cementing value" is meant that quality in finely broken stone which will cause it to cement together when mixed with water. If broken stone or gravel possesses sufficient cementing value, a road surface made with it will compact readily under rolling, or when subjected to traffic, and the individual stones will be held in the surface by the cementing action of the fine dust which surrounds them. If the stone possesses insufficient cementing value, the pieces which make up the surface will be loosened by traffic and will finally be dislodged. When this happens to a great number of pieces in the surface, a serious deterioration results.

The cementing value of a stone is determined as follows: One-half kilogram of the stone to be tested is broken to a size ranging from one-half inch down, and placed in a ball mill along with about 90 cubic centimeters of water. The ball mill is rotated for 2½ hours at 2,000 revolutions per hour. During this time the stone and water will be ground into a stiff paste. The paste is molded under pressure into cylindrical briquettes 25 centimeters in diameter and 25 cm. high. The pressure used is the same for each briquet, and is usually 132 kg. per square cm. cross section from the briquet. The briquets are cured in a uniform manner, and then subjected to repeated blows from a hammer weighing 1 kg. which drops a distance of 1 cm. at each blow. The number of blows required to break the briquet is taken as a measure of the cementing value, and for any sample of stone the average value of five briquets is taken as the cementing value of the stone. The determination is not an exact one and the conditions under which the test is made may affect the results very materially. The test should always be skillfully made in a laboratory so equipped as to enable the operator to duplicate conditions for each test. A cementing value below 10 is low; from 10 to 25, fair; from 26 to 75, good; from 76 to 100, very good; and above 100, excellent. In general, satisfactory results with macadam roads are not obtained if the cementing value of the stone is below 50 and a value of 75 or more is preferable.

Toughness.—The toughness of a stone is its ability to resist the shock of the pounding of horses' hoofs or the jar of heavy vehicles coming upon the stone when it is firmly bedded in the surface of a road.

Hardness.—Hardness is the property of a stone which enables it to resist the abrasive action of the steel tires on heavily loaded vehicles passing over the stone when it is firmly bedded in the surface of the road.

A test was devised by the Department of Bridges and Highways of France, which has been in use for many years for determining both hardness and toughness. It is known as

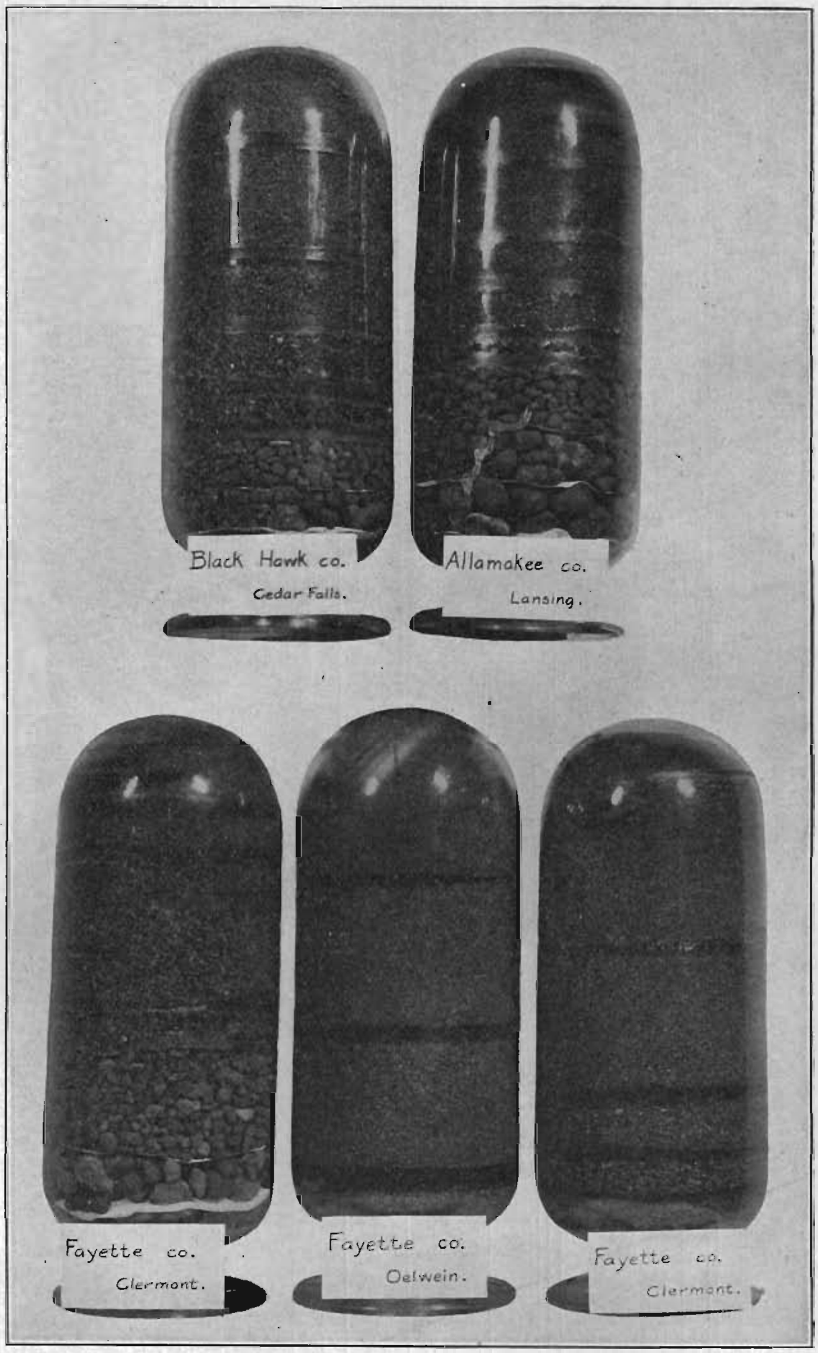


PLATE LXI—Mechanical analyses representative of Iowa sands and gravels.

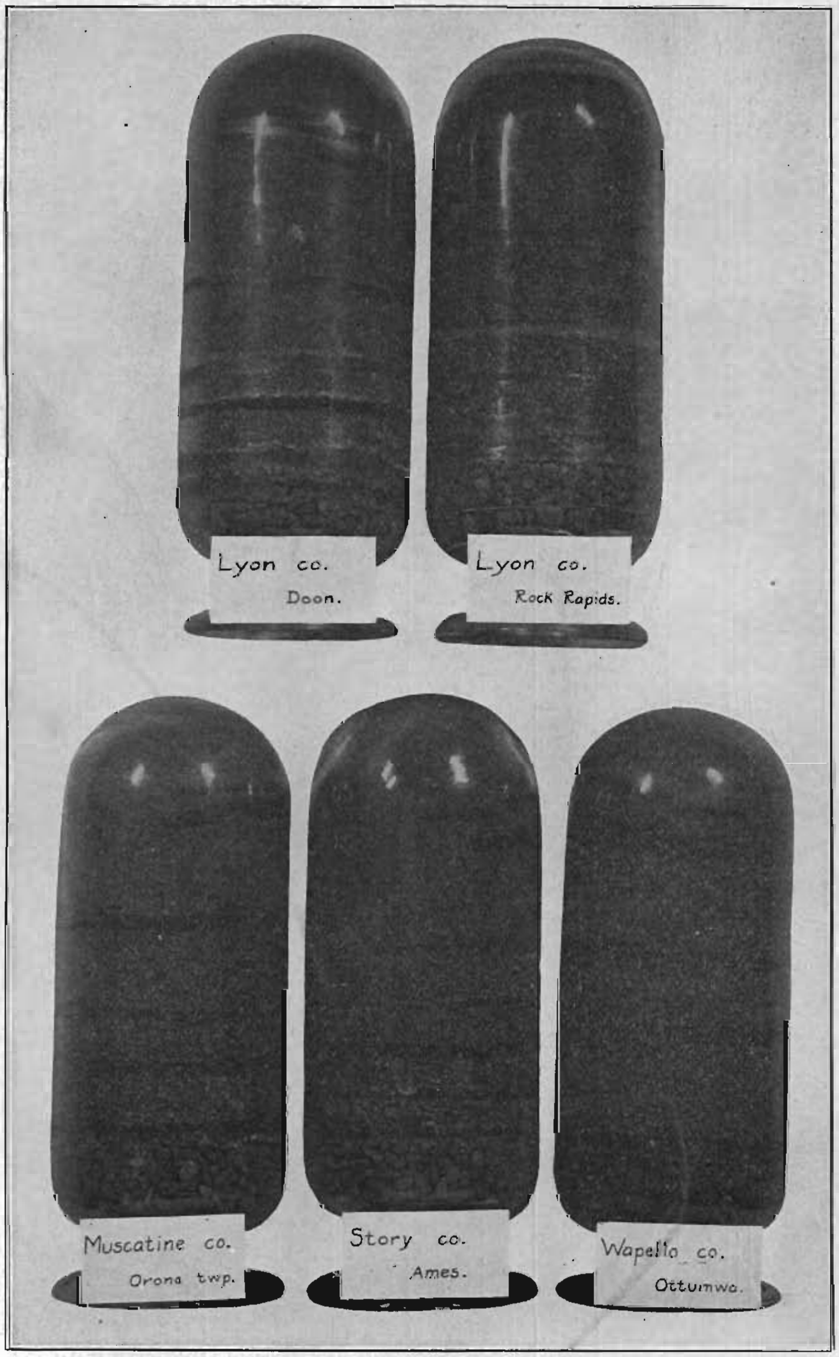


PLATE LXII—Mechanical analyses representative of Iowa sands and gravels.

the "Deval Test," and the results may be expressed as a percentage, or in terms of the French Coefficient of Wear.

The Deval Test.—The machine used for the Deval test is known as the Deval Machine, and consists of two or more hollow cast iron cylinders 20 cm. in inside diameter and 34 cm. long, one end of each being provided with a cover that can be fastened on sufficiently tight to retain all dust resulting from the operation of the machine. The cylinders are attached to a shaft with their axes at an angle of 30° with the shaft. The stone to be tested is placed in one of the cylinders and as it revolves the stone is thrown from one end of the cylinder to the other, thus being subjected to abrasion because of the contact of the pieces with each other, and also being subjected to a mild blow when it strikes the ends of the cylinder. Approximately five kilograms of the stone are used for test, and when possible the charge should consist of 50 pieces as nearly uniform in size as may be selected. The cylinders are rotated for 10,000 revolutions at the rate of 30 to 33 revolutions per minute. When the required number of revolutions has been made the material is taken from the cylinders and screened over a 1-16th inch screen and that which passes through is the amount of loss during the test. If the result is to be expressed in terms of per cent of wear, the per cent would be obtained by dividing the weight of the material which passed the 1-16th inch screen, by the weight of the original sample. If the result is to be expressed in terms of the French Coefficient of Wear:

$$\text{French Coefficient of Wear} = \frac{400}{W}$$

Where W=the loss by abrasion per kg. of the original sample. When expressed in terms of the French Coefficient of Wear a value below 8 is low; 8 to 13 is medium; 14 to 20 is high; and above 20 is very high.

The results of a number of tests for the cementing value of Iowa materials are given in Table III, and it will be noted that there are very few samples having a cementing value less than 50, while a great many of the samples have a cementing value greater than 100. In the column marked "Maximum" is recorded the cementing value of the particular briquet which showed up best and in the column marked "Minimum" is given the cementing value of the briquet which was poorest. It will be noted that in many cases there is a wide difference between these two values. This is due to the fact that the test itself is, in general, inexact, and to variations in the conditions under which the tests are made, such as variations in room temperature, and variation in wetness of the original briquet. In general, however, the test is sufficiently accurate for the purpose for which it is intended, and is a reliable measure of the cementing value of the stone tested.

The results of the Deval test on a number of Iowa limestones are given in Table II, and are tabulated both as per cent of wear and in terms of the French Coefficient of Wear. It will be noted that for a great many of the samples the French Coefficient of Wear is less than 8. That is to say, that while the cementing properties of many of these materials are excellent, the wearing properties are poor. A road constructed with these poorer materials will be apt to be quite dusty due to rapid wear and will require close attention and continual maintenance.

If gravels are to be used for concrete purposes the cementing value, hardness and toughness are relatively of little importance so long as the gravel is not a partially disintegrated material. The gradation of the gravel, the amount of clay or loam present, and the amount of voids in the pebbles are important, however.

In Table IV are given the results of a number of tests of Iowa gravels, in which the above properties were determined. A close study of this table will indicate some significant facts.

First, that the pit-run gravels are exceedingly variable in composition, and for the most part contain a much larger percentage of sand than is necessary for properly proportioned concrete. Concrete made of a fixed proportion of cement and the different pit-run gravels, such as 1 to 4, would therefore

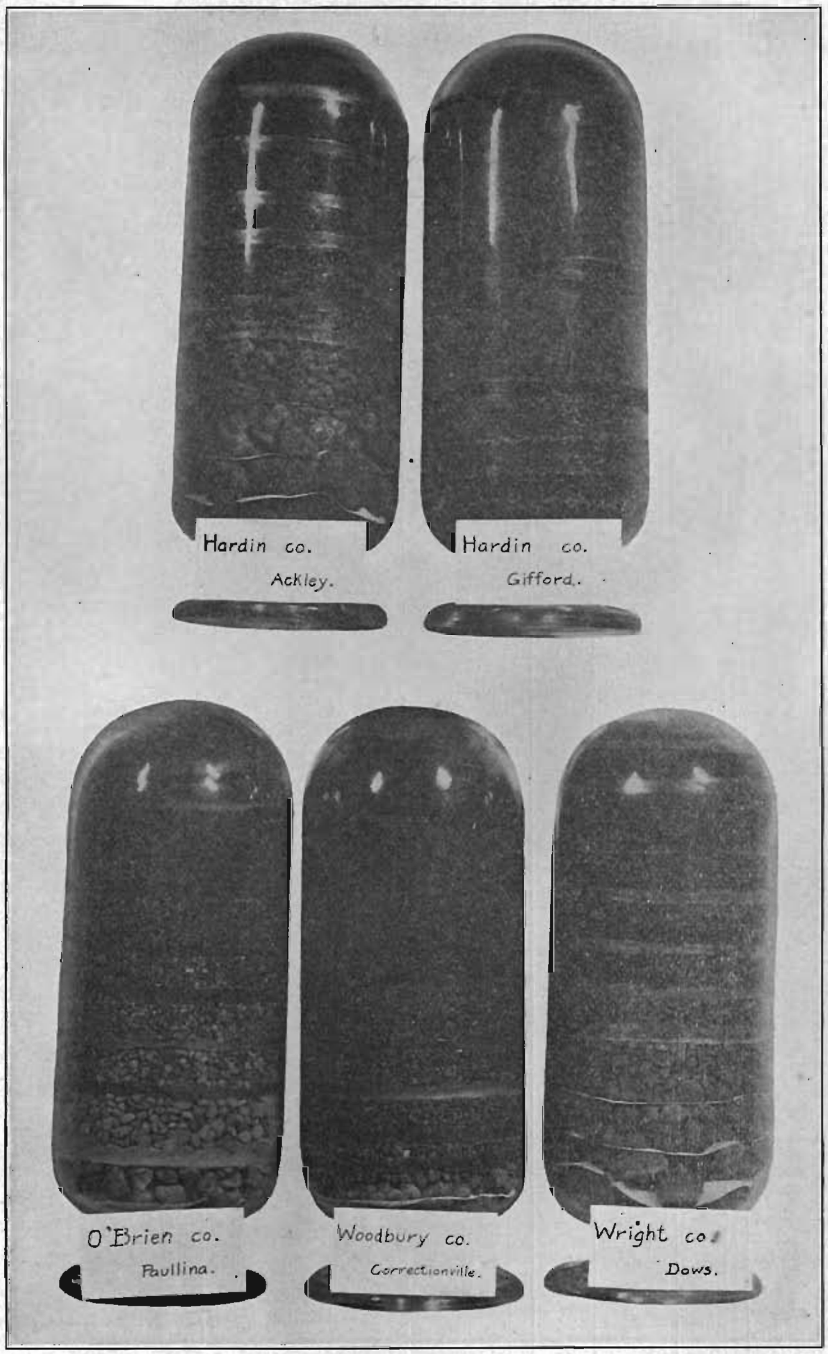


PLATE LXIII—Mechanical analyses representative of Iowa sands and gravels.

vary greatly in strength. It is probable that in most cases it would pay to screen out and throw away the excess sand before making concrete of the gravel. The saving in cement by so doing would be more than enough, in most cases, to pay for the cost of screening.

Second, that the percentage of voids in the pebbles exceeds 40% in only a few cases. Since it is common to proportion concrete on a basis of 40% voids in the pebbles ("coarse aggregate") it would seem that with Iowa gravels this assumption as to percentage of voids may safely be made.

Third, the percentage of clay in a great many of the samples is high, and since clay in excess of about 5% materially decreases the strength of concrete made from the materials, many of the gravels shown in this table would be unsuited for concrete purposes unless the clay or loam were removed by washing.

The percentage of voids in the sand has no particular influence on the proportioning of the concrete, but the fact that the voids in all but a few of the sands shown in the table are about the same is an indication that the sands are fairly uniform in quality and gradation.

ACKNOWLEDGMENTS.

The writers desire to express their appreciation of the courteous co-operation of pit and quarry owners and operators in all parts of the state. Many of the data contained in this report could have been obtained in no other way.

The county reports previously published were used freely in the preparation of this report and references are not always given. The report on Quarry Products was drawn upon extensively, especially the chapter on the Geology of Quarry Products, without any references.

The State Geologist and Assistant State Geologist have facilitated the work in every possible way. The writers take this occasion to make full acknowledgment to all who have aided in any way.

TABLE NO. I.

MECHANICAL ANALYSES OF CRUSHED STONE.

No.	County	Town	Per Cent Retained on 1½ in. Screen	Per Cent Retained on ¾ in. Screen	Per Cent Passed ¾ in. Screen
20	Allamakee	Lansing	73.063	17.750	9.187
7	Appanoose	Centerville	82.50	15.50	2.00
87	Black Hawk	Cedar Falls	86.0	7.4	6.6
88	Black Hawk	Laporte City	84.4	8.	7.6
73	Black Hawk	Waterloo	81.7	9.4	8.9
74	Black Hawk	Waterloo	84.5	6.9	8.6
78	Benton	Vinton	81.4	9.3	9.3
80	Benton	Garrison	79.1	10.	10.9
82	Benton	Mt. Auburn	84.0	8.5	7.5
83	Benton	Shellsburg	83.	8.	9.
85	Benton	Shellsburg	84.4	6.7	8.9
72	Benton	Vinton	83.6	8.8	7.6
79	Bremer	Waverly	84.4	7.7	7.9
48	Buchanan	Independence	78.74	16.37	4.62
89	Butler	Dumont	81.8	9.6	8.6
81	Butler	Greene	83.75	8.5	7.75
75	Cedar	Lowden	81.3	8.2	10.5
63	Cedar	Cedar Valley	80.93	9.31	9.76
64	Cedar	Tipton	81.4	9.5	9.1
6	Cedar	Tipton	89.562	9.407	1.031
3	Cedar	Lowden	69.50	14.30	16.20
66	Cerro Gordo	Mason City	15.5	47.0	41.5
92	Chickasaw	Chickasaw	84.	9.06	6.94
41	Clayton	Luana	85.12	9.86	4.87
42	Clayton	North McGregor	94.07	3.3	2.5
43	Clayton	Elkader	88.12	5.8	5.6
24	Clayton	Guttenberg	75.500	15.656	8.844
76	Clinton	Clinton	81.0	8.4	10.6
21	Clinton	Lyons	67.312	21.781	10.907
62	Clinton	Charlotte	82.	8.9	9.1
44	Decatur	Davis City	84.26	8.9	6.65
60	Des Moines	Cascade	71.60	16.62	11.78
58	Des Moines	Cascade	73.48	12.64	13.84
28	Fayette	Fayette	65.813	24.250	9.937
26	Fayette	Clermont	60.562	25.938	13.500
94	Floyd	Charles City	90.7	6.15	3.15
95	Franklin	Hampton	74.6	11.4	14.0
77	Franklin	Hampton	84.	6.1	9.9
86	Grundy	Conrad	84.	4.	12.
9	Hardin	Iowa Falls	86.8	7.5	5.0
97	Howard	Cresco	74.9	13.3	11.8
23	Jackson	Maquoketa	68.312	17.250	14.438
11	Jackson	Maquoketa	69.469	17.750	12.781
2	Jackson	Monmouth	43.00	24.00	33.00
93	Johnson	Iowa City	84.8	8.6	6.6
91	Johnson	Iowa City	----------	----------	----------
34	Jones	Stone City	61.563	24.250	14.187
25	Jones	Stone City	77.00	15.875	7.125
22	Jones	Olin	65.594	21.469	12.937
10	Jones	Hale	71.906	18.125	9.969
8	Jones	Stone City	65.063	17.687	17.250
5	Jones	Monticello	84.344	10.063	5.594

TABLE NO. I—CONTINUED

No.	County	Town	Per Cent Retained on 1¼ in. Screen	Per Cent Retained on ¾ in. Screen	Per Cent Passed ¾ in. Screen
4	Jones	Monticello	78.80	13.30	7.90
61	Lee	Keokuk	93.80	3.30	2.90
59	Lee	Ft. Madison	76.67	11.25	11.10
54	Lee	Keokuk	81.86	10.00	8.12
55	Lee	Franklin	61.50	27.50	11.00
56	Lee	Keokuk	74.74	14.62	10.62
57	Lee	Keokuk	69.44	20.3	10.2
49	Lee	Keokuk	77.6	15.1	6.1
50	Lee	Keokuk	79.74	11.11	9.10
46	Lee	Montrose	39.0	37.0	24.0
47	Lee	Keokuk	44.7	42.74	2.5
14	Linn	Cedar Rapids	73.25	16.375	10.375
12	Linn	Cedar Rapids	69.156	22.187	8.657
90	Louisa	Morning Sun	84.94	7.06	8.
39	Madison	Winterset	83.38	15.36	.65
36	Madison	Earlham	100.0		
37	Madison	Peru	100.00		
96	Mitchell	Osage	80.1	10.6	9.3
67	Muscatine	Fairport	78.	6.25	15.75
98	Pocahontas	Gilmore City	84.50	8.50	7.00
35	Scott	Buffalo	81.0	19.0	
19	Scott	Le Claire	76.00	17.094	6.906
68	Tama	Montour	89.75	5.75	4.5
69	Tama	Montour	84.1	10.8	4.1
70	Tama	Montour	83.6	9.5	6.9
71	Tama	Montour	87.1	7.1	5.8
51	Van Buren	Keosauqua	79.0	10.8	10.2
52	Van Buren	Keosauqua	76.12	15.86	7.74
53	Van Buren	Farmington	82.32	10.17	6.88
29	Van Buren	Farmington	58.344	32.687	8.969
30	Van Buren	Keosauqua	74.00	17.00	9.00
31	Van Buren	Keosauqua	64.00	25.812	10.187
32	Van Buren	Keosauqua	65.688	23.812	10.500
33	Van Buren	Van Buren	65.500	24.313	10.187
13	Wapello	Cliffland	74.344	9.469	16.187
18	Wapello	Ottumwa	68.938	19.563	11.500
17	Wapello	Ottumwa	63.906	23.906	12.188
16	Wapello	Ottumwa	73.906	16.563	9.531
15	Wapello	Ottumwa	74.750	15.281	9.969
45	Winneshiek	Decorah	75.48	12.52	12.00
40	Winneshiek	Decorah	87.12	7.46	5.12
27	Winneshiek	Ft. Atkinson	68.812	20.500	10.688
1	Winneshiek	Decorah	81.24	9.76	9.00
38	New Ulm	Minnesota	82.96	16.00	.5

TABLE NO. II.

ABRASION AND IMPACT TESTS

No.	County	Size of Specimens		Per Cent of Wear			Mean Coefficient (French)
		Screen Passed	Retained on	Max.	Min.	Mean	
20	Allamakee	2½ in.	1¼ in.	5.4	5.0	5.2	7.70
20	Allamakee	1¼ in.	¾ in.	4.3	4.22	4.26	9.38
7	Appanoose	2½ in.	1¼ in.	4.6	4.5	4.55	8.80
7	Appanoose	1¼ in.	¾ in.	12.6	13.2	12.9	3.12
87	Black Hawk	2½ in.	1¼ in.	6.2	6.	6.1	6.56
87	Black Hawk	1¼ in.	¾ in.	3.	2.4	2.7	11.11
88	Black Hawk	2½ in.	1¼ in.	10.4	10.	10.2	3.92
88	Black Hawk	1¼ in.	¾ in.	8.	6.	7.	5.62
73	Black Hawk	2½ in.	1¼ in.	11.4	11.	11.2	3.57
73	Black Hawk	1¼ in.	¾ in.	4.2	4.	4.1	9.75
74	Black Hawk	2½ in.	1¼ in.	10.4	10.	10.2	3.82
74	Black Hawk	1¼ in.	¾ in.	4.4	4.	4.2	9.58
78	Benton	2½ in.	1¼ in.	6.5	6.5	6.5	6.16
78	Benton	1¼ in.	¾ in.	2.6	2.5	2.55	15.68
80	Benton	2½ in.	1¼ in.	6.6	5.6	6.1	6.55
80	Benton	1¼ in.	¾ in.	3.4	3.	3.2	12.5
82	Benton	2½ in.	1¼ in.	4.	4.	4.	10.
82	Benton	1¼ in.	¾ in.	6.2	6.	6.1	6.55
83	Benton	2½ in.	1¼ in.	8.6	8.2	8.4	4.76
83	Benton	1¼ in.	¾ in.	5.2	4.6	4.9	8.17
85	Benton	2½ in.	1¼ in.	7.4	6.6	7.	5.71
85	Benton	1¼ in.	¾ in.	4.	3.	3.5	11.42
72	Benton	2½ in.	1¼ in.	6.4	6.2	6.3	6.35
72	Benton	1¼ in.	¾ in.	3.8	3.6	3.7	10.8
79	Bremer	2½ in.	1¼ in.	5.4	5.	5.2	7.68
79	Bremer	1¼ in.	¾ in.	3.	2.4	2.7	11.11
48	Buchanan	2½ in.	1¼ in.	7.0	7.0	7.0	5.71
48	Buchanan	1¼ in.	¾ in.	4.6	4.0	4.3	9.3
89	Butler	2½ in.	1¼ in.	5.	4.2	4.6	8.69
89	Butler	1¼ in.	¾ in.	3.	2.6	2.8	14.28
81	Butler	2½ in.	1¼ in.	6.2	6.	6.1	6.55
81	Butler	1¼ in.	¾ in.	2.4	2.2	2.3	17.39
75	Cedar	2½ in.	1¼ in.	17.2	15.6	16.7	2.33
75	Cedar	1¼ in.	¾ in.	9.4	8.4	8.9	4.49
63	Cedar	2½ in.	1¼ in.	16.2	16.	16.1	2.48
63	Cedar	1¼ in.	¾ in.	9.8	9.2	9.5	4.21
64	Cedar	2½ in.	1¼ in.	6.4	6.4	6.4	6.25
64	Cedar	1¼ in.	¾ in.	4.	3.4	3.7	10.81
6	Cedar	2½ in.	1¼ in.	9.6	9.5	9.55	4.18
6	Cedar	1¼ in.	¾ in.	6.2	5.8	6.0	6.67
3	Cedar	2½ in.	1¼ in.			17.5	2.28
3	Cedar	1¼ in.	¾ in.			12.1	3.31
66	Cerro Gordo	2½ in.	1¼ in.			4.4	9.09
66	Cerro Gordo	1¼ in.	¾ in.	2.1	.18	1.14	34.2
92	Chickasaw	2½ in.	1¼ in.	10.2	9.8	10.	4.
92	Chickasaw	1¼ in.	¾ in.	4.	3.8	3.9	10.25
41	Clayton	2½ in.	1¼ in.	8.4	8.2	8.3	4.82
41	Clayton	1¼ in.	¾ in.	6.4	5.6	6.0	6.6
42	Clayton	2½ in.	1¼ in.	9.5	8.5	9.0	4.4
42	Clayton	1¼ in.	¾ in.			4.8	8.3
43	Clayton	2½ in.	1¼ in.	11.0	9.4	10.2	3.9

TABLE NO. II—CONTINUED

No.	County	Size of Specimens		Per Cent of Wear			Mean Coefficient (French)
		Screen Passed	Retained on	Max.	Min.	Mean	
43	Clayton	1¼ in.	¾ in.	5.0	4.6	4.8	8.3
24	Clayton	2½ in.	1¼ in.	5.8	5.5	5.65	7.08
24	Clayton	1¼ in.	¾ in.	5.0	4.8	4.9	8.17
76	Clinton	2½ in.	1¼ in.	13.	11.	12.	3.33
76	Clinton	1¼ in.	¾ in.	6.	5.	5.5	7.27
21	Clinton	2½ in.	1¼ in.	10.60	8.50	9.55	4.18
21	Clinton	1¼ in.	¾ in.	9.10	9.00	9.05	4.42
62	Clinton	2½ in.	1¼ in.	10.	9.4	9.7	4.12
62	Clinton	1¼ in.	¾ in.	17.2	17.	17.1	2.34
44	Decatur	2½ in.	1¼ in.	4.8	2.6	3.7	10.8
44	Decatur	1¼ in.	¾ in.	3.2	2.4	2.8	14.3
60	Des Moines	2½ in.	1¼ in.	8.0	7.0	7.5	5.33
60	Des Moines	1¼ in.	¾ in.	5.8	5.0	5.4	7.4
58	Des Moines	2½ in.	1¼ in.			12.4	3.22
58	Des Moines	1¼ in.	¾ in.			8.4	4.76
28	Fayette	2½ in.	1¼ in.	6.5	5.8	6.15	6.51
28	Fayette	1¼ in.	¾ in.	7.1	6.7	6.9	5.80
26	Fayette	2½ in.	1¼ in.	20.1	16.4	18.25	2.195
26	Fayette	1¼ in.	¾ in.	15.52	14.82	15.17	2.64
94	Floyd	2½ in.	1¼ in.	8.4	7.8	8.1	4.94
94	Floyd	1¼ in.	¾ in.	5.4	3.4	4.4	9.1
95	Franklin	2½ in.	1¼ in.	12.2	10.6	11.4	3.5
95	Franklin	1¼ in.	¾ in.	5.6	4.6	5.1	7.34
77	Franklin	2½ in.	1¼ in.	11.4	10.	10.7	3.73
77	Franklin	1¼ in.	¾ in.	5.2	5.	5.1	7.84
86	Grundy	2½ in.	1¼ in.	10.4	10.	10.2	3.92
86	Grundy	1¼ in.	¾ in.	5.	4.6	4.8	8.33
9	Hardin	2½ in.	1¼ in.			5.1	7.8
9	Hardin	1¼ in.	¾ in.			3.2	12.2
97	Howard	2½ in.	1¼ in.	7.8	7.6	7.7	5.19
97	Howard	1¼ in.	¾ in.	13.4	8.	10.7	3.74
23	Jackson	2½ in.	1¼ in.	10.3	10.1	10.2	3.92
23	Jackson	1¼ in.	¾ in.	7.1	6.8	6.95	5.76
11	Jackson	2½ in.	1¼ in.	12.5	11.5	12.0	3.33
11	Jackson	1¼ in.	¾ in.	13.2	13.2	13.2	3.04
2	Jackson	2½ in.	1¼ in.			10.2	3.9
2	Jackson	1¼ in.	¾ in.			6.45	6.2
93	Johnson	2½ in.	1¼ in.	8.4	8.2	8.3	4.82
93	Johnson	1¼ in	¾ in.			5.0	8.
91	Johnson	2½ in.	1¼ in.			4.2	9.76
91	Johnson	1¼ in.	¾ in.	3.4	3.	3.2	12.5
34	Jones	2½ in.	1¼ in.	7.0	6.6	6.8	5.88
34	Jones	1¼ in.	¾ in.	5.0	4.0	4.5	8.78
25	Jones	2½ in.	1¼ in.	4.2	4.1	4.15	9.64
25	Jones	1¼ in.	¾ in.	3.5	3.46	3.48	11.50
22	Jones	2½ in.	1¼ in.	17.62	17.42	17.52	2.28
22	Jones	1¼ in.	¾ in.	13.2	12.8	13.0	3.08
10	Jones	2½ in.	1¼ in.	7.0	6.6	6.8	5.88
10	Jones	1¼ in.	¾ in.	7.2	6.8	7.0	5.71
8	Jones	2½ in.	1¼ in.	12.44	9.56	10.00	4.00
8	Jones	1¼ in.	¾ in.	11.9	11.8	11.85	3.38
5	Jones	2½ in.	1¼ in.	10.72	10.50	10.61	3.77
5	Jones	1¼ in.	¾ in.	7.16	6.10	6.63	6.04
4	Jones	2½ in.	1¼ in.			7.9	5.07

TABLE NO. II—CONTINUED

No.	County	Size of Specimens		Per Cent of Wear			Mean Coefficient (French)
		Screen Passed	Retained on	Max.	Min.	Mean	
4	Jones	1¼ in.	¾ in.	--------	--------	6.1	6.56
61	Lee	2½ in.	1¼ in.	7.4	7.0	7.2	5.5
61	Lee	1¼ in.	¾ in.	4.0	3.8	3.9	10.2
59	Lee	2½ in.	1¼ in.	--------	--------	8.2	4.87
59	Lee	1¼ in.	¾ in.	--------	--------	6.6	6.06
54	Lee	2½ in.	1¼ in.	--------	--------	4.0	10.00
54	Lee	1¼ in.	¾ in.	--------	--------	2.5	16.00
55	Lee	2½ in.	1¼ in.	3.2	3.0	3.1	12.1
55	Lee	1¼ in.	¾ in.	2.4	2.2	2.1	19.0
56	Lee	2½ in.	1¼ in.	6.2	6.2	6.2	6.4
56	Lee	1¼ in.	¾ in.	4.8	4.4	4.6	8.7
57	Lee	2½ in.	1¼ in.	--------	--------	4.6	8.7
57	Lee	1¼ in.	¾ in.	--------	--------	3.4	11.7
49	Lee	2½ in.	1¼ in.	4.8	4.8	4.8	8.23
49	Lee	1¼ in.	¾ in.	4.0	3.8	3.9	10.2
50	Lee	2½ in.	1¼ in.	7.8	7.6	7.7	5.2
50	Lee	1¼ in.	¾ in.	5.6	4.8	5.2	7.7
46	Lee	2½ in.	1¼ in.	5.0	4.8	4.9	8.01
46	Lee	1¼ in.	¾ in.	4.0	3.2	3.6	11.1
47	Lee	2½ in.	1¼ in.	4.8	4.6	4.7	8.5
47	Lee	1¼ in.	¾ in.	3.6	3.4	3.5	11.4
14	Linn	2½ in.	1¼ in.	9.44	5.56	7.50	5.34
14	Linn	1¼ in.	¾ in.	8.42	4.76	6.59	6.07
12	Linn	2½ in.	1¼ in.	4.40	2.64	3.52	11.37
12	Linn	1¼ in.	¾ in.	7.6	7.6	7.6	5.27
90	Louisa	2½ in.	1¼ in.	7.	6.4	6.7	5.95
90	Louisa	1¼ in.	¾ in.	3.4	3.	3.2	12.5
39	Madison	2½ in.	1¼ in.	4.0	3.6	3.8	10.5
39	Madison	1¼ in.	¾ in.	2.3	2.2	2.25	18.0
36	Madison	2½ in.	1¼ in.	4.8	4.0	4.4	9.1
37	Madison	2½ in.	1¼ in.	4.0	3.6	3.8	10.5
96	Mitchell	2½ in.	1¼ in.	7.2	6.8	7.0	5.72
96	Mitchell	1¼ in.	¾ in.	4.8	4.6	4.7	8.51
67	Muscatine	2½ in.	1¼ in.	53.	47.8	50.4	.79
67	Muscatine	1¼ in.	¾ in.	55.	53.6	54.3	.73
98	Pocahontas	2½ in.	1¼ in.	4.4	4.1	4.25	0.975
98	Pocahontas	1¼ in.	¾ in.	2.8	2.6	2.7	1.54
35	Scott	2½ in.	1¼ in.	4.3	4.0	4.15	9.65
35	Scott	1¼ in.	¾ in.	2.9	2.6	2.75	14.52
19	Scott	2½ in.	1¼ in.	3.6	2.9	3.25	12.30
19	Scott	1¼ in.	¾ in.	4.00	3.80	3.90	10.25
68	Tama	2½ in.	1¼ in.	5.6	5.4	5.5	7.27
68	Tama	1¼ in.	¾ in.	2.4	2.	2.2	18.18
69	Tama	2½ in.	1¼ in.	8.4	8.	8.2	4.87
69	Tama	1¼ in.	¾ in.	4.	3.	3.5	11.42
70	Tama	2½ in.	1¼ in.	15.4	14.	14.7	2.72
70	Tama	1¼ in.	¾ in.	10.2	6.4	8.3	4.81
71	Tama	2½ in.	1¼ in.	6.6	6.	6.3	6.34
71	Tama	1¼ in.	¾ in.	4.	3.6	3.8	10.5
51	Van Buren	2½ in.	1¼ in.	9.0	8.4	8.7	4.6
51	Van Buren	1¼ in.	¾ in.	3.6	3.0	3.3	12.1
52	Van Buren	2½ in.	1¼ in.	5.6	5.4	5.5	7.27
52	Van Buren	1¼ in.	¾ in.	5.2	5.2	5.2	7.7
53	Van Buren	2½ in.	1¼ in.	--------	--------	6.0	6.6

TABLE NO. II—CONTINUED

No.	County	Size of Specimens		Per Cent of Wear			Mean Coefficient (French)
		Screen Passed	Retained on	Max.	Min.	Mean	
53	Van Buren	1¼ in.	¾ in.	--------	--------	3.6	11.1
29	Van Buren	2½ in.	1¼ in.	4.2	4.0	4.1	9.98
29	Van Buren	1¼ in.	¾ in.	3.36	3.36	3.36	11.80
30	Van Buren	2½ in.	1¼ in.	3.4	3.2	3.3	12.12
30	Van Buren	1¼ in	¾ in.	2.9	2.0	2.45	16.32
31	Van Buren	2½ in.	1¼ in.	4.60	4.30	4.45	8.99
31	Van Buren	1¼ in.	¾ in.	3.66	3.5	3.58	11.30
32	Van Buren	2½ in.	1¼ in.	7.16	6.76	6.96	5.82
32	Van Buren	1¼ in.	¾ in.	6.36	5.80	6.08	6.67
33	Van Buren	2½ in.	1¼ in.	3.06	3.36	3.51	11.40
33	Van Buren	1¼ in.	¾ in.	2.86	2.40	2.63	15.22
13	Wapello	2½ in.	1¼ in.	70.18	44.00	57.09	.702
13	Wapello	1¼ in.	¾ in.	43.66	43.40	43.53	.918
18	Wapello	2½ in.	1¼ in.	4.10	3.24	3.67	10.89
18	Wapello	1¼ in.	¾ in.	3.0	2.80	2.90	13.80
17	Wapello	2½ in.	1¼ in.	3.60	3.50	3.55	11.28
17	Wapello	1¼ in.	¾ in.	3.30	2.40	2.85	14.03
16	Wapello	2½ in.	1¼ in.	3.20	2.84	3.02	13.25
16	Wapello	1¼ in.	¾ in.	2.44	2.00	2.22	18.02
15	Wapello	2½ in.	1¼ in.	4.44	3.3	3.87	10.63
15	Wapello	1¼ in.	¾ in.	2.5	2.0	2.25	17.78
45	Winneshiek	2½ in.	1¼ in.	--------	--------	6.00	6.6
45	Winneshiek	1¼ in.	¾ in.	--------	--------	3.5	11.4
40	Winneshiek	2½ in.	1¼ in.	5.6	5.4	5.5	7.45
40	Winneshiek	1¼ in.	¾ in.	4.0	4.0	4.0	8.00
27	Winneshiek	2½ in.	1¼ in.	5.45	5.10	5.27	7.58
27	Winneshiek	1¼ in.	¾ in.	4.3	3.9	4.1	9.98
1	Winneshiek	2½ in.	1¼ in.	--------	--------	13.	3.08
1	Winneshiek	1¼ in.	¾ in.	--------	--------	8.3	4.81
38	New Ulm, Minn.	2½ in.	1¼ in.	1.4	1.2	1.3	30.7
38	New Ulm, Minn.	1¼ in.	¾ in.	1.0	0.7	0.85	49.0

TABLE NO. III.

CEMENTATION TESTS.

o.	County	Town	Cementing Value		
			Maximum	Minimum	Mean
20	Allamakee	Lansing	109	65	82
7	Appanoose	Centerville	75	56	65
87	Black Hawk	Cedar Falls	600	300	450
88	Black Hawk	Laporte City	30	10	20
73	Black Hawk	Waterloo	900	510	754
74	Black Hawk	Waterloo	600	310	470
78	Benton	Vinton	256	114	185
80	Benton	Garrison	552	405	492
82	Benton	Mt. Auburn	1290	908	1099
83	Benton	Shellsburg	460	304	362
85	Benton	Shellsburg	470	200	335
72	Benton	Vinton	300	98	182
79	Bremer	Waverly	894	402	670
48	Buchanan	Independence	180	80	130
89	Butler	Dumont	90	10	50
81	Butler	Greene	514	448	467
75	Cedar	Lowden	103	74	86
63	Cedar	Cedar Valley	96	25	59
64	Cedar	Tipton	325	112	233
6	Cedar	Tipton	360	200	295
3	Cedar	Lowden			N. G.
66	Cerro Gordo	Mason City	*		
92	Chickasaw	Chickasaw	30	12	21
41	Clayton	Luana	162	112	146
42	Clayton	North McGregor	66	50	58
43	Clayton	Elkader	400	100	292
24	Clayton	Guttenberg	198	60	105
76	Clinton	Clinton	430	240	329
21	Clinton	Lyons	25	15	20
62	Clinton	Charlotte	110	39	67
44	Decatur	Davis City	125	75	100
60	Des Moines	Cascade	87	31	65
58	Des Moines	Cascade	20	11	15
28	Fayette	Fayette	220	180	200
26	Fayette	Clermont	19	8	14
94	Floyd	Charles City	†		
95	Franklin	Hampton	‡		
77	Franklin	Hampton	308	245	273
86	Grundy	Conrad	220	40	130
9	Hardin	Iowa Falls	200	125	168
97	Howard	Cresco	40	20	30
23	Jackson	Maquoketa	70	26	43
11	Jackson	Maquoketa			N. G.
2	Jackson	Monmouth	31	25	28
93	Johnson	Iowa City	468	300	384
91	Johnson	Iowa City	230	160	195
34	Jones	Stone City	140	30	87
25	Jones	Stone City	280	91	173
22	Jones	Olin	10	5	7
10	Jones	Hale	20	15	17
8	Jones	Stone City	25	12	16

TABLE NO. III—CONTINUED

No.	County	Town	Cementing Value		
			Maximum	Minimum	Mean
5	Jones	Monticello	112	88	98
4	Jones	Monticello	18	15	16
61	Lee	Keokuk	112	50	79
59	Lee	Ft. Madison	237	100	162
54	Lee	Keokuk	180	50	102
55	Lee	Franklin	85	60	72
56	Lee	Keokuk	160	70	118
57	Lee	Keokuk	245	75	155
49	Lee	Keokuk	300	110	205
50	Lee	Keokuk	75	50	59
46	Lee	Montrose	325	62	147
47	Lee	Keokuk	600	150	350
14	Linn	Cedar Rapids	185	65	112
12	Linn	Cedar Rapids	250	51	123
90	Louisa	Morning Sun	225	175	200
39	Madison	Winterset	100	50	59
36	Madison	Earlham	72	14	40
37	Madison	Peru	152	25	73
96	Mitchell	Osage	274	200	237
67	Muscatine	Fairport	*		
98	Pocahontas	Gilmore City	375	325	350
35	Scott	Buffalo	127	26	78
19	Scott	LeClaire	160	80	120
68	Tama	Montour	285	124	219
69	Tama	Montour	425	236	366
70	Tama	Montour	168	54	117
71	Tama	Montour	334	70	206
51	Van Buren	Keosauqua	50	20	33
52	Van Buren	Keosauqua	200	50	111
53	Van Buren	Farmington	110	50	72
29	Van Buren	Farmington	150	30	75
30	Van Buren	Keosauqua	219	42	91
31	Van Buren	Keosauqua	300	69	208
32	Van Buren	Keosauqua	61	30	46
33	Van Buren	Van Buren	271	20	83
13	Wapello	Cliffland			N. G.
18	Wapello	Ottumwa	290	70	136
17	Wapello	Ottumwa	134	25	93
16	Wapello	Ottumwa	125	63	87
15	Wapello	Ottumwa	42	15	26
45	Winneshiek	Decorah	187	100	150
40	Winneshiek	Decorah	250	125	158
27	Winneshiek	Ft. Atkinson	286	87	190
1	Winneshiek	Decorah	18	18	18
38	New Ulm	Minnesota	100	50	85

*No record—no detritus left.
†Would not make briquets.
‡Briquets crumbled at first blow of hammer.

TABLE NO. IV.

PERCENTAGES OF PEBBLES, SAND AND VOIDS IN REPRESENTATIVE IOWA GRAVELS.

No.	Locality		Mech. Anal. Per Cent			Per Cent Voids		
	County	Town	Pebbles	Sand	Clay	Pebbles	Sand	Mixture
15	Allamakee	Lansing	38.0	60.8	1.2	35.0	36.0	
65	Benton	Vinton	21.0	76.0	3.0	38.0	36.0	
66	Benton	Vinton	42.9	51.8	5.3	43.0	36.0	
67	Benton	Vinton	13.9	74.6	11.5	41.0	28.0	
70	Black Hawk	Cedar Falls	24.9	72.5	2.6	40.0	36.0	
56	Boone	Frazer	5.5	81.2	13.3	40.2	38.0	
63	Boone	Pilot Mound	31.5	65.1	3.4	25.9	25.2	
68	Bremer	Waverly	45.6	49.7	4.7	40.0	32.0	
36	Buchanan	Independence	18.4	58.9	22.7	42.0	42.5	
23	Buena Vista	Sioux Rapids	33.6	62.3	4.1	34.0	35.0	
78	Buena Vista	Storm Lake	30.5	58.2	11.3	40.0	34.0	
76	Butler	Dumont	41.9	51.3	6.8	41.0	32.0	
105	Butler	Shell Rock		95.6	4.4		32.0	
61	Calhoun	Lake City	46.0	49.3	4.7	34.7	35.0	
116	Cherokee	Cherokee	25.8	72.3	1.9	40.6	34.0	
79	Chickasaw	Ionia	32.8	57.9	9.3	42.0	33.0	
125	Clay	Spencer	31.6	60.1	8.3			35.2
14	Clayton	McGregor		99.0	1.0		36.0	
13	Clayton	Elkader	37.8	60.8	1.4	46.0	39.0	
2	Clinton	DeWitt	56.4	38.6	5.0	42.0	33.0	
120	Clinton	DeWitt	54.9	42.5	2.6			32.9
48	Clinton	DeWitt	55.9	32.7	11.4	37.0	36.0	
44	Clinton	Wheatland	2.7	94.6	2.7	38.0	39.0	
42	Clinton	Clinton		99.9	.1	38.0	37.5	
41	Clinton	Albany	53.9	45.0	1.1	28.0	27.5	
37	Clinton	Clinton	84.3	15.1	0.6	32.5	32.5	
49	Crawford	Denison	37.0	60.4	2.6	33.0	38.0	
12	Decatur	Leon	5.8	91.2	3.0	41.0	37.0	
11	Decatur	DeKalb	4.3	91.7	4.0	38.0	39.0	
10	Decatur	Leon	8.6	89.6	1.8	42.0	40.0	
33	Delaware	Manchester	13.4	81.1	5.5	28.0	30.0	
35	Des Moines	Flint River Twp.	35.1	62.9	2.0	35.0	36.0	
16	Dubuque	Dubuque	0.7	97.8	1.5	38.0	34.0	
106	Emmet	Armstrong		91.0	9.0			
3	Fayette	Clermont	25.8	66.4	7.8	40.0	37.0	
5	Fayette	Clermont	33.1	56.7	10.2	46.0	42.0	
7	Fayette	Clermont	66.1	26.7	7.2	40.0	36.5	
17	Fayette	Clermont	48.7	50.8	0.5	38.0	36.0	
18	Fayette	Clermont	4.4	95.1	0.5	36.0	34.0	
34	Fayette	Oelwein	1.4	92.3	6.3	33.5	37.5	
81	Floyd	Charles City	32.6	60.7	6.7	39.0	28.0	
73	Floyd	Marble Rock	52.4	45.9	1.7	40.0	35.0	
92	Franklin	Hampton	40.1	55.4	4.5	45.0	31.0	
84	Franklin	Sheffield	22.3	72.7	5.0	40.0	33.0	
51	Greene	Grand Junction	30.9	65.1	4.0	32.5	32.2	
101	Greene	Grand Junction	24.8	72.0	3.2			37.0
102	Greene	Grand Junction	44.3	46.4	9.3			46.6
103	Greene	Grand Junction	30.7	67.1	2.2			34.0

TABLE NO. IV—CONTINUED

No.	Locality: County	Locality: Town	Mech. Anal. Per Cent: Pebbles	Sand	Clay	Per Cent Voids: Pebbles	Sand	Mixture
104	Greene	Grand Junction	37.6	59.2	3.2	-----	-----	32.0
50	Greene	Jefferson	17.6	81.0	1.4	34.0	37.0	-----
108	Greene	Jefferson	37.5	60.3	2.2	-----	-----	29.6
109	Greene	Jefferson	41.9	54.8	3.3	-----	-----	29.1
126	Greene	Jefferson	14.5	85.2	0.3	-----	-----	30.0
89	Grundy	Grundy Center	43.9	52.9	3.2	41.0	27.0	-----
71	Grundy	Wellsburg	42.1	45.4	12.5	43.0	30.0	-----
87	Hamilton	Kamrar	46.6	41.1	12.3	40.0	33.0	-----
88	Hamilton	Webster City	59.3	39.2	1.5	40.0	35.0	-----
90	Hamilton	Webster City	15.0	77.8	7.2	40.0	33.0	-----
93	Hardin	Ackley	44.6	50.9	4.5	41.0	34.0	-----
40	Hardin	Gifford	18.5	78.5	3.0	35.0	35.0	-----
94	Harrison	Pisgah	28.1	69.4	2.5	36.0	34.0	-----
80	Harrison	Missouri Valley	48.4	42.1	9.5	37.0	26.0	-----
115	Humboldt	Humboldt	-----	98.4	1.6	-----	35.0	-----
117	Humboldt	Humboldt	27.2	69.8	3.0	-----	-----	30.7
118	Humboldt	Humboldt	35.4	61.3	3.3	-----	-----	33.5
127	Humboldt	Humboldt	5.8	92.6	1.6	-----	-----	33.4
128	Humboldt	Humboldt	9.2	89.0	1.8	-----	-----	31.5
25	Ida	Ida Grove	10.1	87.6	2.3	42.0	30.0	-----
69	Iowa	South Amana	10.2	86.5	3.3	42.0	37.0	-----
1	Jackson	Maquoketa	15.8	82.5	1.7	38.0	35.0	-----
129	Jones	Oxford Junction	25.0	73.2	1.8	-----	-----	30.0
130	Jones	Oxford Junction	17.8	79.0	3.2	-----	-----	32.3
107	Kossuth	Algona	31.2	67.0	1.8	-----	34.5	-----
82	Lyon	Rock Rapids	25.4	65.1	9.5	37.0	31.0	-----
27	Lyon	Doon	23.8	74.3	1.9	38.0	32.0	-----
132	Madison	Sec. 19, Monroe Twp.	27.1	61.9	11.0	-----	-----	-----
38	Mahaska	Eddyville	23.9	74.7	1.4	34.0	35.0	-----
123	Mahaska	White City	-----	98.0	2.0	-----	33.0	-----
39	Marion	Tracy	10.8	84.9	4.3	33.0	33.0	-----
53	Marshall	Clemons	43.4	53.5	3.1	34.5	33.0	-----
95	Marshall	St. Anthony	46.6	53.4	-----	-----	-----	-----
119	Marshall	St. Anthony	54.7	42.8	2.5	-----	-----	28.8
8	Mills	Pacific Junction	11.8	86.5	1.7	34.0	34.0	-----
75	Mitchell	Osage	38.1	57.1	4.8	45.0	37.0	-----
91	Monona	Mapleton	9.0	85.3	5.7	43.0	30.0	-----
121	Monona	Blencoe	8.3	88.9	2.8	-----	-----	32.0
122	Monona	Rodney	14.8	84.0	1.2	-----	-----	36.0
6	Montgomery	Red Oak	7.5	88.9	3.6	41.0	40.0	-----
113	Muscatine	Muscatine	34.6	64.4	1.0	-----	-----	26.8
114	Muscatine	Muscatine	39.9	58.7	1.4	-----	-----	29.0
55	Muscatine	Muscatine	-----	94.0	6.0	38.0	39.0	-----
59	Muscatine	Nichols	8.4	84.8	6.8	37.0	35.0	-----
54	Muscatine	Orono Twp.	24.4	73.8	1.8	36.0	35.5	-----
74	O'Brien	Paullina	33.7	62.6	3.7	41.0	33.0	-----
20	Osceola	Sibley	21.7	70.5	7.8	42.0	29.0	-----
9	Page	Clarinda	4.6	93.5	1.9	44.0	37.0	-----
4	Plymouth	Le Mars	8.0	89.7	2.3	38.0	33.0	-----
110	Polk	Des Moines	7.4	90.8	1.8	-----	-----	31.1
22	Sac	Early	19.7	79.0	1.3	39.0	35.0	-----

TABLE NO. IV—CONTINUED

No.	Locality		Mech. Anal. Per Cent.			Per Cent Voids		
	County	Town	Pebbles	Sand	Clay	Pebbles	Sand	Mixture
52	Scott	Davenport	1.9	97.5	0.6	38.0	36.0	-----
62	Story	Ames	36.6	59.9	3.5	25.8	25.4	-----
86	Tama	Clutier	39.8	55.2	5.0	42.0	35.0	-----
64	Tama	Montour	23.7	73.0	3.3	40.0	33.0	-----
32	Van Buren	Farmington	24.2	73.8	2.0	37.0	36.0	-----
31	Van Buren	Farmington	12.8	86.6	0.6	37.0	34.0	-----
29	Wapello	Ottumwa	27.6	72.2	0.2	35.0	35.0	-----
131	Wapello	Ottumwa	90.1	9.9	-----	-----	-----	-----
58	Webster	Badger	33.0	56.6	10.4	33.0	32.0	-----
57	Webster	Fort Dodge	32.0	64.7	3.3	30.0	28.0	-----
19	Woodbury	Correctionville	21.3	75.6	3.1	41.0	36.0	-----
28	Woodbury	Correctionville	44.5	54.9	0.6	39.0	30.0	-----
72	Woodbury	Correctionville	23.7	73.8	2.5	39.0	34.0	-----
124	Woodbury	Sioux City	30.6	61.4	8.0	-----	-----	32.1
43	Worth	Hanlontown	42.6	52.3	5.1	35.0	34.2	-----
47	Worth	Hanlontown	38.6	57.6	3.8	27.0	26.0	-----
85	Wright	Dows	47.9	48.8	3.3	42.0	32.0	-----
83	Wright	Dows	24.7	70.0	5.3	38.0	30.0	-----
46	Wright	Eagle Grove	20.9	76.5	2.6	35.0	33.0	-----
45	Wright	Belmond	35.8	59.1	5.1	36.0	34.0	-----

TABLE NO. V.

ANALYSES OF LIMESTONES.

Location	Horizon	Composition						Authority
		Insoluble	Iron and alumina	Calcium carbonate	Magnesium carbonate	Sulphur trioxide	Moisture and organic matter	
Appanoose County—								
Rathbun	Des Moines	9.90	6.40	83.37	Trace	-------	-------	Lundteigen
Black Hawk County—								
Waterloo	Cedar Valley	1.92	4.20	63.59	30.92	-------	-------	C. E. Ellis
Bremer County—								
Waverly	Devonian	46.34	19.90	18.33	4.20	0.01	3.82	Lundteigen
Waverly	Devonian	2.25	1.32	88.65	6.70	-------	0.35	Lundteigen
Waverly	Devonian	7.74	1.67	86.80	2.35	0.86	1.08	C. E. Ellis
Section 36—Douglas township	Niagaran	1.53	0.48	54.32	43.41	-------	0.26	N. Knight
Quarter Section run	Wapsipinicon	0.71	-------	96.57	1.80	-------	0.51	N. Knight
Section 8—Polk township	Cedar Valley	3.28	2.12	55.23	39.03	-------	0.39	N. Knight
Buchanan County—								
Independence	Wapsipinicon	8.14	1.20	87.36	3.56	-------	0.02	A. O. Anderson
Cedar County—								
Cedar county	Otis	1.52	0.58	93.61	4.20	-------	-------	N. Knight
Rochester	Lower Davenport	0.86	0.30	96.91	1.93	-------	-------	N. Knight
Rochester	Lower Davenport	0.40	0.10	78.75	20.16	-------	-------	N. Knight
Rock Creek	Gower	0.12	0.26	55.76	43.85	-------	-------	N. Knight
Cedar Valley	Gower	0.40	0.70	56.40	42.60	-------	-------	N. Knight
Lime burning rock {Lime City	Gower	0.60	1.40	55.30	43.00	-------	-------	N. Knight
Lime burning rock {Cedar Valley	Gower	0.23	0.35	51.27	48.09	-------	-------	N. Knight

TABLE NO. V—CONTINUED

Location	Horizon	Composition						Authority
		Insoluble	Iron and alumina	Calcium carbonate	Magnesium carbonate	Sulphur trioxide	Moisture and organic matter	
Cedar Valley	Coggan	1.20	0.90	58.20	39.50	--------	--------	N. Knight
Cedar county	Otis	0.24	0.34	96.73	2.94	--------	--------	N. Knight
Cedar county	Wapsipinicon	18.66	2.00	58.21	21.00	--------	--------	N. Knight
Cerro Gordo County—								
Mason City	Cedar Valley	0.72	0.91	94.22	1.32	0.98	2.51	L. G. Michael
Mason City	Cedar Valley	0.63	0.71	97.48	0.99	--------	0.51	A. O. Anderson
Clarke County—								
Carpenter Quarry, Osceola	Missouri	8.64	1.54	88.92	0.62	--------	--------	A. O. Anderson
Carpenter Quarry, Osceola	Missouri	8.90	1.20	89.30	0.06	--------	0.28	A. O. Anderson
Carpenter Quarry, Osceola	Missouri	13.72	1.26	82.50	2.05	--------	0.59	A. O. Anderson
Des Moines County—								
Burlington	Osage	5.18	0.87	93.11	0.84	--------	--------	Geo. Steiger
Dubuque County—								
Cascade	Niagaran	11.34	0.81	48.53	37.34	--------	0.26	
Eagle Point—Lime burning rock	Galena	2.15	0.82	54.84	41.79	--------	0.02	L. G. Michael
Eagle Point—Nonlime burning rock	Galena	8.63	0.85	51.52	39.52	--------	0.04	L. G. Michael
Spechts Ferry—General sample	Platteville	5.00	2.07	89.64	1.72	0.85	--------	Lundteigen
Spechts Ferry	Platteville	8.98	2.58	73.65	12.18	--------	--------	Lundteigen
Spechts Ferry	Platteville	7.28	1.27	83.77	5.42	0.39	--------	Lundteigen
Spechts Ferry	Platteville	2.25	1.32	88.64	6.80	--------	--------	Lundteigen
Spechts Ferry	Platteville	7.50	6.17	79.50	3.97	1.48	0.15	L. G. Michael

Dubuque County—Con.								
Spechts Ferry	Platteville	7.94	12.05	73.38	3.52	1.69	0.10	L. G. Michael
Spechts Ferry	Platteville	10.71	6.69	78.67	0.28	1.51	0.15	L. G. Michael
Spechts Ferry	Platteville	11.24	6.31	78.51	0.24	1.58	0.10	L. G. Michael
Spechts Ferry	Platteville	5.74	6.69	83.56	0.25	1.77	0.10	L. G. Michael
Near Zollicoffer lake, north of Dubuque	Platteville	8.28	4.67	80.14	2.37	2.60	0.13	L. G. Michael
Near Zollicoffer lake, north of Dubuque	Platteville	8.02	5.78	77.93	4.43	0.22	0.16	L. G. Michael
Near Zollicoffer lake, north of Dubuque	Platteville	6.79	4.61	78.24	5.12	1.74	0.04	L. G. Michael
Near Zollicoffer lake, north of Dubuque	Platteville	3.85	6.03	84.16	1.93	0.64	1.71	L. G. Michael
Near Zollicoffer lake, north of Dubuque	Platteville	4.54	2.54	86.33	3.54	0.22	0.08	L. G. Michael
Near Zollicoffer lake, north of Dubuque	Platteville	3.26	0.83	90.20	2.65	1.64	0.06	L. G. Michael
Fayette County—								
Clermont	Maquoketa	11.95	2.80	84.80	0.45	—	—	L. G. Michael
Wilkes Williams' quarry, six miles south of Postville	Hopkinton	8.65	0.66	58.13	32.18	—	—	A. O. Anderson
Wilkes Williams' quarry, six miles south of Postville	Hopkinton	8.50	5.37	41.16	45.18	—	—	A. O. Anderson
Wilkes Williams' quarry, six miles south of Postville	Hopkinton	9.00	3.00	52.12	36.05	—	—	A. O. Anderson
Wilkes Williams' quarry, six miles south of Postville	Hopkinton	10.64	1.06	50.03	38.50	—	—	A. O. Anderson
Wilkes Williams' quarry, six miles south of Postville	Hopkinton	9.52	3.10	52.14	35.72	—	—	A. O. Anderson
Auburn	Hopkinton	0.68	0.50	98.52	—	—	—	L. G. Michael
Hamilton County—								
Webster City	Saint Louis	1.60	0.80	92.85	5.31	—	—	A. O. Anderson
Humboldt County—								
Humboldt	Kinderhook	0.50	1.12	97.20	2.00	—	—	A. O. Anderson
Near Gilmore	Saint Louis	—	—	99.62	—	—	—	J. B. Weems
Humboldt	Saint Louis	0.91	1.21	97.98	—	—	—	Murray

TABLE NO. V—CONTINUED

Location	Horizon	Composition: Insoluble	Iron and alumina	Calcium carbonate	Magnesium carbonate	Sulphur trioxide	Moisture and organic matter	Authority
Jackson County—								
Maquoketa	Hopkinton	0.58	0.36	30.88	21.56	-------	-------	C. E. Ellis
Maquoketa	Hopkinton	0.51	0.47	30.56	21.54	-------	-------	C. E. Ellis
Johnson County—								
Iowa City	Cedar Valley	3.08	1.97	89.79	4.66	0.06	-------	Geo. Steiger
Jones County—								
J. A. Green, Stone City	Gower, Anamosa	0.97	0.42	57.19	41.44	-------	-------	A. O. Anderson
J. A. Green, Stone City	Gower, Anamosa	2.00	1.20	56.00	40.98	-------	-------	A. O. Anderson
J. A. Green, Stone City	Gower, Anamosa	4.46	1.70	56.08	37.80	-------	-------	A. O. Anderson
J. A. Green, Stone City	Gower, Anamosa	0.20	0.72	56.57	52.59	-------	-------	A. O. Anderson
J. A. Green, Stone City	Gower, Anamosa	1.20	0.50	58.86	39.58	-------	-------	A. O. Anderson
J. A. Green, Stone City	Gower, Anamosa	1.88	1.02	51.64	44.76	-------	-------	A. O. Anderson
J. A. Green, Stone City	Gower, Anamosa	0.96	0.72	63.56	34.76	-------	-------	A. O. Anderson
J. A. Green, Stone City	Gower, Anamosa	0.78	0.54	52.12	46.98	-------	-------	A. O. Anderson
J. A. Green, Stone City	Gower, Anamosa	1.13	1.50	58.21	38.60	-------	-------	A. O. Anderson
Dearborn & Sons, Stone City	Gower, Anamosa	1.97	0.89	55.68	41.53	-------	-------	A. O. Anderson
Dearborn & Sons, Stone City	Gower, Anamosa	2.05	0.37	54.64	43.35	-------	-------	A. O. Anderson
Dearborn & Sons, Stone City	Gower, Anamosa	1.70	0.60	55.70	41.74	-------	-------	A. O. Anderson
Dearborn & Sons, Stone City	Gower, Anamosa	1.90	1.43	56.60	39.97	-------	-------	A. O. Anderson
Dearborn & Sons, Stone City	Gower, Anamosa	2.00	0.40	55.18	41.70	-------	-------	A. O. Anderson
Louisa County—								
Morning Sun	-------	1.60	1.20	97.02	0.32	-------	-------	A. O. Anderson

Madison County—								
Earlham	Bethany	7.85	1.00	91.15	0.61	--------	--------	L. G. Michael
Peru	Bethany	17.16	2.64	72.76	2.86	0.95	0.30	L. G. Michael
Earlham	Missouri	10.92	2.37	84.87	1.58	--------	--------	Geo. Steiger
Winterset	Missouri	12.63	1.18	84.34	2.19	--------	0.02	A. O. Anderson
Mahaska County—								
Oskaloosa	Saint Louis	4.01	0.59	95.30	--------	--------	--------	Murray
Marion County—								
Tracy	Saint Louis	1.57	0.66	94.60	6.66	--------	--------	Murray
Pella	Saint Louis	4.92	3.39	84.39	--------	--------	--------	Lundteigen
Marshall County—								
Oolite. Quarry	Kinderhook	0.77	0.18	98.30	0.59	--------	0.16	G. E. Patrick
Blue limestone. Quarry	Kinderhook	0.96	0.41	97.95	0.38	--------	0.30	G. E. Patrick
Iowa caen stone. Quarry	Kinderhook	1.24	0.50	90.28	7.77	--------	0.21	G. E. Patrick
Stratified limestone. Quarry	Kinderhook	1.22	0.50	90.04	8.08	--------	0.16	G. E. Patrick
Mitchell County—								
Osage	Cedar Valley	0.78	0.12	98.01	0.15	--------	--------	A. O. Anderson
Osage	Cedar Valley	0.12	0.12	98.01	0.15	--------	0.35	A. B. Hoen
Osage	Cedar Valley	2.21	3.82	90.17	1.03	--------	2.63	A. O. Anderson
Montgomery County—								
Stennett	Missouri	7.97	1.26	89.44	1.92	--------	--------	A. O. Anderson
Scott County—								
Bettendorf	Wapsipinicon	4.46	0.70	79.60	15.40	--------	--------	C. E. Ellis
LeClaire Stone Co., Bettendorf	Wapsipinicon	2.36	2.20	94.57	0.81	--------	--------	C. E. Ellis
LeClaire Stone Co., Bettendorf	Wapsipinicon	0.54	0.14	98.49	0.72	--------	--------	C. E. Ellis
Bettendorf	Wapsipinicon	1.04	0.28	90.00	8.36	--------	--------	C. E. Ellis
Bettendorf	Wapsipinicon	8.48	0.72	89.25	1.42	--------	--------	C. E. Ellis
Bettendorf	Wapsipinicon	26.40	9.25	44.82	10.84	--------	8.82	C. E. Ellis
Bettendorf	Wapsipinicon	16.08	3.26	49.72	29.06	--------	1.86	C. E. Ellis
Bettendorf	Wapsipinicon	5.98	0.30	90.91	2.77	--------	--------	C. E. Ellis
Bettendorf	Wapsipinicon	1.32	0.38	76.23	22.21	--------	--------	C. E. Ellis
Bettendorf	Wapsipinicon	1.10	0.34	80.95	17.68	--------	--------	C. E. Ellis
Bettendorf	Wapsipinicon	1.20	1.08	97.32	0.76	--------	--------	C. E. Ellis

TABLE NO. V—CONTINUED

Location	Horizon	Composition						Authority
		Insoluble	Iron and alumina	Calcium carbonate	Magnesium carbonate	Sulphur trioxide	Moisture and organic matter	
Scott County—Con.								
LeClaire Stone Co., LeClaire	Gower, Anamosa	4.76	1.22	58.72	35.38			A. O. Anderson
LeClaire Stone Co., LeClaire	Gower, Anamosa	7.44	1.37	51.55	40.36			A. O. Anderson
LeClaire Stone Co., LeClaire	Gower, Anamosa	5.60	1.40	53.96	39.00			A. O. Anderson
LeClaire Stone Co., LeClaire	Gower, Anamosa	7.08	1.24	53.17	35.03			A. O. Anderson
Sioux County—								
Hawarden	Cretaceous	21.92	6.68	64.30	5.38			Newberry
Taylor County—								
Fred Andrews, Bedford	Missouri	1.80	3.20	93.56	1.54			A. O. Anderson
Fred Andrews, Bedford	Missouri	1.48	0.48	97.42	1.14			A. O. Anderson
Fred Andrews, Bedford	Missouri	1.20	0.70	96.96	1.28			A. O. Anderson
Van Buren County—								
West of Farmington	Saint Louis	10.14	0.90	88.73	0.38		0.15	C. E. Ellis
Chequest creek, Keosauqua	Saint Louis	3.12	1.38	94.81	0.52		0.26	A. O. Anderson
Upper twenty feet of limestone east of Bentonsport	Saint Louis	5.28	0.52	93.34	1.00		0.20	C. E. Ellis
Wapello County—								
Ottumwa	Saint Louis	6.83	2.66	88.43	0.15	0.13		Geo. Steiger
Winneshiek County—								
Decorah	Galena	14.53	6.49	72.89	1.03	0.48	0.15	L. G. Michael
Decorah	Galena	3.86	2.54	91.19	0.84		0.05	L. G. Michael
Decorah	Galena	6.87	1.00	88.97	2.86		0.30	C. E. Ellis

TABLE

DETAILED MECHANICAL ANALYSES OF SANDS AND GRAVELS SHOW AND KAME

THE TABLE GIVES AMOUNTS IN PER CENTS RETAINED ON SIEVES RANGING FROM THE ARE ARRANGED ALPHABE

No.	County	Town	2½ in.	1¼ in.	1 in.	¾ in.	½ in.	¼ in.
15	Allamakee	Lansing				6.44	4.37	12.69
65	Benton	Vinton					3.75	9.50
66	Benton	Vinton		1.94		6.25	9.94	10.92
67	Benton	Vinton					0.75	4.37
70	Black Hawk	Cedar Falls					4.50	8.25
56	Boone	Frazer						2.56
63	Boone	Pilot Mound		1.87		1.87	2.00	11.75
68	Bremer	Waverly					4.75	16.11
36	Buchanan	Independence					6.81	5.75
23	Buena Vista	Sioux Rapids					11.25	8.81
78	Buena Vista	Storm Lake				4.12	7.25	9.44
76	Butler	Dumont	9.95	2.10		7.06	6.00	8.75
105	Butler	Shell Rock						
61	Calhoun	Lake City		3.75		4.50	5.00	14.63
116	Cherokee	Cherokee					5.90	7.40
79	Chickasaw	Ionia		3.06		2.50	4.00	9.38
125	Clay	Langdon			5.99		12.08	13.56
14	Clayton	McGregor						
13	Clayton	Elkader		14.88		7.25	2.38	6.06
2	Clinton	DeWitt		20.13		12.69	3.25	8.00
48	Clinton	DeWitt				3.13	5.31	16.00
120	Clinton	DeWitt					31.70	12.60
44	Clinton	Wheatland						1.18
42	Clinton	Clinton						
37	Clinton	Clinton		4.32		18.37	10.25	26.12
41	Clinton	Albany		2.80		13.10	7.40	17.10
49	Crawford	Denison		2.25		0.75	3.19	11.63
12	Decatur	Leon						2.44
11	Decatur	DeKalb					1.25	1.37
10	Decatur	Leon					3.25	1.56
33	Delaware	Manchester					2.12	4.44
35	Des Moines	Sec. 19, Flint River		6.25		10.25	3.87	7.50
16	Dubuque	Dubuque						0.38
106	Emmet	Armstrong						
3	Fayette	Clermont				5.87	1.44	5.88
5	Fayette	Clermont		16.75		3.75	1.94	6.00
7	Fayette	Clermont		8.69		15.06	8.37	18.63
17	Fayette	Clermont		11.44		7.38	5.25	9.38
18	Fayette	Clermont					0.38	1.19
34	Fayette	Oelwein						
81	Floyd	Charles City		9.64		0.00	2.13	3.56
73	Floyd	Marble Rock		3.69		4.00	3.56	19.25
92	Franklin	Hampton				9.25	7.37	11.93
84	Franklin	Sheffield				4.12	2.50	7.05
51	Greene	Grand Junction				1.38	3.19	11.37
101	Greene	Grand Junction						10.13
102	Greene	Grand Junction						26.60
103	Greene	Grand Junction						18.13
104	Greene	Grand Junction						23.13

NO. VI.

ING THE REMARKABLE VARIATIONS IN PIT RUN OF TERRACE, RIVER MATERIALS.

TWO AND ONE-HALF INCH DOWN TO ONE-SIXTIETH INCH MESH. THE ANALYSES TICALLY BY COUNTIES.

$\frac{1}{8}$ in.	$\frac{1}{10}$ in.	$\frac{1}{16}$ in.	$\frac{1}{20}$ in.	$\frac{1}{30}$ in.	$\frac{1}{40}$ in.	$\frac{1}{50}$ in.	$\frac{1}{60}$ in.	Remarks
14.50	5.75	10.44	7.12	18.75	14.25	------	2.69	
7.75	3.00	26.76	9.75	14.62	20.75	------	16.90	
13.89	5.75	7.19	6.82	8.34	15.81	------	9.37	
8.75	4.50	9.00	6.56	13.26	27.30	------	10.05	
12.20	6.68	9.87	8.12	12.69	22.40	------	10.05	
3.00	1.25	3.19	4.63	10.94	33.94	------	19.50	
14.00	5.50	6.25	8.50	11.62	15.25	------	8.12	
24.79	6.87	8.12	5.44	7.50	13.26	------	7.68	
5.81	1.00	5.56	3.25	16.00	38.25	------	6.43	1½ mile E. of town.
13.50	7.31	15.37	7.69	20.31	8.12	------	2.75	From J. K. Salverson.
9.68	3.81	4.81	6.00	9.44	26.28	------	10.25	
8.00	4.00	6.56	6.00	7.25	8.12	------	3.60	
------	17.50	------	18.60	21.30	------	33.30	------	4 miles S. E. of town.
18.12	8.12	12.63	8.38	8.63	9.13	------	2.75	NW. NE. 7-86-33.
12.50	11.20	------	21.90	17.50	0.70	12.50	------	Cherokee S. & G. Co.
13.89	7.19	14.44	8.81	14.62	11.00	------	3.75	
------	------	25.08	------	14.78	7.99	------	------	Sent by County Engineer.
------	------	------	0.19	4.63	40.25	------	29.56	St. Peter sandstone.
7.25	3.75	6.13	4.06	10.06	22.25	------	9.13	Terrace gravel.
12.38	7.38	15.50	6.56	5.13	2.69	------	1.06	Esker gravel, city pit.
31.50	7.06	17.00	5.25	4.12	3.00	------	2.06	Esker gravel, city pit.
10.60	------	13.20	------	16.30	------	------	12.90	From A. R. Boudinot.
1.50	1.43	0.81	10.81	28.75	29.40	------	11.75	Wapsipinicon river sand.
------	0.10	0.05	1.60	11.10	58.90	------	19.10	Mississippi river sand.
25.25	6.06	5.94	2.50	0.12	0.12	------	0.12	From Smith & Oakes.
13.50	3.25	3.60	9.70	12.00	11.25	------	3.60	
19.25	9.75	18.56	11.25	14.31	5.50	------	1.50	From Mills & Son.
3.37	1.88	3.81	3.75	8.37	34.69	------	25.63	
1.69	1.06	4.06	4.13	23.69	32.87	------	20.12	Pit of Geo. South.
3.81	2.00	5.38	5.06	13.19	36.56	------	18.00	
6.87	2.25	5.87	5.00	10.88	14.75	------	11.06	
7.25	3.25	4.25	11.87	13.56	24.25	------	4.13	From Dunn farm.
0.38	0.31	1.44	6.69	25.13	45.19	------	9.19	Mississippi river terrace.
------	51.20	------	31.40	9.70	3.70	1.40	------	
12.63	8.25	27.44	13.38	15.00	4.06	------	1.63	Buchanan gravel.
4.69	2.31	5.63	4.81	10.12	24.63	------	10.12	Buch. pit of W. Williams.
15.37	5.19	9.44	4.75	6.38	3.75	------	1.25	Used on streets.
15.25	7.19	12.81	7.81	12.13	7.81	------	1.56	Stahl's pit.
2.81	2.56	9.31	10.88	35.25	32.56	------	3.38	Finishing sand, Stahl's.
1.44	0.62	1.87	2.50	8.25	34.32	------	29.18	From Ira Hanson.
17.26	6.87	9.14	9.50	14.00	15.25	------	6.18	
21.86	9.00	14.60	6.00	7.75	5.63	------	2.00	
11.57	4.00	5.94	8.00	6.50	16.00	------	7.50	
8.66	4.62	8.12	8.00	19.00	21.75	------	7.31	
15.00	7.31	12.50	12.00	13.06	11.25	------	5.88	
14.66	------	25.20	------	24.66	------	------	18.93	C. & N. W. pit. Note
17.66	------	19.66	------	22.00	------	------	10.13	the wide variation
12.60	------	16.60	------	21.33	------	------	23.60	in samples from
14.53	------	23.33	------	20.83	------	------	13.00	the same place.

TABLE NO. VI—

No.	County	Town	$2\frac{1}{2}$ in.	$1\frac{1}{2}$ in.	1 in.	$\frac{3}{4}$ in.	$\frac{1}{2}$ in.	$\frac{1}{4}$ in.
50	Greene	Jefferson					3.00	5.75
108	Greene	Jefferson					7.30	10.50
109	Greene	Jefferson					8.50	15.00
126	Greene	Jefferson						5.20
89	Grundy	Grundy Center		16.69		4.25	1.50	7.00
71	Grundy	Wellsburg		15.25		6.38	5.25	7.37
87	Hamilton	Kamrar		12.50		5.06	7.44	10.25
88	Hamilton	Webster City				5.75	10.56	21.36
90	Hamilton	Webster City						4.00
40	Hardin	Gifford					4.70	5.75
93	Hardin	Ackley				10.31	7.38	12.00
94	Harrison	Pisgah		6.44		2.50	1.50	6.75
80	Harrison	Missouri Valley				10.81	9.13	12.50
115	Humboldt	Humboldt						
117	Humboldt	Humboldt			6.80		3.80	6.70
118	Humboldt	Humboldt			2.60		5.10	10.30
127	Humboldt	Humboldt						1.30
128	Humboldt	Humboldt						2.50
25	Ida	Ida Grove					1.81	2.50
69	Iowa	South Amana						2.81
1	Jackson	Maquoketa					2.25	4.12
129	Jones	Oxford Junction						9.00
130	Jones	Oxford Junction						6.00
107	Kossuth	Algona					5.90	8.50
82	Lyon	Rock Rapids				1.75	4.00	8.88
27	Lyon	Doon				3.81	3.88	6.37
132	Madison	Monroe Twp.						10.37
38	Mahaska	Eddyville					4.87	7.06
123	Mahaska	White City						
39	Marion	Tracy				1.80	1.00	3.00
53	Marshall	Clemons				3.50	7.31	15.50
95	Marshall	St. Anthony				7.94	8.42	12.72
119	Marshall	St. Anthony						34.80
8	Mills	Pacific Junction					1.75	3.00
75	Mitchell	Osage		9.13		5.94	2.63	8.25
91	Monona	Mapleton						3.12
121	Monona	Blencoe						8.30
122	Monona	Rodney						6.70
6	Montgomery	Red Oak					0.88	1.50
113	Muscatine	Muscatine					14.00	9.40
114	Muscatine	Muscatine					7.36	14.75
55	Muscatine	Muscatine						
59	Muscatine	Nichols						2.94
54	Muscatine	Bet. 20-21, Orono Tp.				3.87	5.19	6.25
74	O'Brien	Paullina					4.00	10.95
20	Osceola	Sibley						
9	Page	Clarinda						1.81
4	Plymouth	Le Mars						0.38
110	Polk	Des Moines					1.10	6.30
22	Sac	Early					4.25	5.88
21	Sac	Sac City					9.25	10.25
52	Scott	Davenport						0.69
62	Story	Ames		10.00		3.38	2.87	8.87
86	Tama	Clutier		3.50		7.00	5.31	10.44
64	Tama	Montour						3.44

CONTINUED

$\frac{1}{8}$ in.	$\frac{1}{10}$ in.	$\frac{1}{16}$ in.	$\frac{1}{20}$ in.	$\frac{1}{30}$ in.	$\frac{1}{40}$ in.	$\frac{1}{50}$ in.	$\frac{1}{60}$ in.	Remarks
8.81	5.69	9.00	10.31	15.31	27.50	------	9.25	Raccoon river sand.
19.70	------	20.40	------	19.70	------	18.10	------	W. end 'Coon river bridge.
18.40	------	15.10	------	14.10	------	17.60	------	E. end 'Coon river bridge.
9.30	9.80	------	23.80	15.80	13.30	11.10	------	Pit of A. S. Tanner.
14.50	6.56	7.69	6.06	6.55	14.68	------	6.94	
7.87	4.13	7.56	8.33	12.38	12.50	------	7.37	
11.30	5.37	6.75	7.37	8.87	9.75	------	4.87	
21.61	8.25	11.38	6.44	4.94	4.44	------	2.13	
11.00	7.50	15.75	9.36	12.00	23.12	------	6.13	
8.10	4.00	5.30	11.10	23.60	25.25	------	5.40	From R. A. Fuller Co.
14.90	4.75	12.00	6.56	9.00	11.25	------	4.50	
10.91	6.68	11.89	11.50	20.30	15.70	------	3.50	
16.00	11.34	15.57	10.25	9.81	3.44	------	1.50	
------	22.70	------	20.50	19.50	18.40	11.30	------	From C. D. Walter.
9.90	3.70	------	19.70	26.00	9.60	3.80	------	From County Engineer.
17.40	5.60	------	17.30	11.70	12.40	6.90	4.50	From County Engineer.
4.50	4.50	------	14.70	22.50	24.30	15.40	------	Hum. Cem. Prod. Co.
6.70	7.30	------	33.20	26.70	10.00	4.90	------	Hum. Cem. Prod. Co.
5.18	3.31	7.13	6.00	13.50	30.44	------	9.94	Ida Grove Concrete Co.
7.36	4.52	9.50	10.43	22.00	25.68	------	7.31	
9.44	4.50	10.38	9.19	29.25	19.87	------	4.48	
16.00	9.50	------	14.70	13.50	20.80	10.50	------	} From G. Ahlff & Sons
11.80	8.10	------	13.30	14.80	25.50	11.20	------	} Grand Mound.
16.79	------	21.49	------	26.10	------	15.32	------	G. J. Ferguson pit.
10.81	4.87	8.00	9.56	17.44	21.93	------	9.63	
9.75	4.69	8.94	6.25	15.94	28.19	------	6.38	Miller & Montgomery.
16.69	7.59	------	27.75	16.48	8.91	3.86	2.60	Washed sand.
11.95	6.68	11.38	16.75	15.25	16.56	------	5.19	
------	20.00	------	13.00	14.10	17.10	14.80	------	From H. R. Baker.
5.00	3.00	4.30	8.80	16.85	33.60	------	10.35	
17.13	6.94	9.87	8.75	9.31	10.25	------	4.56	From O. L. Lundon.
17.57	6.55	9.92	6.72	6.72	12.95	------	3.44	
19.90	------	18.00	------	13.20	------	9.30	------	Sent by Co. Board.
7.00	5.00	14.44	10.63	16.31	26.25	------	6.25	
12.20	4.75	7.19	9.25	13.65	16.45	------	7.06	
5.88	5.13	16.56	16.39	20.00	24.21	------	4.43	
------	31.80	------	23.00	15.00	11.60	5.50	------	Sent by L. I. Hicks.
8.12	10.33	------	19.40	16.58	17.38	11.95	------	
5.13	4.88	18.00	9.00	31.38	22.31	------	4.81	
11.20	7.00	------	21.00	24.00	------	12.00	------	Mississippi river sand.
17.80	------	21.89	------	25.19	------	11.11	------	Mississippi river sand.
------	0.44	0.31	3.06	13.63	55.31	------	16.50	
5.44	4.50	8.00	12.62	26.62	31.69	------	6.44	Ry. bridge in 16, Lake.
9.13	5.50	10.94	9.44	16.75	22.06	------	4.56	
18.75	10.95	8.50	7.88	11.25	16.70	------	7.75	
21.69	11.25	19.63	10.00	14.00	14.00	------	2.69	Sibley Cement Co.
2.81	1.75	4.81	4.63	13.06	32.00	------	26.25	
7.68	3.81	8.06	7.00	25.56	29.75	------	8.56	Kramer pit.
------	13.50	------	12.30	18.30	------	37.10	------	
9.63	5.06	11.50	9.13	19.19	24.75	------	4.56	Early Con. & Stone Co.
14.50	6.69	12.44	9.19	15.19	14.87	------	3.44	From E. W. Robbins.
1.25	1.00	2.95	3.00	15.56	48.37	------	16.00	Mississippi river sand.
11.50	5.00	7.13	6.50	9.12	17.50	------	6.00	College pit.
13.57	5.94	15.50	9.32	9.80	6.75	------	4.31	
20.26	13.75	5.37	5.32	13.50	8.38	------	1.31	

TABLE NO. VI—

No.	County	Town	2½ in.	1¼ in.	1 in.	⅜ in.	½ in.	¼ in.
32	Van Buren	Farmington	----	------	------	------	------	15.56
31	Van Buren	Farmington	----	------	------	------	------	4.81
29	Wapello	Ottumwa	----	------	------	------	------	9.88
131	Wapello	Ottumwa	----	------	------	------	81.30	5.90
57	Webster	Ft. Dodge	----	------	------	2.12	2.81	11.69
58	Webster	Badger	----	------	------	1.19	1.50	7.63
19	Woodbury	Correctionville	----	------	------	------	6.63	5.94
28	Woodbury	Correctionville	----	------	------	------	5.31	16.75
72	Woodbury	Correctionville	----	------	------	3.80	4.63	7.44
124	Woodbury	Sioux City	----	------	------	------	0.84	9.00
43	Worth	Hanlontown	----	------	------	9.06	6.69	13.25
47	Worth	Hanlontown	----	9.00	------	6.94	5.56	8.44
85	Wright	Dows	7.75	0.00	------	11.70	3.50	10.88
83	Wright	Dows	----	------	------	8.68	3.63	5.63
46	Wright	Eagle Grove	----	------	------	------	------	6.19
45	Wright	Belmond	----	4.25	------	3.63	5.25	9.38

CONTINUED

$\frac{1}{8}$ in.	$\frac{1}{10}$ in.	$\frac{1}{15}$ in.	$\frac{1}{20}$ in.	$\frac{1}{30}$ in.	$\frac{1}{40}$ in.	$\frac{1}{50}$ in.	$\frac{1}{60}$ in.	Remarks
8.69	4.63	9.19	9.50	28.50	17.75	------	2.81	
8.00	8.50	23.25	13.50	27.94	9.13	------	2.31	Des Moines river sand.
17.75	10.75	20.50	11.50	19.00	6.69	------	2.50	Des Moines river sand.
2.90	0.65	0.80	0.30	2.10	3.48	1.52	0.55	From G. L. Bissell.
15.38	6.63	9.81	10.25	11.25	14.72	------	7.19	
22.69	10.62	17.50	9.38	10.25	7.81	------	2.69	Center of 10, Deer Creek.
8.75	4.87	11.25	10.56	31.88	13.12	------	3.63	Gilleas pit.
22.44	8.25	12.31	5.81	8.00	7.81	------	5.69	Jno. Fleming pit.
7.80	3.88	6.19	7.31	11.85	22.61	------	10.54	
13.20	6.60	11.90	3.80	10.10	10.00	7.70	8.10	From Co. Engineer.
13.62	5.25	0.12	18.87	9.12	12.62	------	5.00	Sec. 28, Danville.
8.63	5.13	3.50	12.12	11.12	14.56	------	6.75	Sec. 29, Danville Twp.
14.13	6.75	8.00	9.68	9.32	11.25	------	6.31	
6.74	3.50	5.55	7.75	12.56	30.18	------	6.62	
14.75	8.00	11.81	15.00	14.00	16.50	------	7.17	Boone river sand.
13.31	6.00	8.12	14.00	13.50	12.75	------	3.62	

TABLE NO. VII.

COMMERCIAL DIRECTORY OF IOWA STONE PRODUCERS.

*Indicates those producing crushed stone.

Owner	Location of Office	Location of Quarry	Geological Horizon	Kind of Stone
Allamakee County—				
A. V. Fetter	Quincy, Ill.	Lansing	Oneota	Dolomite
C. F. Nagle	Lansing	Lansing	Oneota	Dolomite
*Albert Simons	Waukon	Waukon	Platteville	Limestone
Appanoose County—				
*Wm. B. Swan	Plano	Piano	Des Moines	Limestone
Benton County—				
*W. O. Rambo	Shellsburg	Shellsburg	Cedar Valley	Limestone
Black Hawk County—				
Jens Nielsen	Cedar Falls (1807 Washington)	Cedar Falls	Cedar Valley	Limestone
*E. J. Buchan	Laporte City	Laporte City	Cedar Valley	Limestone
*Bartlett & McFarlane	Waterloo (1165 E. 4th)	Waterloo	Cedar Valley	Limestone
*Waterloo Dredging Co.	Waterloo	Waterloo	Cedar Valley	Limestone
Buchanan County—				
A. B. Kieffer	Hazelton	Hazelton	Hopkinton	Dolomite
Cedar County—				
*Cedar Valley Stone Co.	Cedar Rapids	Cedar Valley	Anamosa	Dolomite
Cerro Gordo County—				
*Henry Kuppinger	Mason City	Mason City	Cedar Valley	Limestone and dolomite
Quimby Stone & Fuel Co.	Mason City	Mason City	Cedar Valley	Limestone and dolomite

43

Clayton County—				
Daniel Ivory	Elkader	Elkader	Platteville	Limestone
J. A. Hempeler	Garnavillo	Garnavillo	Galena	Limestone
E. W. & H. D. Kregel	Garnavillo	Garnavillo	Galena	Limestone
Matthias Burr	Guttenberg	Guttenberg	Platteville	Limestone
A. C. Boyle	McGregor	McGregor	Platteville	Limestone
*Chas. M. Brooks	McGregor	McGregor	Platteville	Limestone
Decatur County—				
*Davis City Stone Crusher Co.	Davis City	Davis City	Missouri	Limestone
Delaware County—				
Jas. A. Johnson	Hopkinton	Hopkinton	Hopkinton	Dolomite
McGlade Bros.	Hopkinton	Hopkinton	Hopkinton	Dolomite
Des Moines County—				
A. V. Fetter	Quincy, Ill.	Burlington	Osage	Limestone
Albert Kirchner	Fountain City, Wis.	Burlington	Osage	Limestone
*Geo. J. Koestner	Burlington	Burlington	Osage	Limestone
Albert Bitsche	Middletown	Middletown	Osage	Limestone
Dubuque County—				
*John Becker	Dubuque	Dubuque	Galena	Dolomite
*Byrne & Saul	Dubuque	Dubuque	Galena	Dolomite
*Eagle Point Lime Works	Dubuque	Dubuque	Galena	Dolomite
*O'Farrell Contracting Co.	Dubuque	Dubuque	Galena	Dolomite
E. P. Sawyer	Dubuque	Dubuque	Galena	Dolomite
Anthony Siege	Dubuque	Dubuque	Galena	Dolomite
Thos. Welsh	Dubuque	Dubuque	Galena	Dolomite
*B. N. Arquitt & Sons	Farley	Farley	Hopkinton	Dolomite
*Tibey Bros.	Dubuque	Julian	Galena	Dolomite
Fayette County—				
Wilkes Williams	Postville	Postville	Hopkinton	Dolomite
J. W. Bopp	West Union	West Union	Devonian	Limestone
Floyd County—				
Geo. W. Kuhnle	Charles City	Charles City	Cedar Valley	Limestone

TABLE NO. VII—CONTINUED

Owner	Location of Office	Location of Quarry	Geological Horizon	Kind of Stone
Hardin County—				
*Bryant-McLaughlin Asph'lt Pav. Co.	Waterloo	Iowa Falls	Kinderhook	Limestone and dolomite
*Ellsworth Stone Co.	Iowa Falls	Iowa Falls	Kinderhook	Limestone and dolomite
Harrison County—				
C. F. Peckenpaugh & Sons	Logan	Logan	Missouri	Limestone
Henry County—				
*Victor McGuire	Mt. Pleasant	Mt. Pleasant	Saint Louis	Limestone
Howard County—				
*Cresco Stone & Concrete Co.	Cresco	Cresco	Wapsipinicon	Dolomitic limestone
Johnson County—				
*Wesley J. Lorence	Solon	Solon	Anamosa	Dolomite
Jones County—				
State Reformatory (Charles C. McCloughry, Warden)	Anamosa	Anamosa	Anamosa	Dolomite
A. M. Henry	Anamosa	Anamosa	Anamosa	Dolomite
Albert Osborne	Hale	Hale	Anamosa	Dolomite
*H. Dearborn & Sons	Stone City	Stone City	Anamosa	Dolomite
*F. Erickson Co.	Stone City	Stone City	Anamosa	Dolomite
*J. A. Green & Sons	Stone City	Stone City	Anamosa	Dolomite
*John Ronen	Stone City	Stone City	Anamosa	Dolomite
Keokuk County—				
Frank Manion	Sigourney	Sigourney	Saint Louis	Limestone
*Russell B. Royce	Sigourney	Sigourney	Saint Louis	Limestone

Lee County—				
*McManus & Tucker	Keokuk	Ballinger	Osage	Limestone
*Cameron & McManus	Keokuk	Keokuk	Osage	Limestone
A. V. Fetter	Quincy, Ill.	Keokuk	Osage	Limestone
Harrison & Dietz	Keokuk	Keokuk	Osage	Limestone
*Keokuk Ry. & Construction Co.	Keokuk	Keokuk	Osage	Limestone
Mississippi River Power Co.	Keokuk	Keokuk	Osage	Limestone
C. F. Nagle	Lansing	Keokuk	Osage	Limestone
*Burlington Quarry Co.	Keokuk	Montrose	Osage	Limestone
August Beach	West Point	West Point	Saint Louis	Limestone
Linn County—				
*C. & N. W. Railway	Chicago, Ill.	Cedar Rapids	Wapsipinicon	Limestone
*Dolese Bros. Co.	Chicago, Ill. (128 N. La Salle)	Cedar Rapids	Wapsipinicon	Limestone
*Ellis Park Stone Co.	Cedar Rapids	Cedar Rapids	Wapsipinicon	Limestone
*J. E. Colton	Mt. Vernon	Mt. Vernon	Anamosa	Dolomite
Louisa County—				
W. C. Bryant	Morning Sun	Morning Sun	Osage	Limestone
*Chas. B. Wilson	Morning Sun	Morning Sun	Osage	Limestone
Madison County—				
*Earlham Land Co.	Des Moines	Earlham	Missouri	Limestone
*Peru Stone & Cement Co.	East Peru	East Peru	Missouri	Limestone
*W. A. Hartman	Winterset	Winterset	Missouri	Limestone
*Southern Iowa Stone Co.	Winterset	Winterset	Missouri	Limestone
Mahaska County—				
H. E. Whitlatch	Beacon	Givin	Saint Louis	Limestone
Marshall County—				
*Dolese Bros. Co.	Chicago, Ill.	LeGrand	Kinderhook	Limestone
*C. & N. W. Railway	Chicago, Ill.	LeGrand	Kinderhook	Limestone
Mitchell County—				
Iowa Sugar Co.	Waverly	Osage	Cedar Valley	Limestone
A. E. Parmelee	Osage	Osage	Cedar Valley	Dolomite

TABLE NO. VII—CONTINUED

Owner	Location of Office	Location of Quarry	Geological Horizon	Kind of Stone
Pocahontas County—				
*Ft. Dodge Portland Cement Corp.	Fort Dodge	Gilmore City	Saint Louis	Limestone
Scott County—				
*Boland Stone Co.	Bettendorf	Bettendorf	Wapsipinicon	Limestone
*Bettendorf Stone Co.	Davenport	Bettendorf	Wapsipinicon	Limestone
G. W. Randall	Big Rock	Big Rock	Gower	Limestone
*Dolese Bros. Co.	Chicago, Ill.	Buffalo	Wapsipinicon	Argillaceous Limestone
*Linwood Quarries Co.	Davenport	Buffalo	Wapsipinicon	Argillaceous Limestone
*LeClaire Stone Co.	Davenport	LeClaire	Anamosa	Dolomite
		Bettendorf	Wapsipinicon	Limestone
Tama County—				
P. C. Smith	Montour	Montour	Kinderhook	Oolitic limestone
Van Buren County—				
*Hinkle Estate	Selma	Selma	Saint Louis	Limestone
Wapello County—				
Eddyville Stone Co.	Eddyville	Eddyville	Saint Louis	Limestone
*Chas. Chilton	Ottumwa	Ottumwa	Saint Louis	Limestone
Winneshiek County—				
John A. Vold	Decorah	Decorah	Galena-Plat'ville	Limestone
Maurice Halloran	Decorah	Decorah	Galena	Limestone

TABLE VIII.

DIRECTORY OF IOWA SAND AND GRAVEL PRODUCERS.

Owner	Location of Office	Location of Pit	Character of Deposit	Products
Black Hawk County—				
Bartlett & McFarlane	Waterloo	Waterloo	River	Sand
Geo. W. Pett	Waterloo	Waterloo	River	Sand
J. E. Sedgwick	Waterloo	Waterloo	River	Sand
Cement Products Co.	Waterloo	Waterloo	River	Sand
Waterloo Dredging Co.	Waterloo	Waterloo	River	Sand
Waterloo Granite Block Co.	Waterloo	Waterloo	River	Sand
P. M. Smith	Cedar Falls	Cedar Falls	Terrace	Sand and gravel
Cedar Falls Sand & Materials Co.	Cedar Falls	Cedar Falls	Terrace	Sand and gravel
Boone County—				
M. & St. L. Railway	Minneapolis, Minn.	Pilot Mound	Kame	Gravel
Ft. D., D. M. & So. Railway	Boone	Frazer	Terrace	Sand and gravel
Frazer Cement Products Co.	Frazer	Frazer	River	Sand and gravel
Bremer County—				
A. L. Woodruff	Waverly	Waverly	Terrace	Gravel
A. McClellan (operator)	Waverly	Waverly	Terrace	Gravel
J. H. Russell	Waverly	Waverly	Terrace	Gravel
Eureka Cement Tile Co.	Janesville	Janesville	Terrace	Gravel
Bremer County	Waverly	Plainfield	River	Sand and gravel
Buena Vista County—				
C. & N. W. Railway	Chicago, Ill.	Sioux Rapids	Terrace	Gravel
Butler County—				
C. G. W. Railway	Chicago, Ill.	Clarksville	Terrace	Sand and gravel
Clarksville Brick Mfg. Co.	Clarksville	Clarksville	Terrace	Gravel

TABLE NO. VIII—CONTINUED

Owner	Location of Office	Location of Pit	Character of Deposit	Products
Butler County—Con.				
P. H. Green	Greene	Greene	Terrace	Gravel
J. W. Butler	Greene	Greene	Terrace	Gravel
Illinois Central Ry.	Chicago, Ill.	Sec. 23, Washington	Terrace	Sand and gravel
T. H. Ahrens	Dumont	Dumont	Upland	Sand and gravel
Carroll County—				
Lanesboro Cement Tile Co.	Lanesboro	Lanesboro	Terrace	Sand and gravel
Cerro Gordo County—				
Mason City Sand Co.	Mason City	Mason City	Terrace	Sand and gravel
Mason City Cement Products Co.	Mason City	Mason City	Terrace	Sand and gravel
Cherokee County—				
Fred Fuhrman	Cherokee	Cherokee	Terrace	Sand
M. J. Gilleas & Co.	Cherokee	Cherokee	Terrace	Sand and gravel
Cherokee Construction Co.	Cherokee	Cherokee	Terrace	Sand and gravel
Cherokee Sand & Gravel Co.	Cherokee	Cherokee	Terrace	Sand and gravel
Illinois Central Ry.	Cherokee	Cherokee	Terrace	Gravel
Clay County—				
F. W. Fais	Spencer	Spencer	Terrace	Sand and gravel
W. T. Harris	Spencer	Spencer	Terrace	Sand and gravel
Clayton County—				
C., M. & St. P. Railway	Chicago, Ill.	Guttenberg	Terrace	Gravel
Clayton White Sand Co.	Clayton	Clayton	St. Peter sandstone	Sand

Clinton County—				
City of DeWitt	De Witt	De Witt	Kame	Sand and gravel
Scott County	Davenport	De Witt	Kame	Sand and gravel
W. H. Mackridge	De Witt	De Witt	Kame	Gravel
C. & N. W. Railway	Chicago, Ill.	Almont and Clinton	Terrace	Gravel
Clinton Sand & Gravel Co.	Clinton	Clinton	River	Sand and gravel
Geo. A. Schneider	Galena, Ill.	Clinton	River	Sand and gravel
John Sampson	Grand Mound	Grand Mound	Kame	Gravel
Dallas County—				
C., M. & St. P. Railway	Chicago, Ill.	Madrid	Terrace	Gravel
C., M. & St. P. Railway	Chicago, Ill.	Bouton	Terrace	Gravel
City of Van Meter	Van Meter	Van Meter	River	Sand and gravel
City of Booneville	Booneville	Booneville	River	Sand and gravel
Delaware County—				
C. G. W. Railway	Chicago, Ill.	Dyersville	Terrace	Gravel
Des Moines County—				
Kelly Sand & Fuel Co.	Burlington	Burlington		Sand and gravel
Zippe & Fletcher Co.	Burlington	Burlington		Sand and gravel
Dickinson County—				
C., M. & St. P. Railway	Chicago, Ill.	Milford	Terrace	Gravel
Dubuque County—				
Frank Beutin	Dubuque	Dubuque	Terrace	Sand and gravel
Dubuque Sand & Gravel Co.	Dubuque	Dubuque	Terrace	Sand and gravel
Illinois Central Ry.	Dubuque	Dubuque	Terrace	Gravel
F. A. Burns	Dubuque	Dubuque	River	Sand
Emmet County—				
C., R. I. & P. Railway	Chicago, Ill.	Graettinger	Terrace	Gravel
M. & St. L. Railway	Minneapolis, Minn.	Estherville	Terrace	Sand and gravel
Estherville Cement Prod. Co.	Estherville	Estherville	Terrace	Sand and gravel

TABLE NO. VIII—CONTINUED

Owner	Location of Office	Location of Pit	Character of Deposit	Products
Fayette County—				
C., R. I. & P. Railway	Chicago, Ill.	Clermont	Terrace	Sand
C. Miller & Son	Clermont	Clermont	Terrace	Sand
Ira Hanson	Oelwein	Oelwein	Terrace	Sand
Martin Stoll Estate	Clermont	Clermont	Terrace	Gravel
Floyd County—				
C., R. I. & P. Railway	Chicago, Ill.	Marble Rock	Terrace	Gravel
Mrs. Eliza Barnes	Charles City	Charles City	Terrace	Sand and gravel
Alfred Laun	Floyd	Floyd	Terrace	Sand and gravel
Franklin County—				
Sheffield Cement Prod. Co.	Sheffield	Sheffield	Terrace	Sand and gravel
Greene County—				
C. & N. W. Railway	Chicago, Ill.	Grand Junction	Terrace	Gravel
A. S. Tanner	Jefferson	Jefferson	Sand bar	Sand and gravel
C., M. & St. P. Railway	Jefferson	Jefferson	Terrace	Gravel
Grundy County—				
Grundy Center Brick & Tile Co.	Grundy Center	Grundy Center	Terrace	Sand and gravel
Hancock County—				
C., R. I. & P. Railway	Chicago, Ill.	Forest City	Terrace	Gravel
Amsterdam Tile Works	Goodell	Amsterdam	Terrace	Sand and gravel
Hardin County—				
C. & N. W. Railway	Chicago, Ill.	Gifford	Terrace	Gravel
M. & St. L. Railway	Minneapolis, Minn.	Gifford	Terrace	Gravel
Gifford Sand & Gravel Co.	Gifford	Gifford	Terrace	Sand and gravel
Fred Berninghausen	Eldora	Eldora	Terrace	Gravel

Harrison County—				
P. R. Cox	Missouri Valley	Missouri Valley	Aftonian	Sand and gravel
Henry County—				
C., B. & Q. Railway	Chicago, Ill.	Coppock	Terrace	Sand and gravel
Howard County—				
Howard County	Cresco	Sec. 11, Afton	Upland	Gravel
Humboldt County—				
W. C. Hayes	Humboldt	Humboldt	Terrace	Sand and gravel
Ida County—				
Robert Hall	Ida Grove	Ida Grove		Gravel
W. E. Rathburn, Jr.	Ida Grove	Ida Grove		Sand
Concrete Stone Co.	Ida Grove	Ida Grove		Gravel
Jackson County—				
Sabula Sand & Gravel Co.	Sabula	Sabula	River	Sand and gravel
Johnson County—				
Hills Sand & Gravel Co.	Hills	Hills	River	Sand and gravel
Horrabin Sand & Materials Co.	Iowa City	Iowa City	River	Sand and gravel
Geo. E. Mathews	River Junction	River Junction	River	Gravel
Kossuth County—				
C. & N. W. Railway	Chicago, Ill.	Irvington	Terrace	Gravel
C. J. Lenander	Bancroft	Bancroft	Terrace	Gravel
Northwestern Drain & Construc. Co.	Bancroft	Bancroft	Terrace	Gravel
Lee County—				
Ft. Madison Sand & Gravel Co.	Ft. Madison	Ft. Madison	River	Sand and gravel
Joseph Jaeger	Montrose	Ft. Madison	River	Sand
J. H. Einspanjer	Ft. Madison	Ft. Madison	River	Sand
Linn County—				
Kings Crown Plaster Co.	Cedar Rapids	Cedar Rapids	River	Sand
Larimer & Shaffer	Cedar Rapids	Cedar Rapids	River	Sand and gravel
Standard Construction Co.	Cedar Rapids	Cedar Rapids	River	Sand

TABLE NO. VIII—CONTINUED

Owner	Location of Office	Location of Pit	Character of Deposit	Products
Linn County—Con.				
Russell J. Tabor	Springville	Springville	River	Sand
Mrs. Rozella Corbett	Viola	Viola	Buchanan	Sand
Lyon County—				
Great Northern Railway	St. Paul, Minn.	Doon	Terrace	Sand and gravel
Miller & Montgomery	Doon	Doon	Terrace	Sand and gravel
Doon Sand & Gravel Co.	Doon	Doon	Terrace	Sand and gravel
C. R. MacDowell	Doon	Doon	Terrace	Sand and gravel
C., R. I. & P. Railway	Chicago, Ill.	Granite	Terrace	Gravel
Lehatchka & Pattengill	Rock Rapids	Rock Rapids	Terrace	Gravel
Mahaska County—				
Eddyville Sand Co.	Eddyville	Eddyville	River	Sand
Marion County—				
C., R. I. & P. Railway	Chicago, Ill.	Harvey	River	Sand
Sand Valley Sand Co.	Harvey	Harvey	River	Sand and gravel
Iowa Sand & Gravel Co.	Oskaloosa	Tracey	River	Sand and gravel
J. A. Wilson	Tracey	Tracey	River	Sand and gravel
Marshall County—				
M. N. Hawkins	Marshalltown	Marshalltown		Sand and gravel
Marshall Sand Co.	Marshalltown	Marshalltown		Sand and gravel
M. & St. L. Railway	Minneapolis, Minn.	Clemons	Terrace	Gravel
Mitchell County—				
Osage Cement Prod. Co.	Osage	Osage	Terrace	Sand and gravel
N. W. Nelson	Osage	Osage	Terrace	Sand and gravel

Muscatine County—				
C., R. I. & P. Railway	Chicago, Ill.	Fruitland	Terrace	Gravel
Muscatine Sand Co.	Muscatine	Muscatine	River	Sand
Northern Gravel Co.	Davenport	Muscatine	Terrace	Sand and gravel
O'Brien County—				
McCracken Bros.	Paullina	Paullina	Terrace	Sand and gravel
		Calumet	Kame	Sand and gravel
——— Peake	Paullina	Paullina	Terrace	Sand and gravel
Thos. Beacon	Sheldon	Sheldon	Terrace	Sand and gravel
Osceola County—				
C., R. I. & P. Railway	Chicago, Ill.	Sibley	Terrace	Gravel
Sibley Cement Co.	Sibley	Sibley	Terrace	Sand and gravel
(Ocheyedan Mound)		Ocheyedan	Kame	Gravel
Palo Alto County—				
Shadbolt Lumber Co.	Emmetsburg	Emmetsburg	Terrace	Sand
Graettinger Tile Works	Graettinger	Graettinger	Terrace	Sand and gravel
Plymouth County—				
Frank Hammon	Kingsley	Kingsley	Upland	Gravel
Kingsley Milling Co.	Kingsley	Kingsley	Upland	Gravel
G. L. Griffith	Kingsley	Kingsley	Upland	Gravel
Geo. Bainbridge	Kingsley	Kingsley	Upland	Gravel
Dalton Co.	Le Mars	Le Mars	Terrace	Sand and gravel
C., St. P., M. & O. Railway	Chicago, Ill.	Le Mars	Terrace	Gravel
Illinois Central Ry.	Chicago, Ill.	Le Mars	Terrace	Gravel
LeMars Brick & Tile Co.	Le Mars	Le Mars	Terrace	Gravel
Polk County—				
C., R. I. & P. Railway	Chicago, Ill.	Avon and Commerce	River	Sand and gravel
Geo. N. Doty	Commerce	Commerce	River	Sand and gravel
F. F. Balzer	Des Moines	Des Moines	River	Sand and gravel
C. G. W. Railway	Chicago, Ill.	Des Moines		Gravel
Coon River Sand Co.	Des Moines	Des Moines	River	Sand and gravel
Frank Cram	Des Moines	Des Moines	River	Sand and gravel
Des Moines Sand Co.	Des Moines	Des Moines	River	Sand and gravel
Leon Harris	Des Moines	Des Moines	River	Sand and gravel

TABLE NO. VIII—CONTINUED

Owner	Location of Office	Location of Pit	Character of Deposit	Products
Oak Park Sand Co.	Des Moines	Des Moines	River	Sand and gravel
Wabash Railroad	St. Louis	Des Moines	Terrace	Gravel
Des M. Building Material Co.	Des Moines	Valley Junction	River	Sand
Commercial Sand Co.	Mitchellville	Valley Junction	River	Sand
Sac County—				
C. & N. W. Railway	Chicago, Ill.	Lake View	Terrace	Sand and gravel
Lake View Sand & Gravel Co.	Lake View	Lake View	Terrace	Sand and gravel
Sac City Cement Prod. Co.	Sac City	Sac City	Terrace	Sand and gravel
Scott Sand & Gravel Co.		Lake View	Kame	Sand and gravel
Phil Shaller	Sac City	Sac City	Terrace	Sand and gravel
Scott County—				
Interstate Material Co.	Davenport	Davenport		Sand and gravel
Builders Sand & Gravel Co.	Davenport	Nahant		Sand and gravel
Sioux County—				
Hosper Cement Products Co.	Hosper	Hosper	Terrace	Sand and gravel
Joseph Hyink	Alton	Alton	Upland	Sand and gravel
John Beltman	Alton	Alton	Upland	Sand and gravel
C. & N. W. Railway	Chicago, Ill.	Hawarden	Terrace	Gravel
Hawarden Sand & Gravel Co.	Hawarden	Hawarden	River	Sand and gravel
——— Briggs	Hawarden	Hawarden	Terrace	Sand and gravel
C., M. & St. P. Railway	Chicago, Ill.	Opposite Hudson, S. D.	Terrace	Gravel
Cornelius Van der Veer	Alton	Alton	Upland	Sand and gravel
Story County—				
Iowa State College	Ames	Ames	Terrace	Sand and gravel
R. E. Carr	Ames	Ames	Terrace	Sand and gravel
Cole Bros.	Ames	Ames	Terrace	Sand and gravel
Greenlee & Greenlee	Ames	Ames	Terrace	Sand and gravel
John Glidden	Ames	Ames	Terrace	Sand and gravel

Union County—				
C. G. W. Railway	Chicago, Ill.	Afton Junction	Aftonian	Gravel
Van Buren County—				
C., B. & Q. Railway	Chicago, Ill.	Farmington	Terrace	Gravel
C., R. I. & P. Railway	Chicago, Ill.	Farmington	Terrace	Gravel
Wapello County—				
Des Moines River Sand Co.	Eddyville	Eddyville	River	Sand and gravel
Empire Sand & Material Co.	Eddyville	Eddyville	River	Sand and gravel
Palmer Sand Co.	Eddyville	Eddyville	River	Sand and gravel
Ottumwa Sand Co.	Ottumwa	Ottumwa	River	Sand and gravel
Webster County—				
Chas. Larrabee	Ft. Dodge	Fort Dodge	Terrace	Gravel
(Coon Mound)		Sec. 9, Lost Grove	Kame	Gravel
Winnebago County—				
Forest City Cement Prod. Co.	Forest City	Forest City	Kame	Sand and gravel
Winneshiek County—				
Decorah Cement Sidewalk Co.	Decorah	Decorah	River	Sand
A. J. Bernatz	Decorah	Decorah	River	Sand
J. I. Tavenor	Decorah	Decorah	River	Sand
Woodbury County—				
John Fleming & Son	Correctionville	Correctionville	Terrace	Sand
M. J. Gilleas & Co.	Correctionville	Correctionville	Terrace	Sand and gravel
H. A. Moran	Correctionville	Correctionville	Terrace	Sand and gravel
Welch Bros.	Correctionville	Correctionville	Terrace	Sand and gravel
Illinois Central Railway	Correctionville	Correctionville	Terrace	Gravel
John Bower	Correctionville	Correctionville	Terrace	Sand and gravel
Wright County—				
Belmond Cement Manufacturing Co.	Belmond	Belmond	Terrace	Sand
C. G. W. Railway	Belmond	Belmond	Terrace	Sand and gravel
C., R. I. & P. Railway	Belmond	Belmond	Terrace	Sand and gravel

Analyses of Iowa Coals

With a Discussion of their Physical and Chemical Properties from the Industrial View Point

BY

W. A. Hixson

CONTENTS

ANALYSES OF IOWA COALS.

BY A. W. HIXSON.

Introductory.

During the summer of 1909 samples of Iowa coals were collected and proximate analyses were made. The results of these analyses were published in the Annual Report of the Iowa Geological Survey (Vol. XIX, pp. 476-519).

After the Report had gone to press it was decided that ultimate analyses of these samples should be made so that the chemical properties of the coals could be studied in greater detail. The following facts brought about this decision: (1) The samples had been taken with great care according to approved scientific methods. (2) The samples had been taken from producing mines in ten different counties, so that practically the whole Iowa coal field was represented. (3) The samples had been taken under the same conditions so that the analytical results could be compared. (4) The samples had been collected at considerable cost. (5) Ultimate analyses of samples of Iowa Coals taken under uniform conditions had never been made. (6) Such information was needed for calculations in power and heating problems, and for use in writing specifications for the purchase of coals.

The ultimate analyses were made by the same chemist who made proximate analyses, the conditions being the same except that the ultimate analyses were made at a little later date.

It has been considered wise to republish the proximate analyses along with the ultimate analyses so that all of the analytical data will appear together in a more useful condition.

Slight errors have been detected in the "analysis corrected to sample as received" as published. The calculations are corrected in this work. A quite complete analysis of the ash of each sample has been made.

Collection of Sample.

The samples were collected by Mr. James H. Lees, Assistant State Geologist of Iowa. Mr. Lees' description of the methods he employed is as follows: Practically the same method of mine sampling was used as was employed by the United States Geological Survey in collecting the samples which were analyzed at its coal-testing station at the Louisiana Purchase Exposition at St. Louis in 1904. The method was about as follows: The room or entry selected for sampling was one from which coal was being mined at the time the sample was taken and thus a fresh face was assured. A portion of the face was cleaned to remove powder smoke or coal which had been exposed to the air for any considerable period of time. A strip was then cut across the seam from floor to roof about three inches wide and one inch deep. All bony streaks or sulphur bands over one-fourth inch thick were thrown out. The coal cut down in this way was collected, as it fell, upon a rubber cloth to avoid any danger of mixture with dirt or moisture on the floor. Immediately upon arrival above ground, the sample was broken up, on a clean hard surface, into fragments one-half inch or less in diameter. It was then thoroughly mixed and quartered, alternate quarters rejected, and the remaining quarters mixed and further pulverized and again quartered, until about a quart remained. This was put into a clean can with a tight fitting lid, which was driven down solid and the joint sealed by wrapping with tire tape, so that it would be air tight. In short, every effort was made to the end that the sample should represent as closely as might be, the commercial output of the mine, and the original characteristics of the coal should be preserved until it was analyzed.

A slip of paper giving the number of the sample together with the name and location of the mine was enclosed in the can to render identification certain. The sample number was also marked on the outside of the can. The sample was later shipped by express to the laboratory at Iowa City.

Proximate Analysis.

Laboratory Methods.—The methods followed in the analytical work were essentially those adopted in the report of the committee on coal analysis of the American Chemical Society and those employed in the laboratory of the coal testing plant of the United States Geological Survey at the Louisiana Purchase Exposition in 1904.

The analytical work consisted of the proximate and ultimate analysis of the coal samples with the determination of Specific gravity and Calorific value in addition. A complete analysis of the ash of each sample was also made.

Preparation of the Sample.—When the sample arrived at the laboratory it was immediately given a serial number for identification purposes in the laboratory. The number and description on the tag were compared with the number and description on the slip of paper within the can to make sure they agreed. The number and description were then entered in a book for permanent record together with notes concerning the condition of the sample when it arrived.

The coal was then poured out upon a well cleaned bucking board, crushed, mixed and quartered down to one pint. One-half of this was spread out upon a shallow tinned iron tray ten inches in diameter. After weighing, this portion was set aside for air drying. The other half was run through a coffee mill. A portion of the well mixed ground sample was placed in a tightly stoppered bottle for the moisture determination. The crushing, quartering and grinding of the sample were done as quickly as possible to prevent loss of moisture.

The coal was air-dried for ninety-six hours and weighed. The time at which the weighing was done together with the temperature and humidity of the air were recorded. The air-dried sample was crushed and quartered down to 150 grams. The final crushing was to 100 mesh. This sample was then placed in a tightly stoppered bottle and was used for the proximate and ultimate analyses and calorific value determinations.

All samples were mixed on a rolling cloth before weighing out for each determination, to insure a perfectly homogeneous sample. All determinations were made in duplicate.

Moisture.—One gram of coarsely ground fresh coal was dried in a weighed porcelain crucible at 105° C. for one hour, in a double walled, electric oven. The covered crucible and its contents were cooled in a dessicator and weighed. Moisture in the air dried sample was determined in like manner.

It was found that the moisture determination cannot be made with any degree of accuracy if the sample is finely ground. This is due to the fact that the fresh sample loses moisture rapidly during the grinding operation. For this reason the fresh sample for the moisture determination was ground in a coffee mill.

Ash.—A portion of powdered coal used for the determination of moisture in the air-dried sample was burned at first over a Bunsen burner with a very low flame until all of the volatile matter was driven off. The final burning was done in a gasoline muffle furnace, the temperature being kept at that of low redness. Ignition was continued until constant weight was obtained.

If the volatile matter is expelled too quickly, as will be the case if too high a temperature is employed at first, considerable difficulty will be experienced in obtaining complete ignition.

Volatile Combustible Matter.—One gram of the air-dried sample was weighed into a previously ignited and weighed platinum crucible with a tightly fitting cover. This was heated for seven minutes over the full flame of a Bunsen burner, then cooled in a dessicator and weighed. The crucible was supported on a pipe clay triangle resting upon a tripod, the bottom of the crucible being seven centimeters above the top of the burner. The burner when burning freely gave a flame from seventeen to twenty centimeters high.

Fixed Carbon.—Fixed carbon is the difference, in percentage, between the sum of the percentages of the other constituents determined and 100. No correction was made for the sulphur which goes partly into the volatile combustible matter and partly into the coke. Fixed carbon may also be found by subtracting the percentage of ash from the percentage of residue left after expelling the volatile matter.

Sulphur.—This was determined by the Escka Method. One gram of the finely powdered air-dried coal was weighed into a platinum dish of 100 cc. capacity. To this was added one and five-tenths grams of an intimate mixture of one part dry sodium carbonate and two parts of magnesium oxide. The coal and the mixture were well mixed together by stirring with a glass rod. The contents of the dish were then heated over a Bunsen burner very gently until all of the volatile matter was expelled. This required about thirty minutes. Then the heat was increased until all traces of carbon disappeared. To prevent any sulphur from the gas from contaminating the determination, the platinum dish was fitted in a hole in a piece of asbestos board.

After all traces of carbon were removed, the contents of the dish were transferred to a numbered beaker and digested with 75 cc. of water for thirty minutes. The solution was then filtered and the residue washed twice by decantation with 50 cc. of boiling water. The residue was then transferred to the filter paper and again washed with hot water until the filtrate gave only a slight opalescence with nitric acid and silver nitrate. The filtrate at this point amounted to about 200 cc.

Ten cc. of saturated bromine water and 3 cc. of concentrated hydrochloric acid were added to the solution, which was then boiled slowly until all of the bromine was expelled. Then the sulphur was precipitated by adding to the boiling solution 10 cc. of a ten per cent barium chloride solution. This was added drop by drop and the solution was vigorously stirred. The solution was allowed to stand two hours at a temperature slightly below boiling. The barium sulphate was then filtered off and washed with hot water until free from chlorides. The filter with the moist precipitate was transferred to a weighed porcelain crucible which was heated over a low flame until the paper was burned off. The heat was then raised until the precipitate became a dull red. The heating was continued until the carbon was burned out. The crucible with the precipitate was then cooled in a dessicator and weighed. Careful ignition was repeated until constant weight was obtained.

Blank determinations were made, using all of the reagents in the same quantities and the determination was carried out exactly as with the coal. Any barium sulphate found was subtracted from that obtained in the coal determination. The true weight of barium sulphate multiplied by 0.1373 gave the weight of sulphur.

Ultimate Analysis.

Carbon and Hydrogen.—The carbon and hydrogen determinations were made in a twenty-seven burner Bunsen combustion furnace. The burners were adjustable so that the temperature in different parts of the furnace could be varied. Kavalier glass combustion tubes, seventeen millimetres in diameter were used. The tubes were cut long enough to project about ten centimetres beyond the ends of the furnace. The rear end of the tube was closed with a single hole rubber stopper into which a branching tube with a two way cock was fitted. The two way cock was used for the alternate admission of air and oxygen into the combustion tube. The rear end of the tube for a distance of thirty centimetres was left empty. The next forty centimetres was filled with wire copper oxide. This was held in place by acid washed, ignited asbestos plugs. Following the copper oxide the tube was filled for a distance of fifteen centimetres with granular fused lead chromate. This also was held in place by an asbestos plug.

The purifying train through which the oxygen and air were passed before entering the combustion tube, was arranged in duplicate, one part for oxygen and the other for air. The purifying apparatus used was Tauber's. The first jar contained concentrated sulphuric acid, the next jar contained potassium hydroxide solution, one limb of the U tube contained fused calcium chloride and the other small pieces of KOH. The potassium hydroxide and fused calcium chloride were separated by glass wool. This arrangement removed carbon dioxide and moisture from the air perfectly.

The absorption apparatus consisted of a glass stoppered U tube which contained concentrated sulphuric acid and a Geissler bulb which contained a potassium hydroxide solution. The Geissler bulb and the sulphuric acid tube were connected by means of a small piece of shellaced rubber tubing. Wherever rubber tubing was used in the combustion train it was shellaced on the outside to prevent leakage from outside. The absorption tubes were protected by a pair of glass stoppered U tubes one of which contained concentrated sulphuric acid and the other potassium hydroxide solution. The absorption tubes were connected to the front end of the combustion tube by a glass tube which was tightly fitted into a well rolled cork.

After the combustion train was assembled it was tested for leakage. No difficulty was experienced in removing all of the CO_2 and moisture from the gas and air drawn through the apparatus.

The analysis in detail was as follows:

Two-tenths of a gram of the well mixed air-dried sample was weighed into a previously ignited and weighed platinum combustion boat. After weighing, this was quickly transferred to the combustion tube and pushed up close to the rear end of the copper oxide. The amount of time required for mixing and weighing sample was two and one-half to three minutes. This part of the operation was hurried as much as possible to avoid change in moisture content. The burners underneath the copper oxide and lead chromate were then lighted. The burners were so adjusted that the copper oxide was brought to bright redness and the lead chromate to low redness before the burners were turned on under the coal. The coal was slowly heated, first by turning the burners on behind the boat and then underneath, to prevent the volatile constituents being driven off too quickly. If the volatile constituents are driven off too quickly a great deal of time is required for complete combustion. The final temperature was kept below that of the fusion point of the ash. While combustion was going on air was slowly pulled through the train. When combustion was almost complete oxygen was passed through the tube to insure complete combustion. After the combustion was complete air was again passed through the train to sweep out the last traces of moisture and carbon dioxide. After complete combustion the temperature of the tube and its contents was slowly lowered to prevent the tube from breaking and to prepare for another combustion.

After cooling for several minutes in the balance case, the absorption apparatus was weighed and the gain in weight of each tube noted. From the gain in weight of the sulphuric acid tube and potash bulbs the hydrogen and carbon contents were calculated.

Nitrogen.—The Kjeldahl method was employed for the determination of nitrogen. One gram of the well mixed air-dried sample was placed in a 200 cc. Kjeldahl digestion flask and was digested for about an hour and a half with 30 cc. concentrated sulphuric acid and about .65 gm. mercury. The time required for the digestion varied slightly with different samples, the digestion being continued in each case for at least forty minutes after oxidation was apparently complete. The vapors from the distillation flask were condensed in a tin condensing coil which was connected to the digestion flask by means of a glass tube and a close fitting rubber stopper. The coil of the condensor was surrounded by cold water.

The ammonia found was absorbed in 10 cc. standard sulphuric acid of which 1 cc. was equivalent to .005 N. The remaining acid was titrated with standard ammonia (1 cc.=.0025 gm. N.).

Calorific value.—This was determined with a Parr Standard Calorimeter, which was installed in a room as free as possible from fluctuations in temperature. The apparatus was carefully standardized, the water equivalent being determined by different methods as follows: (1) Calculation of the water equivalent from weights and specific heats of the different parts of the calorimeter. (2) By burning resublimed naphthalene in the bomb. (3) By burning pure cane sugar in the bomb. The results of the three different determinations agreed closely. The correction components used for the chemicals, iron wire and for the varying compositions of the different coals were those determined by Prof. S. W. Parr, of the University of Illinois. The thermometers used were standardized by the Bureau of Standards in Washington.

One gram of the powdered air-dried coal was weighed into the bomb of the calorimeter. To this was added one gram of accelerator (potassium chlorate) and fifteen grams of perfectly dry pure sodium peroxide. The false cap was then put into position and screwed firmly into place and the ingredients mixed by shaking the bomb thoroughly. The material was then shaken to the bottom of the bomb, the false top removed, the ignition device inserted and firmly screwed in place. The bomb now complete was put in place into the can which contained exactly two litres of distilled water. The lid was then placed on the calorimeter, pulley attached and the thermometer inserted so that the bulb was half way to the bottom of the can. The water was stirred by metal wings attached to the bomb which was revolved by a belt from a small motor.

The motor was started and apparatus allowed to run for five minutes before ignition in order that the rate of change of temperature might be noted by taking a reading each minute. At the end of the fifth minute the charge in the bomb was ignited by closing a switch which allowed an electric current of four and one-half amperes to quickly fuse a thirty-four gauge iron wire, four inches long, which extended into the charge in the bomb. The temperature was read each minute until the maximum was reached, then each minute for five minutes to obtain the rate of change of temperature due to radiation.

The apparatus was then taken apart, each piece dried thoroughly, and prepared for a new charge. The room temperature was taken during each determination.

The calorific value was calculated by multiplying the number of British Thermal Units corresponding to one degree increase in temperature by the total rise of temperature obtained after the correction factors had been subtracted. The calorific value was also calculated in calories. Corrections other than those noted above were made for the formation of nitric acid and combustion of sulphur to sulphuric acid.

Specific Gravity—The true specific gravity of the coal substance was determined by the method described by Stanton and Fieldner in Bureau of Mines Technical Paper, Number 8. The procedure was as follows: Three and five-tenths grams of the finely pulverized coal was dried at 105° C. for one hour. This was placed in 50 cc. pycnometer with 35 cc. of distilled water. The contents of the flask were boiled slowly under reduced pressure on a water bath. To prevent loss of solid particles during boiling, a six inch two bulb drying tube was fitted into a well rolled cork stopper in the neck of the pycnometer. The other end of the drying tube was connected to an aspirator. The boiling was continued under reduced pressure for several hours to insure complete removal of all air. The drying tube was removed from the neck of the pycnometer which was nearly filled with boiled, cooled, distilled water. The pycnometer with contents was allowed to cool to room temperature in the balance case, stoppered and weighed. The temperature of the contents was taken at time of weighing. The pycnometer was emptied, dried and filled with boiled, cooled, distilled water and placed in the balance case until the temperature of the contents was the same as that of the balance room. The pycnometer was then stoppered and weighed. The true specific gravity was then calculated as follows:

$$\text{True specific gravity} = \frac{W}{W-(W^1-P)}$$

W =weight of coal.
W^1=weight of pycnometer+coal+water to fill.
P =weight of pycnometer+water to fill.

Analysis of Ash of Coal Samples.

Quite complete analyses of the ash of the coal samples examined, were made. The procedure was as follows: 100 grams of the air-dried coal sample was placed in a well cleaned, previously ignited, fire clay crucible. Only crucibles which had a perfectly smooth inner surface were used. The crucibles used were furnished by the Denver Fire Clay Company of Denver, Col. The crucible was placed in the cool muffle of a gasoline assay furnace. The temperature was raised very slowly until all of the volatile matter was driven off. The muffle was then heated to low redness and kept at that temperature until ignition was complete. The ash was removed, cooled in a dessicator, well mixed and a small portion weighed into a weighed platinum crucible. The content of the platinum crucible was ignited, cooled and weighed to determine if the ignition in the muffle had been complete. If the ignition in the platinum crucible showed a loss in weight the sample was returned to the muffle and heated until ignition was complete. This method allows large samples of coal to be ashed and a large number of samples to be run at one time, and has the further advantage that the temperature can be easily controlled. After complete ignition in the muffle furnace the samples were cooled in a dessicator and transferred to a previously dried, glass stoppered bottle. The well mixed samples for analysis were weighed out from the bottles as they were needed. CaO, Fe_2O_3, Al_2O_3, SiO_2, MgO, P_2O_5, and SO_3, were determined.

The methods used for these determinations were standard methods and inasmuch as complete analyses of coal ash are rarely ever made, it has not been thought necessary to give details of procedure other than those already given.

Calculation of Results.

The actual determinations were those made upon the air-dried sample. The results tabulated under the heading, "Results corrected to sample as received," were not obtained by analysis of the original sample, but were calculated from the results of the analysis of the air-dried sample. The only determination made on the original sample was moisture.

The calculations from "air-dried" to "as received" conditions were made according to the following formulæ: (Method of statement of formulæ taken from Bureau of Mines Bulletin, No. 22, page 26.)

"Air-dried" condition.		"As received" condition.
Moisture at 105° C.	$\times \frac{100-\text{air-dry loss}}{100} + \text{air-dry loss}$	=moisture
Volatile matter	$\times \frac{100-\text{air-dry loss}}{100}$	=volatile matter
Fixed Carbon	$\times \frac{100-\text{air-dry loss}}{100}$	=fixed carbon
Ash	$\times \frac{100-\text{air-dry loss}}{100}$	=ash
Sulphur	$\times \frac{100-\text{air-dry loss}}{100}$	=sulphur
Hydrogen	$\times \frac{100-\text{air-dry loss}}{100} + \frac{\text{air-dry loss}}{9}$	=hydrogen
Carbon	$\times \frac{100-\text{air-dry loss}}{100}$	=carbon
Nitrogen	$\times \frac{100-\text{air-dry loss}}{100}$	=nitrogen
Calorific value	$\times \frac{100-\text{air-dry loss}}{100}$	=calorific value

The heat values obtained from the ultimate analyses were calculated by DuLong's formula. The form of the formula used is:

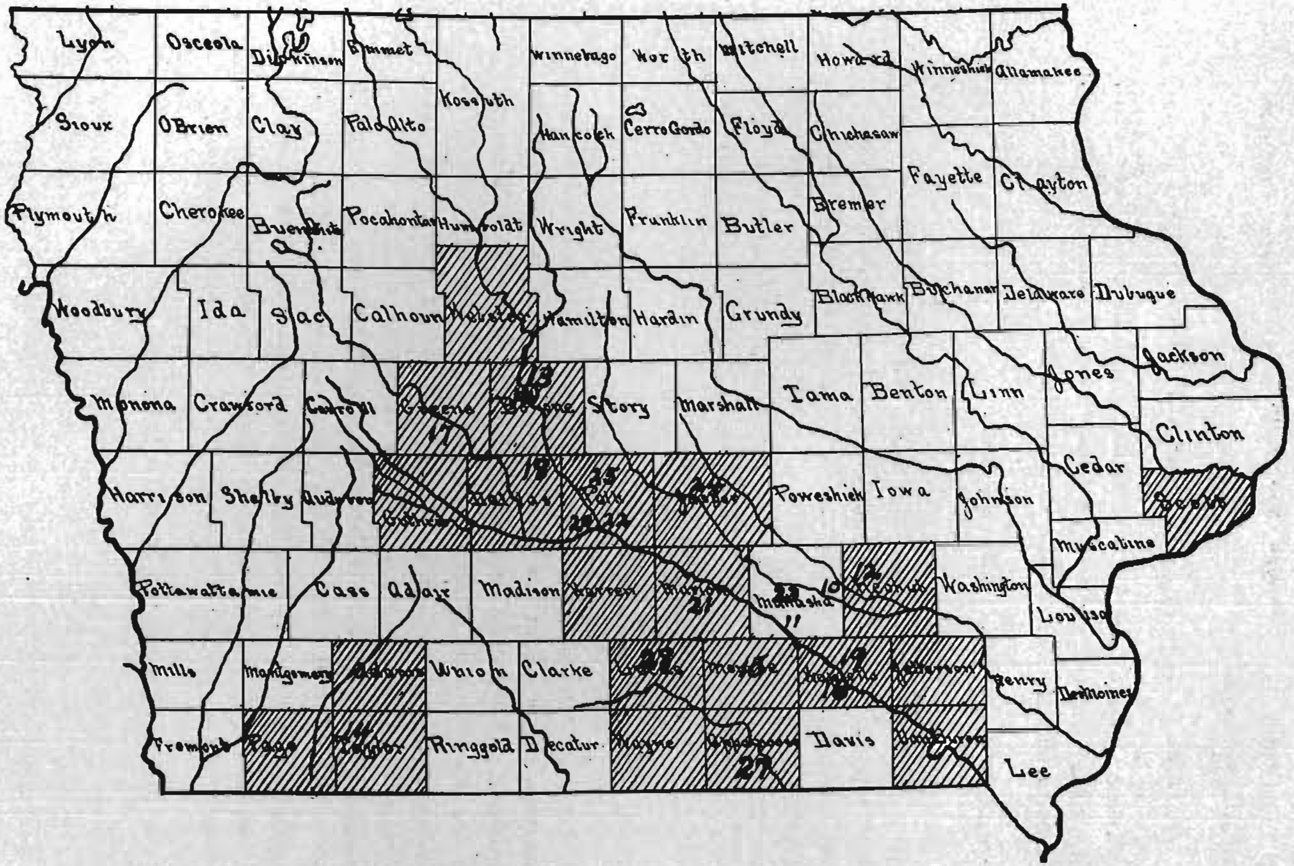
$$\text{Weight carbon} \times 8080 + \left(\text{weight hydrogen} - \frac{\text{weight oxygen}}{8}\right) \times 34460 + \text{weight sulphur} \times 2250 = \text{Calories per gram.}$$

$$\text{Calories} \times 1.8 = \text{British Thermal Units.}$$

The sulphur values in the ultimate analysis were obtained by deducting the amount of sulphur found in the ash from the amount of total sulphur.

Description of Mines Sampled.

The descriptions of the mines sampled, which appear on pages opposite the analyses, were written by Mr. James H. Lees, Assistant State Geologist, who collected the samples. These descriptions are taken from Vol. XIX, pages 482-487, Annual Report Iowa Geological Survey.



Map showing coal producing area and locations from which samples were taken. The numbers on the map correspond to sample numbers used in the following pages with the exception of 27 and 28. 27 is Iowa coal No. 4 and 28 is Iowa coal No. 5, described on pages 79 and 80 and 224 and 225, Professional Paper No. 48, United States Geological Survey. Shaded areas indicates coal producing sections.

Sample Number 10.

Description of Mine.

Operator. Atwood Coal Company, What Cheer.

Mine. Blyth mine, three miles northwest of Rose Hill, Mahaska county, on long switch from Knoxville branch, Chicago, Rock Island and Pacific Railway.

Sample collected. May 18, 1909.

Description. The mine was sampled in the fifth north entry on the west side of the mine, 840 feet from the shaft. The vein dips steeply in this entry. It shows a thickness of 5 feet 1 inch where sampled. The coal is very clean-looking, without sulphur bands or rock. Only one vein is present. The mine when sampled had been running four years and employed 100 men. (See Vol. XIX, page 202, Annual Report of Iowa Geological Survey.)

Discussion of Analytical Results.

Although the coal in place showed no sulphur bands, the analysis shows this element to be present in quite large amount. The presence of so large an amount of sulphur would undoubtedly cause this coal to be more destructive to grates and fire boxes than the average Iowa coal. The loss of moisture on air-drying is that of the average Iowa coal. Slagging will be more noticeable with this coal, if firing is forced, than with some of the other coals examined, due to high pyrite content. The ash contains an abnormal amount of sulphur. The heat value is above average. The oxygen content is one of the lowest found in the coals examined.

Sample Number 10.

	Per Cent.		Per Cent.
Loss of moisture on air-drying	9.53		
Analysis of air-dried sample: Proximate—		Analysis corrected to sample as received: Proximate—	
Moisture	5.58		14.57
Volatile combustible matter	36.34		32.88
Fixed Carbon	44.30		40.08
Ash	13.78		12.47
	100.00		100.00
Total sulphur	6.51		6.00
Analysis of air-dried sample: Ultimate—		Analysis corrected to sample as received: Ultimate—	
Hydrogen	4.95		5.53
Carbon	62.90		56.90
Nitrogen	1.40		1.27
Oxygen	10.93		18.37
Sulphur	6.04		5.46
Ash	13.78		12.47
	100.00		100.00

Calorific value determined on air-dried sample	B. T. U. 11814 Calories 6563
Calorific value corrected to sample as received	B. T. U. 10688 Calories 5938
Calorific value calculated from ultimate analysis of air-dried sample	B. T. U. 11619 Calories 6455
Calorific value corrected to sample as received	B. T. U. 10512 Calories 5840
Specific gravity of air-dried sample	1.295

Analysis of ash from air-dried sample.

SiO_2	18.21	per cent
CaO	17.74	per cent
MgO	1.10	per cent
Fe_2O_3	35.17	per cent
Al_2O_3	17.36	per cent
P_2O_5	.575	per cent
SO_3	8.53	per cent
Undetermined	1.315	per cent
	100.00	

Sample Number 11.

Description of Mine.

Operator. Crescent Coal Company, Oskaloosa.

Mine. Crescent No. 5, White City, Mahaska county, on Buxton branch Chicago and North Western Railway.

Sample collected. May 9, 1909.

Description. This sample was cut from the first room on the eighth north entry on the east side of the mine about one mile from the shaft. The coal was 7 feet 8 inches thick with about 8 inches of slaty coal near the roof. It was dipping steeply away from the entry. (See Vol. XIX, page 216, Annual Report Iowa Geological Survey.)

Discussion of Analytical Results.

The analysis shows the air-dried coal to contain an average amount of moisture, high total sulphur, high sulphur in ash and a lower than average moisture content in sample when taken from mine. The heat value is slightly lower than that of the average Iowa coal. The coal when completely burned gives a brick red ash with higher than average Fe_2O_3 content. The ash content of this coal probably varies considerably in car samples due to presence of varying amounts of the slaty material at the top of the vein. The analysis shows a high ash content.

Sample Number 11.

	Per Cent.		Per Cent.
Loss of moisture on air-drying	6.82		
Analysis of air-dried sample: Proximate—		Analysis corrected to sample as received: Proximate—	
Moisture	6.17		12.56
Volatile combustible matter	36.71		34.21
Fixed Carbon	41.72		38.88
Ash	15.40		14.35
	100.00		100.00
Total sulphur	5.87		5.47
Analysis of air-dried sample: Ultimate—		Analysis corrected to sample as received: Ultimate—	
Hydrogen	5.00		5.41
Carbon	61.40		57.21
Nitrogen	1.23		1.14
Oxygen	11.56		16.85
Sulphur	5.41		5.04
Ash	15.40		14.35
	100.00		100.00

Calorific value determined on air-dried sample	B. T. U. 11497 Calories 6387
Calorific value corrected to sample as received	B. T. U. 10713 Calories 5952
Calorific value calculated from ultimate analysis of air-dried sample	B. T. U. 11353 Calories 6308
Calorific value corrected to sample as received	B. T. U. 10579 Calories 5877
Specific gravity of air-dried sample	1.261

Analysis of ash from air-dried sample.

SiO_2	17.49	per cent
CaO	16.40	per cent
MgO	1.35	per cent
Fe_2O_3	36.02	per cent
Al_2O_3	18.88	per cent
P_2O_5	.692	per cent
SO_3	7.47	per cent
Undetermined	1.698	per cent
	100.00	

Sample Number 12.

Description of Mine.

Operator. Armstrong Brothers Coal Company, What Cheer.

Mine. Armstrong, one mile east of What Cheer, Keokuk county. No railroad connections.

Sample collected. May 19, 1909.

Description. The sample was taken from the first north entry off the west main entry. The coal here showed a thickness of 4 feet 2 inches and was clean and free from impurities. (See Vol. XIX, page 288, Annual Report Iowa Geological Survey.)

Discussion of Analytical Results.

Although the total sulphur content is well above that of the average Iowa coal, the sulphur content shown in the ultimate analysis is normal. The reason for this is that a considerable part of the sulphur is present in such condition that it went into ash. The average SO_3 content of ash of Iowa coals is 6.00 per cent. An abnormal amount of MgO in the ash is also to be noted. Loss of moisture on air-drying is below average. The ash content is above average.

Sample Number 12.

	Per Cent.		Per Cent.
Loss of moisture on air-drying	7.83		
Analysis of air-dried sample: Proximate—		Analysis corrected to sample as received: Proximate—	
Moisture	7.43		14.68
Volatile combustible matter	38.21		35.22
Fixed Carbon	41.10		37.88
Ash	13.26		12.22
	100.00		100.00
Total sulphur	5.15		4.75
Analysis of air-dried sample: Ultimate—		Analysis corrected to sample as received: Ultimate—	
Hydrogen	4.88		5.36
Carbon	62.75		57.84
Nitrogen	1.42		1.32
Oxygen	13.01		18.95
Sulphur	4.68		4.31
Ash	13.26		12.22
	100.00		100.00

Calorific value determined on air-dried sample	B. T. U. 11410 Calories 6339
Calorific value corrected to sample as received	B. T. U. 10517 Calories 5843
Calorific value calculated from ultimate analysis of air-dried sample	B. T. U. 11322 Calories 6289
Calorific value corrected to sample as received	B. T. U. 10435 Calories 5797
Specific gravity of air-dried sample	1.259

Analysis of ash from air-dried sample.

SiO_2	20.81	per cent
CaO	17.50	per cent
MgO	2.06	per cent
Fe_2O_3	32.30	per cent
Al_2O_3	15.85	per cent
P_2O_5	.641	per cent
SO_3	8.53	per cent
Undetermined	1.829	per cent
	100.00	

Sample Number 13.

Description of Mine.

Operator. The Fort Dodge, Des Moines and Southern Railway Company (electric) own controlling interest.

Mine. Ogden No. 1, two miles north of Ogden, Boone county, on switch from main line of Minneapolis and St. Louis Railroad.

Sample collected. May 14, 1909.

Description. The sample was taken from the fourth northeast entry. The coal is here 4 feet 4 inches thick, free from sulphur bands or balls as well as from rock. It is the "lower vein" of the Boone county mines and averages 4½ to 5½ feet. The "upper vein" is about 50 feet above and is about 3½ feet thick.

The shaft is 275 feet deep. It was completed in August of 1907. The mine at the time the sample was taken had an output of 400 tons, of three grades, lump, range and steam. The Minneapolis & St. Louis Railroad Company at that time used about 125 tons daily. About 200 men are employed in the mine. The haulage is done by electricity. (See Vol. XIX, page 74, Annual Report Iowa Geological Survey.)

Discussion of Analytical Results.

This coal is one of the best examined. The ash content is low for an Iowa coal, although the sulphur content is high. The heat value is well above the average. The iron content in the ash is quite high and it is quite probable that this coal will not stand forced firing on account of slagging. All Iowa coals slag, however, under certain conditions. The cause and nature of slagging is discussed at another place. The lime and alumina values in the ash are low.

Sample Number 13.

	Per Cent.		Per Cent.
Loss of moisture on air-drying	10.65		
Analysis of air-dried sample: Proximate—		Analysis corrected to sample as received: Proximate—	
Moisture	8.91		18.61
Volatile combustible matter	37.81		33.78
Fixed Carbon	43.31		38.70
Ash	9.97		8.91
	100.00		100.00
Total sulphur	6.10		5.45
Analysis of air-dried sample: Ultimate—		Analysis corrected to sample as received: Ultimate—	
Hydrogen	5.18		5.81
Carbon	63.80		57.01
Nitrogen	1.63		1.46
Oxygen	13.48		21.49
Sulphur	5.94		5.31
Ash	9.97		8.92
	100.00		100.00

Calorific value determined on air-dried sample	B. T. U. 11894	Calories 6608
Calorific value corrected to sample as received	B. T. U. 10627	Calories 5904
Calorific value calculated from ultimate analysis of air-dried sample	B. T. U. 11687	Calories 6493
Calorific value corrected to sample as received	B. T. U. 10442	Calories 5801
Specific gravity of air-dried sample	1.283	

Analysis of ash from air-dried sample.

SiO_2	23.76	per cent
CaO	15.54	per cent
MgO	.67	per cent
Fe_2O_3	43.49	per cent
Al_2O_3	11.09	per cent
P_2O_5	.627	per cent
SO_3	4.13	per cent
Undetermined	.693	per cent
	100.00	

Sample Number 14.

Description of Mine.

Operator. Campbell Coal Company, New Market.

Mine. Campbell No. 1, nearly one mile east of New Market, on the Keokuk, Shenandoah and Red Oak division of the Chicago, Burlington and Quincy Railroad.

Sample collected. May 22, 1909.

Description. The sample was collected from the second west entry off the second north entry. The bed was 16 inches thick where sampled. It varies from 16 to 20 inches in thickness in different parts of its extent. In some places it shows thin streaks of sulphur or clay one-eighth to one-half inch thick. The coal is brittle and breaks easily with angular fracture. The mine is on the right-of-way and is served by a short siding. (See Vol. XIX, page 383, Annual Report of Iowa Geological Survey.)

Discussion of Analytical Results.

This coal, like several of the other Iowa coals examined, loses more than an average amount of moisture on air-drying. With the exception of the heat value this coal is about an average coal from the Iowa field. The coal has the appearance of one that would weather badly. Appearance, however, is not always a good basis for the judgment of this property. Analysis shows the coal to be better than its appearance indicates.

Sample Number 14.

	Per Cent.	Per Cent.
Loss of moisture on air-drying	10.97	
Analysis of air-dried sample: Proximate—		Analysis corrected to sample as received: Proximate—
Moisture	9.24	19.11
Volatile combustible matter	34.17	30.45
Fixed Carbon	43.60	38.86
Ash	12.99	11.58
	100.00	100.00
Total sulphur	4.78	4.26
Analysis of air-dried sample: Ultimate—		Analysis corrected to sample as received: Ultimate—
Hydrogen	4.73	5.43
Carbon	63.80	56.80
Nitrogen	1.59	1.41
Oxygen	12.51	20.90
Sulphur	4.38	3.90
Ash	12.99	11.56
	100.00	100.00

Calorific value determined on air-dried sample	B. T. U.	11494
	Calories	6385
Calorific value corrected to sample as received	B. T. U.	10233
	Calories	5685
Calorific value calculated from ultimate analysis of air-dried sample	B. T. U.	11422
	Calories	6346
Calorific value corrected to sample as received	B. T. U.	10169
	Calories	5649
Specific gravity of air-dried sample		1.272

Analysis of ash from air-dried sample.

SiO_2	20.97	per cent
CaO	20.79	per cent
MgO	1.10	per cent
Fe_2O_3	30.17	per cent
Al_2O_3	17.11	per cent
P_2O_5	1.22	per cent
SO_3	7.58	per cent
Undetermined	1.06	per cent
	100.00	

Sample Number 15.

Description of Mine.

Operator. Wapello Coal Company, Hiteman.

Mine. Wapello No. 4, three miles northwest of Hiteman, Monroe county, on branch from the main line of the Chicago, Burlington and Quincy Railroad.

Sample collected. May 21, 1909.

Description. The sample is from the seventeenth room off the tenth west entry off the sixteenth north entry. The vein measured, where sampled, 5 feet 4 inches and is free from sulphur and rock. The average thickness is 5½ feet.

The mine uses tail rope haulage for about a mile under ground and the entries run in one-half mile farther. The output was 900 tons daily. (See Vol. XIX, page 242, Annual Report of Iowa Geological Survey.)

Discussion of Analytical Results.

The noticeable feature of this coal is its low sulphur content. The sulphur is present in such condition that much of it goes into the ash. This coal should have little destructive effect upon grates and fire boxes and should stand forced firing better than many Iowa coals. The oxygen content is above average. Silica in the ash is high and iron is low. The ash is lighter colored than most of samples examined. This is probably due to the iron content. The appearance of the coal indicates a higher thermal value than the analysis shows. The amount of moisture retained after air-drying is higher than the average.

Sample Number 15.

	Per Cent.		Per Cent.
Loss of moisture on air-drying	8.21		
Analysis of air-dried sample: Proximate—		Analysis corrected to sample as received: Proximate—	
Moisture	8.40		15.92
Volatile combustible matter	36.26		33.28
Fixed Carbon	42.80		39.29
Ash	12.54		11.51
	100.00		100.00
Total sulphur	2.10		1.93
Analysis of air-dried sample: Ultimate—		Analysis corrected to sample as received: Ultimate—	
Hydrogen	5.10		5.59
Carbon	64.10		58.84
Nitrogen	1.88		1.73
Oxygen	14.55		20.64
Sulphur	1.83		1.68
Ash	12.54		11.52
	100.00		100.00

Calorific value determined on air-dried sample	B. T. U. 11564 Calories 6424
Calorific value corrected to sample as received	B. T. U. 10615 Calories 5897
Calorific value calculated from ultimate analysis of air-dried sample	B. T. U. 11437 Calories 6351
Calorific value corrected to sample as received	B. T. U. 10498 Calories 5832
Specific gravity of air-dried sample	1.274

Analysis of ash from air-dried sample.

SiO_2	30.87	per cent
CaO	16.25	per cent
MgO	1.31	per cent
Fe_2O_3	28.05	per cent
Al_2O_3	16.12	per cent
P_2O_5	.663	per cent
SO_3	5.41	per cent
Undetermined	1.357	per cent
	100.00	

Sample Number 16.

Description of Mine.

Operator. Phillips Fuel Company, Ottumwa.

Mine. Bear Creek mine, at Bear Creek, Wapello county, four miles southwest of Ottumwa, on the Chicago, Milwaukee and St. Paul Railway.

Sample collected. May 20, 1909.

Description. The sample is from the first south entry. Here the coal is 4 feet 6 inches thick and is in the main clean and free from rock except near the roof, where some bowlders occur. One of these near the place of sampling measured ten inches in thickness.

The mine was opened in the fall of 1908. At the time of sampling forty miners were employed and tail rope haulage was installed. Hoisting is done by duplex engine geared to the drum. (See Vol. XIX, page 302, Annual Report Iowa Geological Survey.)

Discussion of Analytical Results.

The moisture in sample "as received" is low for an Iowa coal. The moisture in the air-dried sample is also considerably below the average. The ash content is high, due mostly to earthy material. The ash is dark in color and quite high in iron oxide. The iron in the ash of this sample does not come entirely from pyrites (FeS_2) which is present in considerable quantities in all Iowa coals, but also from earthy material with a dark soily appearance. The heat value is a little below that of the average coal from the Iowa field. The writer is convinced that washing would greatly improve this coal.

Sample Number 16.

	Per Cent.		Per Cent.
Loss of moisture on air-drying	7.49		
Analysis of air-dried sample: Proximate—		Analysis corrected to sample as received: Proximate—	
Moisture	4.79		11.92
Volatile combustible matter	37.59		34.78
Fixed Carbon	43.22		39.98
Ash	14.40		13.32
	100.00		100.00
Total sulphur	6.63		6.13
Analysis of air-dried sample: Ultimate—		Analysis corrected to sample as received: Ultimate—	
Hydrogen	5.19		5.63
Carbon	62.04		57.40
Nitrogen	1.39		1.29
Oxygen	10.64		16.49
Sulphur	6.34		5.87
Ash	14.40		13.32
	100.00		100.00

Calorific value determined on air-dried sample	B. T. U. 11695 Calories 6497
Calorific value corrected to sample as received	B. T. U. 10819 Calories 6011
Calorific value calculated from ultimate analysis of air-dried sample	B. T. U. 11674 Calories 6486
Calorific value corrected to sample as received	B. T. U. 10800 Calories 6000
Specific gravity of air-dried sample	1.269

Analysis of ash from air-dried sample.

SiO_2	21.70	per cent
CaO	15.29	per cent
MgO	1.92	per cent
Fe_2O_3	38.62	per cent
Al_2O_3	15.63	per cent
P_2O_5	.259	per cent
SO_3	4.95	per cent
Undetermined	1.731	per cent
	100.00	

Sample Number 17.

Description of Mine.

Operator. Willow Grove Coal Company, Angus.

Mine. Willow Grove mine, on northwest border of Angus in Greene county. No railroad connections.

Sample collected. May 14, 1909.

Description. This sample was taken from the fourth east-south entry. The seam is here 4 feet 2 inches thick. The coal breaks with angular fracture and shows bright clean faces. Thin films of lime occur along stratification planes. The vein worked is called the lower vein. Its thickness ranges from 4 to 5½ feet. The middle vein is separated from the lower by a sandstone roof 3½ to 20 feet thick, with an average of 14 feet. Owing to the character of the roof the mine is very wet. (See Vol. XIX, page 361, Annual Report Iowa Geological Survey.)

Discussion of Analytical Results.

Although this mine is wet the sample as received did not show high moisture content. After air-drying the moisture value is lower than that of the average coal. The carbon content is lower than that of any coal examined. The ash is high, due to the lime bands mentioned above. The ash is light in color, low in iron oxide and the magnesia content is the highest found in any of the samples examined. This constituent is undoubtedly present in the lime bands mentioned. The calorific value is lower than that of any of the samples in this group. Washing would undoubtedly increase the value of this coal. Much of the ash-forming material could be removed. This treatment would also remove much of the sulphur, thereby decreasing whatever destructive effect the coal has upon grates and fire boxes.

Sample Number 17.

	Per Cent.		Per Cent.
Loss of moisture on air-drying	8.08		
Analysis of air-dried sample: Proximate—		Analysis corrected to sample as received: Proximate—	
Moisture	5.57		13.20
Volatile combustible matter	38.73		35.60
Fixed Carbon	40.40		37.14
Ash	15.30		14.06
	100.00		100.00
Total sulphur	5.37		4.94
Analysis of air-dried sample: Ultimate—		Analysis corrected to sample as received: Ultimate—	
Hydrogen	5.14		5.62
Carbon	60.48		55.59
Nitrogen	1.45		1.33
Oxygen	12.53		18.71
Sulphur	5.10		4.69
Ash	15.30		14.06
	100.00		100.00

Calorific value determined on air-dried sample	B. T. U. 11234 Calories 6241
Calorific value corrected to sample as received	B. T. U. 10326 Calories 5737
Calorific value calculated from ultimate analysis of air-dried sample	B. T. U. 11219 Calories 6233
Calorific value corrected to sample as received	B. T. U. 10313 Calories 5730
Specific gravity of air-dried sample	1.262

Analysis of ash from air-dried sample.

SiO_2	26.50	per cent
CaO	18.21	per cent
MgO	2.11	per cent
Fe_2O_3	27.77	per cent
Al_2O_3	18.44	per cent
P_2O_5	.996	per cent
SO_3	4.35	per cent
Undetermined	1.624	per cent
	100.00	

Sample Number 18.

Description of Mine.

Operator. High Bridge Coal Company, Madrid.

Mine. High Bridge mine, High Bridge, Dallas county, on Boone division of the Chicago, Milwaukee and St. Paul Railway.

Sample collected. May 12, 1909.

Description. The sample was collected from the face of the west entry about 1,300 feet from the shaft. The coal is here 3 feet 11 inches thick. It has a clay roof and about three inches of black shale on the floor. This is underlain by gray fire clay. The capacity of the mine at the time of sampling was 300 tons daily. (See Vol. XIX, page 89, Annual Report Iowa Geological Survey.)

Discussion of Analytical Results.

The sample as received was high in moisture, much of which was lost on air-drying. The air-dried sample, however, retained about two per cent more moisture than the average. This coal has the lowest sulphur content of any of the coals examined. A considerable part of the sulphur went into the ash. The ash is light in color. The lime content is high. Iron oxide is low as might be expected from the low amount of sulphur. The thermal value is about average. Fixed carbon is above and volatile combustible matter is below the average.

Sample Number 18.

	Per Cent.		Per Cent.
Loss of moisture on air-drying	10.47		
Analysis of air-dried sample: Proximate—		Analysis corrected to sample as received: Proximate—	
Moisture	8.68		18.21
Volatile combustible matter	33.14		29.67
Fixed Carbon	45.00		40.29
Ash	13.21		11.83
	100.00		100.00
Total sulphur	2.75		2.46
Analysis of air-dried sample: Ultimate—		Analysis corrected to sample as received: Ultimate—	
Hydrogen	4.69		5.36
Carbon	65.92		59.03
Nitrogen	1.67		1.50
Oxygen	12.17		20.18
Sulphur	2.34		2.10
Ash	13.21		11.83
	100.00		100.00

Calorific value determined on air-dried sample	B. T. U.	11675
	Calories	6486
Calorific value corrected to sample as received	B. T. U.	10452
	Calories	5807
Calorific value calculated from ultimate analysis of air-dried sample	B. T. U.	11648
	Calories	6471
Calorific value corrected to sample as received	B. T. U.	10428
	Calories	5793
Specific gravity of air-dried sample		1.275

Analysis of ash from air-dried sample.

SiO_2	23.34	per cent
CaO	25.03	per cent
MgO	.76	per cent
Fe_2O_3	24.28	per cent
Al_2O_3	17.10	per cent
P_2O_5	.329	per cent
SO_3	7.90	per cent
Undetermined	1.261	per cent
	100.00	

Sample Number 19.

Description of Mine.

Operator. Phillips Fuel Company, Ottumwa.

Mine. Rutledge No. 5, at Rutledge, Wapello county, on the Chicago, Milwaukee and St. Paul Railway.

Sample collected. May 20, 1909.

Description. The mine was sampled in the seventeenth west entry on the north side of the shaft, about one mile from the bottom. The seam is here 3 feet 10 inches thick and is free from rock, although there are some sulphur concretions. The average thickness of the bed is 42 inches. (See Vol. XIX, page 298, Annual Report Iowa Geological Survey.)

Discussion of Analytical Results.

The sulphur content is high. Ash is low for an Iowa coal. The ash was a dark brick red due to the iron oxide content. The carbon value is high and as a result the thermal value is correspondingly high. Moisture in sample as received is lower than the average. Except for the large amount of pyrite present this coal has an excellent appearance.

Sample Number 19.

	Per Cent.		Per Cent.
Loss of moisture on air-drying	7.53		
Analysis of air-dried sample: Proximate—		Analysis corrected to sample as received: Proximate—	
Moisture	5.84		12.93
Volatile combustible matter	38.78		35.86
Fixed Carbon	44.14		40.82
Ash	11.24		10.39
	100.00		100.00
Total sulphur	6.26		5.79
Analysis of air-dried sample: Ultimate—		Analysis corrected to sample as received: Ultimate—	
Hydrogen	5.09		5.54
Carbon	64.20		59.36
Nitrogen	1.67		1.54
Oxygen	11.80		17.63
Sulphur	6.00		5.54
Ash	11.24		10.39
	100.00		100.00

Calorific value determined on air-dried sample	B. T. U. 12010	Calories 6672
Calorific value corrected to sample as received	B. T. U. 11106	Calories 6170
Calorific value calculated from ultimate analysis of air-dried sample	B. T. U. 11822	Calories 6568
Calorific value corrected to sample as received	B. T. U. 10931	Calories 6073
Specific gravity of air-dried sample		1.293

Analysis of ash from air-dried sample.

SiO_2	13.61	per cent
CaO	14.49	per cent
MgO	.97	per cent
Fe_2O_3	47.81	per cent
Al_2O_3	15.53	per cent
P_2O_5	.677	per cent
SO_3	5.80	per cent
Undetermined	1.113	per cent
	100.00	

Sample Number 20.

Description of Mine.

Operator. Keystone Coal Mining Company, Des Moines.

Mine. Keystone mine, Des Moines, Polk county, at west city limits, on Chicago, Milwaukee and St. Paul Railway.

Sample collected. June 21, 1909.

Description. The sample was taken from the face of the second north entry, where the vein has just risen from a swamp to the top of a hill. Where sampled the vein measured 4 feet 3 inches. In the swamp it was seven feet thick. It will vary from 3 feet 8 inches to 7 feet in different parts of the mine. Some thin sulphur streaks were present in the face, but no rock or thick sulphur bands.

The shaft is 165 feet deep. It was sunk July, 1908. The mine at the time of sampling was not well opened, but had an output of 75 to 80 tons daily, and employed 23 men. (See Vol. XIX, page 114, Annual Report Iowa Geological Survey.)

Discussion of Analytical Results.

The sample as received was lower in moisture than the average Iowa coal. Ash and sulphur contents are high. The ash is a dark buff colored mass and contains more than the average amount of phosphorus. In this coal as in nearly all of the Iowa coals a large amount of sulphur goes into the ash. The lime content in the ash is noticeably low. The thermal value is a little below the average.

Sample Number 20.

	Per Cent.		Per Cent.
Loss of moisture on air-drying	8.64		
Analysis of air-dried sample: Proximate—		Analysis corrected to sample as received: Proximate—	
Moisture	4.78		13.01
Volatile combustible matter	38.06		34.77
Fixed Carbon	41.83		38.22
Ash	15.33		14.00
	100.00		100.00
Total sulphur	6.26		5.72
Analysis of air-dried sample: Ultimate—		Analysis corrected to sample as received: Ultimate—	
Hydrogen	5.12		5.64
Carbon	61.10		55.82
Nitrogen	1.37		1.25
Oxygen	11.20		17.91
Sulphur	5.88		5.37
Ash	15.33		14.01
	100.00		100.00

Calorific value determined on air-dried sample	B. T. U.	11481
	Calories	6378
Calorific value corrected to sample as received	B. T. U.	10483
	Calories	5824
Calorific value calculated from ultimate analysis of air-dried sample	B. T. U.	11433
	Calories	6352
Calorific value corrected to sample as received	B. T. U.	10445
	Calories	5803
Specific gravity of air-dried sample		1.256

Analysis of ash from air-dried sample.

SiO_2	23.15	per cent
CaO	10.83	per cent
MgO	1.26	per cent
Fe_2O_3	35.87	per cent
Al_2O_3	19.59	per cent
P_2O_5	1.04	per cent
SO_3	6.26	per cent
Undetermined	2.00	per cent
	100.00	

Sample Number 21.

Description of Mine.

Operator. English Creek Coal Company, Oskaloosa.

Mine. Hawkeye mine at Hawkeye, about two miles east of Knoxville, Marion county, on Washington and Knoxville line of the Chicago, Rock Island and Pacific Railway.

Sample collected. June 16, 1909.

Description. The sample is from room 5, thirteenth entry east. The coal here showed a face of six feet, with some thin streaks of sulphur and occasional bowlders. The mine at time of sampling employed 125 men. (See Vol. XIX, page 192, Annual Report Iowa Geological Survey.)

Discussion of Analytical Results.

This coal contained a large amount of moisture in the "as received" condition and lost a very large amount of the moisture on air-drying. The hydrogen content is high and oxygen is unusually low. Although this coal has a high ash content its thermal value is above average. The sulphur content is also high.

Sample Number 21.

	Per Cent.		Per Cent.
Loss of moisture on air-drying	13.80		
Analysis of air-dried sample: Proximate—		Analysis corrected to sample as received: Proximate—	
Moisture	4.50		17.68
Volatile combustible matter	36.37		31.35
Fixed Carbon	44.36		38.24
Ash	14.77		12.73
	100.00		100.00
Total sulphur	6.03		5.20
Analysis of air-dried sample: Ultimate—		Analysis corrected to sample as received: Ultimate—	
Hydrogen	5.21		6.02
Carbon	63.42		54.67
Nitrogen	1.21		1.05
Oxygen	9.71		20.62
Sulphur	5.68		4.90
Ash	14.77		12.74
	100.00		100.00

Calorific value determined on air-dried sample	B. T. U. 11939	Calories 6633
Calorific value corrected to sample as received	B. T. U. 10291	Calories 5717
Calorific value calculated from ultimate analysis of air-dried sample	B. T. U. 11932	Calories 6629
Calorific value corrected to sample as received	B. T. U. 10285	Calories 5725
Specific gravity of air-dried sample	1.289	

Analysis of ash from air-dried sample.

SiO_2	26.01	per cent
CaO	18.68	per cent
MgO	1.22	per cent
Fe_2O_3	32.84	per cent
Al_2O_3	14.03	per cent
P_2O_5	.382	per cent
SO_3	6.11	per cent
Undetermined	.728	per cent
	100.00	

Sample Number 22.

Description of Mine.

Operator. Bennett Brothers Coal Company, Des Moines.

Mine. Bennett mine, Des Moines, Polk county, south side Raccoon river. No railroad connections.

Sample collected. June 21, 1909.

Description. The mine was sampled at the end of the fourth west entry. The vein here measured 4 feet 6 inches. Its average thickness is 4 feet 4 inches, with occasional portions up to 5 or 6 feet. The coal is clean, without rock or sulphur bands and breaks into angular fragments. The mine is 125 feet deep and employed 100 men who put out 100 to 300 tons daily. The mine at time of sampling had been running six years and supplied a large local trade. (See Vol. XIX, page 120, Annual Report Iowa Geological Survey.)

Discussion of Analytical Results.

This coal is high in hydrogen and carbon and as a result has a high calorific value. The coal in the "as received" condition was low in moisture for an Iowa coal. Much of this was lost on air-drying. The ash is light gray in color. The iron oxide content is low. Magnesia, alumina, and silica are high. The appearance of the coal is good and the analyses from it show it to be better than the average Iowa coal.

Sample Number 22.

	Per Cent.		Per Cent.
Loss of moisture on air-drying	8.77		
Analysis of air-dried sample: Proximate—		Analysis corrected to sample as received: Proximate—	
Moisture	4.62		12.99
Volatile combustible matter	38.88		35.47
Fixed Carbon	44.20		40.32
Ash	12.30		11.22
	100.00		100.00
Total sulphur	5.15		4.70
Analysis of air-dried sample: Ultimate—		Analysis corrected to sample as received: Ultimate—	
Hydrogen	5.32		5.83
Carbon	64.82		59.14
Nitrogen	.98		.90
Oxygen	11.68		18.42
Sulphur	4.90		4.48
Ash	12.30		11.23
	100.00		100.00

Calorific value determined on air-dried sample	B. T. U.	12139
	Calories	6744
Calorific value corrected to sample as received	B. T. U.	11064
	Calories	6147
Calorific value calculated from ultimate analysis of air-dried sample	B. T. U.	12020
	Calories	6678
Calorific value corrected to sample as received	B. T. U.	10965
	Calories	6092
Specific gravity of air-dried sample		1.277

Analysis of ash from air-dried sample.

SiO_2	26.13	per cent
CaO	17.04	per cent
MgO	2.09	per cent
Fe_2O_3	26.99	per cent
Al_2O_3	20.66	per cent
P_2O_5	.458	per cent
SO_3	5.58	per cent
Undetermined	1.482	per cent
	100.00	

Sample Number 23.

Description of Mine.

Operator. Bolton-Hoover Coal Company, Oskaloosa.

Mine. Bolton No. 2, Bolton, Mahaska county, on a long switch from the Oskaloosa and Tracy line of the Chicago, Burlington and Quincy Railroad.

Sample collected. June 15, 1909.

Description. The sample is from the first room on the fifth north, about 1,200 feet in from the mouth of the slope and seventy feet below the surface. The face was here 5 feet 3 inches in height. It showed a few thin sulphur streaks, some up to 1½ inches in thickness, and a few bowlders. The mine at time of sampling had a daily capacity of 400 tons. The coal is hauled out of the mine and overland to the top works, about 1,200 feet distant, by rope. The top works are located on the railroad at the old slope. The haulage engine is located here also and serves both slopes. The tail rope runs on the surface nearly one-fourth mile beyond the mouth of the slope and enters the mine through an old drill hole. (See Vol. XIX, page 205, Annual Report Iowa Geological Survey.)

Discussion of Analytical Results.

Volatile combustible matter is high. The total carbon content is unusually high for an Iowa coal. This fact largely accounts for the high thermal value. Ash and sulphur are low. Silica in the ash is very high.

Sample Number 23.

	Per Cent.		Per Cent.
Loss of moisture on air-drying	9.16		
Analysis of air-dried sample: Proximate—		Analysis corrected to sample as received: Proximate—	
Moisture	5.48		14.14
Volatile combustible matter	40.15		36.48
Fixed Carbon	44.88		40.77
Ash	9.49		8.61
	100.00		100.00
Total sulphur	3.26		2.96
Analysis of air-dried sample: Ultimate—		Analysis corrected to sample as received: Ultimate—	
Hydrogen	5.30		5.82
Carbon	67.01		60.87
Nitrogen	1.41		1.28
Oxygen	13.64		20.55
Sulphur	3.15		2.86
Ash	9.49		8.62
	100.00		100.00

Calorific value determined on air-dried sample	B. T. U. 12183 Calories 6768
Calorific value corrected to sample as received	B. T. U. 11067 Calories 6145
Calorific value calculated from ultimate analysis of air-dried sample	B. T. U. 12102 Calories 6724
Calorific value corrected to sample as received	B. T. U. 10993 Calories 6107
Specific gravity of air-dried sample	1.30

Analysis of ash from air-dried sample.

SiO_2	35.34	per cent
CaO	16.60	per cent
MgO	.56	per cent
Fe_2O_3	28.56	per cent
Al_2O_3	14.03	per cent
P_2O_5	.710	per cent
SO_3	3.00	per cent
Undetermined	1.20	per cent
	100.00	

Sample Number 24.

Description of Mine.

Operator. Colfax Consolidated Coal Company, Colfax.

Mine. Mine No. 8, four miles southeast of Colfax on the Colfax Northern Railway.

Sample collected. June 17, 1909.

Description. The sample was cut from the end of the main west entry, 1,700 feet west from the shaft. The seam was here 5 feet 7 inches thick and presented a clean face except for a half inch sulphur band one foot from the bottom.

The shaft is 164 feet deep and penetrates the "first vein," one or two feet thick, eighty feet from the surface. The mine employed 400 men at time of sampling and had an output of 800 to 900 tons per day. (See Vol. XIX, page 159, Annual Report Iowa Geological Survey.)

Discussion of Analytical Results.

This coal in the "as received" condition contained a large amount of moisture. Air-drying removed much of this. The sulphur content is quite low for an Iowa coal and but little of this constituent went into the ash. The oxygen content is above the average. The ash is dark buff in color and high in iron oxide. The thermal value is a little below average.

Sample Number 24.

	Per Cent.		Per Cent.
Loss of moisture on air-drying	12.68		
Analysis of air-dried sample: Proximate—		Analysis corrected to sample as received: Proximate—	
Moisture	5.47		17.46
Volatile combustible matter	39.17		34.20
Fixed Carbon	42.94		37.49
Ash	12.42		10.85
	100.00		100.00
Total sulphur	3.49		3.05
Analysis of air-dried sample: Ultimate—		Analysis corrected to sample as received: Ultimate—	
Hydrogen	5.02		5.79
Carbon	63.60		55.53
Nitrogen	1.53		1.33
Oxygen	14.09		23.58
Sulphur	3.34		2.92
Ash	12.42		10.85
	100.00		100.00

Calorific value determined on air-dried sample	B. T. U.	11588
	Calories	6438
Calorific value corrected to sample as received	B. T. U.	10119
	Calories	5620
Calorific value calculated from ultimate analysis of air-dried sample	B. T. U.	11407
	Calories	6337
Calorific value corrected to sample as received	B. T. U.	9961
	Calories	5533
Specific gravity of air-dried sample		1.249

Analysis of ash from air-dried sample.

SiO_2	21.13	per cent
CaO	19.27	per cent
MgO	1.66	per cent
Fe_2O_3	35.34	per cent
Al_2O_3	17.55	per cent
P_2O_5	.247	per cent
SO_3	3.12	per cent
Undetermined	1.683	per cent
	100.00	

Sample Number 25.

Description of Mine.

Operator. Enterprise Coal Company, Des Moines.

Mine. Mine No. 2, Enterprise, Polk county, on the St. Paul and Kansas City Railway.

Sample collected. June 22, 1909.

Description. This sample was cut from the break-through near the face of the second west entry off the first south entry. The coal was 5 feet thick here and carried a two-inch sulphur band one foot from the top. Clay slips are present in places. The mine is considered to be in the second vein and was the only one working in this horizon with the possible exception of the Bennett mine. A daily output of 400 tons is maintained. (See Vol. XIX, page 143, Annual Report Iowa Geological Survey.)

Discussion of Results.

This coal is characterized by a high carbon content, the highest of any coal of this series. The volatile combustible matter is high. Ash is very low for an Iowa coal. Total sulphur is below average. The ash is gray in color and quite flaky. Alumina is high. The calorific value is the highest found in any Iowa coal examined.

Sample Number 25.

	Per Cent.		Per Cent.
Loss of moisture on air-drying	8.61		
Analysis of air-dried sample: Proximate—		Analysis corrected to sample as received: Proximate—	
Moisture	6.08		14.17
Volatile combustible matter	41.01		37.48
Fixed Carbon	44.17		40.36
Ash	8.74		7.99
	100.00		100.00
Total sulphur	3.79		3.46
Analysis of air-dried sample: Ultimate—		Analysis corrected to sample as received: Ultimate—	
Hydrogen	5.23		5.73
Carbon	68.11		62.24
Nitrogen	1.58		1.44
Oxygen	12.78		19.35
Sulphur	3.56		3.25
Ash	8.74		7.99
	100.00		100.00

Calorific value determined on air-dried sample	B. T. U. 12454 Calories 6919
Calorific value corrected to sample as received	B. T. U. 11382 Calories 6320
Calorific value calculated from ultimate analysis of air-dried sample	B. T. U. 12303 Calories 6835
Calorific value corrected to sample as received	B. T. U. 11244 Calories 6247
Specific gravity of air-dried sample	1.301

Analysis of ash from air-dried sample.

SiO_2	23.12	per cent
CaO	17.10	per cent
MgO	1.86	per cent
Fe_2O_3	26.41	per cent
Al_2O_3	23.30	per cent
P_2O_5	.293	per cent
SO_3	6.72	per cent
Undetermined	1.197	per cent
	100.00	

Average Coal.

The data on the opposite page, which have been termed "average coal," were not obtained by the analysis of a sample, but by averaging the corresponding values obtained from analyses of the sixteen Iowa coals discussed in the preceding pages.

The coal dealer is seldom furnished with analyses of the particular coals he is handling and about the only information he can furnish the consumer is that it is an Iowa coal. In such a case the analytical data of the "average coal" will be of value. It will also be valuable when coal from the Iowa fields in general is to be compared with that of other fields.

A discussion of the average Iowa coal is unnecessary. The data will speak for themselves.

Average Coal.

	Per Cent.		Per Cent.
Loss on air-drying	9.33		
Analysis of air-dried sample: Proximate—		Analysis corrected to sample as received: Proximate—	
Moisture	6.34		15.07
Volatile combustible matter	37.60		34.09
Fixed Carbon	43.24		39.21
Ash	12.82		11.63
	100.00		100.00
Total sulphur	4.67		4.52
Analysis of air-dried sample: Ultimate—		Analysis corrected to sample as received: Ultimate—	
Hydrogen	5.07		5.64
Carbon	63.71		57.77
Nitrogen	1.47		1.33
Oxygen	12.27		19.42
Sulphur	4.66		4.23
Ash	12.82		11.61
	100.00		100.00

Calorific value determined on air-dried sample	B. T. U. 11754 Calories 6530
Calorific value corrected to sample as received	B. T. U. 10657 Calories 5921
Calorific value calculated from ultimate analysis of air-dried sample	B. T. U. 11650 Calories 6472
Calorific value corrected to sample as received	B. T. U. 10563 Calories 5865
Specific gravity of air-dried sample	1.27

Analysis of ash from air-dried sample.

SiO_2	23.26	per cent
CaO	17.31	per cent
MgO	1.38	per cent
Fe_2O_3	31.10	per cent
Al_2O_3	17.02	per cent
P_2O_5	.548	per cent
SO_3	6.00	per cent
Undetermined	1.372	per cent
	100.00	

General Discussion and Conclusion.

Coal is composed of two classes of substances, viz., (1) those which have heat value and (2) those which do not. In the first class carbon and hydrogen are the important ones. Sulphur on oxidation does evolve heat but the amount of heat contributed by this element is practically negligible. In the second class are ash, moisture, nitrogen and oxygen. Of these moisture and ash are the most important. These two substances not only displace their own weights of combustible matter but they absorb a large amount of the heat of the fuel in being heated up to the temperature of the fire box or furnace. Each per cent of moisture and ash displaces twenty pounds of combustible matter per ton. Both ash and moisture increase the cost of handling the coal for the producer and consumer. If the ash contains slagging or clinkering constituents the efficiency of the furnace is decreased and the cost of handling greatly increased. Sulphur which was mentioned above as having heat value, is also classed as an impurity on account of its low heat value and its injurious properties when coals are used for certain purposes.

The physical and chemical properties of Iowa coals are discussed under the following headings:

Moisture.—Coals from the Iowa field before mined contain a high percentage of moisture. In this respect they are similar to many coals in other fields of the mid-continental regions, averaging a little higher in this component than Illinois coals and about the same as Missouri coals. The loss of moisture on air-drying is practically the same as that of Illinois and Missouri coals. The Iowa coals are compared with those of Illinois and Missouri for the reason that they must compete in the market with these coals.

A study of the analyses reveals the fact that the loss of moisture by air-drying is not uniform in Iowa coals. This difference, the writer believes, is due to difference in structure. A microscopic examination was not made, but it is believed that such an examination would reveal differences in structure.

Iowa coals as they exist in the mine contain a little over fifteen per cent of moisture. When air-dried they contain 6.34 per cent of moisture on the average. The importance of allowing the coal plenty of time to air-dry is here evident. In this work, ninety-six hours was the time allowed for air-drying. The coal was crushed much finer than is used in practice and for that reason the loss of moisture was more rapid than it is when the coal is in the lump sizes. Averaging the moisture content of the five mine samples and car samples of the same Iowa coals analyzed at the coal testing plant of the United States Geological Survey in 1904 (See Professional Paper No. 48, page 151, U. S. G. S.), we find that the difference in moisture in the mine samples and in the car samples after shipping to St. Louis is 2.42 per cent. From extensive studies at the Coal Testing Plant in St. Louis in 1904, the following conclusion was reached: "In sampling coals which run 5 per cent or over in the mine sample, the probable amount of moisture in the commercial sample can be obtained by multiplying by the coefficient 0.915." (See reference above.) In other words the moisture content of the commercial sample will average 91.5 per cent of that of the mine sample. This value is too high for Iowa coals. The coefficient of decrease of moisture from mine samples, calculated from the five Iowa coals referred to above is .844, or in other words the moisture content of the commercial sample of Iowa coal will average about 84.4 per cent of that of the mine sample.

The amount of moisture lost on air-drying after mining depends upon (1) the fineness of the coal, (2) atmospheric conditions, (3) time that elapses between mining and consumption, (4) conditions of storage. The finer the coal, within certain limits, the more rapid and greater will be the moisture loss. It is plain that weather conditions, such as variations in temperature and moisture content in atmosphere, will affect air-drying. Other things being equal the sooner the coal is used after mining the less will be the air-drying loss. This is true only within certain time limits. If coal is stored immediately after mining, the rate at which air-drying will take place may be affected by the condition of the bins. A bin with good ventilation will naturally give better drying conditions than one with poor ventilation. As mentioned before, the structure of the coal will undoubtedly have something to do with the rate of air-drying.

Volatile Combustile Matter.—This includes the volatile matter of coal with the exception of moisture. This term is objected to as being misleading, for the reason that not all of the volatile matter of coal, exclusive of moisture, is combustible. However, the term is in such general use in the coal trade that it has seemed wise to continue its use.

Iowa coals generally average quite high in volatile combustible matter. The exact nature of the volatile constituents has not been carefully studied. An investigation along this line is being planned.

Like most mid-continental and western coals, a large portion of the volatile matter is distilled off at rather low temperatures. This is one of the causes of a serious heat loss in the burning of these coals. Many furnaces in which Iowa coals are burned are not properly designed and as a result too often the fuel is blamed instead of the furnace. Better results would be obtained if greater combustion space or means of furnishing an ample supply of heated air be provided. The economic combustion of the volatile combustible matter in these coals is an important factor too often overlooked or neglected in furnace design. The low efficiency obtained from many western coals is often due to the fact that combustible volatile matter escapes from the flue unburned.

Closely associated with the volatile combustible matter of coals is the smoke nuisance problem. "Visible smoke* consists of solid carbon particles and solid or liquid hydrocarbon particles or tar vapors." These result from the incomplete combustion of the volatile matter of the fuel. The black particles of the smoke are free carbon deposited by the cooling of hot dissassociated gases. This carbon is evidence of a great waste of fuel. "Flame† is a phenomenon accompanying the chemical union of certain gases, one of which is usually oxygen; and the incandescent solid particles make a flame visible. If some of these particles in the flame are carbon, formed by the dissociation of hydrocarbons, luminosity results, and if the temperature of these particles is reduced below the point at which they combine with oxygen, or if sufficient oxygen is not at hand to effect

*Bureau of Mines bulletin, No. 1, page 9, Volatile Matter of Coal.
†Bureau of Mines bulletin, No. 1, page 9, Volatile Matter of Coal.

the union, they fail to unite with oxygen, and pass off as solid carbon in smoke." "The essential requirements of smokeless combustion are, therefore, three—(1) sufficient combustion space, (2) sufficient air at a high temperature, and (3) sufficient thorough mingling of gases and air—these three conditions to be adapted to the type of fuel and nature of its volatile products."

The property that many coals possess to disintegrate and change in heat value, known as "weathering," is associated to a certain extent with the volatile matter of the coal. Parr* and Wheeler found that upon liberation of coal from the vein immediately an exudation of hydrocarbons began, followed by an absorption of oxygen. The loss† of hydrocarbons caused a loss in calorific value averaging about one per cent for the first week and three to three and five-tenths per cent for a year. Iowa coals no doubt are very similar to Illinois coals in this respect. Weathering will be further discussed under sulphur.

For the manufacture of illuminating gas, coals with high volatile matter content are usually preferred. Experience has shown, however, that not only the percentage of volatile matter is important, but also its composition. Careful studies have shown that the composition of the volatile matter of coals varies greatly. Concerning the value of coals in general for coal gas manufacture, Fuhlweiler‡ states:

It is notable that some of the newer Western coals yield considerably less gas than the Eastern coals having the same content of volatile matter. The ultimate analysis of a coal does not throw very much light on its suitability for the manufacture of gas, although certain general indications may be derived from it. In general, increasing percentages of hydrogen result in more volatile constituents, and high percentages of oxygen apparently decrease the yield of gas and increase the yield of tar. The higher percentages of nitrogen usually result in more ammonia. The presence of sulphur is to be avoided as far as possible, yet its manner of occurrence is important in determining whether it will be volatile and go off in the gas and have to be removed, or whether it will remain in the coke. Where the

*University of Illinois bulletin, No. 32.
†University of Illinois bulletin, No. 38.
‡Indust. Chem. for Student and Mfg.—Rogers & Aubert, page 418.

coke is to be used for the manufacture of water gas, the composition and fusion point of the ash is important, while in case it is to be used for foundry work the absence of sulphur and phosphorus is essential.

In the manufacture of coal gas four commercial products are obtained. They are coal gas, ammoniacal liquor, coal tar and coke. The value of these products, as has been stated, depends upon the coal from which they are obtained. Iowa coals are high in oxygen, consequently large yields of tar may be expected. In this respect they differ very little from Illinois and Missouri coals. The oxygen content of Eastern coals is very much lower. The hydrogen and nitrogen contents of Iowa, Illinois and Missouri coals are about the same. Sulphur in Iowa coals is high and much of this substance, as will be seen by examining the analyses, will go into the gas and will have to be removed. The coke, which is very poor, will be high in ash and consequently high in sulphur, which will prevent its use for forge and metallurgical purposes.

For the manufacture of gas a good grade of marketable coke is essential. In Iowa a coal for gas purposes that will not yield a good coke cannot be used. The yield of gas from Iowa coals is low compared with Pennsylvania and West Virginia coals. Illinois and Missouri coals are much the same in this respect. Iowa coals are not used for gas purposes for the reasons given above and the additional reason that the ash-disposal problem is very difficult. The cost of operation of a gas plant using Iowa coal is very much higher than one using Pennsylvania or West Virginia coals. Specifications for gas coals usually call for a maximum of not more than one per cent of sulphur. This excludes all Iowa coals.

Fixed Carbon.—Experience has shown that in bituminous and semi-bituminous coals the steam values are proportional to the percentage of fixed carbon. Although the fixed carbon evaporates less water than an equivalent weight of volatile combustible matter when properly burnt, so much of the latter is lost through careless firing and faulty furnace construction that the relative steam value of a coal may be approximated by assuming the fixed carbon to be the only useful constituent. For steam tests of Iowa coals see Vol. XIX, pages 417-458, Annual Report Iowa Geol. Surv. Usually the fixed carbon is the principal constituent of the coke produced by the destructive distillation of the coal. Coke produced from Iowa coals has little value. It has little strength and is high in ash and sulphur.

Ash.—Iowa coals are high in ash. This is the most detrimental of the inert constituents. From each ton of coal burned from 200 to 300 pounds of ash are produced. When the fact that the ash is quite fusible under certain conditions is taken into consideration the ash problem is more serious. The labor charge, in a power plant burning Iowa coal, against handling the ash, is high.

The fact that Iowa coals clinker and slag is due very largely to the high iron content. An examination of the analyses of Iowa coals reveals a high ash content. Further examination shows that the iron content in the ash is high. The ash analysis shows the iron to be present as ferric oxide. The fact is that much of the iron is present in the coals as pyrite (FeS_2).

When the furnace temperature approaches low redness the pyrite breaks up as follows:

$$FeS_2+heat=FeS+S.$$

Oxygen from the air then reacts with the sulphur ($S+2O=SO_2$) to form sulphur dioxide. It will also react with FeS to form ferrous oxide (FeO) and sulphur dioxide (SO_2). The equation is $FeS+3O=FeO+SO_2$. If the temperature of the furnace does not get too high the ferrous oxide will go over to ferric oxide.

$$2FeO+O=Fe_2O_3.$$

If the iron stays in the form of ferric oxide little or no slagging or clinkering will take place. In the case where the furnace temperature is high, the ferrous oxide will react with the silica (SiO_2) to form a ferrous silicate. The silicate formed will depend upon the temperature and the amount of constituents present. The following reactions take place when firing is pushed:

$$\underset{\text{Ferrous oxide}}{FeO} + \underset{\text{silica}}{SiO_2} = \underset{\text{ferrous silicate}}{FeSiO_3}$$

$$\underset{\text{Ferrous oxide}}{2FeO} + \underset{\text{silica}}{SiO_2} = \underset{\text{ferrous silicate}}{Fe_2SiO_4}$$

Both of these silicates have comparatively low formation temperatures, and these temperatures are readily obtained in furnace or boiler firing. The above silicates at their formation temperatures are sticky viscous masses which when cooled are clinkers. If the temperature is raised above the formation temperature of these silicates the mass will fuse and run through the grates, forming when cool, either a glassy or stony slag. If the temperature is high enough, as is often the case, the ferrous sulphide (FeS) mentioned above will fuse and cause clinkering. In the presence of carbon (C) at temperatures above 1000 degrees C ferric oxide will be reduced to ferrous oxide, which will then react with silica to form a slag. The formation temperatures of calcium and aluminum silicates are very high, but in some cases calcium silicate will be formed and clinkering will result. The reaction is

$$\underset{\text{Lime}}{CaO} + \underset{\text{Silica}}{SiO_2} = \underset{\text{Calcium silicate}}{CaSiO_3}$$

In most cases the lime and alumina will dissolve in the ferrous silica to form a complex slag.

If Iowa coals are to be used for the manufacture of producer gas, it is probable that the slagging type of gas producer will work well. At any rate this method of getting rid of the ash seems feasible.

Few gas-producer tests have been made on Iowa coals. Those which have been made indicate that a much higher fuel efficiency can be obtained by using the coal in a producer plant. One test made "*showed that to produce one electrical horsepower hour with this coal in the producer required 1.73 pounds of dry coal, whereas under the steam boiler it required 4.95 pounds to produce the same result, a gain in efficiency for the producer of 186 per cent. As this coal ran nearly 17 per cent

*Vol. XIX, page 411, Annual Report Iowa Geol. Surv.

of ash in the car sample, the great advantage of using it in the producer plant will be apparent, and these results seem to open the way to a much better utilization of Iowa coals."

No thorough washing tests of Iowa coals have been made. The writer believes that thorough experiments along this line would give valuable results. Much of the ash and sulphur content could no doubt be removed and the value of the coal thereby be greatly increased.

Sulphur.—Iowa coals are noted for their high sulphur content. This constituent renders them practically valueless at the present time for the manufacture of gas. Iron and sulphur at a temperature above low red heat react to form FeS. This is the principal cause of the corrosion of grates and fire boxes when coals high in sulphur are burned. Not all of the sulphur in Iowa coals is present as FeS_2. Some of it is present as calcium sulphate ($CaSO_4$), magnesium sulphate ($MgSO_4$), and as organic sulphur. The sulphate sulphur does little damage, and unless very high temperatures are reached, goes into the ash.

Deterioration and spontaneous heating of coal in storage is thought by some authorities to be due to a large extent to the oxidation of pyrite. Other authorities attribute spontaneous combustion to oxidation of the available hydrogen and a small part of the carbon by occluded oxygen. This causes an evolution of heat. When the sulphur of the pyrite (FeS_2) oxidizes, heat is also given up. If the coal is fine and the pile is large, there is little chance for the heat so generated to escape. The temperature having been raised the velocity of the oxidation of the sulphur, hydrogen and carbon increases and a correspondingly large amount of heat is evolved. The increase in temperature followed by increased velocity of reaction takes place until the ignition temperature of the coal is reached. The rise in temperature causes an increased amount of volatile matter to be distilled off. Unless this volatile matter can escape, it will ignite and burn. A certain amount of moisture seems to aid in spontaneous combustion. Lump sizes are not as liable to ignite by spontaneous combustion as finer coal. The larger the pile and the poorer the ventilation, the greater is the tendency to ignite by spontaneous combustion.

Storing large amounts of fine coal in large piles is not to be recommended. Storing under water will prevent spontaneous combustion and the disintegration of the coal. However, the storage of coal in larger sized lumps than is to be used will overcome the difficulties of spontaneous combustion to a great extent. The storing of Iowa coal in large lumps for a very long time is not recommended, for the reason that disintegration takes place due to the taking up of oxygen, part of which oxidizes the available hydrogen and a little carbon, as has been stated before. In time the coals will almost completely slack. Then the danger of spontaneous combustion is great. This danger is not greater in Iowa coals than in many Illinois and Missouri coals. There is a great deal of difference of opinion concerning the factors that are most important in spontaneous combustion. An excellent summary of the opinions of many investigators is given in Illinois University Bulletin No. 46, entitled, "The Spontaneous Combustion of Coals," by Parr and Kressman.

Summary.—Iowa coals on account of their high ash and moisture contents have correspondingly low heat value. Their high sulphur content excludes them from the manufacture of coal or water gas, and renders them destructive to grates and fire boxes. Their tendency to disintegrate by weathering prevents their being stored for a great length of time. The experimental evidence at hand indicates that from 100 to 150 per cent greater efficiency can be obtained by the manufacture of producer gas. This method of use should create a preference for Iowa coal for steaming purposes in Iowa. Washing will undoubtedly increase the value of Iowa coals by removing much of the ash and sulphur content. Whether this can be done economically has not been demonstrated, but it is thought that an experiment on an industrial scale would yield favorable results. The use of Iowa coal at the present time is confined to steam and household use in the immediate vicinity of the mines. The use of Iowa coals for power purposes is discussed in Bulletin No. 29, of the Engineering Experiment Station of Iowa State College at Ames. Iowa coals are of little value for the manufacture of coke on account of their high sulphur content and low crushing strength. Iowa coals compare favorably with those of Northern Illinois and Missouri.

Purchase Of Coal Under Specification.

The purchase of coal under specification depending on the heating value of the coal, its content of ash and of moisture, rather than upon the reputation of the coal dealer or the trade name of the coal, is recommended. The United States Government has been purchasing coal for a number of years under specification with great profit. The specifications used are quoted below and may be adapted, by the Iowa coal consumer and dealer, to Iowa coals. Only that part of the specification which deals with Bituminous coal is given. For complete specifications for different types of coal, consult Bureau of Mines Bulletin, No. 63, entitled, "Sampling Coal Deliveries and Types of Government Specifications for the Purchase of Coal," by George S. Pope.

Specifications and proposals for bituminous coal for steam power plants.

I. Proposals.

1. Sealed proposals, in duplicate, to furnish the quantities of coal specified in the schedule herewith, required for the use of (the name of the department, bureau, or institution) for the fiscal year ending June 30, 19.., will be received until 2 o'clock p. m., ... 19.., at the office of .... and then opened.

2. Each bidder shall have the right to be present either in person or by attorney when the bids are opened.

II. Address of Proposals.

3. Proposals, in duplicate, must be forwarded to ...., postage prepaid. Addressed envelope for mailing is inclosed herewith.

III. Proposals—Guaranty.

4. *Signature.* Proposals must be made in duplicate on the form furnished by ...., and must be signed by the individual, partnership, or corporation making the same; when made by a partnership, the name of each partner must be signed. If made by a corporation, proposals must be signed by the officer thereof authorized to bind it by contract, and be accompanied by a copy, under seal, of his authority to sign.

5. *Cash or Certified Check.* The proposals must be accompanied by cash or by a certified check drawn payable to the order of the Secretary of the................................., in an amount equal to 2 per cent of the estimated cost of the items for which bids are submitted, the minimum amount in any case to be $10. This requirement is solely to guarantee, if an award is made on the proposal, that within 10 days after notice is given that an award has been made, the bidder will enter into a contract in accordance with the terms of the proposal and execute a bond for the faithful performance thereof, with good and sufficient sureties as hereinafter required. In the event of the failure of the bidder to enter into contract or execute bond, the cash or check guaranty will be forfeited.

IV. Contractor's Bond.

6. *Sureties.* Each contractor shall be required to give a bond, with two or more individual sureties or one corporate surety duly qualified under the act of Congress approved August 13, 1894, in which they shall covenant and agree, in case the said contractor shall fail to do or perform any or all of the covenants, stipulations, and agreements of said contract on the part of the said contractor to be performed as therein set forth, the said contractor and his sureties shall forfeit and pay to the United States of America any and all damages sustained by the United States by reason of any failure of the contractor fully and faithfully to keep and perform the terms and conditions of his contract to be recovered in an action at law in the name of the United States in any proper court of competent

jurisdiction. Such sureties (except corporate sureties) shall justify their responsibility by affidavit showing that they severally own and possess property of the clear value in the aggregate of double the amount of the above-mentioned forfeiture over and above all debts and liabilities and all property by law exempt from execution; the affidavit shall be sworn to before a judge or a clerk of a court of record or a United States attorney, who must certify of his own personal knowledge that the sureties are sufficient to pay the full penalty of the bond.

7. *May be waived.* If the estimated amount involved in the contract does not exceed the sum of $200, then the bond may be waived with the consent of the department involved.

V. Reservations.

8. *Rejection and annulment.* The right will be reserved by the Secretary of..............to reject any and all bids, to waive technical defects, and to accept any part of any bid and reject the other part, if, in his judgment, the interests of the Government shall so require; also the right to annul any contract, if, in his opinion, there shall be a failure at any time to perform faithfully any of its stipulations, or in case of a willful attempt to impose upon the Government coal inferior to that required by the contract; and any action taken in pursuance of this latter stipulation shall not affect or impair any right or claim of the United States to damages for the breach of any of the covenants of the contract by the contractor. Bidders are cautioned against guaranteeing higher standards of quality than can be maintained in delivered coal (this applies more especially to bituminous coal), as the Government reserves the right to reject any and all bids if the analyses and test results which the Government may have on record indicate that higher standards have been offered than can probably be maintained.

9. *Estimated quantity.* The estimated quantity of coal to be purchased will be based upon the previous annual consumption, but the right will be reserved to order a greater or less quantity, subject to the actual requirements of the service.

10. *Tests.* The right will be reserved by the Government to purchase, for the purpose of making boiler tests, other coal than that herein contracted for, provided the amount so purchased does not exceed five per cent (5 per cent) of the coal used at the plant during the period covered by this agreement.

11. *Lowest bids may not be considered.* If it should appear to the best interests of the Government to do so, the right is reserved to award the contract for supplying coal at a price higher than that named in a lower bid or in lower bids, on the basis of the quality of the coal offered.

12. *Failure to contract.* If the bidder to whom the award is made should fail to enter into a contract as herein provided, then the award may be annulled and the contract let to the next most desirable bidder without further advertisement, and such bidder shall be required to fulfill every stipulation expressed herein, as if he were the original party to whom the contract was awarded.

13. *Contracts non-transferable.* No contract can be lawfully assigned.

14. *Default.* No proposal will be considered from any person, firm, or corporation in default of the performance of any contract or agreement made with the United States, or conclusively shown to have failed to perform satisfactorily such contract or agreement.

VI. Description of Coals Desired.

15. *Coal desired.* Bids are desired on coal as specified below:

The coal must be a good steam..............	coking noncoking	run-of-mine slack lump (give size)	, bitu-

minous coal, free from bone, slate, dirt, and excessive dust, and adapted for successful use in the particular furnace equipment.

16. *Lowest quality acceptable.* Bituminous coal that shows on analysis a quality lower than that indicated below will not be considered:*

Moisture in "delivered coal"......	....per cent
Ash in "dry coal"...............	....per cent
Volatile matter in "dry coal".....	....per cent
Sulphur (separately determined) in "dry coal"	....per cent
British thermal units in "dry coal" below	....

17. *Information to be supplied by bidder.* Bidders are required to specify the coal offered in terms of moisture, "as received"; ash, volatile matter, sulphur, and British thermal units, "dry coal"; which values become the standards for the coal of the successful bidder. In addition, the bidders are required to give the name and location of the mine producing the coal, the name or other designation of the coal bed, name of operator of mine, and the trade name of the coal. This information to be furnished in spaces provided under section 57 (A).

VII. Award.

21. *Considerations.* Bids will be considered on each item separately; and in determining the award of the contract consideration will be given to the quality of the coal (expressed in terms of ash in "dry coal," of moisture in coal "as received," and of British thermal units in "dry coal") offered by the respective bidders, to the operating results obtained with the coals on previous Government contracts, as well as to the price per ton.

22. *Method of comparing bids.* In order to compare bids as to the quality of the coal offered, all proposals will be adjusted to a common basis. The method used will be to merge all four variables—ash, moisture, calorific value, and price bid per ton—into one figure, the cost of 1,000,000 British thermal units, so that one bid may readily be compared with another. The procedure under this method will be as follows:

*The percentages and the heating value to be filled in by the office inviting bids.

(*a*) All bids will be adjusted to the same ash percentage by selecting as the standard the proposal that offers coal containing the highest percentage of ash. Each 1 per cent of ash content below that of this standard will be assumed to have a positive value of 2 cents per ton, and the price will be accordingly increased 2 cents, the amount of premium that is allowed under the contract for 1 per cent less ash than the standard established in the contract. Fractions of a per cent will be given proportional values. The adjusted bids will be figured to the nearest tenth of a cent.

(*b*) To reduce bids to a common basis with respect to the moisture in the coal offered, the price quoted, adjusted in accordance with the above, will be divided by the difference between 100 per cent and the per cent of moisture guaranteed in the proposal. The adjusted bids will be figured to the nearest tenth of a cent.

(*c*) On the basis of the adjusted price, allowance will then be made for the varying heat values by computing the cost of 1,000,000 British thermal units for each coal offered. This determination will be made by multiplying the adjusted price per ton by 1,000,000 and dividing the result by the product of 2,240, multiplied by the number of British thermal units guaranteed.

23. *Service results and test.* If from practical service experience or by test any of the coals have in the past proved unsuited for the furnace and boiler equipment, or have failed to meet the requirements of the city smoke ordinances, the bids thereon may be eliminated from further consideration, regardless of their calculated costs per million B. t. u. The selection of the lowest bid of the remaining bids on the basis of the cost per million B. t. u. will be considered as a tentative award only, the Government reserving the right to have practical service test or tests made under the direction of the Bureau of Mines, the results to determine the final award of contract. The interested bidder or his authorized representatives may be present at such test.

25. *Service test.* Before making final award of contract, practical service tests, under the direction of the Bureau of

Mines, will be made of selected coals to determine the suitability and adaptability of the coals for the particular furnace and boiler equipment concerned. The interested bidders or their authorized representatives may be present at such tests. Samples will be collected from the coals tested, and complete analyses and calorimetric determinations will be made, as well as determinations of the fusing temperature of the coal ash.

26. *Test results part of contract.* The results of the service test of the coal that proves a satisfactory fuel and the results of the analyses and tests of the samples of that coal will become a part of the contract establishing the standard of the coal offered by the bidder to whom the final award is made. The results become the basis for determining rejectable coal during the life of the contract.

VIII. Delivery.

27. *Quantity.* The coal shall be delivered in such quantities at such times as the Government may direct.

28. *Rapidity.* All the available storage capacity of the Government coal bunkers will be placed at the disposal of the contractor to facilitate delivery of coal under favorable conditions. When an order is issued for coal, the contractor upon commencing a delivery on that order shall continue the delivery with such rapidity as not to waste unduly the services of the Government inspector. Information is furnished in the schedule herewith in relation to the several places, etc., for the delivery of coal, but the bidder is invited to visit those places and inspect the conditions for his own information.

29. *Notices.* After verbal or written notice has been given to deliver coal under this contract, a second notice may be served in writing upon the contractor to make delivery of the coal so ordered within 24 hours after receipt of said second notice. Should the contractor, for any reason, fail to comply with the second request, the Government will be at liberty to buy coal in the open market and for coal so purchased to charge against

the contractor and his sureties any excess in price over the contract price.

30. *Hours.* The contractor will be allowed to deliver coal during the usual hours of teaming, that is, between 8 a. m. and 5 p. m.

31. *Weighing.* The coal will be weighed by representatives of the Government without expense to the contractor.

IX. Sampling.

32. *Imperative for bituminous coal.* As payment for bituminous coal is based upon the quality of coal delivered as shown by analyses of representative samples, it is imperative that samples representing every order of coal be taken and that the proper official of the Government buildings see that such samples are obtained. The Bureau of Mines will have general direction of sampling, giving instructions in the methods of obtaining representative samples, and lending all practicable assistance.

33. *Contractor may be present.* If desired by the coal contractor, permission will be given to him or his representative to be present and witness the collection and preparation of the samples to be forwarded to the Government laboratories.

34. *During unloading.* The coal will be sampled at the time it is being loaded or unloaded from railroad cars, ships, barges or wagons, or when discharged from contractors' supply bins, except as provided for in section 27 of the specifications for anthracite broken, egg, stove, and chestnut.

35. *Size of increments.* When the coal is being unloaded, a shovel or specially designed tool will be used for taking portions or increments of 10 to 30 pounds of coal. For slack or small sizes of anthracite increments as small as 5 to 10 pounds may be taken. The size of the increments depends on the size and weight of the largest pieces of coal and impurities.

36. *Collection of gross sample.* The increments will be regularly and systematically collected, so that the entire delivery

will be represented proportionately in the gross sample. The frequency of collecting the increments should be regulated so that a gross sample of not less than 1,000 pounds will be collected. If the coal contains an unusual amount of impurities, such as slate, and if the pieces of such impurities are very large, it will be necessary to collect gross samples of even 1,500 pounds or more. For slack coal and for small sizes of anthracite, if the impurities do not exist in abnormal quantities or in pieces larger than three-quarters of an inch, a gross sample of approximately 600 pounds may prove sufficient. The gross sample should contain the same proportion of lump coal, fine coal, and impurities as is contained in the coal delivered. As the increments are collected, they will be deposited in a receptacle having a tight-fitting lid and provided with a lock.

37. *Preparation of gross sample.* After the gross sample is collected, it will be systematically crushed, mixed, and reduced in quantity to convenient size for transmittal to the laboratory. The crushing will be done by a mechanical crusher or by hand with an iron tamping bar on a smooth and solid floor. In the absence of a smooth, tight floor, the crushing may be done on a heavy canvas, to prevent the accidental admixture of any foreign matter. The mixing and reduction will be done by hand with a shovel, or mechanically by means of riffles or sampling machines.

38. *Hand preparation.* When prepared by hand the pieces of coal and impurities will be crushed to the approximate size indicated in the table below before each reduction:

Weight of sample to be divided	Size to which coal and impurities should be broken before each division
1,000 pounds or more	1 inch
500 pounds	$\frac{3}{4}$ inch
250 pounds	$\frac{1}{2}$ inch
125 pounds	$\frac{3}{8}$ inch
60 pounds	$\frac{1}{4}$ inch

The 60-pound sample will then be reduced by quartering, or by the use of riffles or sampling machines, to the desired quantity for transmittal to the laboratory.

39. *Mixing and reduction by "alternate shovelfuls."* After each crushing, the sample will be thoroughly mixed before reduction in quantity, the procedure being as follows:

The crushed coal will be shoveled into a conical pile. A new long pile will then be formed by taking a shovelful at a time and spreading it out in a straight line (8 to 10 feet long for a shovel holding 15 pounds). Each new shovelful will be spread over the top of the preceding one, beginning at opposite ends, and so on, until all the coal has been formed into one long pile. By walking around the long pile and systematically taking shovelfuls, and shoveling the coal to one side, alternate shovelfuls being discarded, the sample will be halved in quantity.

40. *Mixing and reduction by "quartering."* The above "long-pile" and "alternate-shovel" method of mixing and reducing the sample will be followed with samples of 125 to 250 pounds or more. Samples smaller will be mixed on a canvas about 8 feet square by raising first one end of the canvas and then the other, thereby rolling the sample back and forth. After thoroughly mixing in this manner, the sample will be formed in a conical pile and reduced in quantity by quartering.

41. *Crushing of increments.* Whenever the different increments of samples are collected throughout some considerable period of time, each increment may be crushed as soon as taken and the pieces of coal and impurities broken sufficiently small to permit two or three reductions of the total accumulated sample before further crushing is necessary.

42. *Special moisture sample.* In the reduction of the gross sample to the sample for transmittal to the laboratory the gross sample will unavoidably lose moisture. To determine the moisture content in the coal delivered, a separate special moisture sample must be taken. This will be accumulated by placing in a hermetically sealed receptacle small parts of the freshly taken increments of the gross sample.

43. *Moisture samples discretionary.* The collection of special moisture samples shall be discretionary with the Government. Special moisture samples will be taken if in the opinion of the Government inspector the coal contains moisture in excess of the amount guaranteed by the contractor. The special moisture samples will be taken so as to represent the coal with respect to the moisture contained at time of weighing.

44. *Extended deliveries.* If deliveries extend over any considerable period, what would otherwise be a gross sample may be worked down in successive stages to samples of a size suitable for transmittal to the laboratory, and the samples representing the several equal parts of a delivery may be analyzed and the several analyses averaged, or the several samples may later be mixed (at the delivery point or in the laboratory and reduced to one sample) and one analysis made.

X. Analysis.

45. Immediately on receipt of a sample in the laboratory it will be analyzed and tested by the Government in accordance with the method recommended by the American Chemical Society, and by the use of a bomb calorimeter.

XI. Causes for Rejection.

46. *Character.* All coal delivered during a fiscal year is expected to be of the same character as that specified by the contractor. It should, therefore, be supplied as nearly as possible from the same mine or group of mines.

47. *Quality.* It is important that the standards furnished with bids shall not establish a higher value than can be actually maintained under the terms of the contract. In this connection it should be recognized that the small "mine samples" usually indicate a coal of higher economic value than that actually delivered in carload lots, because of the care taken to separate extraneous matter from the coal in the "mine samples." It is evident, therefore, that it will be to the best interests of the contractor to furnish a correct description with average values of

the coal offered, as a failure to maintain the standard he establishes will result in deductions from the contract price, and may cause a cancellation of the contract, whereas deliveries of coal of higher grade than quoted will be paid for at an increased price per ton.

48. *Unsatisfactory fuel.* Coal containing percentages of volatile matter or sulphur higher than the limits indicated under "Description of Coals Desired," or having a moisture content in excess of that guaranteed, or containing percentages of ash greater than indicated in the column "Maximum limits for ash" in the table in the section entitled "Price and Payment," or failing to give satisfactory results because of excessive clinkering or a prohibitive amount of smoke, or proving for any other cause to be an undesirable fuel, will be subject to rejection, and the Government will have the right to cause the contractor to remove such coal at no cost to the Government. Such event may result in the Government purchasing in the open market, or through competitive bidding, such quantity of coal to supply the deficiency caused by such failure, or annulling the contract by giving notice in writing to that effect to the contractor, and the Government, in its discretion, purchasing such coal in the open market or by contract upon competitive proposals; the contractor to remain liable for all damages sustained by the United States on account of such failure, including the difference, if any, between the cost of purchasing and delivering said coal and the price at which the contractor agreed to furnish it. The contract price must be understood to be the corrected price per ton based upon analysis, as hereinafter described under the section entitled "Price and Payment." If it shall be impracticable to cause the contractor to remove coal subject to rejection, the Government may use such rejectable coal, deducting penalties as determined under the section entitled "Price and Payment," and may in addition, as circumstances warrant in the opinion of the Government, deduct a further penalty of twenty-five (25) per cent of the amount of the bill, based on the tonnage of the coal under question and at the contract price per ton.

XII. Price and Payment.

52. *Prompt payment.* Payment will be made promptly upon receipt of a report from the Bureau of Mines on the quality of the coal under consideration. The Bureau of Mines will furnish such report in not more than fifteen (15) days after the receipt of the sample or samples.

53. *Determination of price.* Payment for coal specified in the proposal will be made upon the basis of the price therein named, corrected as follows for variations in heating value, ash, and moisture from the standards specified in the contract (see section 48 for an additional deduction on coal subject to rejection):

(*a*) Considering the coal on a "dry-coal" basis, no corrections in price will be made for variations of 2 per cent or less in the number of British thermal units from the guaranteed standard. When the variation in heat units exceeds 2 per cent of the guaranteed standard, the correction in price will be a proportional one and will be determined by the following formula:

$$\frac{\text{B. t. u. delivered coal ("dry-coal" basis)}}{\text{B. t. u. ("dry-coal" basis) specified in contract}} \times \text{bid price=price resulting from B. t. u. corection.}$$

For example, if coal delivered on a contract guaranteeing 14,000 British thermal units on a "dry-coal" basis at a bid price of \$3 per ton shows by calorific test results varying between 13,720 and 14,280 British thermal units, there will be no price correction. If, however, the delivered coal shows by calorific test 14,300 British thermal units on a "dry-coal" basis for example, the price for this variation from the contract guarantee is, by substitution in the formula:

$$\frac{14{,}300}{14{,}000} \times \$3 = \$3.064$$

The correction will be figured to the nearest tenth of a cent.

(*b*) For all coal that by analysis contains less ash on a "dry-coal" basis than the percentage specified herein, a premium of 2 cents per ton for each whole per cent less will be paid. An increase in the ash content of 2 per cent above the standard established by the contractor will be tolerated without exacting a penalty. When such excess is greater than 2 per cent, deductions will be made in acordance with the following table:

Ash as established in proposal	No deduction for limits below—	Cents per ton to be deducted: 2	4	7	12	18	25	35	Maximum limits for ash*
		Percentages of ash in dry coal							
Per Cent	Per Cent								
4 ----------	6, inclusive--	6.01- 7.00	7.01- 8.00	8.01- 9.00	9.01-10.00	10.01-11.00	11.01-12.00	12.01-13.00	11
5 ----------	7, inclusive--	7.01- 8.00	8.01- 9.00	9.01-10.00	10.01-11.00	11.01-12.00	12.01-13.00	13.01-14.00	12
6 ----------	8, inclusive--	8.01- 9.00	9.01-10.00	10.01-11.00	11.01-12.00	12.01-13.00	13.01-14.00	14.01-15.00	13
7 ----------	9, inclusive--	9.01-10.00	10.01-11.00	11.01-12.00	12.01-13.00	13.01-14.00	14.01-15.00	15.01-16.00	14
8 ----------	10, inclusive--	10.01-11.00	11.01-12.00	12.01-13.00	13.01-14.00	14.01-15.00	15.01-16.00	16.01-17.00	14
9 ----------	11, inclusive--	11.01-12.00	12.01-13.00	13.01-14.00	14.01-15.00	15.01-16.00	16.01-17.00	17.01-18.00	15
10 ----------	12, inclusive--	12.01-13.00	13.01-14.00	14.01-15.00	15.01-16.00	16.01-17.00	17.01-18.00		16
11 ----------	13, inclusive--	13.01-14.00	14.01-15.00	15.01-16.00	16.01-17.00	17.01-18.00	18.01-19.00		16
12 ----------	14, inclusive--	14.01-15.00	15.01-16.00	16.01-17.00	17.01-18.00	18.01-19.00	19.01-20.00		17
13 ----------	15, inclusive--	15.01-16.00	16.01-17.00	17.01-18.00	18.01-19.00	19.01-20.00			18
14 ----------	16, inclusive--	16.01-17.00	17.01-18.00	18.01-19.00	19.01-20.00	20.01-21.00			19
15 ----------	17, inclusive--	17.01-18.00	18.01-19.00	19.01-20.00	20.01-21.00				19
16 ----------	18, inclusive--	18.01-19.00	19.01-20.00	20.01-21.00					20
17 ----------	19, inclusive--	19.01-20.00	20.01-21.00	21.01-22.00					21
18 ----------	20, inclusive--	20.01-21.00	21.01-22.00	22.01-23.00					22

*These limits are used in determining rejectable coal, see section 48, marginal heading "Unsatisfactory fuel."

As an example of the method for determining the deduction in cents per ton for coal containing ash exceeding the standard by more than 2 per cent, suppose coal delivered on a contract guaranteeing 10 per cent ash on the "dry-coal" basis shows by analysis between 14.01 and 15 per cent (both inclusive), or, for instance, 14.55 per cent, the deduction according to the table is 7 cents per ton (reading to the right on line beginning with 10 per cent on the extreme left, which in this case is the standard, to the column containing "14.01-15," the deduction at the top of this column is seen to be 7 cents).

NOTE.—If the ash standard is an uneven percentage, the table will be revised in order to determine deductions on account of excessive ash. For example, if the ash standard is 6.53 per cent, each percentage value beginning with 6 in the left-hand column and all figures in the line reading to the right of 6 will be increased by 0.53. There would be no deduction then in price for ash in delivered coal up to and including 8.53 per cent, while for coal having an ash content, for instance, between 11.54 and 12.53 per cent the deduction would be 12 cents per ton.

(*c*) The price will be further corrected for moisture content in excess of the amount guaranteed by the contractor, the deduction being determined by multiplying the price paid by the percentage of moisture in excess of the amount guaranteed. The correction will be figured to the nearest tenth of a cent. For example, if coal delivered on a contract guaranteeing 3 per cent moisture with bid price of $3.50 per ton shows by analysis 4.65 per cent moisture, the bid price is multiplied by 1.65 (the excess moisture), which gives 5.8 cents ($0.058) as the deduction per ton.

[$3.50 × (4.65—3.00=1.65 per cent)=5.775 cents.]

XIII. Information to be Supplied.*

55. Estimated quantity of coal required,——tons (2,000 or 2,240 pounds).

56. (The point of delivery, method of delivery, capacity and facilities for storage, etc., are here furnished.)

57. The bidder must insert in the blank space below the information called for on the coal he proposes to furnish, without which information the proposal will be informal:

(*a*) Commercial name of the coal..........................

(*b*) Name of the mine or mines..........................

(*c*) Location of the mine or mines (town, county, state)....

....

(*d*) Railroad on which mine is located....................

(*e*) Name or other designation of the coal bed or beds.......

....

(*f*) Name of operator of mine or mines....................

(*g*) British thermal units per pound of "dry coal"..........

(*h*) Percentage of ash in "dry coal"......................

(*i*) Percentage of sulphur in "dry coal"..................

(*j*) Percentage of volatile matter in "dry coal"...........

(*k*) Moisture in coal "as received"........................

(*l*) Additional description of coal as deemed of importance by bidder ....

....

(*m*) Price per ton of....pounds (this price is understood to be the bid price per ton, see section 53 for method of determining price for delivered coal)................

....

*Bidders are cautioned against specifying higher standards than can be maintained, for to do so may result in the bid being rejected (sec. 8), or may result in rejection of delivered coal or cancellation of the contract and the Government purchasing coal in the open market and charging against the contractor the difference in cost (see secs. 47 and 48).

THE SECRETARY OF THE .... DEPARTMENT:

The undersigned hereby propose.. to furnish and deliver to ....the coal as above specified, and at the price stated above, for the fiscal year commencing on the 1st of July,..... and ending on the 30th of June,.....

The undersigned ha... read the specifications and proposal and agree.. to comply therewith in every particular.

Signature of each member of the firm and firm name. If a corporation, its name, and signature of the officer authorized to sign for the corporation, together with a copy, under seal of his authority to sign; also, the name of the state in which incorporated.

....

....

....

....

Doing business under the firm name of...................

Place of business, ...

....

NOTE.—Owing to the difficulty in deciphering signatures, a typewritten copy of same should be attached.

INDEX

C

D

G

H

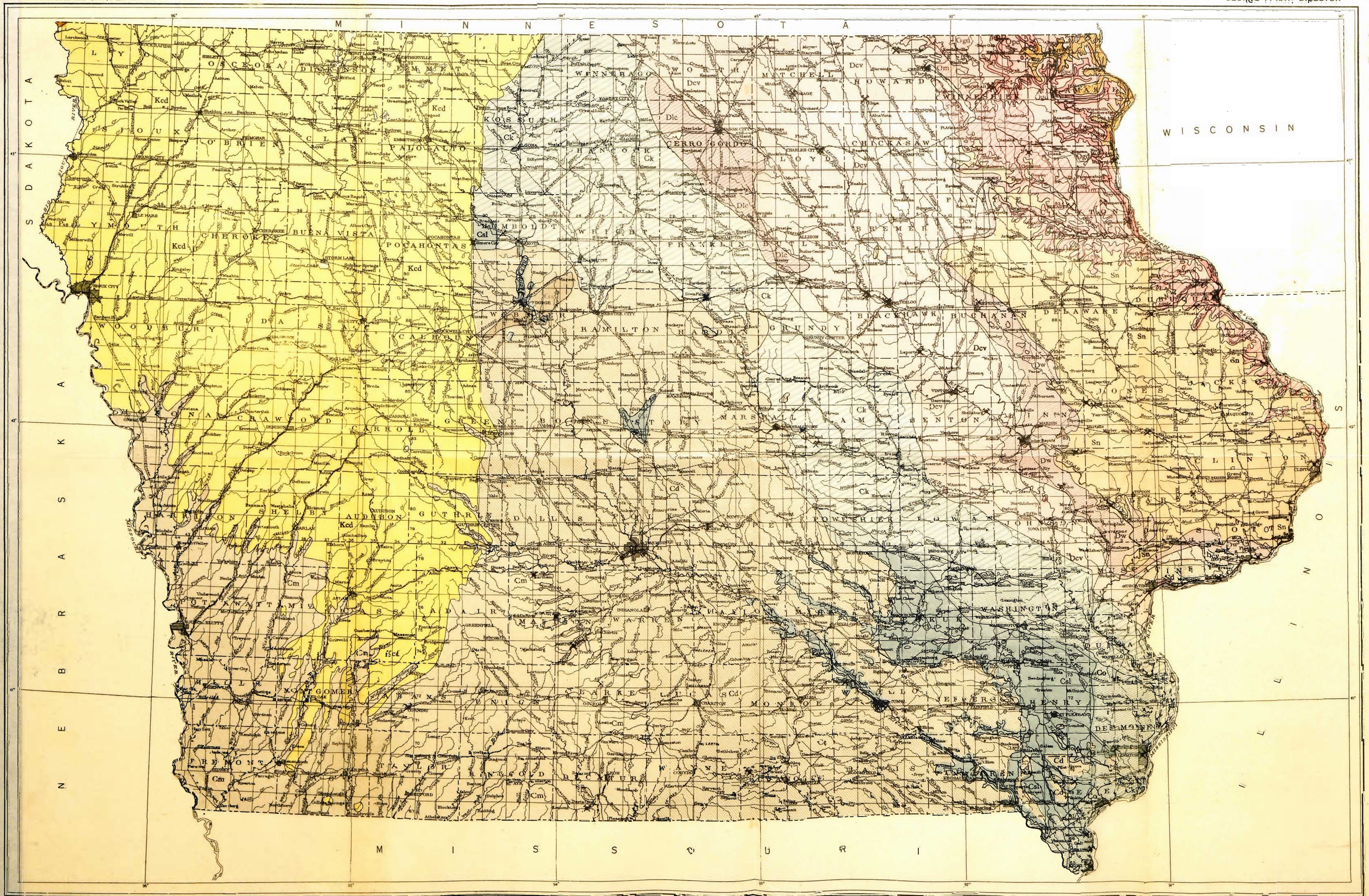
I

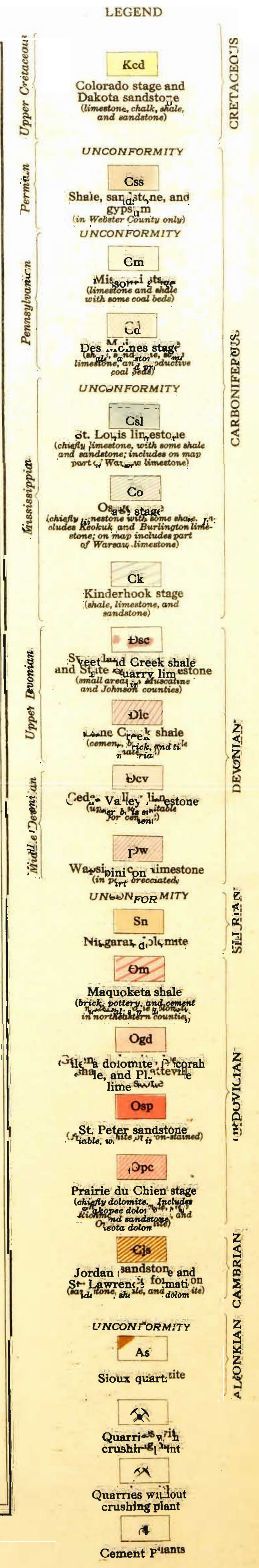
M

Q

Y

IOWA GEOLOGICAL SURVEY
GEORGE F. KAY, DIRECTOR





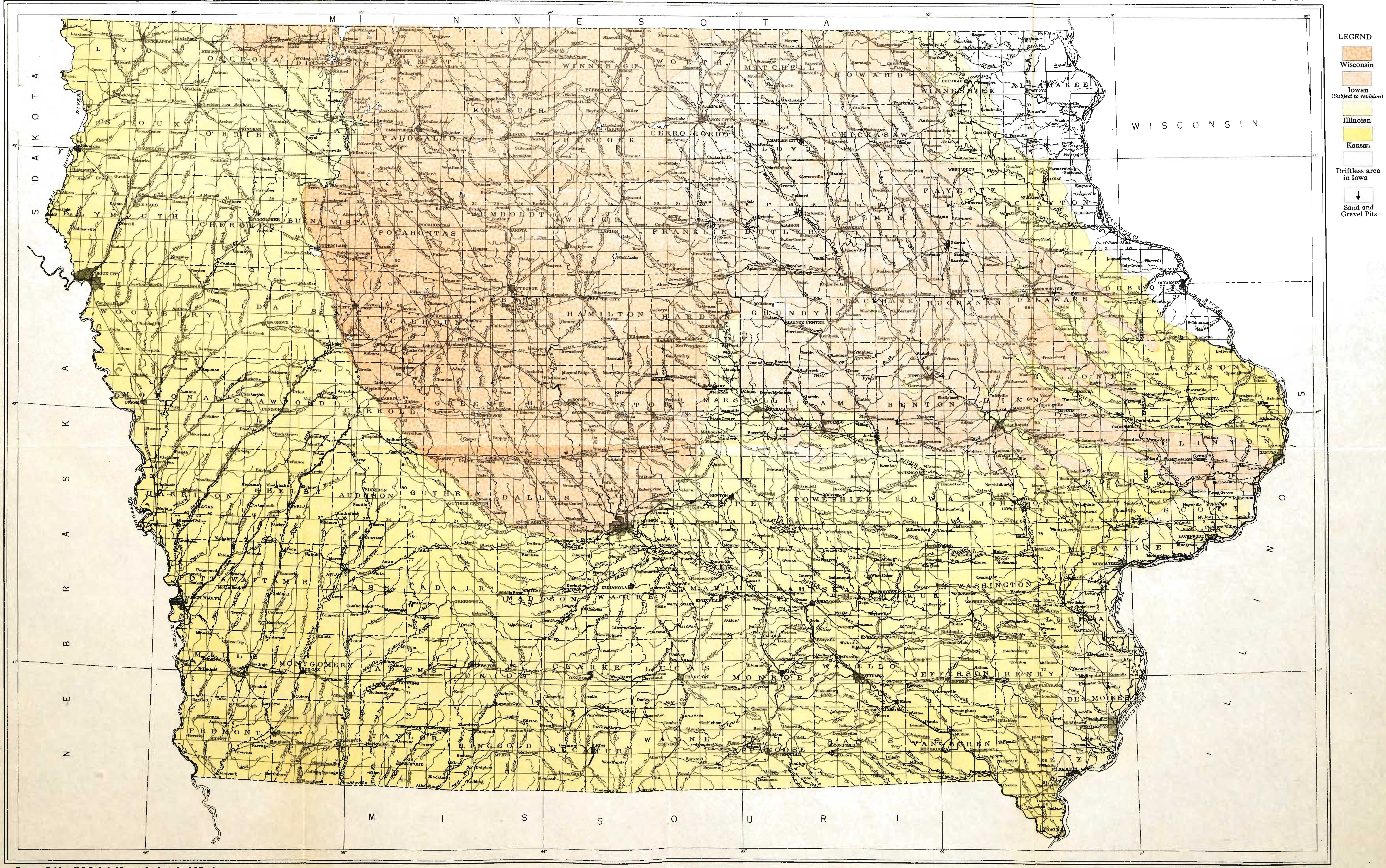
Base compiled from U. S. Geological Survey atlas sheets, Land Office data, surveys by Mississippi and Missouri River commissions, county maps, and other sources. Used by permission of the U. S. Geological Survey.

GEOLOGIC MAP OF IOWA

Scale 1:1000000
10 0 10 20 30 40 50 Miles
1914

IOWA LITHO. CO. D. M.

Geology by Iowa Geological Survey



Base compiled from U. S. Geological Survey atlas sheets, Land Office data, surveys by Mississippi and Missouri River commissions, county maps, and other sources. Used by permission of the U. S. Geological Survey.

MAP OF IOWA SHOWING DRIFT SHEETS

Scale 1:1,000,000

10 0 10 20 30 40 50 Miles

1914

IOWA LITHO. CO. D.M.

Compiled from reports of the Iowa Geological Survey